Master Energy Science

'Building a bridge between the Climate Agreement and actual energy savings in the Dutch retail sector'

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Acronyms

BAG	Dutch national register of addresses and buildings (Basisregristratie adressen en gebouwen)
c	Construction period
CBS	Dutch Central Bureau of Statistics (Centraal Bureau voor de statistiek)
CF	Capacity factor
e	Energy application
ECU	Energy check-up
EPA	Energy performance Advise (Energie prestatie advise)
EPBD	Energy performance building directive
FA	Floor area, refers to GBO, unless defined otherwise
GBO	Usable floor area (gebruikersoppervlak)
GHG	Greenhouse gasses
HP	Heat pump
HW	Hot water
i	year
INT	Intensity effect
kWh	Kilowatt-hour
LHV	Lower Heating Value (natural gas=31.65 MJ/m^3)
N	Number of cases
NF	Non-food shops
NG	Natural gas
NTA	Dutch Technical Agreement (Nederlandse technische afspraak)
NZEB	Nearly zero energy building (=BENG)
PE	Local energy production effect
PV	Photovoltaic
r	Reference building (Small or Large)
s	Energy carrier (NG or electricity)
SE	Structure effect
SUB	Substitution effect
TNO	Dutch organisation for applied scientific research
v	Percentage vacant buildings
VE	Volume effect
w	Retail sub-sector (NF shops or supermarkets)
WE	Weather effect
WVO	Shop floor area (winkelvloeroppervlak)

Abstract

Becoming climate neutral by 2050 is the overarching target for the Dutch service sector. However, there is little insight in current energy usage patterns and opportunities for energy savings in the sector. Therefore, a quantitative and qualitative analysis in the retail sub-sectors, supermarkets and non-food shops was performed. The results of the trend analysis between 2010 and 2019 indicate a significant decrease in final energy consumption for non-food shops (-26%), and a marginal decrease for supermarkets (-5%). The driving forces of these changes were quantified with a decomposition analysis. The decrease in energy intensity was the largest contributor for both sub-sectors, with the chilly winter of 2010 compared to 2019 being the second largest driver. Floor area increased in both sectors, but more so in the supermarket sub-sector. The change in energy intensity was broken down in energy applications. As for supermarkets the decrease was driven foremost by product cooling and space heating. For non-food shops, the strongest drivers were the decrease in indoor lighting and space heating. Based on expert interviews, the perceived drivers and barriers to energy savings were analysed. Corporate responsibility and economic incentives are drivers for supermarkets. As for large non-food shops, the policy 'Recognized Energy Efficiency Measures List (EML)' is a driver. The recent increase in energy prices is another driver for both small and large non-food shops. One perceived barrier is the split incentive, which is induced by half of the shops being rented. Furthermore, the required investment capital is an economic barrier. Knowledge and technical barriers, like the lack of technical employees are also perceived. This study concludes with proposed strategies for energy savings in the retail sector, such as the implementation of a pilot project to quantify energy savings, as well as improved collaboration and knowledge sharing in the non-food sub-sector. Additionally, the long-term national energy intensity target needs to be specified in the service sector and its sub-sectors, to provide guidelines along the pathway towards climate neutrality.

1. Introduction

1.1 Context

At the current pace, there is a high chance of reaching anthropogenic global warming of 1.5 °C, already by 2032 (Masson-Delmotte et al., 2018). Extreme weather events such as droughts, flooding, and biodiversity loss are inevitable in the absence of immediate and significant emission reduction. (Frame et al., 2020). A large contributor to the global CO_2 emissions is the energy consumption in the built environment, 28% in 2019 (IEA, 2020). The built environment can be divided in the residential and service sector. The service sector comprises among others, offices, shops, and hospitals. Environmental impact of the built environment is associated indirectly with the energy and resource use for construction and disposal of buildings, and directly with the energy consumption during operation, for instance, for space heating (Deetman et al., 2020). The International Energy Acency (IEA) has predicted that the energy consumption in the built environment will grow due to more extreme weather events, like heatwaves leading to a vast increase in air-conditioning, and growing demand for buildings electric services, like appliances and devices (IEA, 2020). To drastically cut emissions and environmental impact, the EU aims to be 'climate neutral' by 2050 (EC, n.d.). In the Netherlands intermediate goals are formulated in the Dutch Climate Agreement, like local emission reduction in the built environment. The Dutch service sector is responsible for about 30% of the emissions in the built environment (Hammingh et al., 2020). It makes up 10% of the Dutch total primary energy consumption in 2019, a share which has slightly increased over the past decade see Figure 1 (based on CBS, 2021).

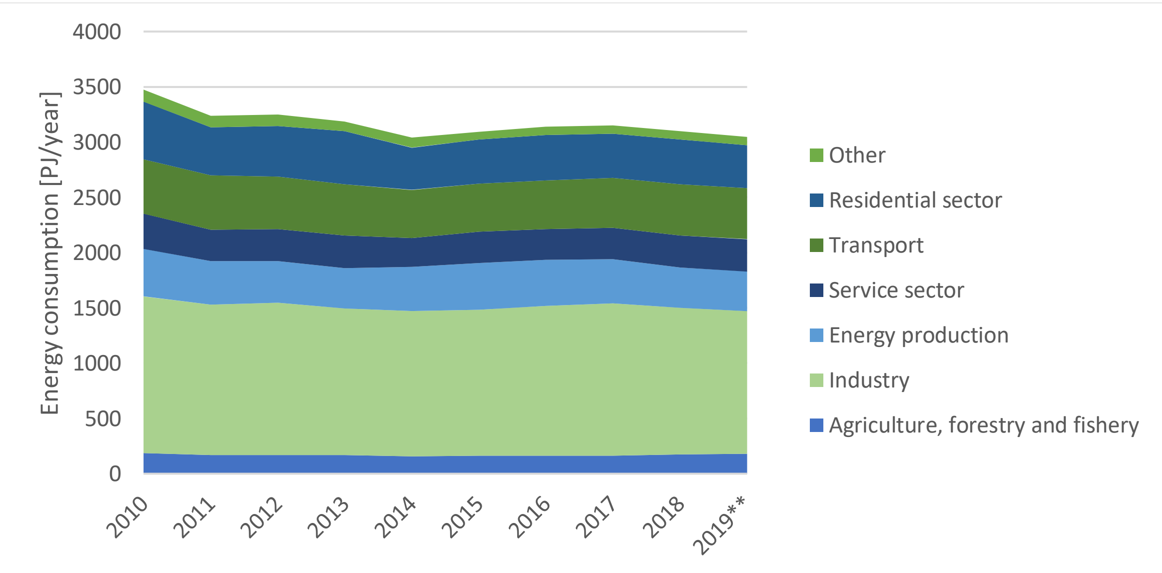

*Figure 1. Primary energy consumption per sector in the Netherlands ** preliminary data (CBS, 2021)*

1.2 Problem definition

Although the service sector's energy consumption has slightly declined by 7% over the previous decade, climate neutrality is still a long way off, and it is yet unknown how effectively GHG emission reduction may be accomplished (CBS, 2021; Mulder et al. 2021). There are various explanations for this. First, data quality and availability are limited, since data collection is not controlled centrally, and therefore the overview is fragmented (Kruit et al., 2022; Economidou & Román-Collado, 2017). Furthermore, the heterogeneous nature of functions and building types, make research in the service sector more complex (Pels et al., 2018; Parliamentary papers/ 2020, 30196-716). Additionally, there is a split incentive in decision making regarding renovations and investments, because it mostly concerns rental buildings in the service sector (Pels et al., 2018). So far, the academic field is more strongly focused on the residential sector when it comes to emission reduction (Mairet & Decellas, 2009).

Although most research in the service sector focuses on offices, the Dutch retail sector is of special interest due to the extensive efforts of supermarkets to reduce their energy consumption (Raji, Tenpierik & van den Dobbelsteen, 2016; CLB, 2020). Furthermore, the DGBC (Dutch Green Building Council) has established goals for final energy consumption based on the remaining carbon budget, also for the retail sector (DGBC, n.d.). These goals are signed voluntarily by several retail chains, like Ahold Delhaize. Shops make up about 9% of the service sector, see Figure 2, and is often split in shops with and without cooling due to the dominating energy requirement for product cooling and food preparation.

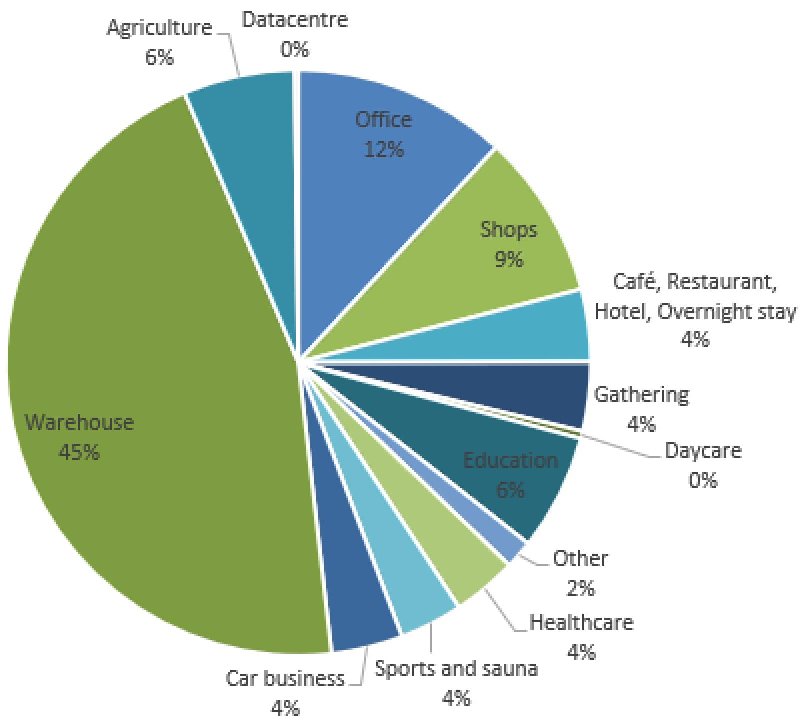

Figure 2. Share of floor area in non-residential sector in 2021 (based on CBS, 2022)

1.3 Research objective

The aim of this study is to gain insight in the final energy consumption of the Dutch retail sector and identify strategies for energy savings. The following two research questions are answered:

1. *Which trends can be identified in final energy consumption in the retail sub-sectors between 2010 and 2019 and how much did driving forces like activity change, structure change, and intensity change of energy applications contribute to the observed change in final energy consumption?*
2. *What are perceived drivers and barriers to energy saving in the retail sub-sectors?*

The study is performed for supermarket and non-food shops (NF) individually and will cover the period 2010 to 2019. This period offers the most data and the influence of COVID-19 can be excluded in the interpretation of changes. Contributing drivers and their historic mechanisms are used to provide useful insights in energy savings (Xu & Ang, 2014). Subsequently, drivers and barriers of energy savings measures are identified, and strategies to establish energy savings are proposed.

To answer these research questions, first the theory and relevant concepts are introduced, and then the methodology is presented. The data preparation and intermediate results are presented in a separate chapter. The results for the two questions are presented, followed by the discussion. The research is finalized with a conclusion and policy recommendations.

2. Theoretical background

In this section, relevant theoretical concepts are explained. First, the retail sector and the data availability in terms of energy consumption is presented. Next, the methodology for the quantitative analysis of energy consumption is described, namely the trend and decomposition analysis. Lastly, the evaluation of drivers and barriers for energy savings is discussed. Additionally, energy policy relevant for the retail sector are discussed. The section is concluded with a research framework.

2.1 Retail sector

Dutch shops are present in diverse types, differing in size and type of commodities sold. By 2020, the building stock is estimated at 5997 supermarkets and 128,129 shops (CBS, 2022). Supermarkets are characterized by the sale of food related products. Other food related shops are food speciality shops, like bakeries and butchers. Among non-food shops (NF), various specialization exists, for instance, consumer electronic shops, or clothing shops. In Figure 3**Error! Reference source not found.** it is shown what the distribution is of shops. By floor area, 'supermarkets', 'clothing, shoes and sports', 'home and garden', and 'furniture and interior design' are the largest shop types. A first distinction in terms of energy consumption can be made between food and NF shops. Where food shops require a higher energy intensity due to product processing and product cooling. Within the category 'food shops', supermarkets and speciality food shops are incomparable due to their differentiating floor area. A further breakdown in terms of reference buildings can be made to analyse the energy consumption. Dutch shops are commonly located in a type of shopping street, a so called 'outdoor shopping mall' (winkelplint). These are characterized by a street with multiple shops next to each other and apartments on top, see Figure 4. This mostly applicable to smaller shops. Larger shops are often (semi-)detached, like garden or furniture shops, see Figure 5.

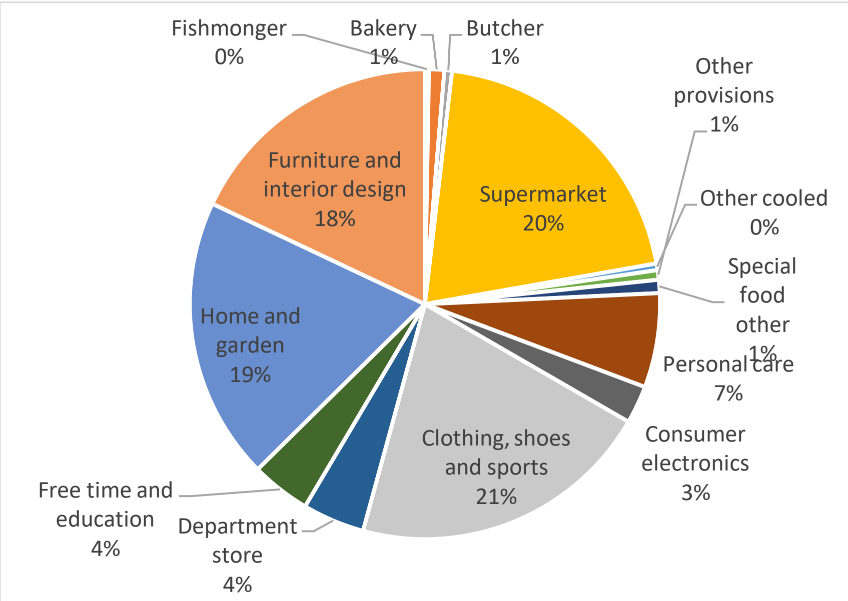

Figure 3. Floor area distribution retail sector (based on CBS microdata, 2022)

Figure 4. Shop in an 'outdoor mall' (Huispedia, n.d.)

Figure 5. Detached shop (Tuincentrumdenieuwestad, n,d,)

2.2 Available data

To analyse and compare the drivers of energy consumption in the retail sector, the data availability and the corresponding level of aggregation is evaluated. The quality and completeness of the quantification of drivers of energy consumption is dependent on the data availability (Su & Ang, 2012). In theory, further disaggregation leads to more refined results, but in practice the data availability is limited (idem). In the section below, the data availability for the main drivers of energy consumption for the Dutch retail sub-sectors is discussed.

2.2.1 Floor area

In terms of floor area, several definitions exist and are used interchangeably in the sector (BRO, 2007). The relation between different terminologies is visualized in Figure 6 (BRO, 2007). The difference originates from the inclusion of staff, storage and space behind the counter, and the inclusion of walls and low-roof space in the area. The Dutch Central Bureau of Statistics (CBS) building matrix provides the 'useable' floor area (GBO), based on the 'Dutch national register of addresses and buildings' (BAG) data (CBS, 2021a). The BAG excludes the shared spaces in a building in the floor area of one specific object (Sipma & Rietkerk, 2016). Locatus, a specialized research institute in retail, collects 'shop' floor area (WVO) of supermarkets, this data is openly available for several years (Consultancy.nl, 2013; Vastgoedmarkt, 2016). A more extended version of the openly available CBS buildingmatrix is made accessible for this research by TNO, the Dutch organisation for applied scientific research. It comprises the GBO for supermarkets and shops without cooling, furthermore, it distinguishes the yearly new built shops for the years 2011 until 2019. Among the shops without cooling are the food speciality shops.

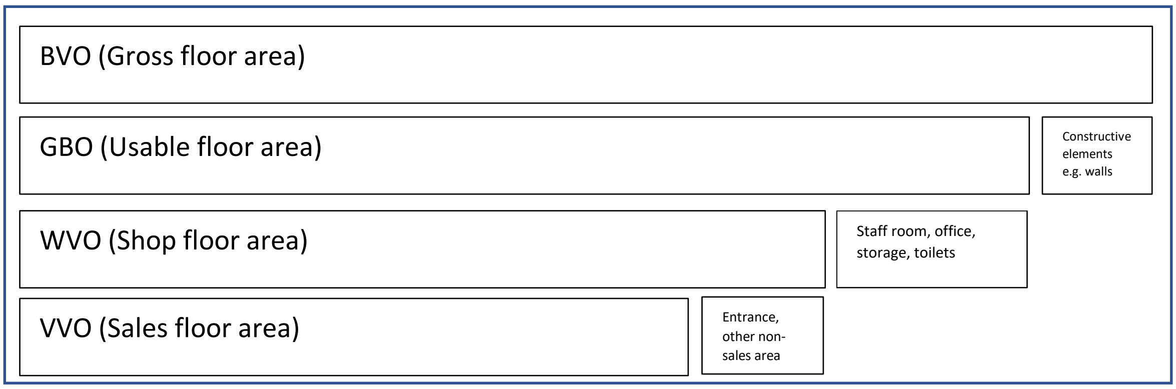

Figure 6. Types of floor area in the retail sector (based on BRO, 2007)

2.2.2 Energy intensity

The annual final energy intensity for the period 2010 to 2019 for a sample in the sub-sector is provided in CBS microdata, which is made available for this research by TNO. This dataset includes the final energy intensity for delivered natural gas [m^3/m^2 GBO], and electricity delivered by the grid [kWh/m^2 GBO], per year. The dataset includes details like shop type, floor area, and construction year. For a smaller selection in the sample, the theoretical energy intensity is provided. The theoretical energy intensity is the simulated building related energy intensity based on the energetic characteristics of the building, like insulation thickness and type of space heating appliance (NEN, 2020). The results of two methodologies are present: the Dutch Technical Agreement (NTA 8800) and the Energy Performance Advise (EPA). Both methods translate the theoretical energy consumption in a score, the NTA provides three BENG (Almost Energy Neutral Buildings) scores for a building, which have replaced the EPA 'energy label' (Jansen & Spruit, 2021).
Not all consumed electricity is delivered by the grid since some shops produce electricity on-site with solar PV panels. Therefore, the self-consumed electricity is calculated, which is based on theoretical electricity production by the PV panels, and feed-in electricity. District heating is excluded from the analysis, since disaggregated consumption data is not shared by district heating companies and is therefore not available in the dataset (Keller & Vroom, 2021). Overall, district heating makes up about 3% of the total final consumption, a small but considerable share (based on Hammingh et al., 2021).

2.2.3 Final energy consumption

The CBS (2018) has developed a 'Retaildashboard', for 2018, which provides insights in terms of energy consumption by shop type, floor area, construction period, region various of the retail sector. In collaboration with Locatus, the population is estimated, and the energy consumption is extrapolated to the Dutch retail population, to arrive at that the total energy consumption in 2018. A bottom-up method to determine final energy consumption is applied, by means of a sample, the final energy consumption of the population is estimated (CBS, 2018). This leads to different final energy consumption compared to a top-down method (idem).

2.2.4 Energy application

Research on the energy by application in the Dutch retail sector has been performed once in 2009, with reference year 2007 (Verweij & Meijer, 2009). This was performed for supermarkets and shops without cooling. This means that food speciality shops, like bakeries and butchers were not included. Meijer & Verweij based their analysis on three data sources, namely measured energy data, research by ECN (now part of TNO) on energy saving measures and, theoretical (EPA) calculations. The recognised end uses are displayed in Table 1. They can be split in building and user related consumption. The final energy intensity [MJ/m^2] for electricity and natural gas were provided.

Table 1. Energy applications as analysed by Meijer & Verweij for the retail sector

Category Based on Meijer & Verweij (2009)	**Description** (idem)	**Energy carrier** Based on Meijer & Verweij (2009)
Space heating	Heating of building to comfortable temperature	NG and/or electricity
Space cooling	Cooling of building to comfortable temperature	Electricity
Hot water	Water use for cleaning and cooking	NG or electricity
Humidification	Humidification of building	Electricity
Others	Energy for applications like security, air curtain, and other not included categories	
Food and drink facility	Food and drinks for employees, customers like coffee corners, and vending machines	

ICT central	Server rooms	
ICT decentral	Computers, laptops, screens, payment systems	
Auxiliary energy	Energy for pumping for heating and cooling	
Product processing	Product preparation with ovens, stoves and grills	
Product cooling	Refrigeration and freezing of products	
Transport	Inside transport with elevators and escalators	
Ventilation	Ventilation in the building	
Lighting inside	Lighting in the building	
Lighting outside	Lighting outside the building	
Lighting emergency	Lighting for escape route	

Regarding more recent data, the Energy check-up (ECU) is openly available (2018) and the theoretical 'Energylabel database' is made available through TNO. The ECU presents data for shops with and without cooling, which was last updated in 2018 (Energy check-up, 2018a). It is based on energy audits performed in small and medium-sized enterprises (MKB) in the Netherlands. The attempts to gain more insight in the methodology or sample size have not been successful. In Table 2 the distinguished energy applications are presented. It is observed that ECU recognizes less categories than Meijer & Verweij (2009).

Table 2. Breakdown electricity consumption in shops (Energy check-up, 2018)

Breakdown	**Non food**	**Food**
Lighting	65%	20%
Ventilation	3%	1%
Airconditioning	14%	6%
Space heating	3%	3%
Production appliances	10%	10%
Other	5%	-
Product cooling	n.a.	60%

The EPA dataset of the research by Nuiten (2020) about building related characteristics of Dutch shops was made available for this research by TNO. This dataset was last updated on April 12 2021, , but includes data from multiple collection dates. It consists of more than 31 thousand energy labelled shops in the Netherlands. A drawback is that it makes no distinction between type of shop. Implying that further disaggregation than the retail sector is not possible. Also, it only concerns the installations which belong to the building. For instance, mobile ventilators are not included. With EPA and NTA 8800 input, theoretical construction-related electricity and natural gas consumption is calculated for a labelled individual building, as shown in Table 3. The extent to which theoretical consumption estimates actual building related consumptions is widely debated (Pels et al., 2018; Sipma, 2021).

Table 3. Building related energy applications as available in the EPA-database

Category **Based on EPA database**	**Energy carrier** **Based on EPA database**
Space heating	NG, electricity, district heat
Hot water	NG, electricity, district heat
Cooling	Electricity
Ventilation	Electricity
Auxiliary equipment, including pumps	Electricity
Humidification	Electricity

Lighting inside	Electricity
Energy production (with solar PV panels)	Electricity

2.3 Drivers of energy demand

To analyse the energy consumption of the retail sector, the drivers of energy demand in the sector are reviewed in literature. The change in energy consumption between 2010 and 2019 is studied for the two sub-sectors independently. Due to data limitation, the change in energy consumption of food speciality shops is not analysed. The focus of this research is on the final energy consumption, as visualized on the right-hand side of Figure 7. This implies that energy conversions in the production of energy are not allocated for, since this is determined by the national electricity mix and cannot be influenced by the individual customer (Blok & Nieuwlaar, 2017). The demand side of energy consumption is determined by the type of applications and the application's conversion i.e., efficiency. In the next paragraph, it is described how total sectoral energy consumption can be broken down to the level of individual energy applications. The identified drivers of energy consumption are addressed successively.

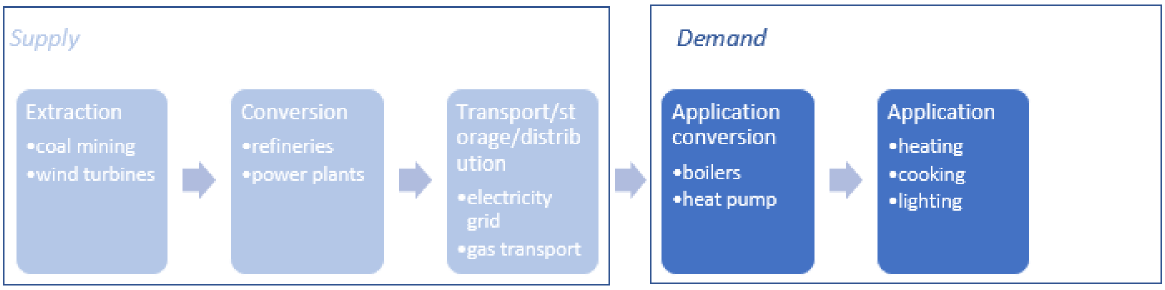

Figure 7. Energy demand and supply (based on Blok & Nieuwlaar, 2017)

The first driver of total final energy consumption is the activity level of the sector. To quantify the volume of the sector, several indicators can be used like value added, employment and floor area (Mairet & Decellas, 2009). Value added quantifies the economic activity directly, whereas employment and floor area quantify it indirectly (idem). For the service sector, floor area is a better indicator for energy consumption, and is therefore chosen as volumetric indicator (idem).

A second driver is the structure of the sector (Xu & Ang, 2014). Based on data availability and suitability, indicators like, building type or building occupant type reflect the structure effect (Xu & Ang, 2014). To analyse changes within existing buildings and the new build buildings separately, a structural effect based on construction period is chosen. Since the base year is 2010, the decision is made to use the periods 'constructed before and in 2010', and 'constructed after 2010'.

The third driver is the energy intensity, being the final energy consumption over the volumetric indicator (Mairet & Decellas, 2009). This is reflected by the energy consumption over the floor area. This energy intensity can be broken down into the energy intensities for each energy application (idem). This enables the analysis of efficiency improvement, occupant behaviour, and equipment implementation rate (idem). For instance, the increased use of air-conditioning results in higher energy intensity for the application space cooling (Mairet & Decellas, 2009; Behidj et al., 2006). The energy applications are used to determine their contribution to the change in energy intensity for the construction period. Due to the limited data availability, the share of energy applications cannot be disaggregated for the construction periods separately. Therefore, the share of each application in the total energy intensities is assumed constant within the sub-sector. The applications as recognized by Meijer & Verweij (2009), (see Table 1) are compared.

A fourth driver of energy consumption is the type of energy carrier consumed. In the Netherlands, electricity, natural gas (NG), and district heating are most common (Keller & Vroom, 2021). Some solar thermal heat is consumed too, but this is considered marginal for Dutch shops (Panteia, 2020). In this study, only the change in electricity and NG consumption is analysed. Most energy applications use electricity. For space heating and hot water both electricity and NG are considered (Keller & Vroom, 2021). Due to differences in conversion efficiency, the type of energy carrier determines the energy consumption for an application (Blok & Nieuwlaar, 2017). To identify a potential change in energy consumption originating from the substitution for NG with electricity (or vice versa), the energy intensity of the application by energy carrier is analysed for each construction period and sub-sector.

A fifth driver of energy consumption is the outside temperature (Blok & Nieuwlaar, 2017). Since the heat loss and gain of a building are dependent on the outside temperature, it is useful to consider outdoor temperature when determining annual heating and cooling demand (idem). The Netherlands is a heating dominated country, but average temperatures are rising (Abels-van Overveld et al., 2019; CBS, n.d.). This means that this driver affects mainly space heating, and potentially space cooling. Only the weather effect for NG space heating is considered since the space heating requirement for electricity is assumed to be concerned with more uncertainty. A normalized cooling demand is more complex to determine, since it is dependent on the presence of a cooling system and consumes electricity, which has many more applications. Since monthly electricity consumption in the retail sector is not available, a correction for cooling demand is not applied. A method to correct for year-to-year variation in outside temperature is the 'Heating Degree Days' (HDD) method. This method results in a normalized or relative energy demand for heating based on national HDD (Spinoni et al., 2018).

2.4 Trend analysis

Based on statistical datasets, a trend analysis is used to identify quantitative trends over multiple years, which are presented visually with line-graphs (Köne & Büke, 2010). The direction of change can be interpreted for the trends. These trends can be extrapolated to analyse future trends (idem). For the retail sub-sectors, the trend analysis is used to gain first insight in the changes in total energy consumption, and for NG and electricity separately. Furthermore, the trends are broken down by the energy consumption for the construction periods. To gain further insight in the driving forces of these trends, additional analysis is necessary.

2.5 Decomposition analysis

To quantitatively assess the drivers of the identified trends, a decomposition tool can be used (Harmsen & Crijns-Graus, 2021). This tool enables an analysis on various levels of detail and decomposes the contribution of each driver independently (Wang & Wang, 2015). It is used to quantify the mechanism associated with changes in energy consumption and GHG emissions (Román-Collado, Cansino & Botia, 2018; Tunç, 2009).

In the academic field, two general approaches for decomposition analysis exist, namely the Structural Decomposition Analysis (SDA), and Index Decomposition Analysis (IDA) (Xu & Ang, 2014). The latter is the most preferred one due to the ability to analyse any aggregate type (e.g., value or ratio), and requires less data, which is needed to perform an input/output analysis. For IDA, two main methods exist, namely the Divisa and the Laspreyres, of which the first is most dominant in application (Marrero & Ramos-Real, 2013). Since the Logarithimic Mean Divisia Index (LDMI 1) is also used in studies quantifying energy demand determinants, it will also be used for this study (Mairet & Decellas, 2009; Huang, 2020). The additive approach decomposes the absolute changes in an aggregated (Ang, 2005). It is favoured over the multiplicative approach, due to the more straightforward interpretation of the results (Blok & Nieuwlaar, 2017).

In IDA, the changes in energy consumption are categorized in at least three effects, namely activity, structure, and efficiency (Andreoni & Galmarini, 2012). Activity is the total level of activities, the structure is the mix of activities, and energy efficiency describes the energy intensity (Blok & Nieuwlaar, 2017). To identify each components' respective contribution, various disaggregation levels can be chosen. In section 2.3, the four drivers that are analysed are described. These are analysed on overall level of the sub-sector, the level of the construction period, and the intensity and substitution effect are analysed on the level of the energy applications. Lastly, space heating and hot water are also analysed by their energy carrier. The total change in energy consumption is determined by Equation 1.

Equation 1. $$\Delta E_{tot} = E_t - E_0 = (\Delta E)_{act.} + (\Delta E)_{str} + (\Delta E)_{int} + (\Delta E)_{sub}$$

E_t and E_0	*Energy consumption in period t and period 0*
E_{act}	*The change in activity*
E_{str}	*The change in structure*
E_{int}	*The change in energy intensity for applications*
E_{sub}	*The change in fuel mix substitution*

2.6 Driver and barrier evaluation

Based on the quantitative historic trends and driving forces, further insight in strategies for energy savings is gained by a driver and barrier evaluation. This analysis is used to identify why not all energy efficient measures are implemented in a sector (Lee, 2015; Olsthoorn, Schleich & Hirzel, 2017). The barriers and drivers experienced in the sector are analysed qualitatively with surveys or interviews (Cagno et al., 2015; Lee, 2015). Drivers and barriers in relation to energy efficiency are discussed below.

2.6.1 Drivers

Lee (2015) identified the drivers market pressure, public awareness of environmental sustainability, and rising energy costs, and volatility. The drivers identified in earlier research are categorized as regulatory, economic, informative, and vocational training (Cagno et al., 2015). An example of a regulatory driver is the perceived clarity of information of the prescriptive policy (idem). An important economic driver is the cost reduction for lower energy consumption. As for informative drive, the availability of information is important. Additionally, vocational training is perceived as a driver in previous studies, which is due to programs of education and training in energy knowledge (idem).

2.6.2 Barriers

Five main barriers are identified by Blok & Nieuwlaar (2007), namely, knowledge barriers, economic barriers, organisational barriers, split incentives, and bounded rationality. Knowledge barriers are related to the information gap between the company and the market availability of innovative technologies (idem). Economic barriers originate from the economic viewpoint of companies, where innovative technologies are not implemented if they do not pay back or if the payback time is too long. Also, it might be that the company does not have the capital to make the investment in a technology. An organisational barrier is related to the complex decision-making process in large companies. For small companies it can also be related to the low priority of energy issues within the business. Another barrier is the split incentive; the investor does not benefit (directly) from the energy efficiency improvement. For building specific split incentive, it is referred to as the landlord-tenant problem. The last boundary is the bounded rationality. This is caused by the fact that for many companies the energy costs are insignificant to the total production costs. Due to limitations in time and resources of the company, energy efficiency is not high on the agenda.

2.7 Energy policy

When interpreting the drivers and barriers in a sector, it is important to know which energy policies are present, and which targets are pursued. Therefore, a concise overview of the energy policy in the service sector is provided.

2.7.1 Dutch policy target

The objectives in the service and retail sector are a result of the EU Green Deal's aim of climate neutrality. Substantiated by the intermediate goals of 55% emission reduction by 2030, also referred to as 'fit for 55', and 80% by 2050. The terms 'climate', 'carbon' and 'energy' neutrality are intertwined, yet different. Climate neutrality refers to no net GHG emissions, including carbon dioxide (CO2), where neutralization of emissions is possible through (carbon) sequestration or offsetting (EC, 2021). Energy neutrality refers to an annual net zero energy demand, due to on-sight energy (over)production. In the Netherlands, the climate neutrality objective is most likely translated in a BENG-2 norm (Nearly Energy Neutral Building), which implies a maximum primary fossil building-related energy requirement per m^2 floor area or 'endnorm' by 2050 (BZK, 2022; Nieman, 2021). The quantification of the BENG-2 target has not been finalized, but the aimed start date is July 1st 2024 (Parliamentary papers/ 2020, 30196-716; BZK, 2022). Furthermore, by 2050 NG needs to be phased out of the built environment (RVO, n.d.). Several policies are introduced to reach the objectives.

2.7.2 Dutch energy policy

The present policy objective is threefold (BZK, 2022). Namely, efficient and NG free heating systems, saving energy by behaviour change and enhancing the energetic performance of buildings, and lastly, producing energy renewable energy (idem). In policy, a first differentiation is made between newly constructed buildings and existing buildings.

1. *Building directive 2021*
   New buildings and renovations need to adhere to the building directive. For new retail, the requirements regarding energy consumption of retail are; maximum energy demand per floor area of 70 kWh/m²; maximum primary fossil energy consumption per floor area of 60 kWh/m²; minimum 30% renewable energy (idem). (DGBC, n.d.). Since 2018, buildings are no longer obligated to be connected to the NG grid.
2. *Energy Performance of Building Directive (EPBD III)*
   Introduced in 2020, this directive prescribes minimum standards for building related installations, like space heating, ventilation, and indoor lighting (RVO, 2022a). It is in place when an installation is replaced.
3. *EU Eco-design Directive*
   The directive prescribes minimum energy performance standards for energy efficiency or emissions of new electrical appliances (Kruit et al., 2022). It concerns, ICT, lighting, cooling and freezing appliances, gas boilers, electrical boilers and ventilators, elevators, and escalators (van den Born et al., 2021). The directive is complemented by the Energy Labelling Directive.
4. *Recognised Energy Efficiency Measures Lists (EML).*
   The energy saving obligation was introduced in 2009 for companies with a minimum electricity (>50 000 kWh/yr) or NG (>25 000m^3) consumption (RVO, 2021; Joeles, 2019). It prescribes specific replacements requirements which have a payback period of less than five years and need to be performed once every four years (RVO, 2020). They are enforced and checked by

Omgevingsdienst and monitored by RVO, but only since 2019 included in an 'information obligation'.

5. *Multiple year agreement energy efficiency (MJA-3)*
   The MJA-3 is a voluntary agreement between the government and companies to improve the energy efficiency of products, services, and processes (Kruit et al., 2022). Aimed especially at larger companies (Anonymous 5, 2022).

Subsidies

6. *Subsidy sustainable small and medium-sized enterprises (MKB) (SVM)*
   Published in 2021 and aimed to subsidize energy advice for MKB enterprises. The subsidy is on-hold, due to signs of misuse of the subsidy (RVO, 2022).
7. *Promotion renewable energy (SDE++)*
   Subsidy to promote sustainable energy, in the service sector used mainly for solar pv (Kruit et al., 2022).
8. *Investment subsidy sustainable energy (ISDE)*
   Subsidy for HP, solar thermal panels, currently only available for existing buildings (Van der Born et al., 2022). It also covers subsidies for entrepreneurs for small wind turbines or solar PV panels (idem).

2.8 Research framework

The framework of this study is shown in Figure 8. The research consists of a qualitative and quantitative analysis, which together lead to policy recommendations for energy saving. The first phase of the study is the data preparation for floor area, energy intensity, energy consumption and energy applications in 2019. The results of the decomposition analysis are tested in the sensitivity analysis. In the last phase of the research, drivers and barriers of energy savings measures are identified with expert interviews. In the method section it is further elaborated how this research is performed.

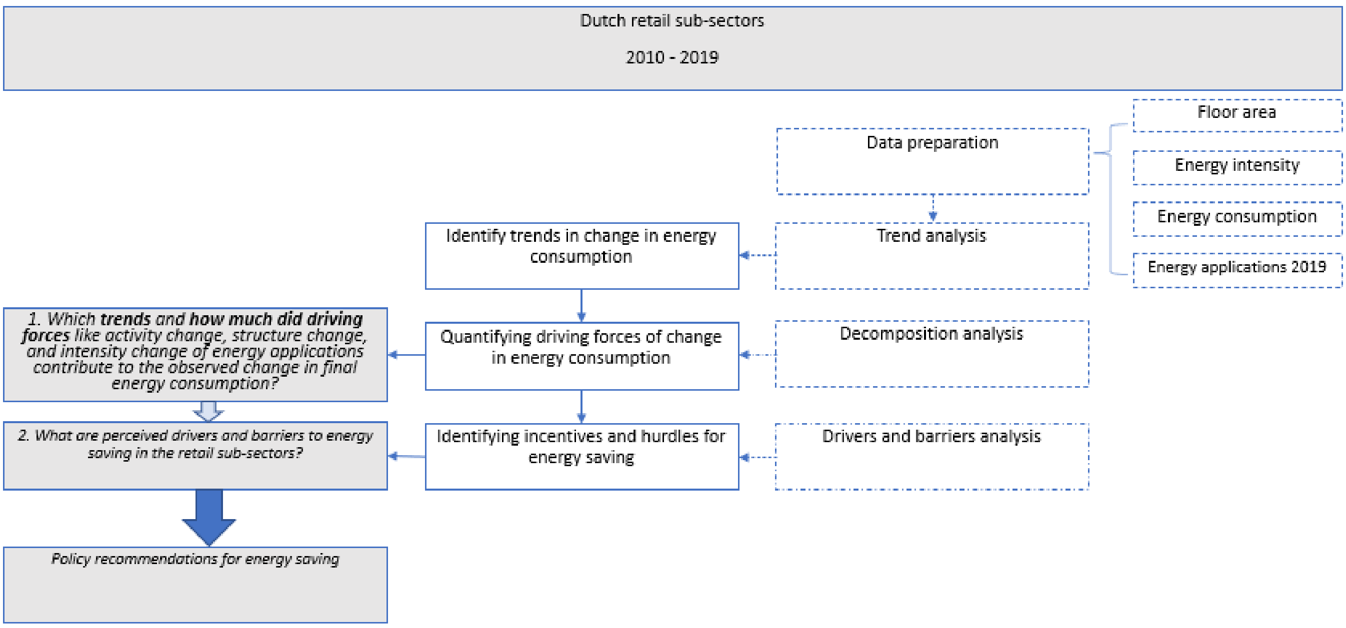

Figure 8. Research framework

3. Method

In this section, it is explained how this research is carried out. The data preparation is discussed first, followed by the trend, decomposition, and sensitivity analysis. Lastly the approach for the driver and barrier analysis is explained.

A: Data preparation

The methodology for the data preparation for floor area, energy intensity, energy consumption and energy applications is explained. In chapter 4, the intermediate results of this research phase are provided.

3.1.1 Floor area

Regarding the floor area of NF shops, the CBS buildingmatrix from the 'save S model' is expected to be an overestimation of the total area, when comparing to the CBS retaildashboard, however, no other yearly data is available (CBS, 2018). For supermarkets the openly available data from Locatus is not available for 2014, 2017 and 2019. For 2019, the CBS updated buildingmatrix is used (CBS, 2022). For the years 2014 and 2017 the average value of succeeding and preceding year is taken, see Equation 2.

Equation 2.

$$FA_i = \frac{FA_{i-1} + FA_{i+1}}{2}$$

The save S models' yearly newly constructed objects were summed and interpreted as a cumulative share of new buildings by 2019, corrected for a share of vacant buildings. This follows an underlying assumption that no 'new' buildings are added to the stock due to transformation in the building stock. An example of this could be when an office built after 2010 is transformed into a shop. To determine the share of 'constructed after 2010' for the supermarket sector, the shares from the CBS buildingmatrix are determined and applied to the floor area found by Locatus. For both supermarkets and NF shop, the cumulative share of shops 'constructed after 2010' are calculated by summing the annual new built from 2010 to 2019. This is done in the following steps.

Step i.

Calculate the percentage vacant building for each retail sector.

Equation 3.

$$Share\ vacant\ objects\ (v)_{w,i} = 1 - \frac{excl.\ vacant_{w,i}}{incl.\ vacant_{w,i}}$$

Excl. vacant	*Excluding the vacant objects for sub-sector w, and in year i [m^2]*
Incl. vacant	*All retail objects for sub-sector w, and in year i [m^2]*

Step ii.

CBS only distinguishes between supermarkets and shops without cooling. The category shops without cooling includes food speciality shops, like bakery and butchers. Since these are not included in this analysis, they need to be excluded. This is done based on the floor area found in the CBS microdata. This results in 96% of total floor area for CBS 'shops without cooling' is allocated to NF shops, therefore, 4% is excluded.

Step iii.

The shop floor area for the shops 'constructed after 2010' is determined. The cumulative (cum) newly built, is calculated while correcting for the share of vacant buildings, as determined in Equation 3. This is under the assumption that among the new buildings the share of vacant buildings is as high as for the total building stock. It seems more realistic that this share is lower for new buildings. However, no data is available, and therefore the same share is assumed.

Equation 4.

$$cum\ FA > 2010_{w,i} = \left[\sum_{i=2010}^{i} new\ buildings_w \right] * v_{w,i}$$

Step iv.

The size of building 'constructed before and in 2010' is determined as the other share of the population, see Equation 5. The buildings constructed before 2010 are approximated by:

Equation 5.

$$FA_{\leq 2010_{w,i}} = FA_{total_{w,i}} - cum. FA_{>2010_{w,i}}$$

Step v.

The share of 'constructed after 2010' and 'constructed before and in 2010' is calculated for each year between 2010 and 2019 and add up to 1.

Equation 6.

$$S_{>2010_{w,i}} = \frac{FA_{total_{w,i}}}{FA_{>2010_{w,i}}}$$

Equation 7.

$$S_{\leq 2010_{w,i}} = \frac{FA_{total_{w,i}}}{FA_{\leq 2010_{w,i}}}$$

To gain insight in the representativeness of the sample, the floor area is compared to the population for each construction period and sub-sector.

3.1.2 Energy intensity

The final energy intensity is calculated by the CBS as the energy consumption, over the usable floor area (GBO), per object for 2010 to 2019. The most recent available data is the energy consumption for 2019. The mean energy intensity for each category is calculated as the weighted mean of the sample. This means, that the mean is corrected for the object's floor area, referred to as the weighted mean. An unweighted mean, results in larger buildings weighting less heavily relative to their size than smaller buildings in the overall mean. The unweighted mean will also be collected, for the purpose of the allocation of energy by the energy applications, since it is simpler in relation to the type of appliances present. These is transformed in shares, to continue the analysis with the weighted mean.

Several filters and categorizations have been applied to the CBS microdata. These filters are applied to analyse a representative sample of shops. The first filter allows for the exclusion of 'invalid' energy intensities, these can arise due to the wrongly coupling of an object to an energy meter. The validity check therefore prescribes boundaries for energy consumption for different shop types, dependent on the floor area (Sipma, 2021, p. 222).

Filter:

1. The CBS performs a validation for the gas and electricity consumption. Shops with invalid consumption are excluded. A filter which checks for valid electricity and NG consumption and for electricity consumption only (all-electric) are applied.
2. The district heating consumption is not known by the CBS, therefore, shops attached to a DH network are excluded in the analysis.
3. Category shop function. To exclude other building function (e.g., cooled warehouse of a supermarket has a light industrial function).
4. The figures unrelated to energy consumption presented in this report, are filtered only for a valid electricity consumption in 2019 (e.g., **Error! Reference source not found.** and **Error! Reference source not found.**).

To analyse whether the NF shops can all be analysed and aggregated, a comparison of energy intensity for each type of NF shop is performed. When this analysis yields a substantial difference in energy intensity. It is decided that for the determination of the energy applications by 2019, the NF shops are categorized with two reference buildings, namely small and large.

Categories used in the analysis

1. Supermarkets and NF shops.
2. Reference buildings small and large
3. Construction period 'constructed before and in 2010' and 'constructed after 2010'
4. New variable: Als/Ag. Heat loss area compared to floor area.

The filters and categorizations are applied, and the weighted energy intensity is calculated, with Equation 8.

Equation 8.

$$EI_{w,i,c} = \frac{E_{w,i,c}}{FA_{w,i,c}}$$

The overall energy intensity is weighted for the construction period's share in the building stock.

Equation 9.

$$EI_{total_{w,i,s}} = EI_{\leq 2010_{w,i,s}} * S_{\leq 2010_{w,i}} + EI_{>2010_{w,i,s}} * S_{>2010_{w,i}}$$

The share of all-electric shops in the categories is evaluated by comparing the number of NG connections to the number of electricity connections. This could lead to a slight overestimation of all-electric shops in the sub-sector since the shops with district heating are excluded in the population.

Equation 10.

$$S_{i,c,all-electric} = 1 - \frac{N_{NG,w,i,c}}{N_{elec,w,i,c}}$$

To check the validation of the sample, it is tested for a normal distribution and analyzed for each shop type on the statistical indicators like, the median, the 25^{th} and 75^{th} quartiles, and the 5 and 95% outliers. Results are only presented when at least ten observations are present. Lastly, the energy intensity for each shop type is compared to the energy intensity found by CBS for the Dutch population (2018).

The electricity intensity provided in the CBS microdata is based on the electricity delivered by the grid. Therefore, the (marginal) share of self-consumed locally produced electricity is included manually in the total electricity consumption of 2019 in the decomposition analysis.

Equation 11.

$$E_{PE,c} = EI_{self-consumed,c} * F_c$$

3.1.3 Energy consumption

The bottom-up total energy consumption and self-consumption of locally produced energy are calculated along the following steps.

The total annual electricity consumption in a sub-sector is calculated with Equation 12.

Equation 12

$$E_{i,c,elec} = EI_{i,c,elec} * FA_{i,c}$$

The total annual natural gas consumption is calculated with the energy intensity but corrected for the number of all-electric shops.

Equation 13

$$E_{i,c,NG} = EI_{i,c,NG} * (1 - S_{i,c,all-electric}) * FA_{i,c}$$

Additionally, the temperature corrected NG consumption is calculated, see Equation 14. A simple ratio-based normalization is be applied (Ouf & Issa, 2017). For simplicity, a relative temperature correction is applied with normalization year 2019.

The relative temperature correction is performed with the following formula.

Equation 14.

$$EI_{i,c,NG\_temp\ corr} = (EI_{i,c,NG} - EI_{tapwater}) * \frac{HDD_{2019}}{HDD_i}$$

Based on (Ouf & Issa, 2017)

HDD_i	*Number of heating degree days for normalized year 2019 and specific year i*
$EI_{i,c,NG}$	*Natural gas demand in year i [m³/m²]*
$EI_{tapwater}$	*Natural gas demand for hot water [m³/m²]*
$EI_{i,c,NG\_temp\ corr}$	*Normalized heating demand [m³/m²]*

The overall energy consumption of a sub-sector in year *i* is calculated by summing the electricity and natural gas consumption for the two construction periods, see Equation 15. This is also done for temperature corrected NG consumption, leading to a temperature corrected final energy consumption.

Equation 15

$$E_i = \sum_{c,s}^{4} E_{i,c,s}$$

3.1.4 Energy application

The energy intensity by application is determined for 2010 and 2019. The approximation of energy by application for 2019 requires extensive data preparation. A combination of a bottom-up, or energy audit methodology is applied to break down the electricity consumption in applications. For NG, only two energy applications are relevant, i.e., space heating and hot water, therefore, a top-down method is applied. Space heating is assumed to be the residual of theoretical hot water consumption. For electricity, the intensity for each application is determined individually, which are summed and compared to the total electricity intensity. This is done for supermarkets, and for two reference NF shops, to account for heterogeneity in shop types. NF shops large, and small, result in NF shops average. The route to determine the consumption of energy applications is visualized in Figure 9.

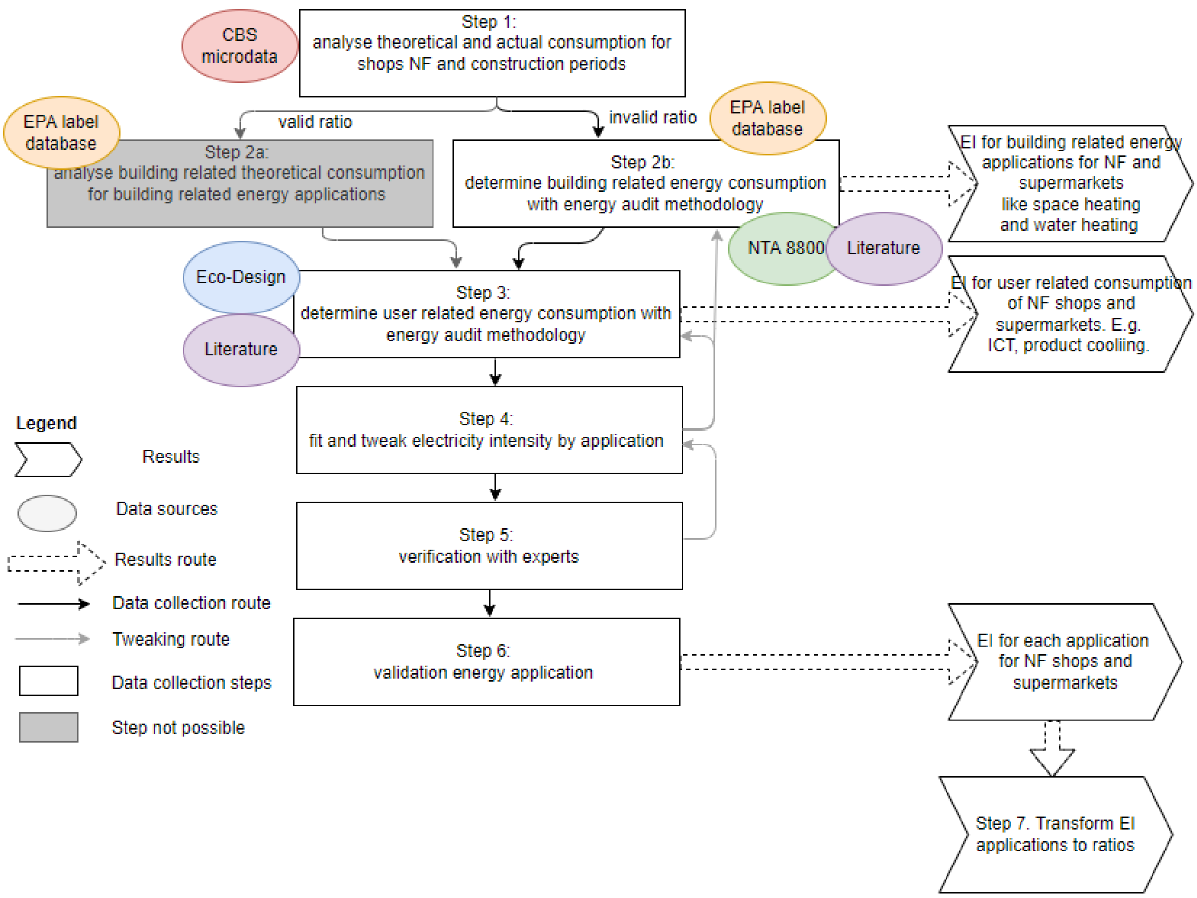

Figure 9. Route to establish sub-sectoral energy end-use with data sources in ovals

Step 1: *ratio theoretical and actual energy consumption*

Analyse ratio theoretical and actual consumption for NF shops and construction periods, since it shows the ratio of building related over total energy consumption. Only NF shops are analysed, to exclude for the influence of product cooling and product processing in supermarkets. The validity of the ratio is evaluated with the ratios found for building related over total energy by the Energy check-up (2018) and Meijer & Verweij (2009).

Step 2b: ***bottom-up approach building related consumption***
Since no valid ratio is found in step 1, the bottom-up, or energy audit methodology is chosen. Based on interviews with energy audit experts, insight in the usual energy audit procedure is gathered. Energy audit companies estimate the capacity, operating time and load factors of the installed appliances based on an in-house visit and available data (AN7). The energy label database is used to estimate the relevant appliances for electricity and NG. Methodology of the NTA 8800 (NEN, 2020), survey research by Panteia (2020), and other literature is used to gather the capacity, operating time and capacity factors, as shown in Equation 16. The following building-related energy applications are approximated.

- Space heating
- Hot water
- Space cooling
- Ventilation
- Auxiliary equipment
- Indoor lighting
- Solar PV or 'self-consumed produced energy'

Equation 16.

$$E = P * t * CF$$

(Blok & Nieuwlaar 2017)

E	Energy consumption (kWh/year)
P	Capacity (kW/m^2)
t	Operating time (h/year)
CF	Capacity factor

Step 3: ***user related applications***
The user related consumption is directly dependent on the building related consumption. Again, the energy audit methodology is applied, see Equation 16 above. The assumptions for capacities are based on literature, such as Freitas (2007). For NF shops, a table is set-up to determine for each shop type, to what extent an energy application is relevant. For instance, many home and garden shops have a coffee corner whereas most clothing shops do not. Below, the considered user related energy applications are listed.

Equation 17.

$$EI_{user} = EI_{actual} - EI_{building}$$

The considered applications are

- Product processing
- Product cooling
- ICT centralized
- ICT decentralized
- Transport
- Light outside

- Light emergency
- Food and drink facility
- Other

Step 4: *tweaking*
The building and user related consumption are gathered and compared with the actual energy intensity, and tweaked. To make the allocation of appliances more straightforward, to this extent the unweighted mean is used. This is a continuous process, with insights from the steps 5 and 6 below. This method is often applied in energy audits when data and time are limitedly available (AN7).

Step 5: *validation*
For the verification, energy audit experts are approached, AN7, AN11, INNAX, were willing to cooperate. The results of the bottom-up methodology are shared, and the experts are asked to review the results. These insights are applied when seemed relevant and applicable to the reference buildings.

Step 6: *verification*
Similarities and differences to the results from the Energy check-up (2018) and Meijer & Verweij (2009) are evaluated, and further tweaking is applied. This results in the final energy intensity by application for the two sub-sectors, for two reference buildings for NF shops.

Step 7. *transform to shares*
In the last step, both the energy consumption by application of gas and electricity are transformed into shares (*S*), see Equation 18. This enables the calculation with the weighted mean, instead of the unweighted mean.

Equation 18.

$$S_e = \frac{EI_e}{EI_{total}}$$

The intermediate results of the data preparation are presented in chapter 4.

B: Trend analysis

To answer SQ1, for each sub-sector a trend analysis is performed. This analysis is done both the total energy consumption, and the driving forces, the energy carriers natural gas and electricity, floor area, construction period, and share of all electric, for the period 2010 to 2019. Temperature corrected and uncorrected results are shown. The analysis is visualized with line diagrams and is interpreted on the direction of change. Additionally, the overall change between 2010 and 2019 is determined for the energy consumption. This is done with the basic formula, Equation 19. The trend analysis should also evaluate whether the proposed two datapoint comparison is valid, which is evaluated by the stability of a trend over the years. The trend analysis will then be broken down in a decomposition analysis. The change in energy applications energy intensity is also evaluated. This is visualized, and Equation 19 is used to evaluate the change. Based on expert insights and literature, it is evaluated whether the observed change in intensity is in line with expectations. This provides a first indication for the robustness of the results and indicates whether the energy application should be further considered in the decomposition analysis. It also provides as input for the sensitivity analysis.

Equation 19.

$$Per\ centage\ change = \frac{new - old}{old} * 100\%$$

C: Decomposition analysis

The decomposition analysis is performed in an Excel sheet. Ang, Liu & Chew (2003) recommends the substitution of zeros with a small positive constant. This is relevant for some energy applications, like electric space heating in 2010, and the energy consumption of 'constructed after 2010' in 2010. So, zeros are replaced by $10*10^{-100}$. The calculations steps are internally checked since the sum of an effect for an application should represent the overall change in energy consumption of that application. Internal checks are performed throughout the process. The decomposition effects are described in Table 4., and are calculated with the following equations.

Table 4. Identities decomposition analysis

Effect	Indicator	Formula form
	Energy consumption in sub-sector [PJ]	E
Activity	Floor area [m²]	F
Structure	Share area of total for construction period	$\frac{F_c}{F}$
Intensity	Energy intensity for construction period and end use [PJ/m²]	$\frac{E_{c,e}}{F_c}$
Substitution effect	Energy carrier substitution (natural gas and electricity), for construction period for HW and SH	$\frac{E_{c,e,s}}{E_{c,e}}$

Where:

c	*Construction period*
e	*Energy application*
s	*Energy carrier*

For both years, the energy consumption is written as Equation 20. Where *F* represents the activity in the sub-sector, G_c the activity share in construction period *(c)*, H_c is the comparison of energy intensity for the in the end use *(e),* and construction period *(c)*. $I_{c,s}$ is the substitution effect of the fuel mix *(s)*. It represents the replacement of natural gas by electricity for the construction period *(c)*. It is evaluated for applications *(e),* space heating and hot water. The weather correction is calculated separately with Equation 25, and is only applicable to 2010.

Equation 20.

$$E = \left[\sum_{c,s,e} F * \frac{F_c}{F} * \frac{E_{c,e}}{F_c} * \frac{E_{c,s,e}}{E_{c,e}}\right] = \left(\sum_{c,s,e} F * G_c * H_{c,e} * I_{c,s,e}\right)$$

Equation 21.

$$\Delta E_{act} = \sum_{c,s,e} L\left(E^T_{c,s,e}\,, E^0_{c,s,e}\right) \ln\left(\frac{F^T}{F^0}\right) = \sum_{c,s,e} \frac{\left(E^T_{c,s,e} - E^0_{c,s,e}\right)}{\ln E^T_{c,s,e} - \ln E^0_{c,s,e}} \ln\left(\frac{F^T}{F^0}\right)$$

Equation 22.

$$\Delta\mathrm{E_{str}} = \sum_{c,s,e} \frac{\left(E^{T}_{c,s,e} - E^{0}_{c,s,e}\right)}{\ln E^{T}_{c,s,e} - \ln E^{0}_{c,s,e}} \ln\left(\frac{G^{T}_{c}}{G^{0}_{c}}\right)$$

Equation 23.

$$\Delta\mathrm{E_{int}} = \sum_{c,s,e} \frac{\left(E^{T}_{c,s,e} - E^{0}_{c,s,e}\right)}{\ln E^{T}_{c,s,e} - \ln E^{0}_{c,s,e}} \ln\left(\frac{H^{T}_{c,e}}{H^{0}_{c,e}}\right)$$

Equation 24.

$$\Delta\mathrm{E_{sub}} = \sum_{c,s,e} \frac{\left(E^{T}_{c,s,e} - E^{0}_{c,s,e}\right)}{\ln E^{T}_{c,s,e} - \ln E^{0}_{c,s,e}} \ln\left(\frac{I^{T}_{c,s,e}}{I^{0}_{c,s,e}}\right)$$

The weather correction is calculated for 2010 and is visualized separately in the waterfall diagrams. It is only performed for space heating with NG.

Equation 25.

$$E_{WE,c} = \left(E_{space\ heating,\,NG} * \left[\frac{HDD_{2019}}{HDD_{i}}\right]\right) - E_{space\ heating,\,NG}$$

The results are visualized with waterfall diagrams. The results by energy applications are visualized in a histogram. The analysis is performed by breaking down the effects one by one. First, the overall summed effects are evaluated for the two sub-sectors. These overall effects are further broken down for the intensity effect of the energy applications. To prevent repetition in the presentation of the results, the further break down is only performed for the construction period ‘constructed before and in 2010’, which enables the analysis of changes within the same type of building. Both the intensity and substitution effect are broken down by energy application. The substitution effect is broken down in the energy carriers NG and electricity for ‘space heating’ and ‘hot water’, to analyse fuel substitution in the sub-sectors.

D: Sensitivity analysis

The outcomes of the decomposition analysis are evaluated on their robustness with a sensitivity analysis. A sensitivity analysis is a systematic evaluation of the results, by changing non-controllable inputs (Kleijnen, 1994). Two types of sensitivity analyses are applied. The deterministic sensitivity analysis is performed by manually adjusting input parameters (Perraillon, 2020). To quantify the likeliness of an outcome, a probabilistic sensitivity analysis is used to account for the probability of these extreme values (Kleijnen, 1994). The common distributions are described in further detail below.

Table 5. Probability distributions

Probability Distribution	**Description** **Based on (McMurray, Pearson & Casarim, 2017)**
Normal	Specified by a mean and standard deviation. Applied when the range of uncertainty is small and symmetric relative to the mean
Uniform	Specified by minimum and maximum value. It is used when insufficient information is available to assess which distribution is most likely, therefore it assumes that the values are equally likely.

Triangular	specified only by minimum, maximum and most likely value. Also used for limited data availability.
Lognormal	Used to replace a normal distribution when it is assumed that most data is positive. Applied for >30% coefficient of variation.

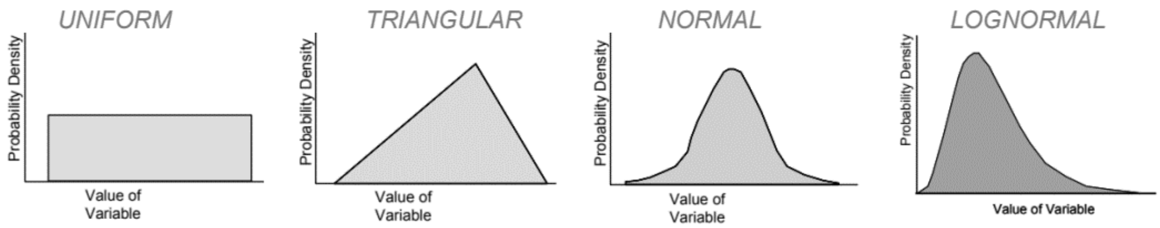

Figure 10. Common probability distributions (IPCC, 2006)

The sensitivity analysis is performed in two steps. First, a deterministic sensitivity analysis is performed. The overall trend in energy consumption is validated, based on insights from literature, as it was already shown that floor area is related to uncertainty. Based on literature insights, applicable steps in deviation are applied.

Second, a probabilistic analysis of the energy applications is performed. Uncertain applications are replaced by a distribution. One application is chosen as the residual, so that the total energy consumption remains constant. The results are compared to the original results. The difference is visualized and is interpreted quantitatively.

The deterministic sensitivity analysis is performed empirically with a Monte Carlo simulation, which is modelled with '@Risk' in Excel. For the simulation, 10,000 iterations and 4 simulations are run to calculate the results. When the direction of sensitivity of an energy application is unknown, a normal distribution is applied. The general approach is, to keep the mean constant, and to set the standard deviation as 10 per cent of the mean. When the direction of sensitivity is known, a triangular distribution is applied. If applicable, changes of 1 per centage points are applied, otherwise, changes in steps of 10% of the mean are analysed.

The following steps in the uncertainty analysis are taken.

1. Determine which applications are associated with large uncertainty. The expert interviews performed earlier on are input to this.
2. Determine the residual application.
3. Fit distributions to these input data.
4. Run Monte Carlo simulations with 10,000 iterations and 4 simulations.
5. Compare sensitivity results to original results, by subtracting the new from the old results. Also the per centage change is evaluated. Based on these insights it is determined if the results are robust.

E: Driver and barrier evaluation

The last sub-questions are related to the interpretation and implications for energy savings. The evaluation of drivers and barriers of energy saving measures is performed with semi-structured interviews. Actors were asked to bring forward drivers and barriers for energy savings. Retail specific experts were interviewed to gather information on energy consumption. Firstly, multiple researchers in terms of energy consumption of the service sector were interviewed. Secondly, a sustainability and asset manager advisor were consulted. Thirdly, a representative of a networking organisation for sustainability in the retail sector was included for interviewing. Fourthly, interviews were conducted with several energy advisors, who are specialized in the study of energy consumption and savings in the retail sector or specifically supermarkets. Furthermore, to gain insight in the energy consumption 'on the workplace' an energy manager of a supermarket and two shop employees of NF shops were interviewed. The aim for the interviews was to gather information from experts from diverse backgrounds. An overview of the interviewees is found in the Table 6.

Table 6. Overview interviewees and their expertise

Field of expert	Interview reference	Field of expertise	Interview specific questions
Service sector researchers	AN1, AN4, AN2, AN5	Service sector/policy	Reflect on policy
Retail and sustainability advisor	AN3	Retail/asset management	Reflect on split incentive and view asset owners
Non-profit networking organization for sustainability in retail	AN6	Retail/sub-sector collaboration	Reflect on support for maximized consumption
Energy advisor retail	AN7, AN11, INNAX	Supermarkets, retail/energy consumption	Reflect on energy savings
Energy manager supermarket	AN8	Supermarkets/in practice/sub-sector collaboration	Reflect on energy savings
Shop employee NF	AN9, AN10	NF/in practice	Reflect on awareness and energy spill ‘in the workplace’

The interviews were semi-structured. Dependent on the field of expertise, the interviewees were asked to reflect further on topics, as shown in Table 6. The interviews were able to view the results of the quantitative analysis before-hand, and several open-ended questions and topics were sent as preparation. These questions are provided in Annex B: Interview questions. The interviewees got the chance to review the documentation of the interview and had the opportunity to make remarks in relation to the interpretation of the interview.

4. A: Data preparation

4.1 Floor area

The floor area of the Dutch population of retail is determined. The floor area of and underlying assumption for supermarkets is shown in Table 7**Error! Reference source not found.**, the population is shown in Table 8.

Table 7. Shop floor area (WVO) for supermarkets

Year	Floor area [million m^2]	Assumptions	Source
2010	3,69		Consultancy.nl, 2013
2011	3,72		Consultancy.nl, 2013
2012	3,74		Consultancy.nl, 2013
2013	3,75		Consultancy.nl, 2013
2014	3,79	Interpolation 2013 and 2015	
2015	3,83	Only the 19 largest supermarket operators	Vastgoedmarkt, 2016
2016	3,74	Only the 19 largest supermarket operators (until October 2016)	Vastgoedmarkt, 2016
2017	3,91	Interpolation 2018 and 2016	
2018	4,09		CBS, 2018
2019	4,20	No WVO floor area found, therefore CBS updated building matrix with GBO is used	CBS, 2022

Table 8. Floor area of the population in the retail sector [million m2] (based on

	Overall		**'before and in 2010'**		**'after 2010'**	
	Supermarkets	NF shop	Supermarkets	NF shop	Supermarkets	NF shop
2010	3,69	45,0	3,69	45,0	0,00	0,0
2011	3,72	45,4	3,70	45,1	0,02	0,3
2012	3,74	46,1	3,70	45,5	0,04	0,5
2013	3,75	46,9	3,68	46,0	0,07	0,9
2014	3,79	47,3	3,70	46,1	0,09	1,2
2015	3,83	47,6	3,72	46,1	0,11	1,5
2016	3,74	48,0	3,62	46,3	0,12	1,7
2017	3,91	48,6	3,78	46,6	0,13	1,9
2018	4,09	48,9	3,94	46,7	0,15	2,2
2019	4,20	48,5	4,05	46,2	0,15	2,3

Sample compared to population

This sample of buildings originates from the CBS microdata with verified energy consumption. The sample consists of 9258 shops, where NF shops are in absolute terms mostly represented, see Table 9. The Dutch population of shops is estimated at 125 thousand shops without cooling and 900 supermarkets (CBS, 2021a). For NF shops, the sample represent about 7 to 9% of the population. For supermarkets this is considerably higher. It is shown that the number of supermarkets 'constructed after 2010' is larger in the sample than the estimated population. This could be due to transformation of buildings, which implies that a building 'constructed after 2010' is first delivered as a non-supermarket but is transformed into a supermarket afterwards. Also, the estimate of 'newly constructed' supermarkets is most likely an underestimation, which is a consequence of earlier recognized wrong estimates of floor area of supermarkets. Although the ratios have been taken for newly constructed buildings, it can still be an explanation for underrepresentation. The new supermarkets are also monitored very intensively regarding the energy consumption (AN7). This leads to extensive data availability compared to the other categories. Furthermore, it is by far the smallest category, which makes it more sensitive to errors in estimates.

Table 9. Sample and population comparison

Category	Sample (based on electricity in 2019) [m²]	Population (based on Save S) and Locatus [m²]	Share sample of population	Share construction period of total
NF ≤ 2010	3,155,701	46,159,908	6.8%	95.2%
NF > 2010	212,966	2,333,164	9.1%	4.8%
NF Total	3,368,667	48,493,072	6.9%	
Supermarkets ≤ 2010	738,831	4,047,554	18.3%	96.3%
Supermarkets > 2010	156,525	153,446	102%	3.7%
Supermarkets total	895,356	4,201,000	21.3%	

4.2 Energy intensity

4.2.1 Energy intensity analysis

The energy retrieved from the CBS microdata is analyzed. First the statistical distribution and next the intensity for each shop type is shown.

Check for normal distribution

To perform statistical analysis, a normal distribution is desired (Glass et al., 1972). The analysis for the distribution of energy intensities showed a right skewed distribution, both for electricity, see Figure 11 and NG, see Figure 12. The Smirnov normality test did not give normality for any type of shop and energy carriers. Adjusting the data with log, cube, square root, did not change this result. Therefore, it needs to be noted that while performing and presenting the results, they are not evenly distributed. However, Glass et al. (1972) stated that for larger sample sizes, result can be used without the normality condition.

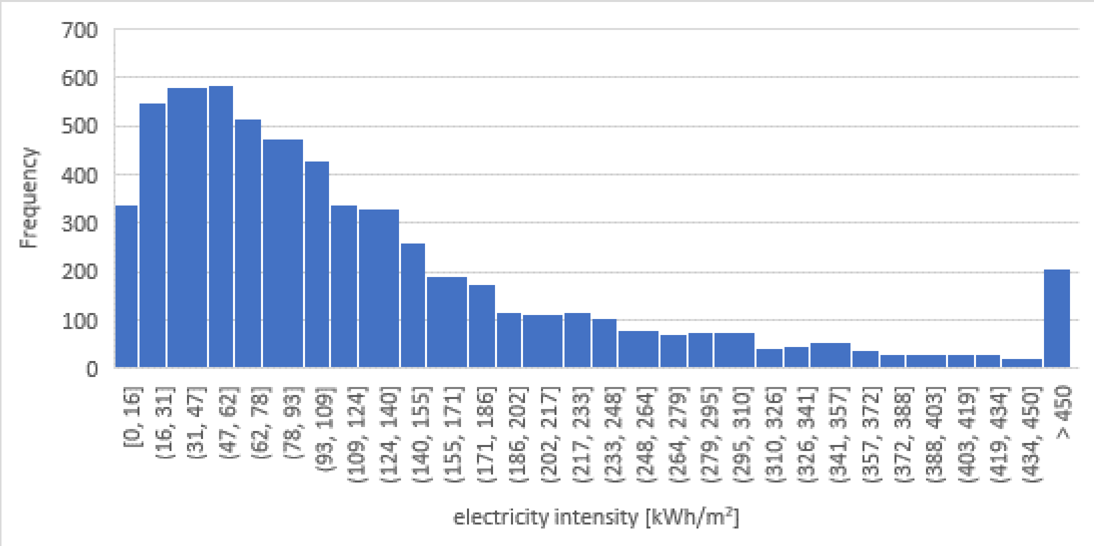

Figure 11. Frequency table of electricity intensity of all shops in 2019 (CBS microdata, 2022)

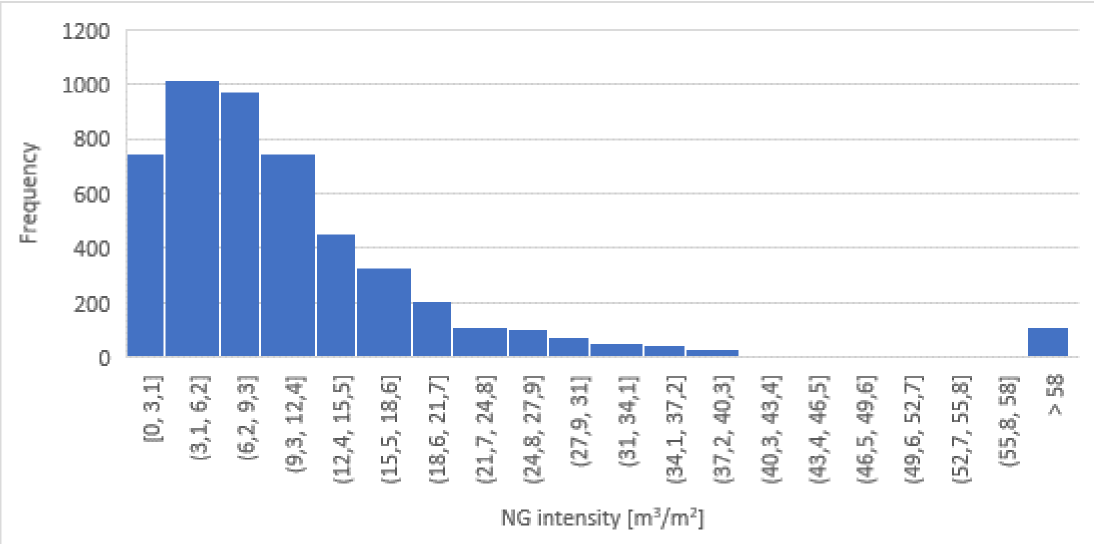

Figure 12. Frequency table of NG intensity of all shops in 2019 (CBS microdata, 2022)

Analysis energy intensity by shop type

It is shown that for NG, the mean and median differentiate substantially, see Figure 13. This is a result of the right skewed distribution earlier. The whiskers show the large variation in the population even within shop types. In Figure 14, the variation for electricity is shown. This is largest for supermarkets.

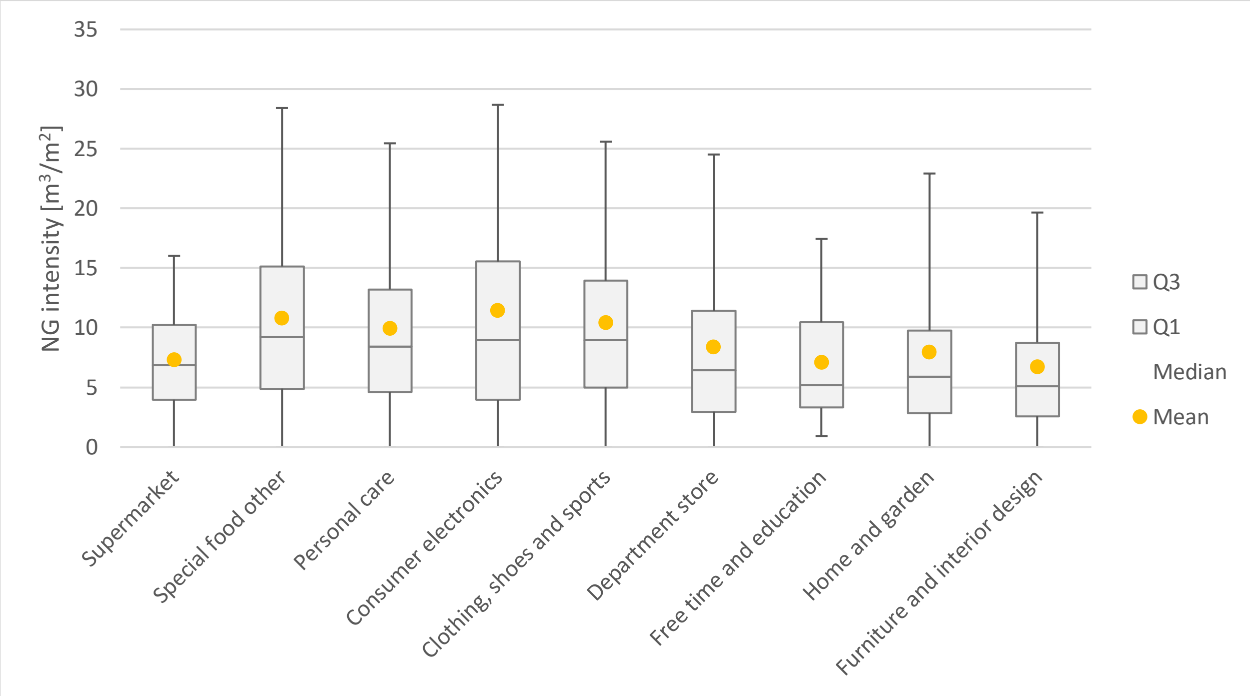

Figure 13. NG intensity statistical analysis for the shop types, in the whiskers the 5% and 95% are visualized (CBS microdata, 2022)

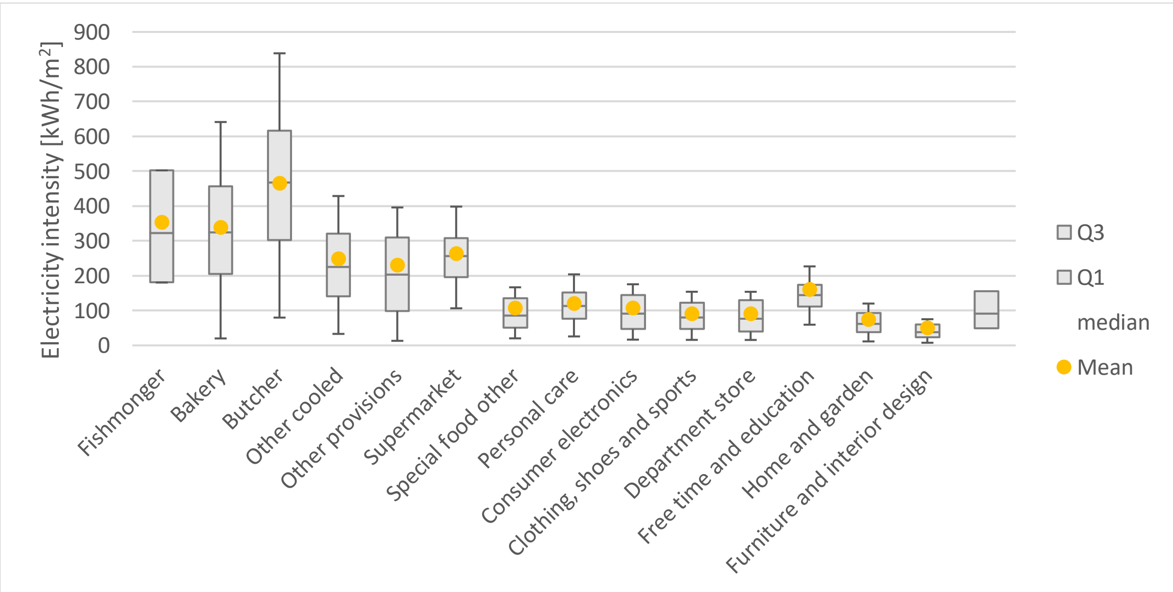

Figure 14. Electricity intensity statistical analysis for the shop types, in the whiskers the 5% and 95% are visualized (CBS microdata, 2022)

4.2.2 Validation energy intensity

To gain insight in the sample validity, the CBS retail dashboard is used for comparison and validation. Since this research calculates the energy consumption based on the floor area and the intensity, the energy intensities are compared in Figure 15 and Figure 16. It is shown that for several shop types, the energy intensities vary substantially. A first explanation is that a different filter is applied in the retail dashboard, namely a minimum floor area of 50 m^2. About 20% of the retail is excluded with this filter (CBS, 2018). NG intensity is known to decrease steadily with a larger floor area (CBS, 2019). Smaller shops have a higher energy intensity, therefore, excluding small shops would lead to a lower overall energy intensity in the dashboard. This could explain the NG intensity varying more for the smaller shops (e.g., consumer electronics) than for the larger shops (e.g. home and garden shops). Dutch supermarkets are never smaller than 50 m^2 (CBS, 2018). For electricity, this trend is less clear, although a steady difference is visible in Figure 15. Another explanation could be that it is not provided whether the CBS retaildashboard works with average values based on floor area or on number of shops. A comparison has been made between the two methods, and based on the NG intensity, it is assumed that it is most likely that the energy intensities are based on the number of shops. A last reason could be the definition of shop type, which could differ between the BAG and Locatus. Data from Locatus is not included in the sample, whereas Locatus and the BAG are combined in the dashboard (CBS, 2018). Especially when an object has multiple functions, ambiguousness in the type of shop could arise and therefore allocation of energy consumption to the wrong shop type.

To conclude, the validation of the energy intensity of shop types is complicated, due to several reasons. Nevertheless, the intensities are still assumed to be appropriate for further analysis, due to the large sample size.

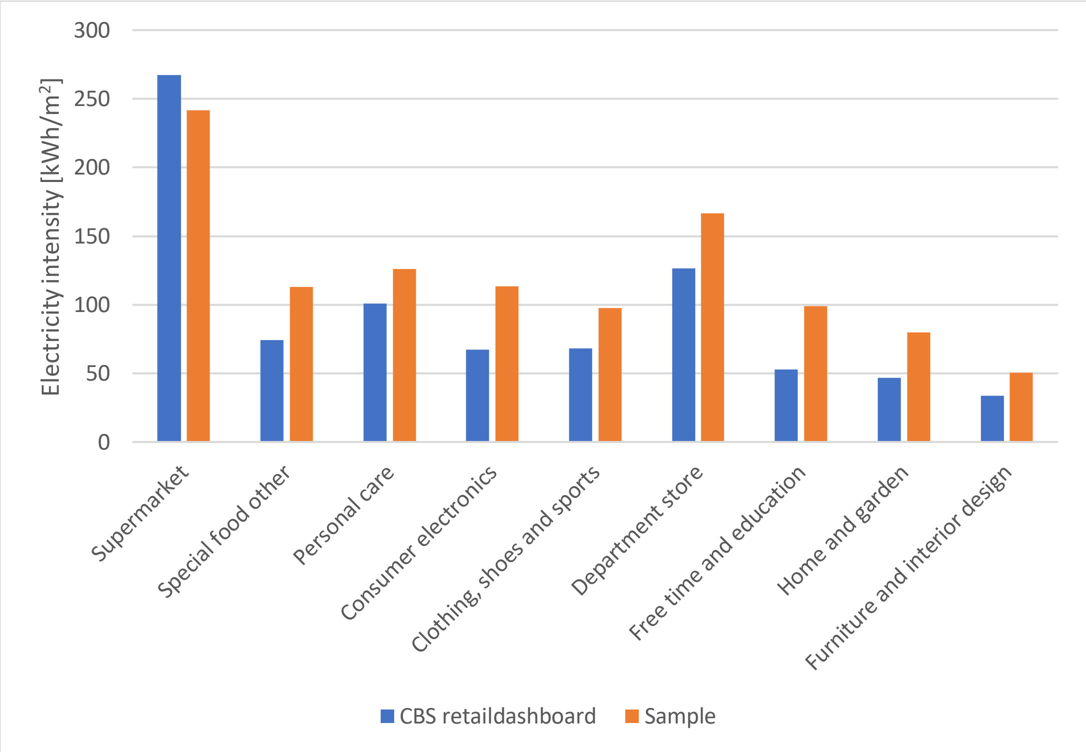

Figure 15. Unweighted comparison of electricity intensity in 2018 for shop types (Based on CBS Microdata, 2022; CBS, 2018)

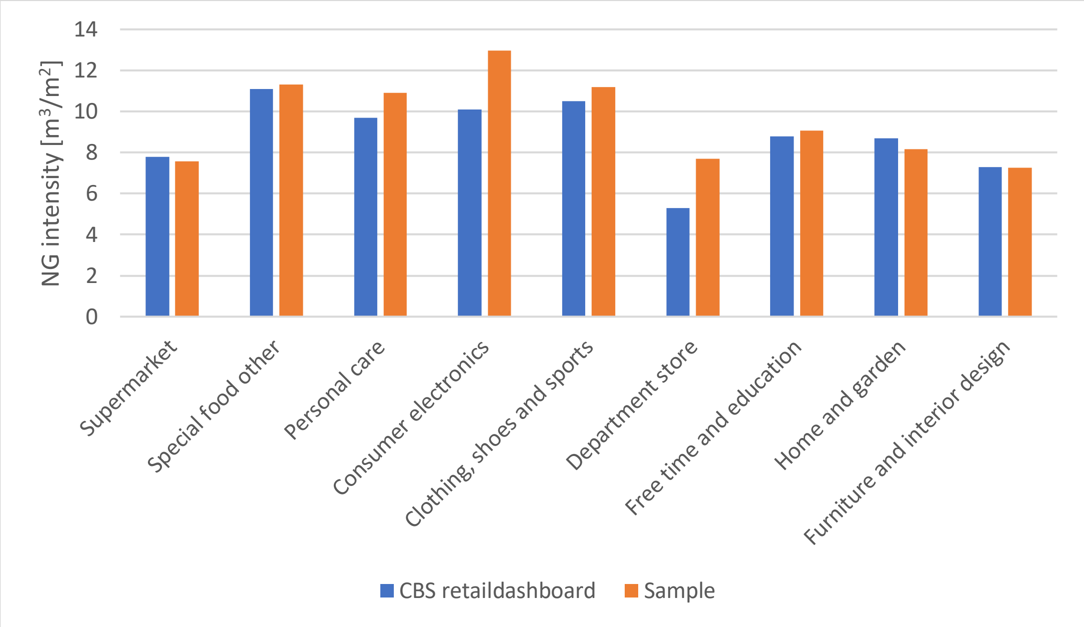

Figure 16. Unweighted comparison of NG intensity in 2018 for shop types (Based on CBS Microdata, 2022; CBS, 2018)

4.2.3 Reference buildings

The combined insight of the energy intensities, shown in Figure 15 and Figure 16, and the characteristics of the shop types, shown in Table 10, the categorization for two reference buildings of NF shops is made. For ‘large’, home and garden, furniture and interior design and department stores are considered. For ‘small’, special food other, personal care, consumer electronics, clothing shoes and sports and free time and education are considered. The characteristics of the reference buildings are shown in and Figure 17. It is found that the construction year of remarkably low, namely 1931. This is caused by the many shops being present in historic city centres.

Table 10. Characteristics of shop types (based on CBS microdata, 2022)

	Category	N shops	Mean floor area [m^2]	Reference building
Supermarket	supermarket	651	1326	Large
Special food other	non food	309	136	Small
Personal care	non food	1221	241	Small
Consumer electronics	non food	411	277	Small
Clothing, shoes and sports	non food	2976	316	Small
Department store	non food	108	1777	Large
Free time and education	non food	691	255	Small
Home and garden	non food	1067	874	Large
Furniture and interior design	non food	853	930	Large
Food	Large	651		
Non-food	**Sub-total**	**7636**		
Non-food	Small	5608		
Non-food	Large	2028		
	Total	**10095**		

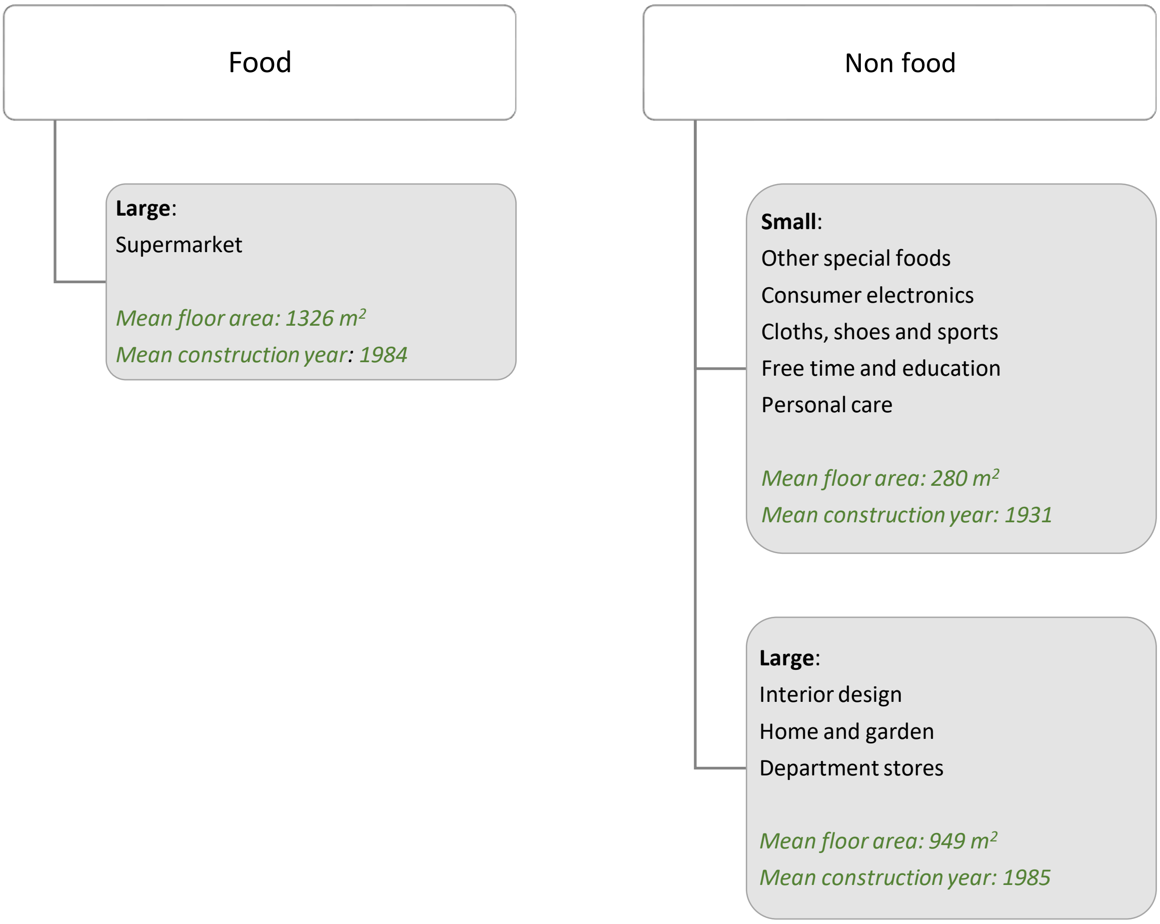

Figure 17. Food and NF categorization with mean floor area and construction year (based on CBS microdata, 2022)

4.2.4 Intermediate results

The resulting energy intensity for 2019 are shown, in Table 11 the unweighted energy intensity is presented for the reference buildings. These results will only be used for the allocation of energy by application. In Table 12, the weighted energy intensities and share of all-electric is shown.

Table 11. Unweighted energy intensity in 2019 (based on CBS microdata, 2022)

Energy carrier	**NF small**	**NF large**	**NF average**	**Supermarket**
NG [Nm^3/m^2]	9.2	6.8	8.5	5.5
Electricity [kWh/m^2]	99.5	68.4	91.3	264

Table 12. Weighted energy intensity in 2019 (based on CBS microdata, 2022)

	Overall		**'Before and in 2010'**		**'After 2010'**	
	Supermarkets	NF shop	Supermarkets	NF shop	Supermarkets	NF shop
All-electric [%]	21	10	21	9	55	17
NG [Nm³/m²]	5.8	6.0	8.6	6.1	7.74	2.52
Electricity [kWh/m²]	247	75	258	75	199	68

4.3 Energy application

4.3.1 Step 1: Analyse ratio

The comparison of theoretical and actual intensity for reference buildings for NF shops are shown, and further differentiated by building period. The NTA method largely overestimates the actual electricity consumption, see Figure 18. The EPA method seems more accurate, but still seems to overestimate the building related consumption. Based on previous research by Meijer & Verweij (2009), 79% building related is expected for electricity, and the Energy check-up (2018) estimated 85%. A difference in electricity consumption between small and large NF shops is observed.

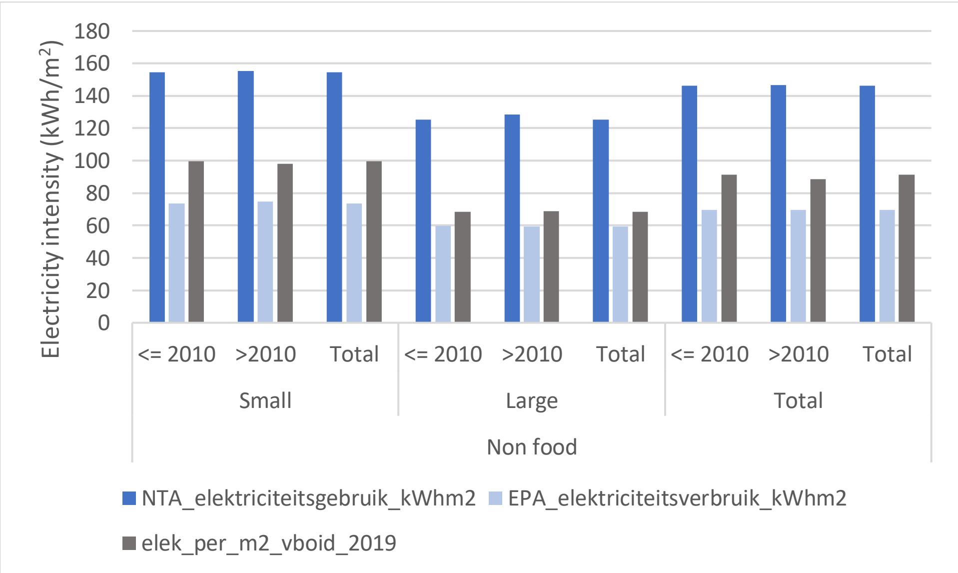

Figure 18. Theoretical and actual electricity consumption of NF shops in 2019 (CBS microdata, 2022)

For natural gas both the EPA and NTA method yield an overestimation of the consumption, see Figure 19. Meijer & Verweij (2009) considered all NG consumption to be building related. Again, difference between small and large shops is observed. Smaller buildings having a higher natural gas and electricity intensity. For NG also a clear difference between the construction periods is observed.

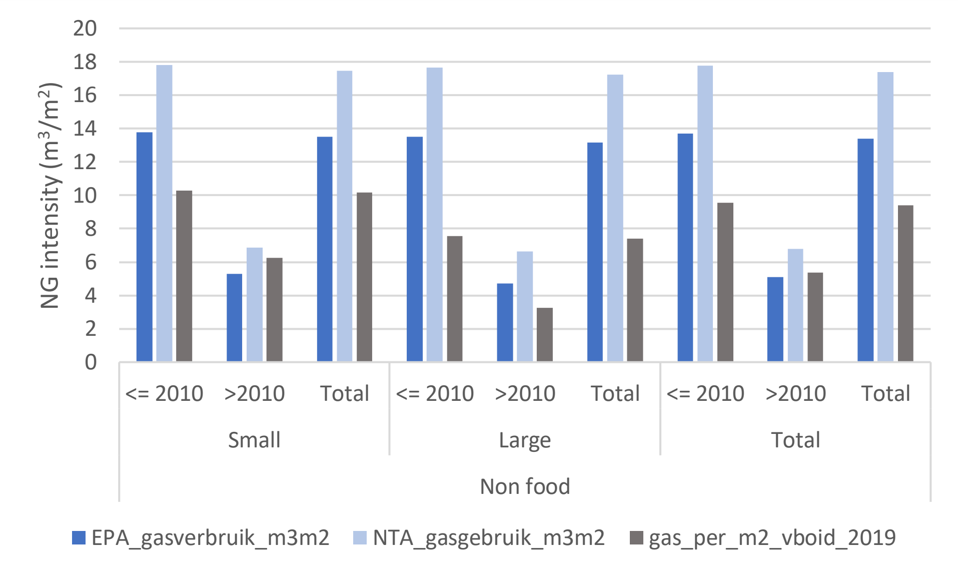

Figure 19. Theoretical and actual natural gas consumption of NF shops in 2019 (not temperature corrected) (CBS microdata, 2022)

To analyse whether the overestimation of NG can be allocated to the temperature correction, the HDD methodology is applied. Performing a temperature correction yields the following building related fit, Table 13. The EPA accounts for 3125 HDD, the NTA for 2725 HDD and 2019 were 2648 HDD (corrected for the density of NG in the Netherlands) (KWA, 2022).

Table 13. Theoretical building related fit for shops non food

Construction period	NTA elec	NTA gas	EPA elec	EPA gas
<= 2010	160%	115%	76%	121%
>2010	166%	62%	79%	81%
Total	160%	114%	76%	121%

Since the results for theoretical calculations for both theoretical methods do not yield the desired building related consumption, route 2B is taken.

4.3.2 Step 2b: Building related

A concise summary of how the bottom up building related energy consumption is determined is described in Table 14. The steps are performed for all three reference buildings, Annex 1.1, a detailed description of the method, assumptions, and intermediate results are given.

Table 14. Overview determination method building related energy application

Energy application	Description method
Hot water	Theoretical energy consumption based on the NTA. Correct for storage losses and efficiencies. Share NG and electricity boilers based on Energy label dataset.
Space heating	Determined with based on NG intensity correcting for hot water and share of all-electric, based on the CBS microdata. Calculate average efficiency of NG heating. To determine electric heating demand with heat pump. Assumption that all shops are heated with appliance.

Space cooling	Theoretical indication of cooling demand, based on reference buildings. Correct for the number of shops with cooling appliances according to Energy label dataset.
Ventilation	Based on NEN 2916 method ventilation requirement with new building directive requirement. Number of shops with ventilation is based on Energy label dataset.
Auxiliary equipment	Based on INNAX, correct for share of pumps needed for heating and cooling.
Indoor lighting	Monitoring research for share of efficient lighting. Account for capacity factor and opening hours of the shop.
Emergency lighting	Theoretical data for shops
Solar PV	CBS microdata weighted averages of NTA theoretical production minus the feed in electricity is self-consumption of electricity

4.3.3 Step 3: User related

The user related energy consumption is estimated with the method described below, see Table 15. In Appendix 1.2, a detailed description of the method, assumptions and results is given.

Table 15.Overview determination method user related energy application

Energy application	**Description method**
Outdoor lighting	Estimations on number of lamps per reference building
ICT decentralized	Estimations on number of laptop, monitors, PC and cash registers per reference building. Energy consumption via Eco-design.
ICT centralized	Assumption that all supermarkets require a server room. Several NF shop types are also assumed to have a server room. Literature for energy consumption.
Food/drink facilities	Staff kitchen, lunch or coffee corner and vending machine. Assumptions on applicability per shop type. Energy consumption via Eco-design, literature like Freitas (2007).
Transport	Indoor transport by escalators and elevators. Applicability based on CBS microdata. Literature research for energy consumption.
Product processing	Electric product processing with grills and ovens. Assumptions made on operating time and number of appliances.
Product cooling	Number of refrigerators and freezers based on the share of cooled supermarket area. Additional cooling island added. Eco-Design, best available technology.
Other	Residual

4.3.4 Step 4: Combine and tweak

For the NF shops, tweaking of 'other' has taken place, as the residual electricity was allocated fully to other. For supermarkets, tweaking of 'product cooling' and 'product preparation' has taken place. For product cooling, the shares of the floor area of the store cooled (Table 63) and the number of open coolers (self-service counters) were tweaked. Initially 5 and 10% of frozen and cooled floor area was chosen, with insights from INNAX, the open coolers were added, and the shares were tweaked down.

Product preparation refers to the bake-off, with insight from INNAX they operating time was intensified.

4.3.5 Step 5: Verification

Firstly, the building and user related consumption shares are compared. In Table 16 the results are shown. Regarding the Energy check-up (2018), it is unclear what is included in the category 'shops cooled'. Since most literature refer to supermarkets, this is assumed. In the table it is shown that the 'bottom up' shares are comparable to previous research.

Table 16. Validation building and user related energy

	2007 (Meijer, 2009)			**2017 (Energy check-up, 2018)**	**2019**		
	energy	**NG**	**electricity**	**electricity**	**energy**	**NG**	**electricity**
Shops non food							
Building related	92%	100%	79%	85%	82%	100%	67%
User related	8%	0%	21%	15%	18%	0%	33%
Supermarkets				*Shops cooled			
Building related	45%	100%	20%	30%	43%	100%	23%
User related	55%	0%	80%	70%	57%	0%	77%

The shares of electricity consumption are directly compared to that of the Energy check-up (2018), for several electricity applications. It needs to be noted that the shops cooled is compared to supermarket even though it is unclear what is included in this category. In Figure 20, the results from the ECU over the bottom-up results are visualized. They have been compared by applying the shares to the total electricity consumption of 2019 and categorizing the results from this research to the ECU energy applications. Since ECU did not share further insight, this was not straightforward for every application. Some insights are, summed lighting is comparable. Ventilation and air conditioning are much lower than ECU. Which could be due to the exclusion of mobile appliances. Production appliances is rather low, for NF shops, even when the energy application 'others' is included. Product cooling is comparable but higher for ECU. These insights were further validated in the next step.

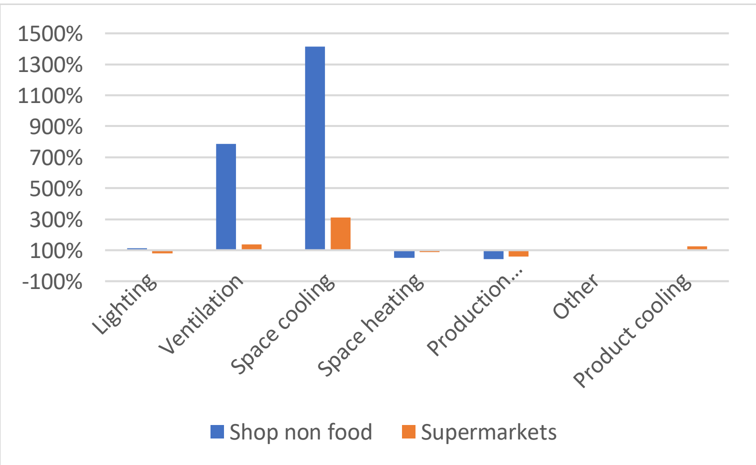

Figure 20. ECU over calculated results (without correction for HDD or CDD)

4.3.6 Step 6: Validation

Expert validation

Expert validation was performed with an energy audit expert and a smart metering expert. The energy intensity of hot water and product cooling were adjusted based on insights from INNAX (2022). The use of ventilation was verified. Also, trends which are observed when comparing the research to Meijer & Verweij (2009) were discussed. This resulted in the finding that the increase in intensity for transport is not in line with expectations. The change in intensity could be due to overestimation of the current numbers, or an unrepresentative sample or underestimation in the previous research. INNAX's estimations for ICT centralized are significantly higher, however, this is based on a small sample of supermarkets and has therefore not been implemented. Product preparation refers to the bake-off, with insight from INNAX the operating time was intensified. Expert insight has also highlighted the penetration of heat exchangers in product cooling (WTW), the renovated or new build supermarkets make only use of waste heat from product cooling and ovens for space heating (Thijssen, 2017; INNAX, 2022). However, since quantification and allocation of these energy streams is challenging, this has not been considered. Validation with AN7 confirmed the methodology and the overall results. They also note that they normally consider less energy applications, due to the large uncertainty related to the small applications. AN11 validated that the energy balance represents a good share of the Dutch supermarkets, highlighting the appropriate shares for product cooling (41%), product processing (10%) and indoor lighting (20%). AN11 also stressed that much deviation exists around the 'average' supermarket.

4.3.7 Step 7: Intermediate results

The results of the analysis of energy consumption per energy application is described for each energy application below, first for 2019, then for 2010.

4.3.7.1 NF shops

The bottom-up method results in the following overview of energy breakdown, shown in Table 17 and Figure 21Figure 20, the 'average' NF shops is shown, which is the weighted average of small and large shops without cooling. The breakdown for the reference buildings can be found in Annex D: Split small and large NF shops.

Table 17. Energy intensity per energy application for average NF shop

Energy application	Energy carrier	Energy intensity [kWh/m²]	NG intensity [m³/m²]	Share electricity	Share NG
Space heating	Natural gas	74.6	8.49		99.3%
	Electricity	3.2		3.6%	
Space cooling	Electricity	0.9		1.0%	
Hot water	Electricity	1.3		1.5%	
	Natural gas		0.06		0.7%
Other	Electricity	17.5		19.2%	
Food/drinks	Electricity	5.5		6.0%	
ICT centralized	Electricity	0.8		0.9%	
ICT decentralized	Electricity	3.1		3.4%	
Auxiliary	Electricity	2.0		2.2%	
Inside transport	Electricity	4.6		5.1%	
Ventilation	Electricity	0.3		0.4%	
Indoor lighting	Electricity	48.3		53.0%	
Outdoor lighting	Electricity	0.6		0.7%	
Emergency lighting	Electricity	2.9		3.2%	
Solar PV	Electricity	0.08			
Total					
	NG [Nm³/m²]	8.5			
	NG [kWh/m²]	75.2			
	Electricity [kWh/m²]	91.3			

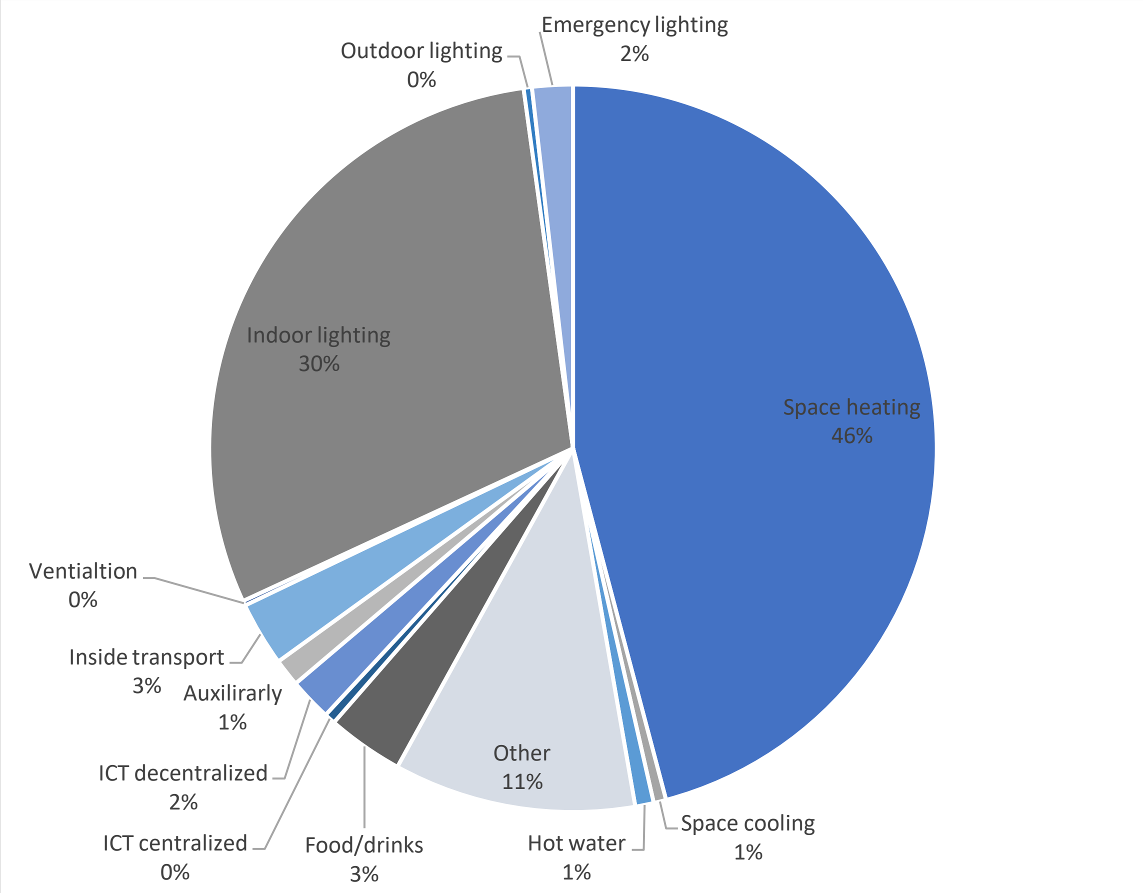

Figure 21. Energy breakdown of average NF shop in 2019

4.3.7.2 Supermarkets

The results for the breakdown by energy application are shown in Table 18 and Figure 22. To approximate the actual energy intensity, tweaking of 'product cooling' and 'product preparation' has taken place. For product cooling, the shares of the floor area of the store cooled and the number of open coolers (self-service counters) were tweaked. Initially 5 and 10% of frozen and cooled floor area was chosen, with insights from INNAX, the open coolers were added, and the shares were tweaked down.

Table 18. Energy intensity per energy application for average supermarkets

Energy application	Energy carrier	Energy intensity [kWh/m^2]	NG intensity [m^3/m^2]	Share electricity	Share NG
Space heating	Natural gas	47.4	5.4		98.9%
	Electricity	7.1		2.7%	
Space cooling	Electricity	5.1		1.9%	
Hot water	Electricity	1.3		0.5%	
	Natural gas	0.5	0.1		1.1%
Other	Electricity	0.0		0.0%	
Food/drinks	Electricity	8.1		3.1%	
ICT centralized	Electricity	13.1		5.0%	
ICT decentralized	Electricity	1.6		0.6%	

Auxiliary	Electricity	2.0		0.8%	
Product preparation	Electricity	30.8		11.6%	
Product cooling	Electricity	124.5		47.1%	
Inside transport	Electricity	4.1		1.5%	
Ventilation	Electricity	1.9		0.7%	
Indoor lighting	Electricity	61.3		23.2%	
Outdoor lighting	Electricity	0.6		0.2%	
Emergency lighting	Electricity	2.9		1.1%	
Solar PV	Electricity	0.05			
Total				100%	100%
	NG [Nm^3/m^2]	5.5			
	NG [kWh/m^2]	47.9			
	Electricity [kWh/m^2]	264.4			

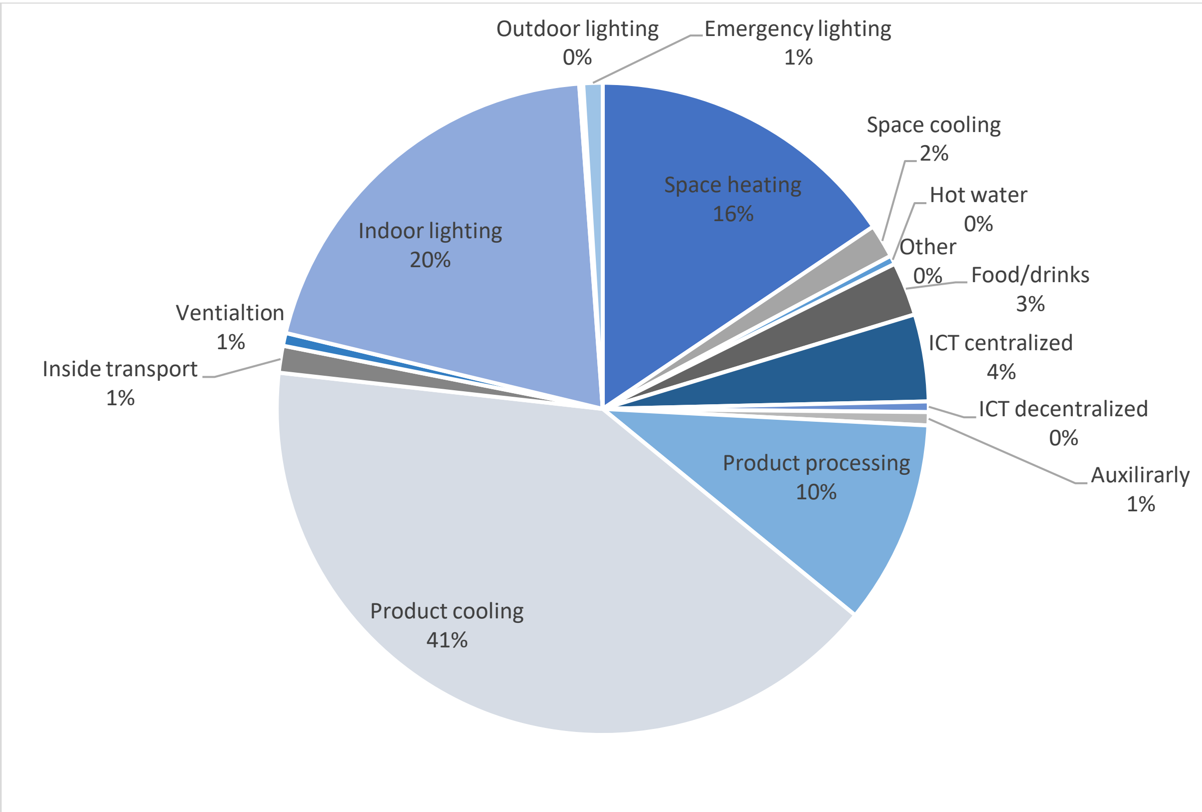

Figure 22. Energy breakdown of average supermarket in 2019

4.3.7.3 Energy applications 2010

The results of Meijer & Verweij (2009) are transformed into percentages, shown in Table 19 and Table 20.

Table 19. Shares NF shops in 2010 (based on of Meijer & Verweij, 2009)

Energy application	Energy carrier	Share electricity	Share NG
Space heating	Natural gas		100%
	Electricity		

Space cooling	Electricity	8.1%	
Hot water	Electricity	1.0%	
	Natural gas		
Other	Electricity	8.1%	
Food/drinks	Electricity	2.0%	
ICT centralized	Electricity	2.4%	
ICT decentralized	Electricity	2.4%	
Auxiliary	Electricity	3.3%	
Inside transport	Electricity	1.5%	
Ventilation	Electricity	3.3%	
Indoor lighting	Electricity	61.9%	
Outdoor lighting	Electricity	4.9%	
Emergency lighting	Electricity	1.1%	
Total		100%	100%

Table 20. Shares supermarkets in 2010 (based on of Meijer & Verweij, 2009)

Energy application	Energy carrier	Share electricity	Share NG
Space heating	Natural gas		99.9%
	Electricity		
Space cooling	Electricity	0.8%	
Hot water	Electricity	0.2%	
	Natural gas		0.1%
Other	Electricity	1.8%	
Food/drinks	Electricity	0.3%	
ICT centralized	Electricity	0.4%	
ICT decentralized	Electricity	0.4%	
Auxiliary	Electricity	0.6%	
Product preparation	Electricity	7.6%	
Product cooling	Electricity	60.8%	
Inside transport	Electricity	0.3%	
Ventilation	Electricity	0.6%	
Indoor lighting	Electricity	24.2%	
Outdoor lighting	Electricity	1.8%	
Emergency lighting	Electricity	0.2%	
Total		100%	100%

5. Results

5.1 B: Trend analysis

To address the first research question, the trend analysis is carried out separately for the NF shops and supermarket. For each sub-sector, first the overall trend in energy consumption is discussed, followed by the trends of the driving forces. Finally, the change in energy intensity of the energy applications discussed.

5.1.1 Shops NF

First, the trend in energy consumption is discussed. In Figure 23it is shown that the overall energy consumption has decreased for NF shops. Between 2010 and 2019, the uncorrected energy consumption decreased by 26%, and the corrected by 18%. Electricity is the dominant energy carrier in temperature corrected energy consumption, nevertheless, this share has dropped slightly between 2010 and 2019, from 60% to 59% respectively. For NG, the influence of the cold winters of 2012 and 2013 is visible. In Figure 24**Error! Reference source not found.**, the trend in energy consumption of the construction period 'constructed before and in 2010' is presented. The share of electricity is slightly lower by 2019, namely 58%.

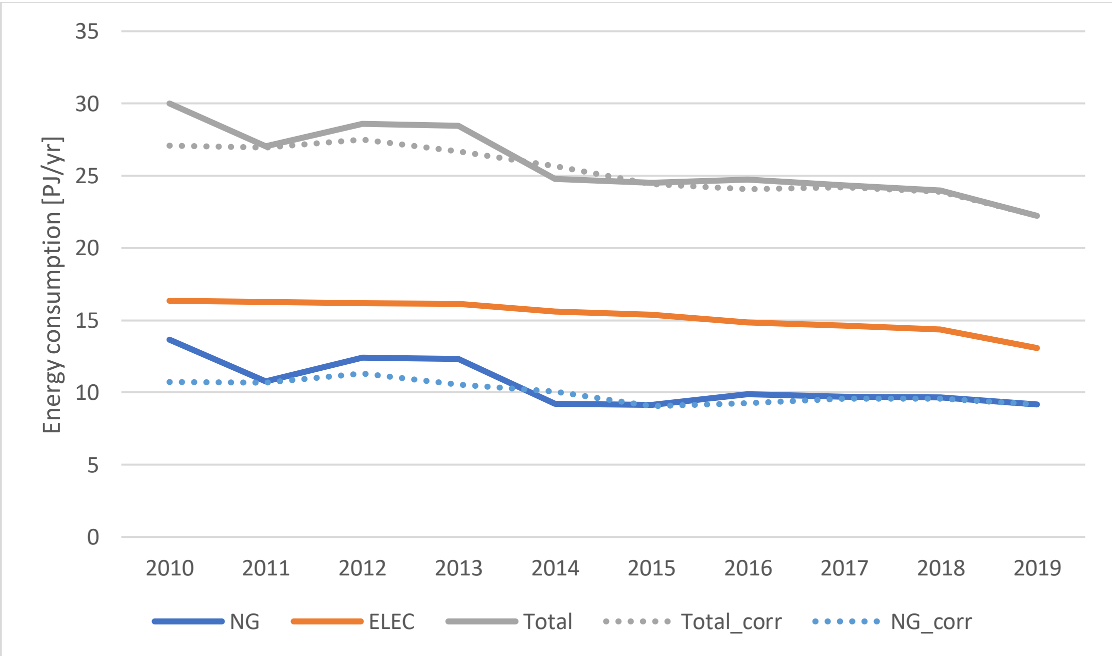

Figure 23. (Temperature corrected) energy consumption by energy carrier for NF shops

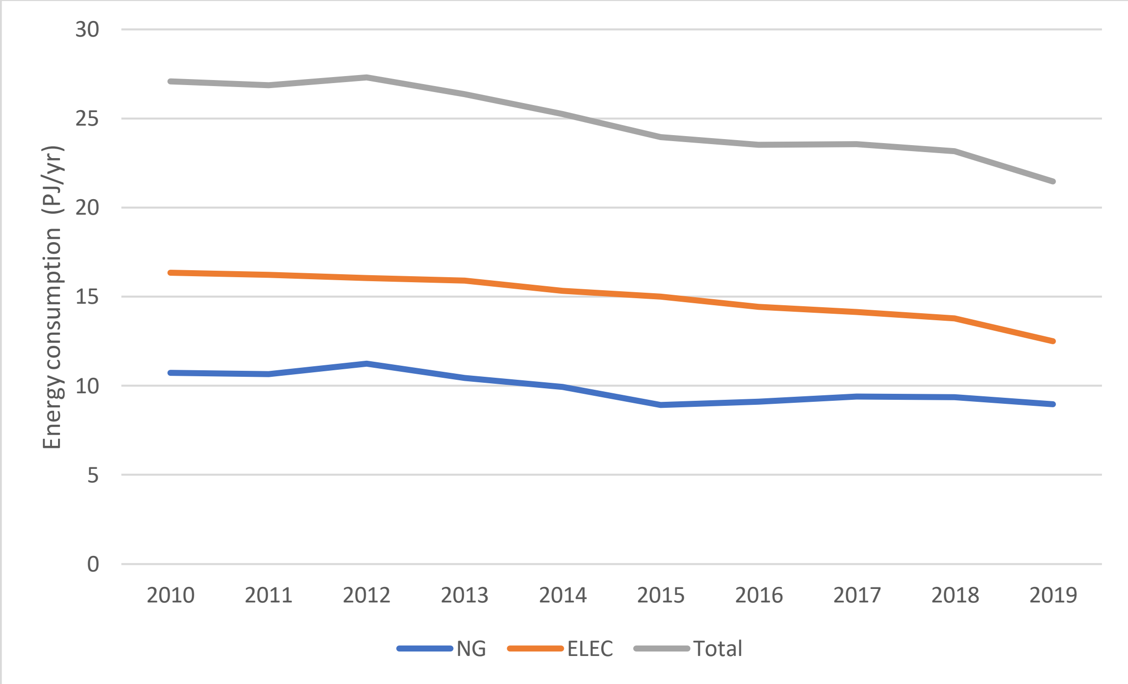

Figure 24. Temperature corrected energy consumption by energy carrier for NF shops 'constructed before and in 2010'

Driving forces

Next, the driving forces and their trends are discussed individually. As seen in Figure 25, the electricity intensity for NF, 'constructed before and in 2010' shows a steady decrease in. The electricity intensity of shops 'constructed after 2010', show an increasing but stabilizing trend. By 2019, the difference between the two construction periods is about 10%. For the peaks in 2012 and 2013, the most relevant argument is that the electricity intensity is not temperature corrected, and the winters were relatively cold, requiring more space heating. Among the 'new shops', there is a relatively high share of shops without a NG grid connection, namely 19% of the 57 shops in 2011. Only 9% of the shops 'constructed before and in 2010' are all-electric (in 2011), see Figure 28. Another explanation is the influence of the small number of observations, namely only 94 shops in 2012, making the numbers more sensitive to administrative irregularities in the 'into-service' date of a shop, however, this is not reflected in the NG intensity figures.

For NG a clear difference between construction categories is visible in Figure 26. For both, a steady decrease, but slow stabilization is shown. The effect of cold winters is shown by the dotted line for 2010, 2012 and 2013. In Figure 27, it is shown that overall, the NF sector has been growing in terms of floor area between 2010 and 2019, peaking in 2018. The shops 'constructed after 2010' make a marginal contribution to the NF stock, by 2019, only 4.8%. In Figure 28, the trend of the share of all-electric shops is shown. A jump is observed in 2015, for both construction periods, no convincing argumentation could be found except for the influence of the number of observations. The share all-electric for the shops 'constructed after 2010', is based on 210 shops in 2015. For the construction period 'constructed before and in 2010', 7104 observations are found. Overall, it is concluded that the share remains rather constant over the years.

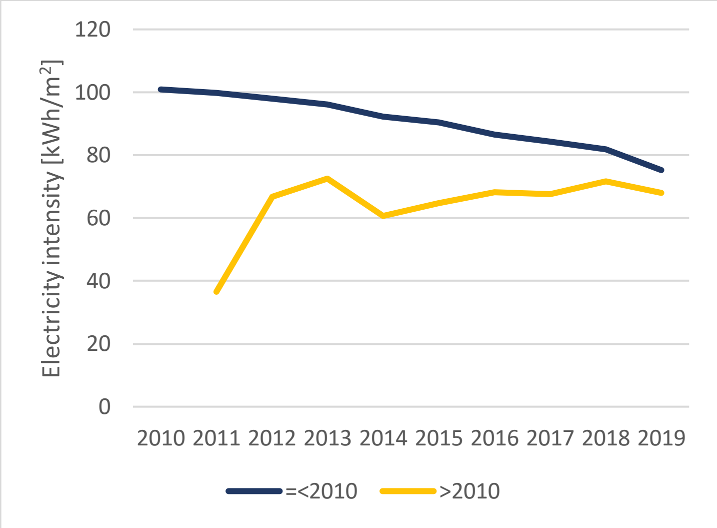

Figure 25. Electricity intensity for NF shops differentiating for construction period

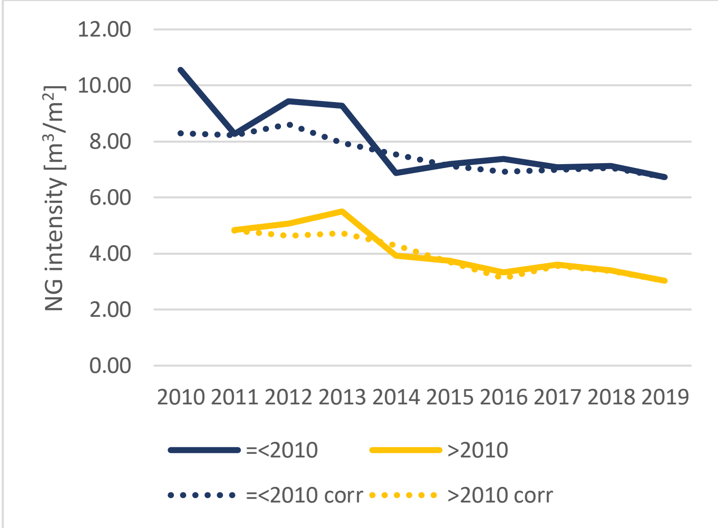

Figure 26. NG intensity for NG connected NF shops differentiating for the construction period

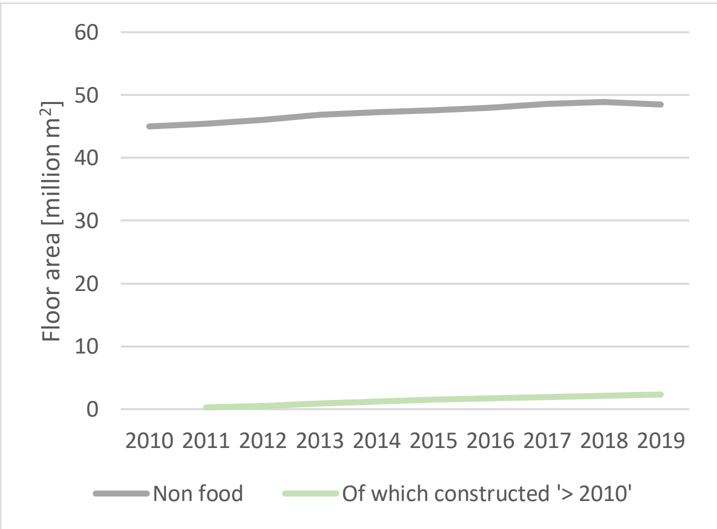

Figure 27. Floor area for NF shops and the contribution of 'newly constructed shops' to the building stock

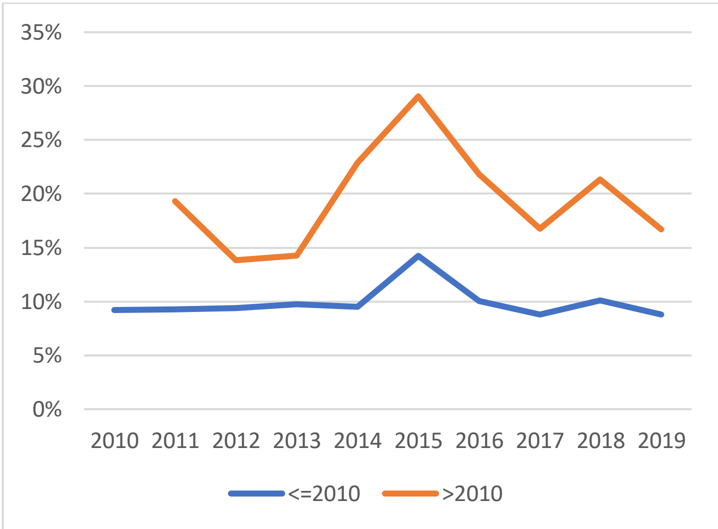

Figure 28. Share all-electric for NF shops differentiating for construction period

Energy intensity by application

The energy intensity by application of 2010 is compared with 2019. In Figure 29, it is observed that space heating and indoor lighting are the most dominant energy applications. Overall, the changes vary between -91 to + 158%.

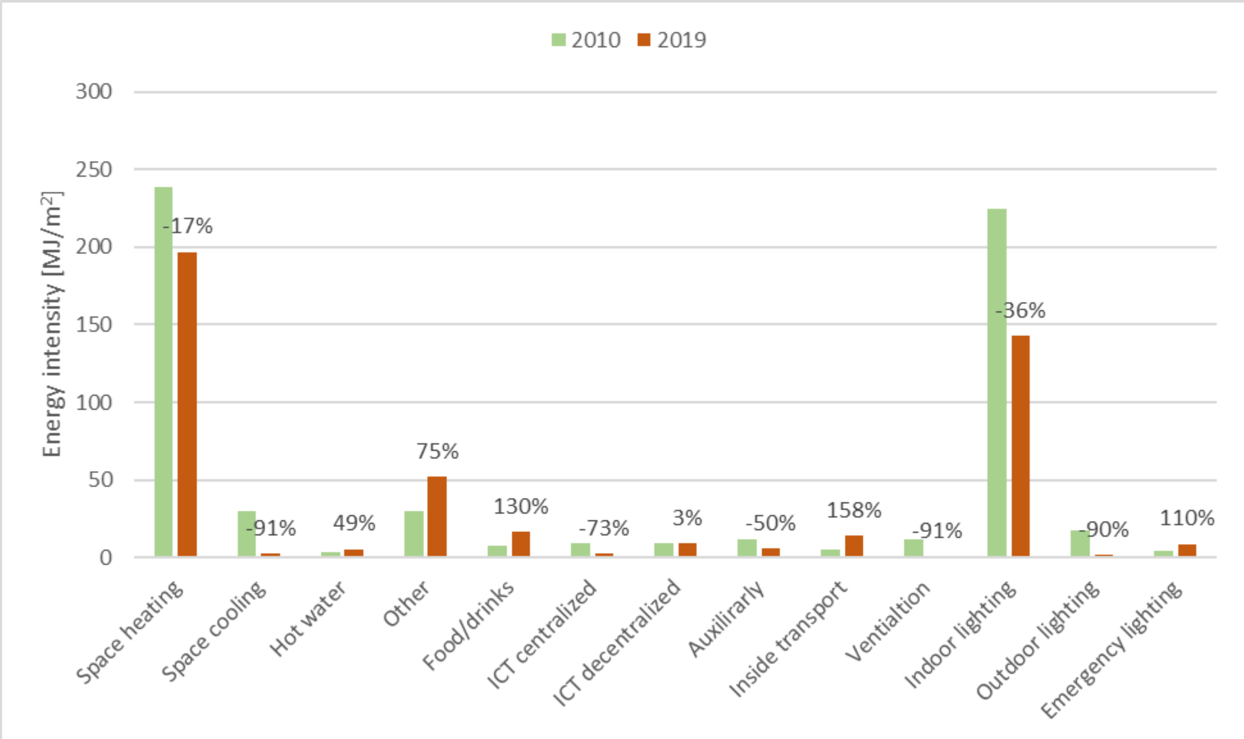

Figure 29. Energy intensity by energy application comparison and per centage change between 2010 and 2019 for NF shops

The analysis based on the energy carriers for space heating and hot water is shown in Figure 30 and Figure 31. For space heating, a decrease and substitution of NG for electricity is observed. For hot water, an increase and substitution to NG is observed.

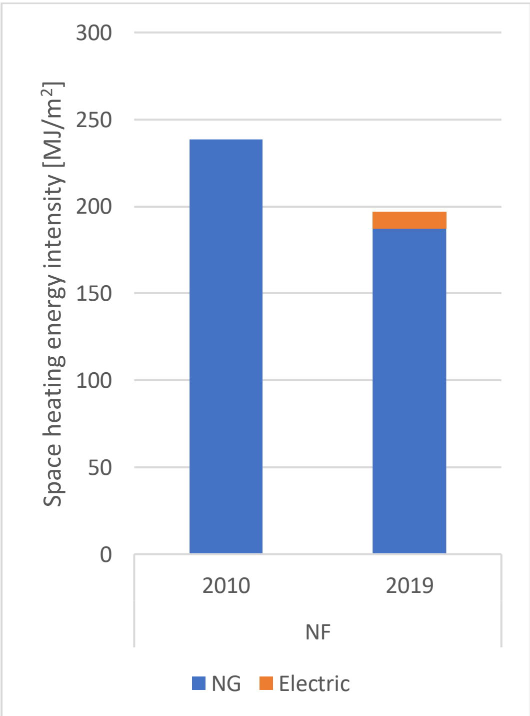

Figure 30. Space heating energy intensity in 2010 and 2019 by energy carrier for NF shops

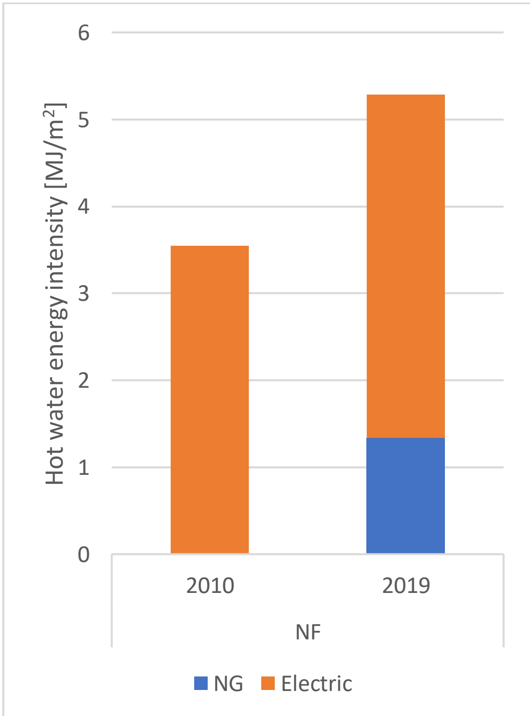

Figure 31. Hot water energy intensity in 2010 and 2019 by energy carrier for NF shops

For each application the evaluation of the observed change is discussed in Table 21. It is concluded that the observed intensity decrease for space heating and indoor lighting is in line with expectations. As well as the observed substitution of energy carriers. For the applications space cooling and ventilation, unexpected outcomes are observed. This should be considered in the further analysis and studied with the sensitivity analysis. For several applications, like, outdoor lighting and auxiliary equipment, it was not possible to validate to observed trend. This is also considered in the further analysis.

Table 21. Interpretation observed changes in energy intensity

Energy application	Observed trend	Expected?
Space heating	Decrease	Yes, increased efficiency. A small switch to electricity due to more all-electric shops.
Space cooling	Decrease	No, more cooling demand and higher penetration rate expected.
Hot water	Increase	Reversed substitution effect was not expected. Possibly wrongly estimated for 2010.
Other	Increase	Neutral. Potentially more surveillance camera.
Food/drink	Increase	Yes, due to increased luxury, more coffee served, lunch corners in shops.
ICT centralized	Decrease	Neutral, due to increased digitalization, but efficiency increase.
ICT decentralized	(Marginal) Increase	Yes, due to large-scale digitalization.
Auxiliary equipment	Decrease	Neutral, increased efficiency, but more space cooling.
Transport	Increase	Not expected but calculated with sample of 1500 shops. Potential underestimation in previous research.
Ventilation	Decrease	Yes, increased efficiency, but higher penetration rate expected.
Indoor lighting	Decrease	Yes, increased efficiency.
Outdoor lighting	Decrease	Neutral
Emergency lighting	Increase	Neutral

5.1.2 Supermarket

The trend in total energy consumption of supermarkets is discussed first. In Figure 32, it is shown that the overall energy consumption decreased slightly, by 5%. The corrected energy consumption has decreased, but only by 0.02%. An electrification of the energy demand is recognized, as the share increases, from 79 to 83%, for corrected energy consumption. In Figure 33 the aggregated result for 'constructed before and in 2010' is shown. This trend closely resembles both the overall outcomes and the degree of electrification.

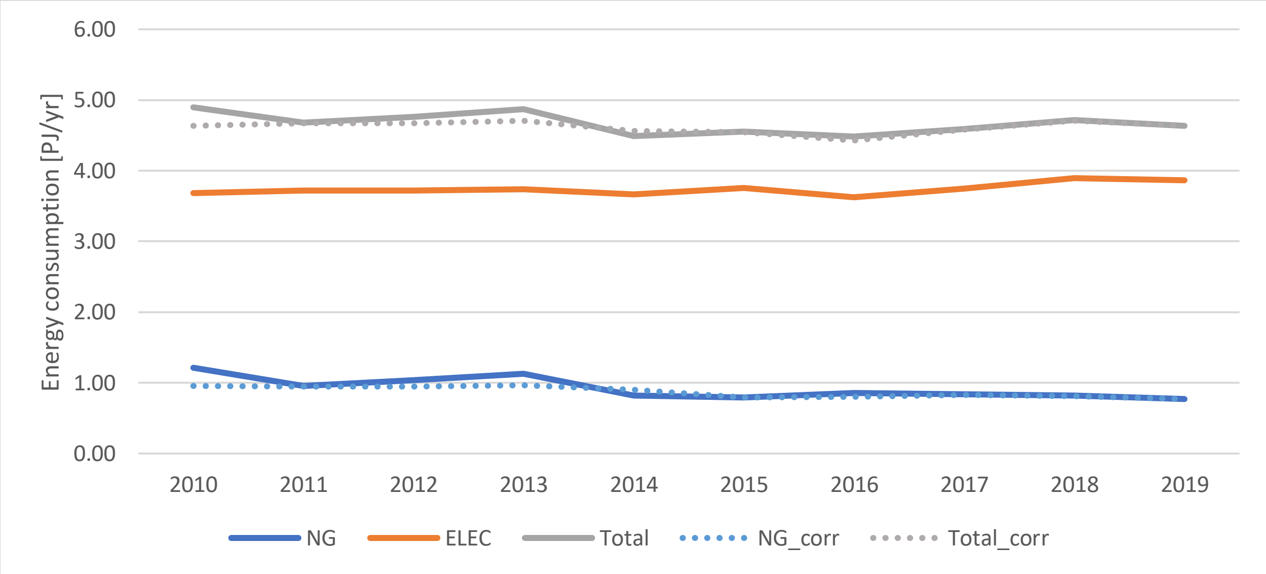

Figure 32. Temperature corrected energy consumption by energy carrier for all supermarkets

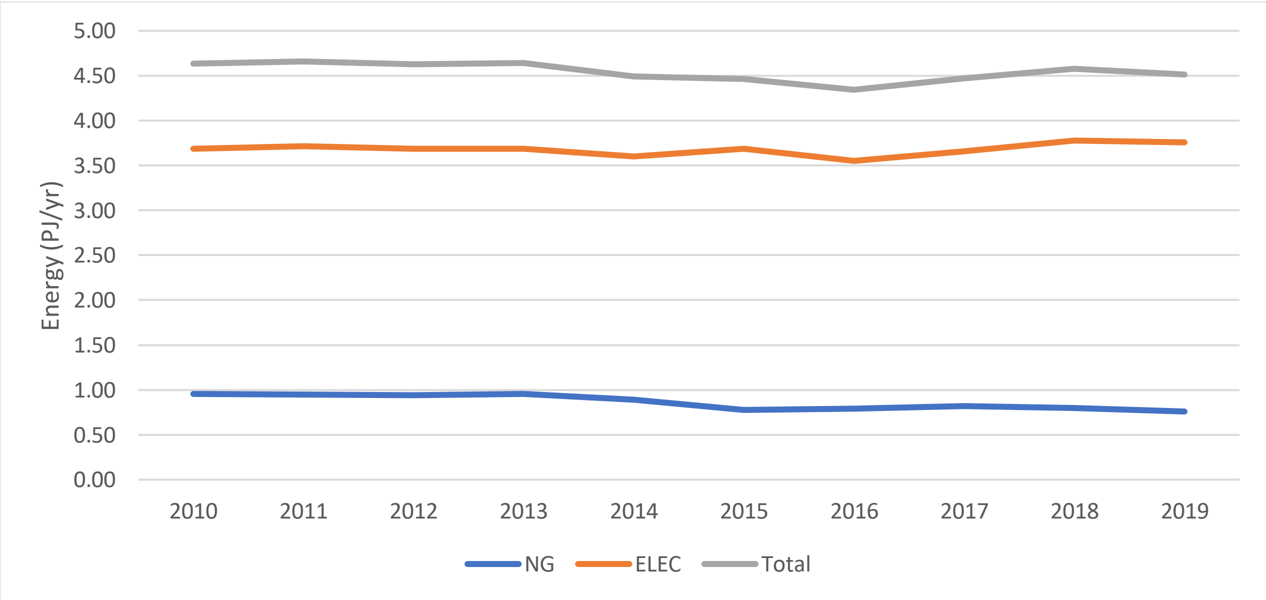

Figure 33. Temperature corrected energy consumption by energy carrier for supermarkets 'constructed before and in 2010'

Driving forces

Next, the underlying trends in driving forces are analysed for the supermarkets. The electricity intensity of 'constructed before and in 2010' shows a slight decrease in electricity intensity, see Figure 34. The electricity intensity of 'constructed after 2010', has increased over time, but is still lower compared to 'constructed before and in 2010', by 2019. The same peaks in 2012 and 2013 are observed as for shops NF, this is allocated to the uncorrected electricity intensity. Due to the high share of all-electric supermarkets, see Figure 37, and relatively cold winters more space heating was required. For NG a clear distinction between construction categories is visible in Figure 35. For both, a steady construction periods, a decrease is shown, the decrease is steepest for 'constructed before and in 2010'. In Figure 36, it is shown that the sector is growing in terms of floor area between 2010 and 2019. The new buildings, 'constructed after 2010' make a marginal contribution to the supermarket stock, only 3.7% by 2019. Among the 'new shops', there is a relative high share of shops without a NG grid connection, so called all-electric, but due to the small number of observations, volatile to errors in individual cases, see Figure 37. Overall, a clear increase in all-electric supermarkets is visible for 'constructed after 2010'.

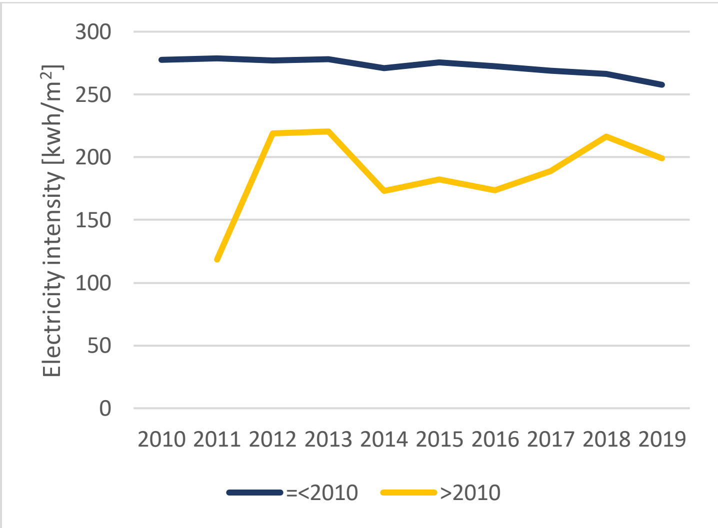

Figure 34. Electricity intensity over the years for supermarkets differentiating for construction period

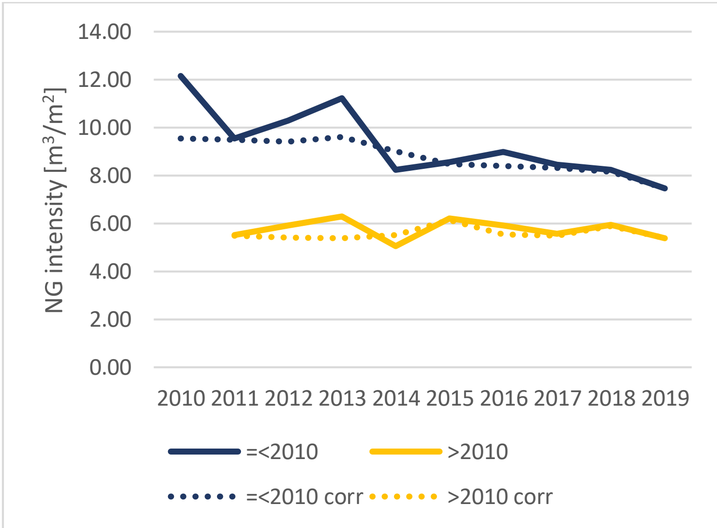

Figure 35. NG intensity over the years for NG connected supermarkets differentiating for construction period

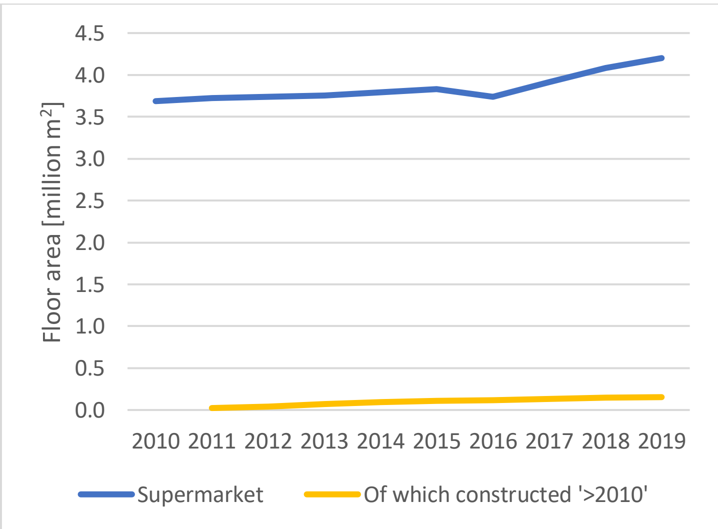

Figure 36. Floor area over the years for supermarkets and the contribution of 'newly constructed shops' to the building stock

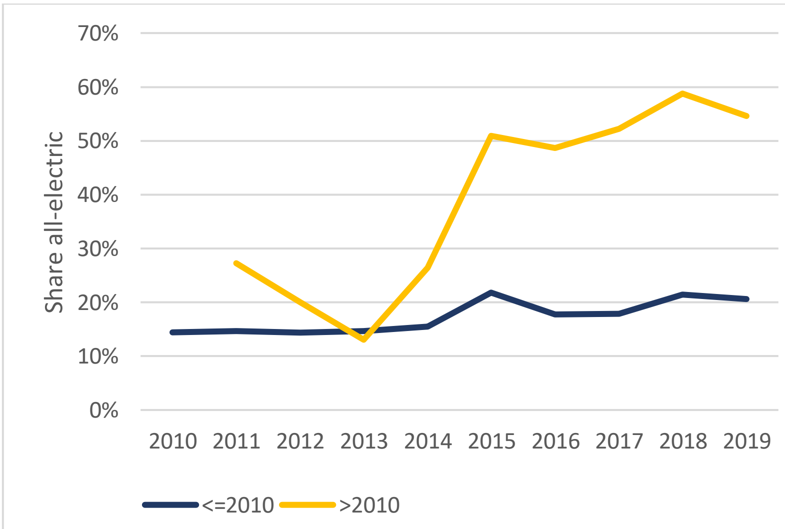

Figure 37.Share all-electric over the years for supermarkets differentiating for construction period

Energy application

The trend in energy intensity by energy application is shown in Figure 38. Product cooling, space heating, indoor lighting and product processing are the largest energy applications. For several applications substantial changes are observed, ranging up to 984% increase from 2010 to 2019.

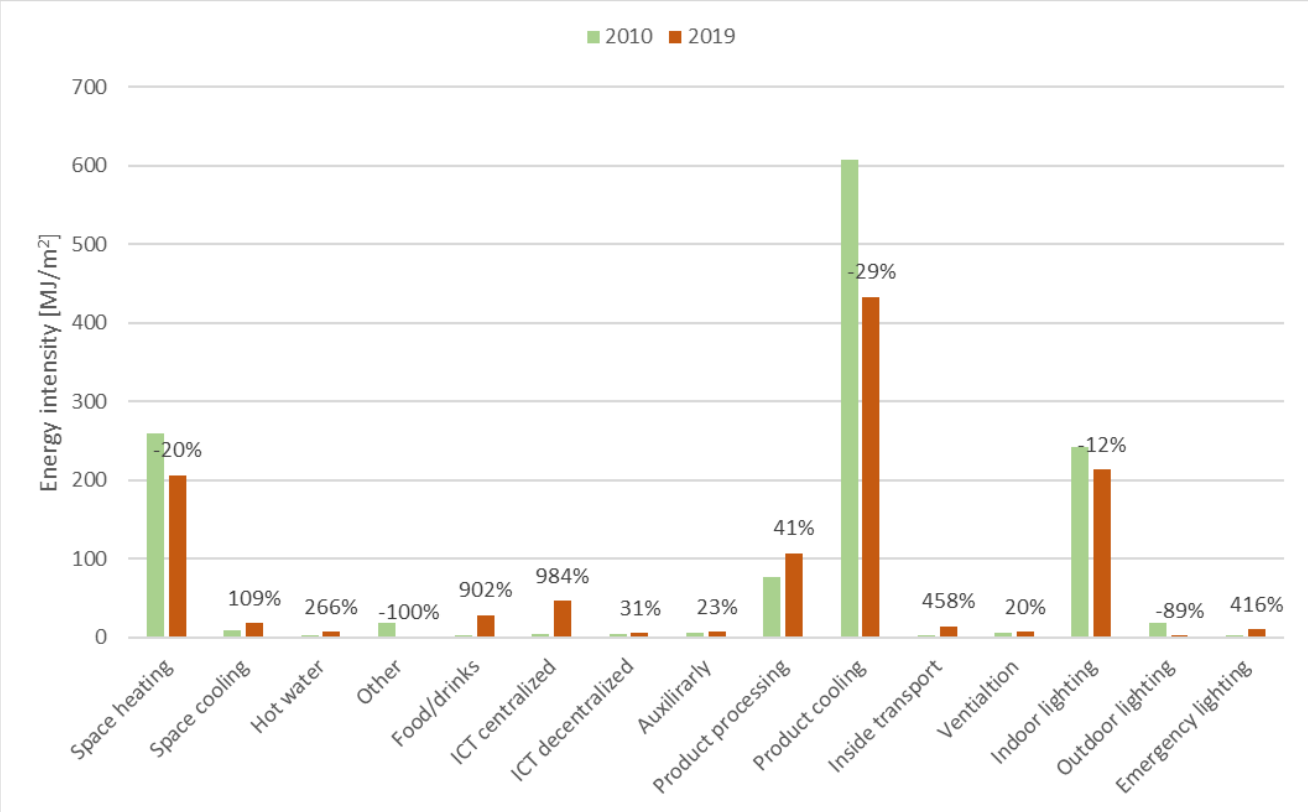

Figure 38. Energy intensity by energy application comparison and per centage change between 2010 and 2019 for supermarkets

The applications space heating and hot water and their energy carriers are shown in Figure 39 and Figure 40. For space heating, a shift to electricity and a decrease in overall intensity is observed. For hot water, an increase, and a shift to NG is observed.

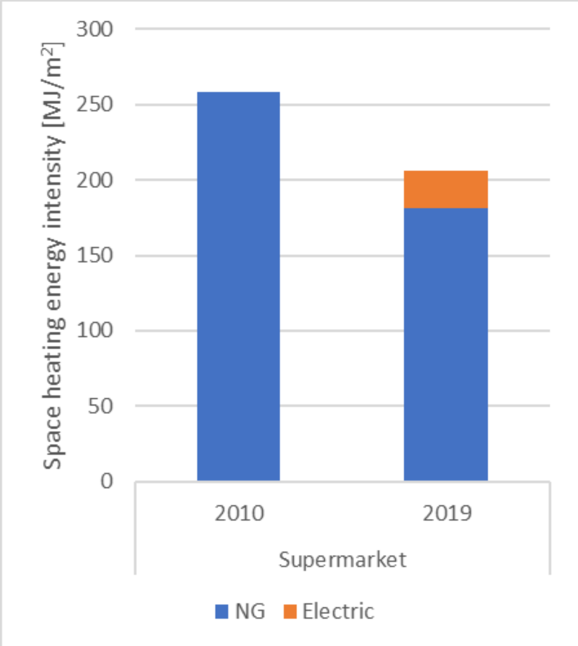

Figure 39. Space heating energy intensity in 2010 and 2019 by energy carrier for supermarkets

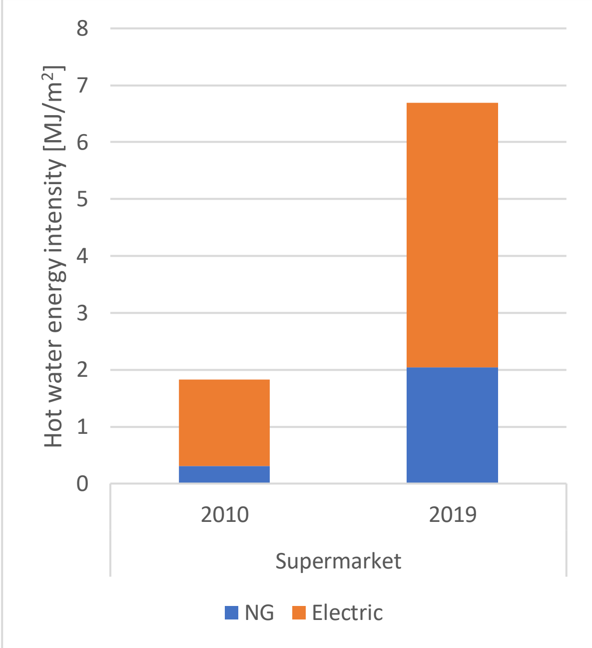

Figure 40. Hot water energy intensity in 2010 and 2019 by energy carrier for supermarkets

The observed trend is discussed in Table 22. For several applications, an expected trend is observed, like for space heating, food/drinks, ICT and indoor lighting. However, for several applications, the trends are not in line with expectations, like for space cooling, hot water, others, transport, ventilation and emergency lighting. For several applications it could not be concluded whether the observed trend was expected, like for outdoor lighting. The unexpected outcomes are considered in the further analysis.

Table 22. Reflection on observed trend for each energy application

Energy application	**Observed trend**	**Expected?**
Space heating	Decrease	Yes, increased efficiency. But could be underestimation due to the interplay of using waste heat for space heating.
Space cooling	Increase	No, because more CDD and higher penetration rate expected
Hot water	Increase	No, efficiency increase. Potential underestimated share of NG hot water in 2010. Unexpected reversed fuel substitution.
Other	Decrease	No, security surveillance is not included in 2019.
Food/drink	Increase	Yes, more coffee machines and some ‘take-away’ in supermarkets
ICT centralized	Increase	Yes, digitalization and self-check-out counters
ICT decentralized	(Marginal) increase	Yes, digitalization, but efficiency increase
Auxiliary equipment	(Marginal) increase	Increased efficiency expected
Product processing	Increase	More product processing, especially bake-off
Product cooling	Decrease	Increased efficiency, but fresher product served
Inside transport	Increase	No explanation. Efficiency assumed to have increased. For 2019 based on extensive sample.
Ventilation	(Marginal) increase	No, increased efficiency expected
Indoor lighting	Decrease	Yes, increased efficiency, but longer opening times

Outdoor lighting	Decrease	Neutral, data limitations
Emergency lighting	Increase	No, increased efficiency expected
Solar PV	Increase	Yes

5.1.3 Conclusion

For the NF shops an overall decrease of 26 % (not temp. corrected) in energy consumption between 2010 and 2019 is found. For supermarkets, the corrected energy consumption has remained stable, and uncorrected decreased by 5%. For both sub-sectors, contrasting trends like increase in floor area and decrease in energy intensity are shown. To gain further understanding in how much these driving forces have contributed to the trend in energy consumption, a decomposition analysis is performed.

5.2 C: Decomposition analysis

The main drivers in terms of energy application have been analysed by a decomposition analysis. The sub-sectors are discussed separately. First the overall results are shown, succeeded by a break down in energy application, construction period and energy carrier.

5.2.1 Shops NF

For NF shops, first, the overall results for each effect are presented in

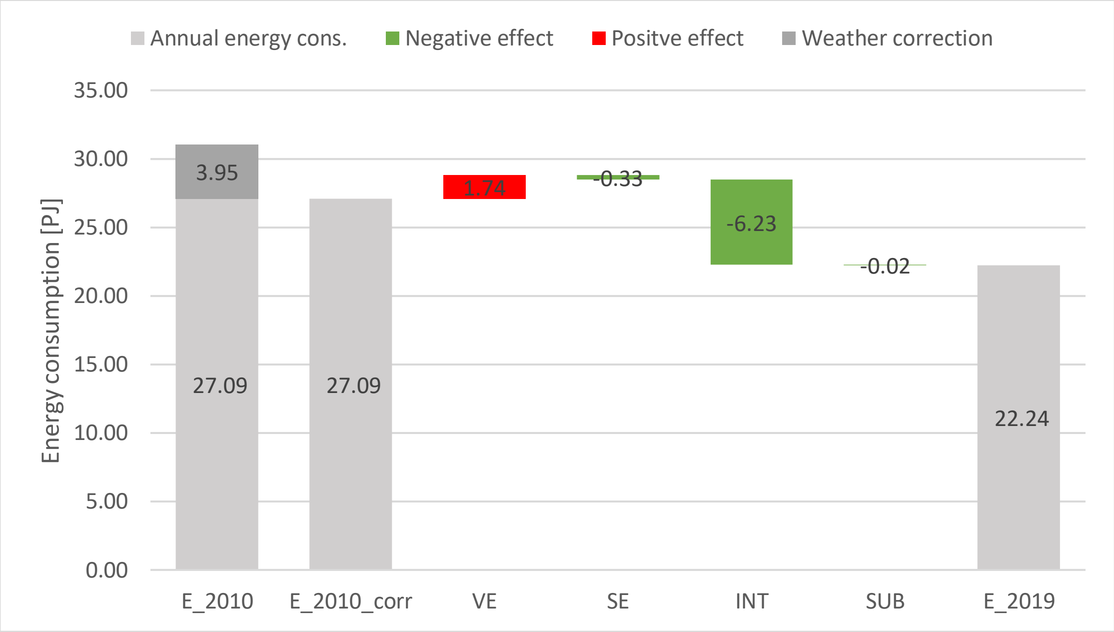

Figure 41. It is shown how the decrease in energy consumption is decomposed by the effects. The weather correction shows 2010 was a colder year than 2019. The volume effect was positive, implying the floor area has grown. The intensity effect is negative, implying that the energy intensity has decreased. Furthermore, the structure effect is negative, implying that the decrease in share of 'constructed before and in 2010' was larger than the increase in share 'constructed after 2010'. The substitution effects are marginally negative, meaning that the switch from NG to electricity has led to a slight decrease in overall energy consumption.

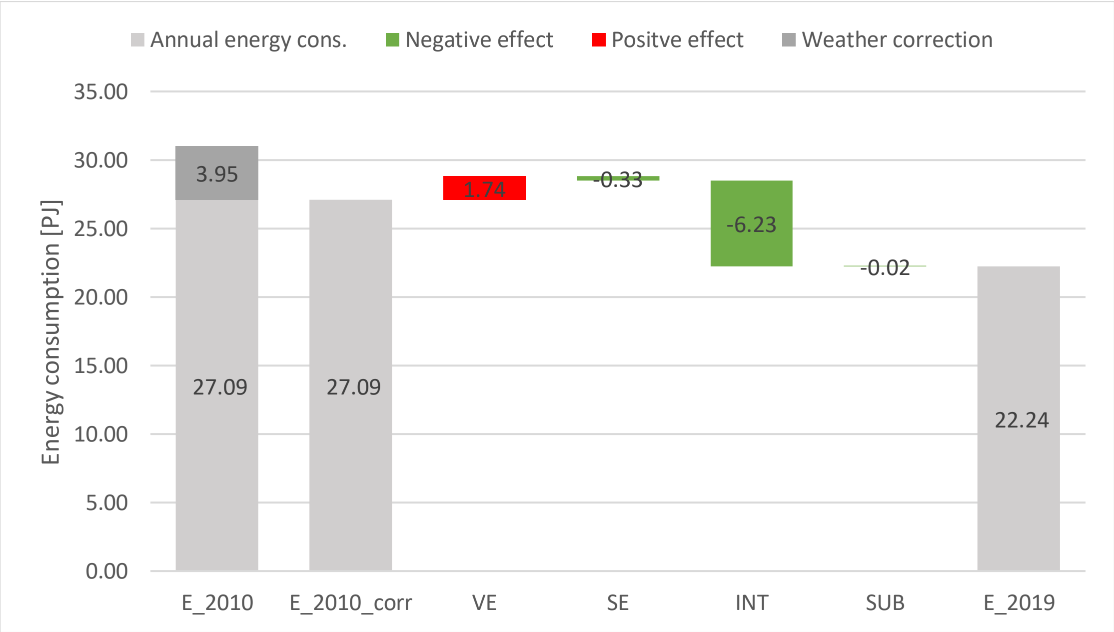

Figure 41. Decomposition effects for NF shops summed for construction periods, energy applications and energy carriers

These results of the intensity effect are broken down by energy application, see Figure 42Figure 44. It is shown that indoor lighting has shown the largest decrease in energy intensity. Additionally, space heating, space cooling, outdoor lighting and ventilation have decreased. The other, food/drinks and inside transport applications have increased. The trends for outdoor lighting, ventilation and inside transport were already discussed in section 5.1.1, where it is concluded that these trends cannot be validated. This is also used as input to the sensitivity analysis.

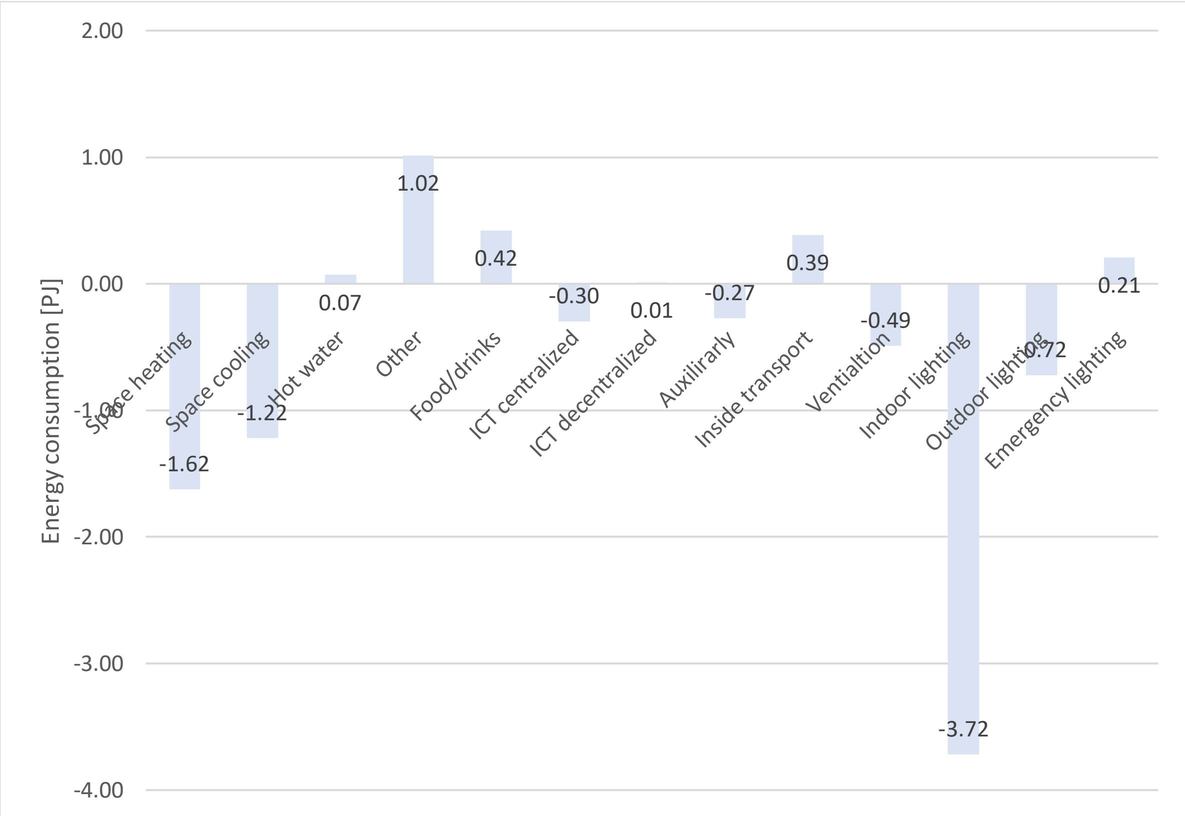

Figure 42. Change in energy intensity decomposed by energy application for NF shop between 2010 and 2019

5.2.1.1 NF 'constructed before and in 2010'

The results are further broken down by the construction period, 'constructed before and in 2010'. In Figure 43 it is observed that the volume effect has increased compared to the overall sub-sector, the structure effect has decreased, meaning that the shift to the other category has led to a decrease in this construction period. The intensity effect is still a large contributor to the decrease in energy consumption.

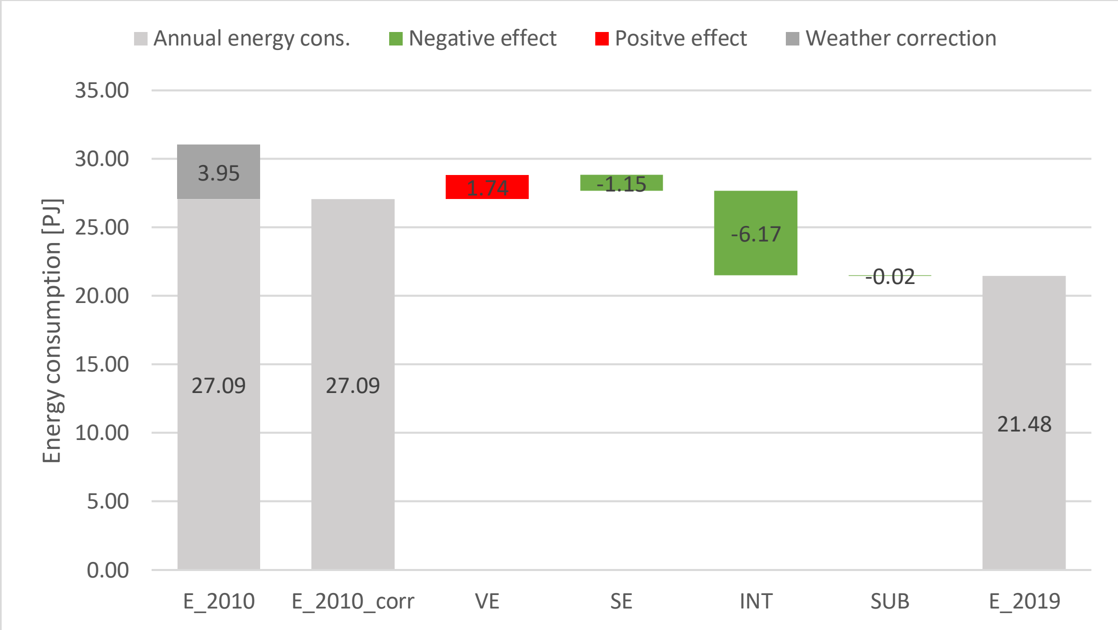

Figure 43. Decomposition analysis NF shops for the construction period 'constructed before and in 2010'

When analysing the intensity and substitution effect by energy application for this construction period, it is shown in Figure 44, that the same trends are observed as for the overall NF shops, which results due to the large contribution (95%) of this construction period to the overall results.

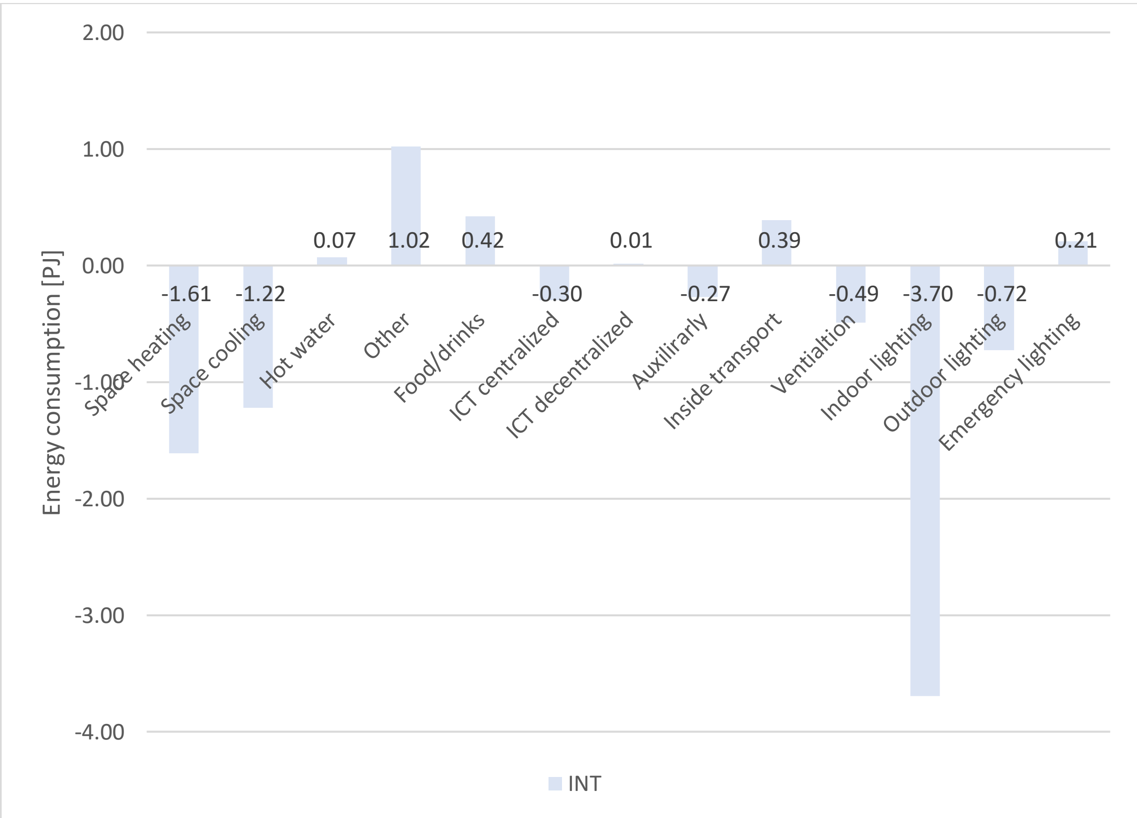

Figure 44. Change in energy intensity decomposed by energy application for the NF shops 'constructed before and in 2010' between 2010 and 2019

The substitution effect is broken down by energy application and energy carrier for this construction period, as shown in **Error! Reference source not found.** and Figure 46. It is shown that for space heating, NG is replaced by electricity, leading to an overall decrease in energy consumption. However, the other way around is observed for hot water, leading to an overall increase in energy consumption, the robustness of this results is low, as discussed in section 5.1.1.

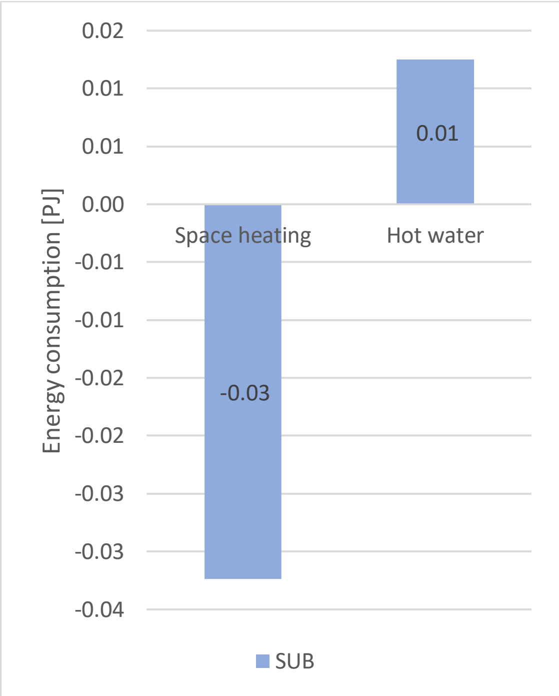

Figure 45. Substitution effect for space heating and hot water for supermarkets 'constructed before and in 2010' summed by energy carrier between 2010 and 2019

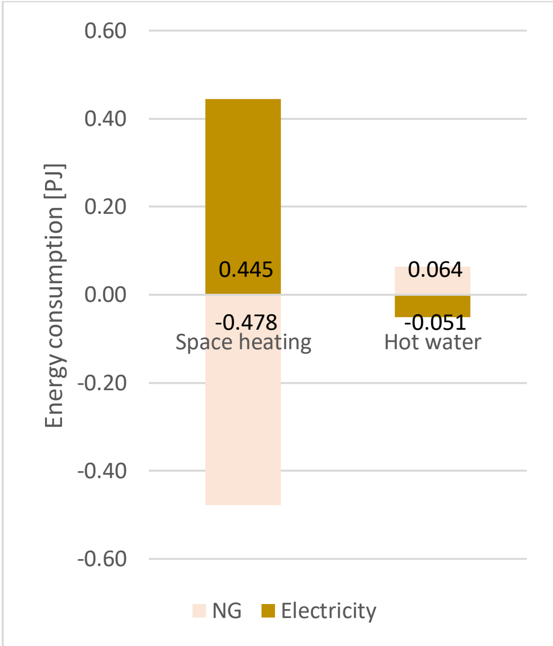

Figure 46. Substitution effect for space heating and hot water for supermarkets 'constructed before and in 2010' for NG and electricity between 2010 and 2019

5.2.1.2 Conclusion NF shops

It is identified that the weather correction was a large contributor to the overall decrease in energy consumption. The volume effect induces an increase; however, the intensity decrease is higher, resulting in an overall decrease. The effects of substitution and structure effect are marginal. A further breakdown by applications shows that the decrease in intensity effect is driven by a decrease in energy intensity of space heating and indoor lighting. Substitution effect is driven by space heating. The sensitivity analysis is performed to further interpret the results.

5.2.2 Supermarkets

The overall results for the DA of supermarkets are shown in

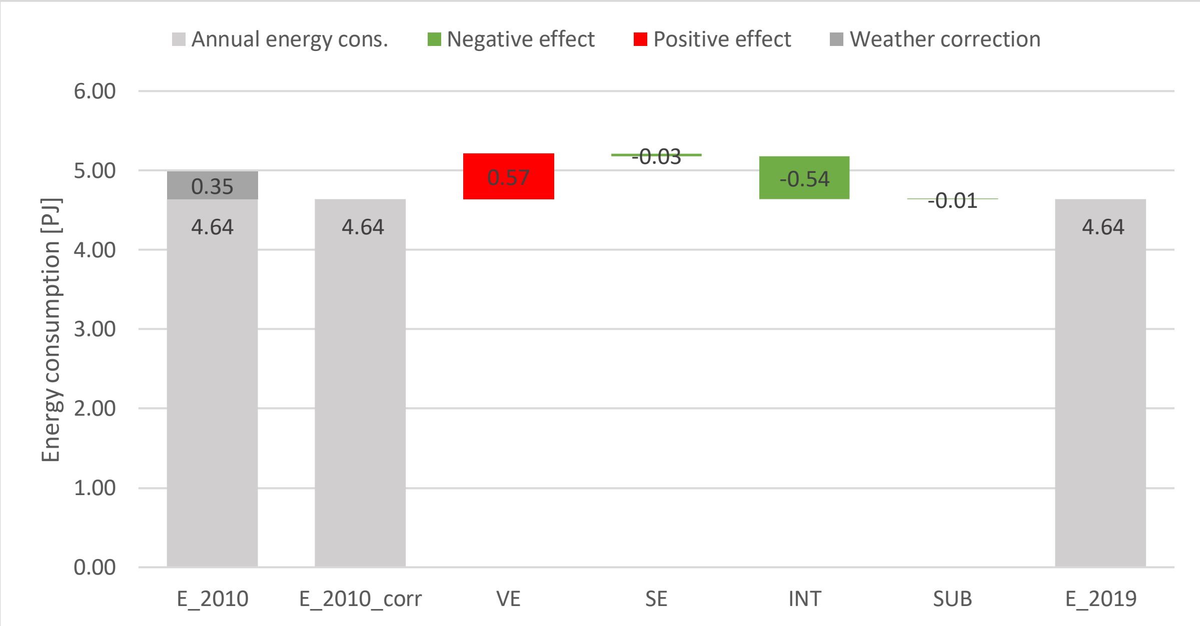

Figure 47. The decrease is driven by the weather correction and intensity effect. The volume effect shows an increase, implying that the floor area has grown over the period. The intensity effect shows the strongest decrease, which implies a decrease in energy intensity. The structure effect has led to a decrease, implying that the decrease in the category ‘constructed before and in 2010’ is larger than the increase in share of ‘constructed after 2010’. The fuel substitution effect is marginal, but negative, meaning that the shift from NG to electricity has led to a decrease in energy consumption.

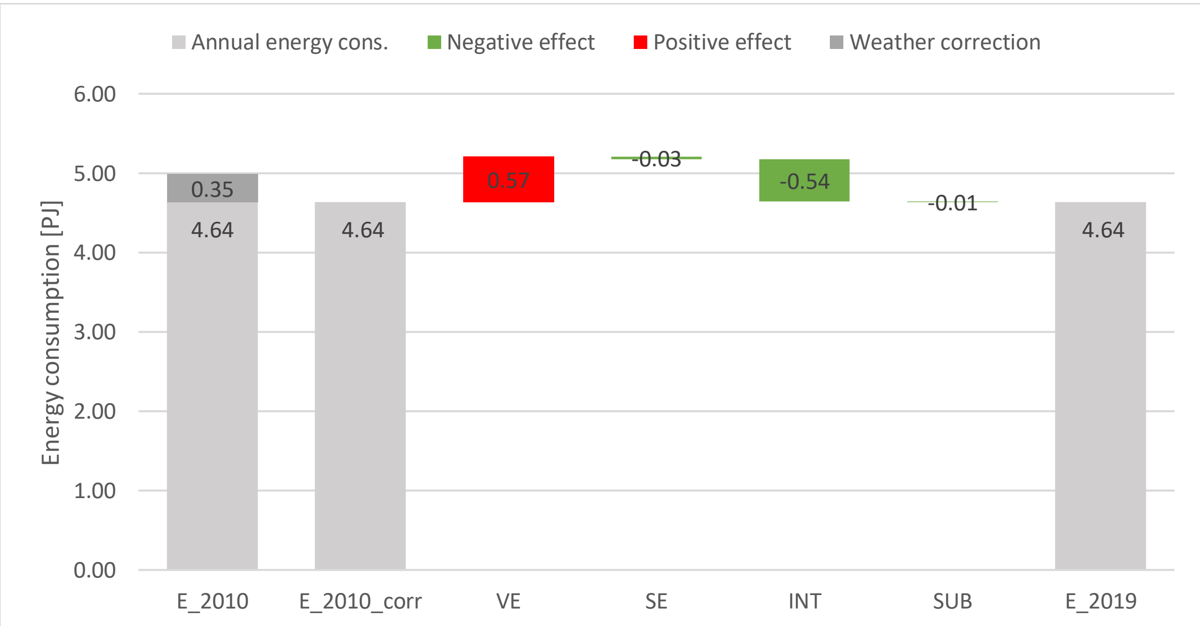

Figure 47. Decomposition analysis for supermarkets summed for energy application and energy carrier

When analysing the intensity effect for each energy application, a clear intensity decrease is shown for space heating, product cooling, indoor lighting and outdoor lighting shown in Figure 48. Especially the decrease in intensity of product cooling stands out. An increase in intensity is shown for food/drinks, ICT centralized and product processing.

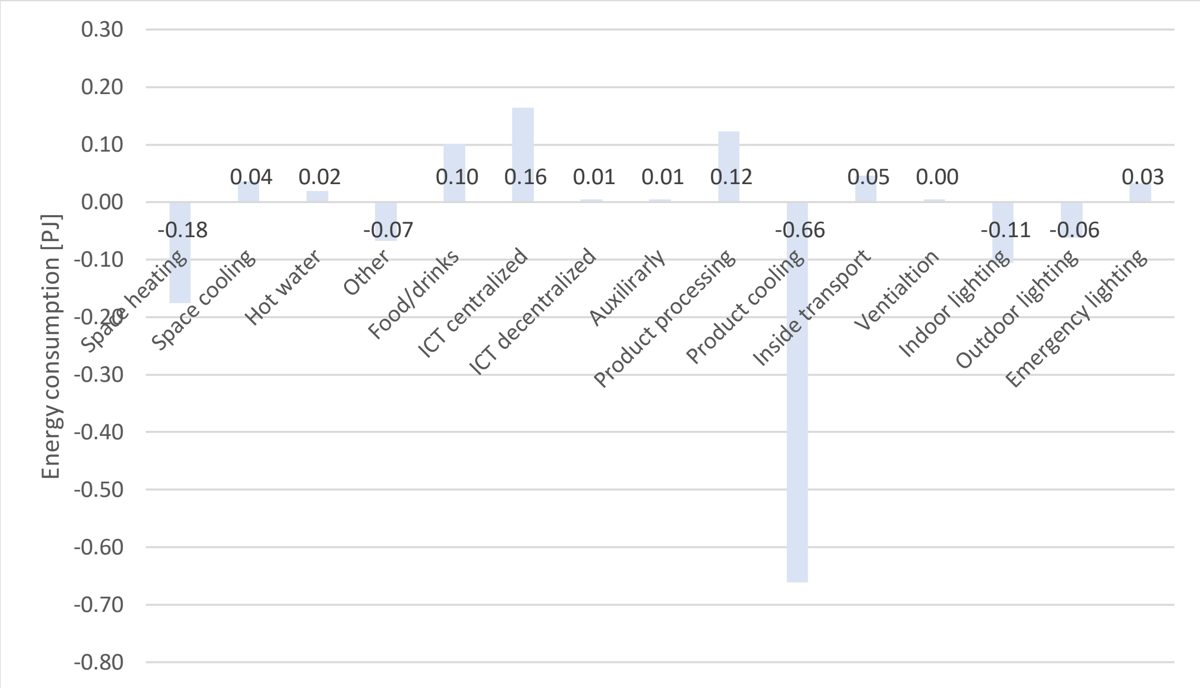

Figure 48. Intensity effect for the energy applications for supermarkets between 2010 and 2019

5.2.2.1 Supermarkets 'constructed before and in 2010'

The results are further broken down by the construction period, for the category 'constructed before and in 2010' some marginal changes are observed compared to the overall picture, see

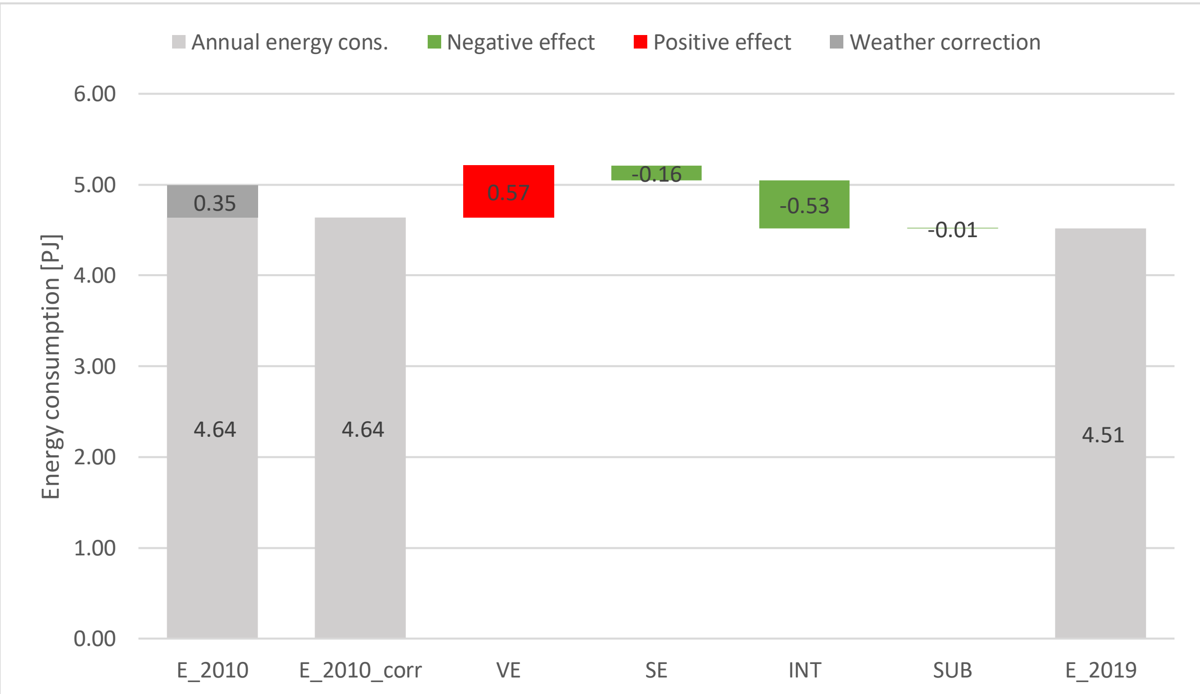

Figure 49. Only the influence of the structure effect is stronger. Which is explained by a smaller share of the total population being built in this construction period in 2010 compared to 2019. It needs to be concluded that the differences between the construction period and the overall picture is marginal due to its large share (96%) in the sub-sector.

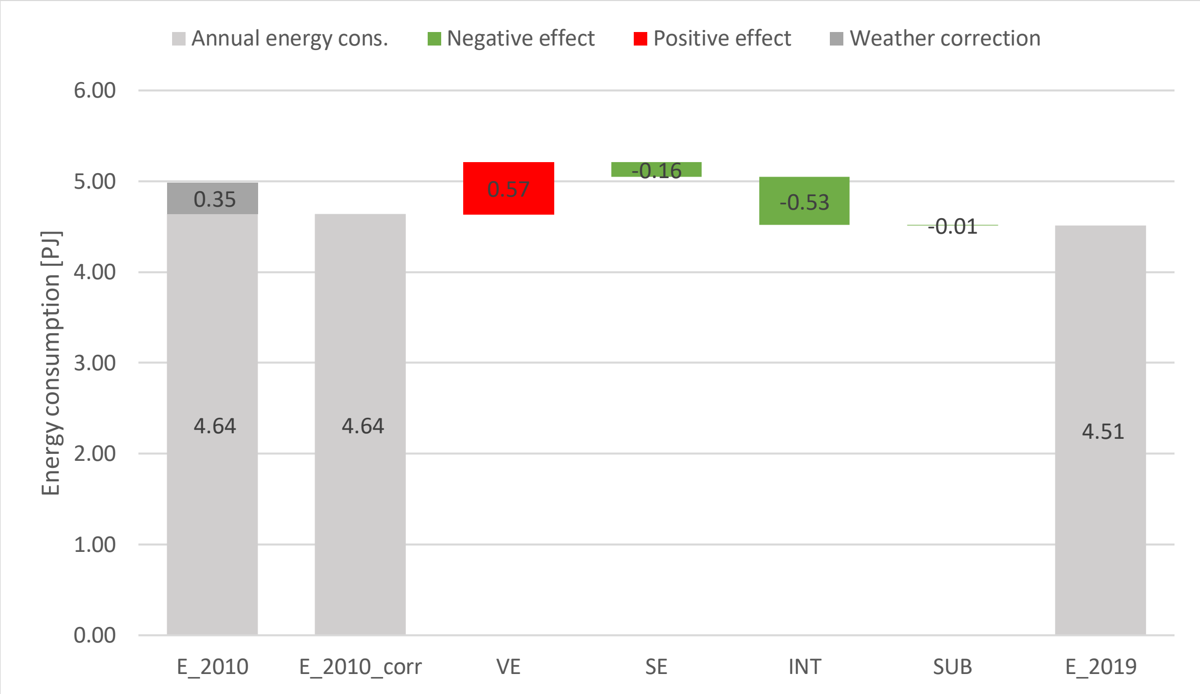

Figure 49. Decomposition analysis supermarkets 'constructed before and in 2010'

The intensity and substitution effect are broken down by energy application in Figure 50. The same conclusions as for the overall analysis is shown. Namely, product cooling is by far the most dominant in terms of decrease, and space heating contributes to some extent. ICT centralized, food/drinks and product processing contribute to an increase.

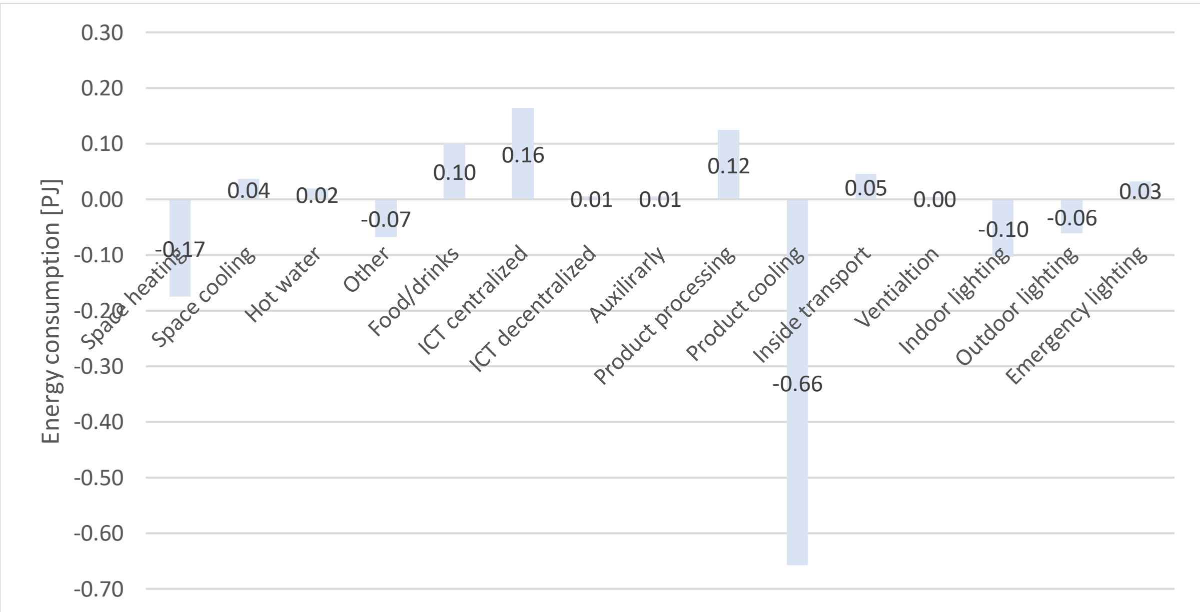

Figure 50. Intensity effect for the energy applications supermarkets 'constructed before and in 2010' between 2010 and 2019

For space heating and hot water, the break down in NG and electricity is provided for the substitution effect, in *Figure 51* and Figure 52. It is observed that the overall, less energy is used for space heating, since the consumption of NG decreased more than that electricity increased. For hot water, marginal changes are observed, showing an increase in NG use and a decrease in electricity, leading to a marginal increase due to substitution. This is considered an unrobust results, see section 5.1.2.

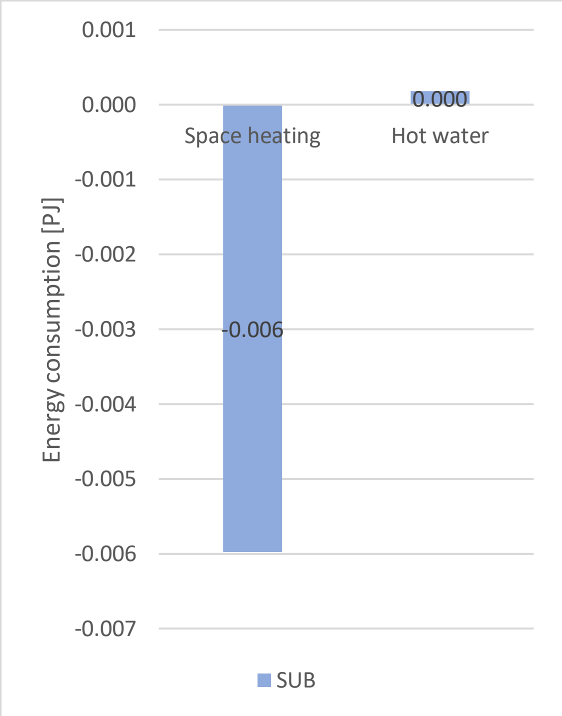

Figure 51. Substitution effect for space heating and hot water for supermarkets 'constructed before and in 2010' summed by energy carrier between 2010 and 2019

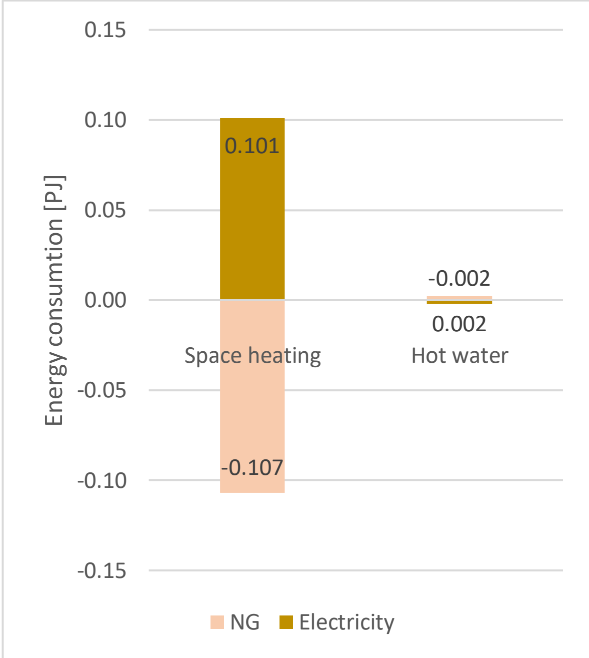

Figure 52. Substitution effect for space heating and hot water for supermarkets 'constructed before and in 2010' for NG and electricity between 2010 and 2019

5.2.2.2 Conclusion supermarkets

To conclude, the overall minor decrease in energy consumption is caused by the decrease in energy intensity and the weather correction. The volume effect is increasing due to the larger floor area. The effects of substitution and structure are marginal to the total energy consumption. The observed decrease in energy intensity is mostly driven by the decrease in intensity of product cooling. Space heating has decreased, also due to the substitution effect. Other categories like, product processing and food/drinks have increased between the period. The robustness of the results in energy application and structure effect are further studied in the sensitivity analysis.

5.3 D: Sensitivity analysis

The sensitivity analysis for the floor area, share of newly constructed, local energy production, and the energy applications is described below.

5.3.1 Sensitivity analysis floor area

The total energy consumption has been compared with two validation sources. This is shown in Table 23. It is observed that the estimations for energy consumption of the retail sector in 2018 range widely, from 20 to 24 PJ. This study results in 29 PJ. The research by Menkveld, Sipma & Niessink provides comparable overall results for the retail sector, however due to a lack of additional information, this comparison is not further examined. It is observed that for NF shops the largest disparities occur. The source of this variance is identified by an analysis of the CBS Retaildashboard's (2018) underlying assumptions.

Table 23. Total energy consumption in 2018

	Reference year	Total energy [PJ/year]	NG [PJ/year]	Electricity [PJ/year]	Source
NF shops	2018	13.42	6.01	7.41	Based on CBS, 2018 incl. shopping malls and food speciality
		23.99	9.6	14.3	
Supermarkets	2018	6.36	1.03	5.34	Based on CBS, 2018
		4.71	0.82	3.89	
Retail total	2017	27	13	14	(Menkveld, Sipma & Niessink, 2017)
		28.9	10.4	18.2	
	2018	19.78			Based on CBS, 2018. Incl food speciality

5.3.1.1 Shops NF

This research leads to a large overestimation of total energy consumption for the NF sector, when comparing to the CBS retaildashboard for 2018. For electricity, this overestimation appears to be nearly twice as great. For NG it is also extensive, about 1.6 times larger. It could be explained by several reasons. Firstly, and assumed most dominantly, the floor area assumed in this research seems to be an overestimation. The retaildashboard is based on 21.61 million m^2 'shop floor area' (WVO) compared to the 48.9 million m^2 building area (GBO), in this research (CBS, 2018). However, the type of floor area makes the numbers difficult to compare, but it is assumed that the factor two is too large, estimations range between 80 and 94 per cent (BRO, 2007; *AN11*). Furthermore, the sample size in this research could be unrepresentative for the NF shops. However, it accounts for 8% of the 'population', a number which would be even higher if the population is smaller, as concluded by the CBS (2018). However, it is possible that a certain shop type is overrepresented in the sample. Another difference could originate from the differences observed in the energy intensity of the shop types, as described in Data preparation section Validation energy intensity. Lastly, the share of all-electric could also be unrepresentative. As well as the share of construction periods, however due to low data availability, this is complicated to validate and check. Several uncertainties were identified, but only the influence of the floor area is analysed further with a sensitivity analysis. The other uncertainties should be considered when interpreting the results, but cannot be quantified.

It is concluded that the CBS buildingmatrix most likely provides an oversetimation of the floor area, both in 2010 as in 2019. Since there is no reasons to assume that the floor area of the NF shops has doubled between 2010 and 2018. Lowering the floor area of 2010 and 2019 by 50 to 60% provides a more realistic estimate. A sensitivity analysis is performed, where the shares of construction periods is kept constant. In Figure 53, it is shown it leads to a linear decrease of all effects. All effects are directly proportional to the floor area, therefore the visualization shows a similar relation between floor area and change in effects for all effects. It is concluded that although the results are effected significanlty, the relative results can still be interpreted. However, the floor area should most realistically be scaled down by a factor.

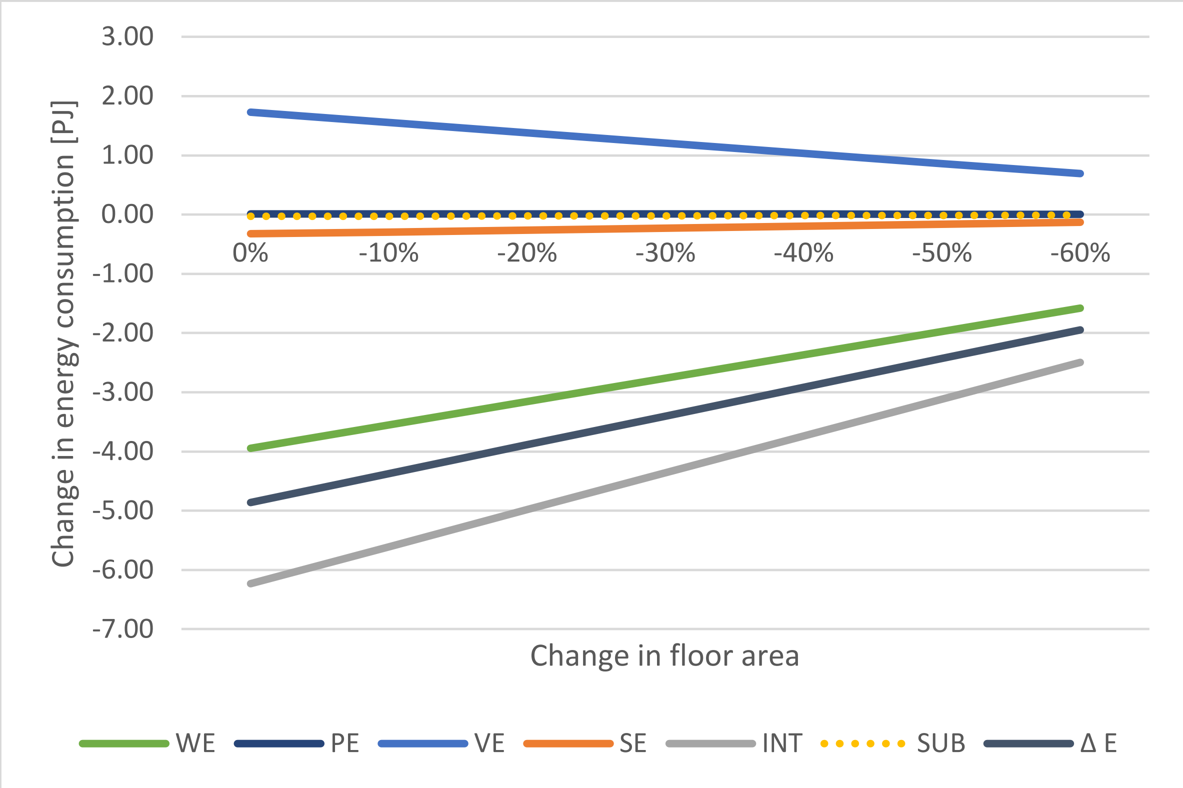

Figure 53. Sensitivity analysis floor area for NF shops in absolute effect.

5.3.1.2 Supermarkets

For supermarkets, an underestimation of total energy consumption is observed when comparing to the retaildashboard, in Table 23. The factor is this time more comparable, 1.4 for electricity and 1.3 for NG. Several reasons for deviation are discussed. Firstly, again, the floor area of supermarkets is not a fixed number, Locatus, which collects most reliable data, only reports 'shop floor area'. It is assumed that the floor area used in this research is a slight underestimation of the actual floor area. Furthermore, in the Data preparation section 4.2.2, the energy intensities for supermarkets were found to differ slightly. Lastly, it was shown in Table 9, that the sample of construction period '>2010' represents 102% of the population. The underestimation of the construction period does not clarify the underestimation of the found energy consumption, however, it could still affect the outcomes of the decomposition analysis. Therefore, a sensitivity analysis is performed on the share of supermarkets 'constructed after 2010'. The share is increased by steps of 10%. Therefore, the share of supermarkets 'constructed before and in 2010' is decreased, so the sum remains 100%. In

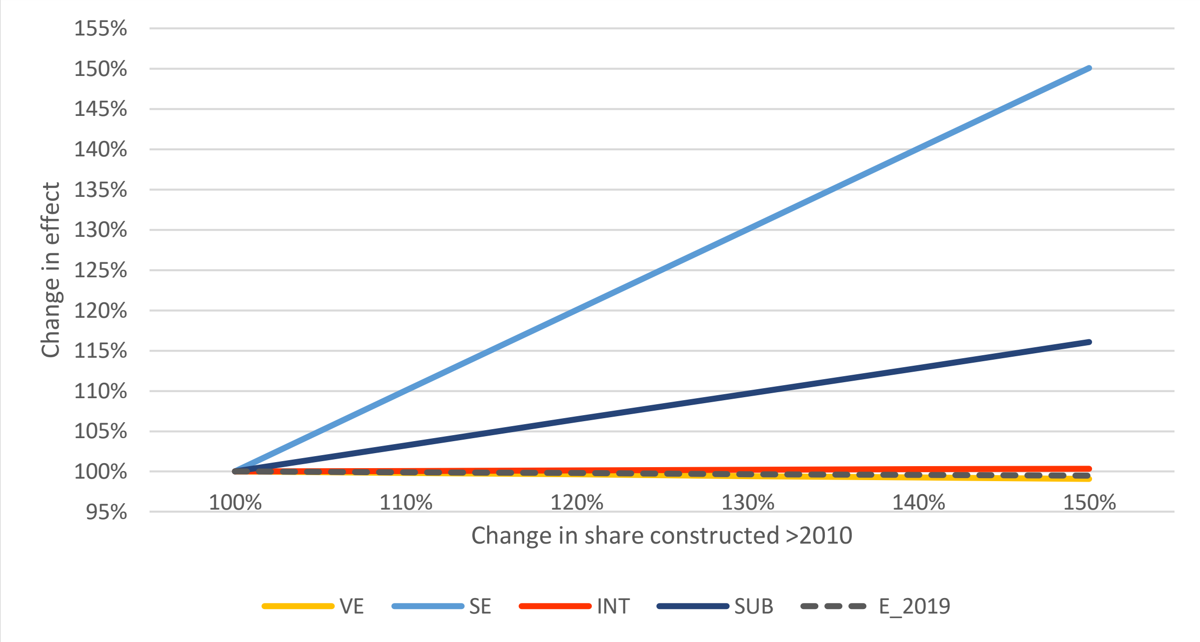

*Figure 54*4 it is shown that the structure effects are sensitive to changes in the share, it has a larger negative contribution to the change in energy consumption. Also, the local energy production increases, as the new supermarkets have a higher self-consumption intensity of locally produced energy. Furthermore, the substitution effect becomes more negative, as new supermarkets have a much lower NG intensity.

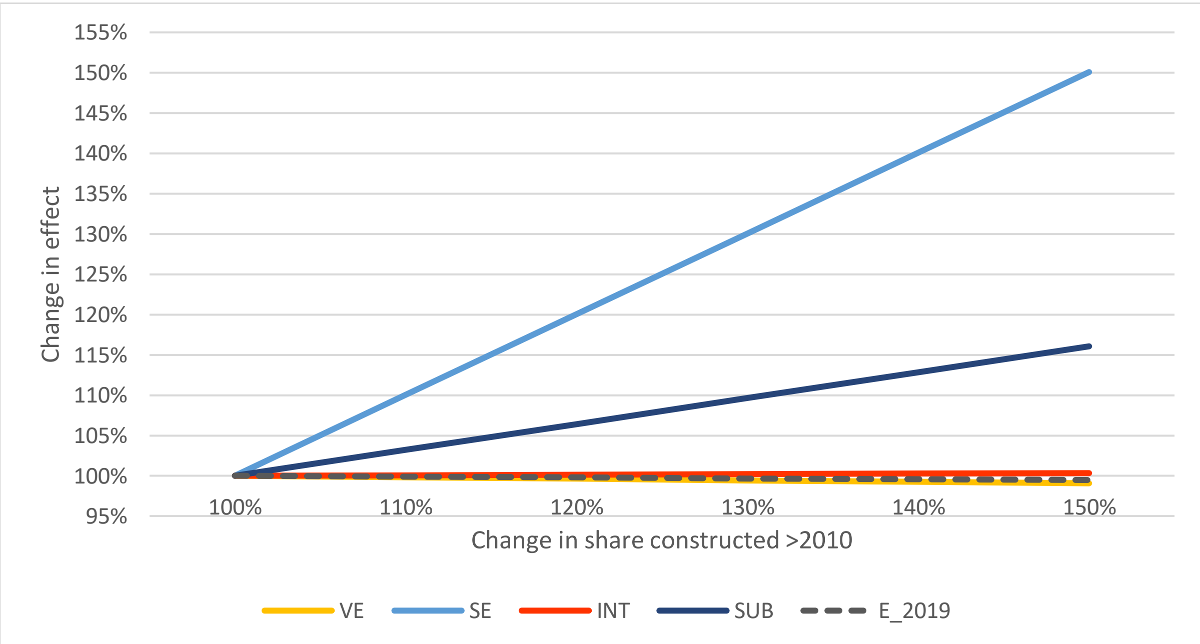

Figure 54. Sensitivity analysis share floor area 'constructed after 2010' for supermarkets.

5.3.2 Sensitivity analysis solar power

To gain insight in the sensitivity of self-consumption of locally produced energy, a sensitivity analysis is performed for the sub-sector supermarkets. The intensity as found in the sample, namely 0.17 MJ/m^2, was based on theoretical estimates of produced electricity with solar PV panels, calculated with the NTA 8800 method. It could not be found in literature whether this is an under or overestimation. Therefore, a negative and positive change is applied. It is concluded that the sensitivity of the change in total energy consumption to self-consumption is low. Therefore, the self-consumption effect as found in the DA can be interpreted. This is also assumed to be the case for NF shops.

5.3.3 Sensitivity analysis energy applications

The energy applications were determined bottom-up for 2019, which was for several energy applications related to large uncertainty. Also, the transparency for the method of the energy applications in 2010 was rather low. Therefore, a sensitivity analysis for energy applications is performed for NF and supermarkets.

5.3.3.1 NF shops

The applications 'space cooling', 'ventilation', and 'other' were selected to analyse for 2019. Those were chosen due to the deviations found to the Energy Check-Up. Based on these insights, the triangular distribution was selected, as shown in Table 24. For 2010, only the most dominant energy application was chosen to analyse. Since it is not known whether this was an under or overestimation, a normal distribution is applied.

Table 24. Applied distributions for uncertainty analysis NF

Application	Distribution	Original	µ	σ or min and max	Motivation
2019					
Space cooling	Triangular	0.0099	original+0.01	Min: original Max: original+0.02	Energy check-up (2018) shows large underestimation. Per centage points change.
Ventilation	Triangular (0.38)	0.0038	original +0.01	Min: original Max: original +0.02	Energy check-up (2018) shows underestimation. Per centage points change.
Other	100% - sum electricity other applications	0.19			Residual application
2010					
Indoor lighting	Normal	0.62	original	10% *original	Account for uncertainty in methodology.
Other	100% - sum electricity other applications				Residual application

In Figure 55, it is observed that only the applied distribution of 2019 affects the results. On the one hand, the intensity effects of 'ventilation', becomes 25% less, and 'space cooling', 10% less, meaning that less intensity gain would have been established by 2019. On the other hand, the initial intensity effect increases for 'other' becomes 24% smaller. Which leads to the conclusion that the decrease in ventilation and the increase in other is not robust.

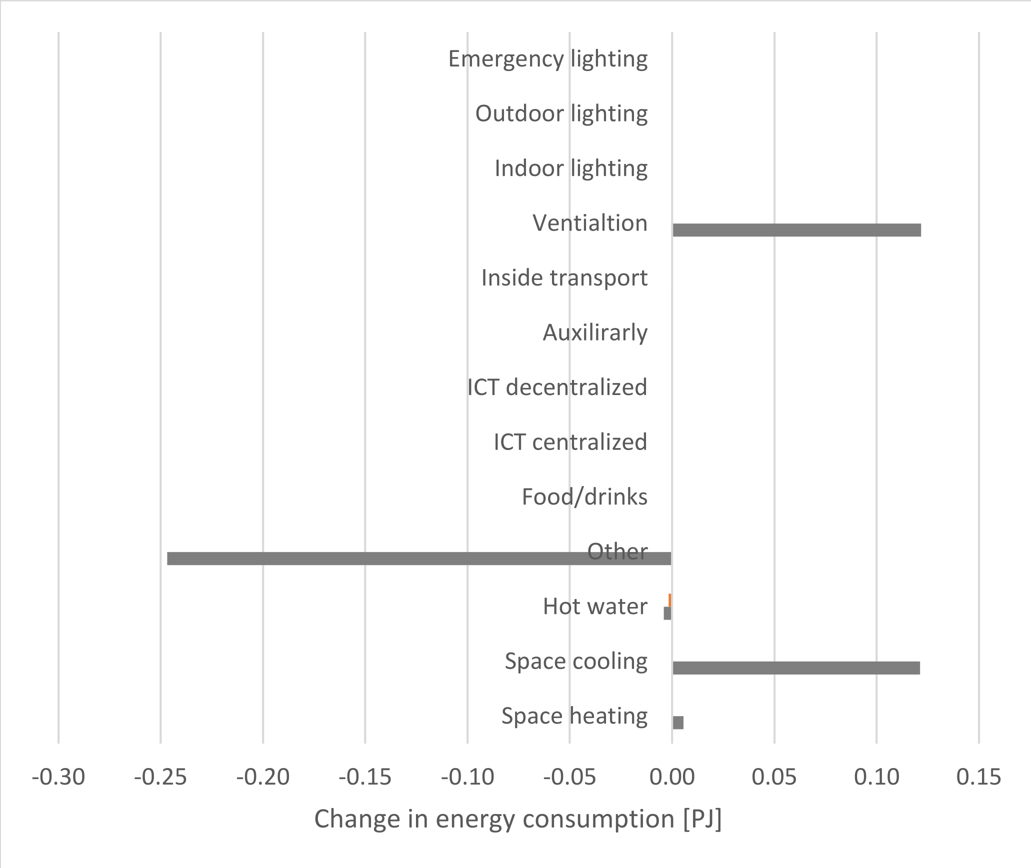

Figure 55.Sensitivity analysis for energy applications of NF shops

5.3.3.2 Supermarkets

For supermarkets, the interviews have unravelled the intertwinement of product cooling and space heating, when waste heat is utilized. Furthermore, the interviews showed that active space cooling was not relevant for supermarkets. The application 'other' is most likely underestimated, as it would imply that no energy is consumed for security surveillance. Lastly, the substantial increase of 'inside transport' could not be explained. In Table 25, the distribution for each energy application is listed. Regarding the application shares of 2010, the most dominant applications, 'product cooling' and 'indoor lighting' were analysed.

Table 25. Applied distributions for sensitivity analysis energy applications supermarket

Application	Distribution	Original share	µ	Ơ or min and max	Motivation
2019					
Space cooling	Triangular	0.02	90%*original	Min: 80%*original Max: original	0.019 original value. Interviews showed that space cooling not/barely applied in supermarkets (AN8). Deviation of 10 and 20% assumed.
Product cooling	Triangular	0.47	original	Min: original+0.01 Max: original +0.02	Compensate for waste energy used for more product cooling and space heating. One percentage point increase

Space heating electricity	1-sum share electricity				Less heating necessary when waste heat is used from product cooling (AN8).
Other	Triangular	0	0.01	Min 0.005 Max 0.015	Initially zero, seems underestimation of security surveillance. Increase by half per centage points.
Inside transport	Triangular	0.015	90%*original	Min: 80%* Max: original	Surprisingly large contributor without explanation. Deviation of -10 and -20% assumed.
2010					
Product cooling	Normal	0.61	Original	10%	Account for uncertainty in methodology.
Indoor lighting	Normal	0.24	Original	10%	Account for uncertainty in methodology.
Other	100%-sum				Residual application

These distributions result in the changes to the results, as shown in Figure 56. For ‘space heating’ the intensity effect has decreased by 37%. Which implies that the energy intensity has *decreased more* than assumed in the first place (i.o.w. = 2019 is even better than 2010 then approximated in the first place). Also, its substitution effect decreases by 195%. However, this does not represent the actual situation, since it is shifted to regenerated electricity. ‘Product cooling’s’ intensity effect has *increased* slightly, by 5%, meaning the energy intensity has *decreased less* than assumed in the first place. Space cooling has decreased by 19%, implying the initial intensity increase is less than assumed. Inside transport intensity has decreased by 12%, again, implying the initial intensity increase is less than assumed. The increase in ‘other’ shows that the initial strong decrease would be 46% less.

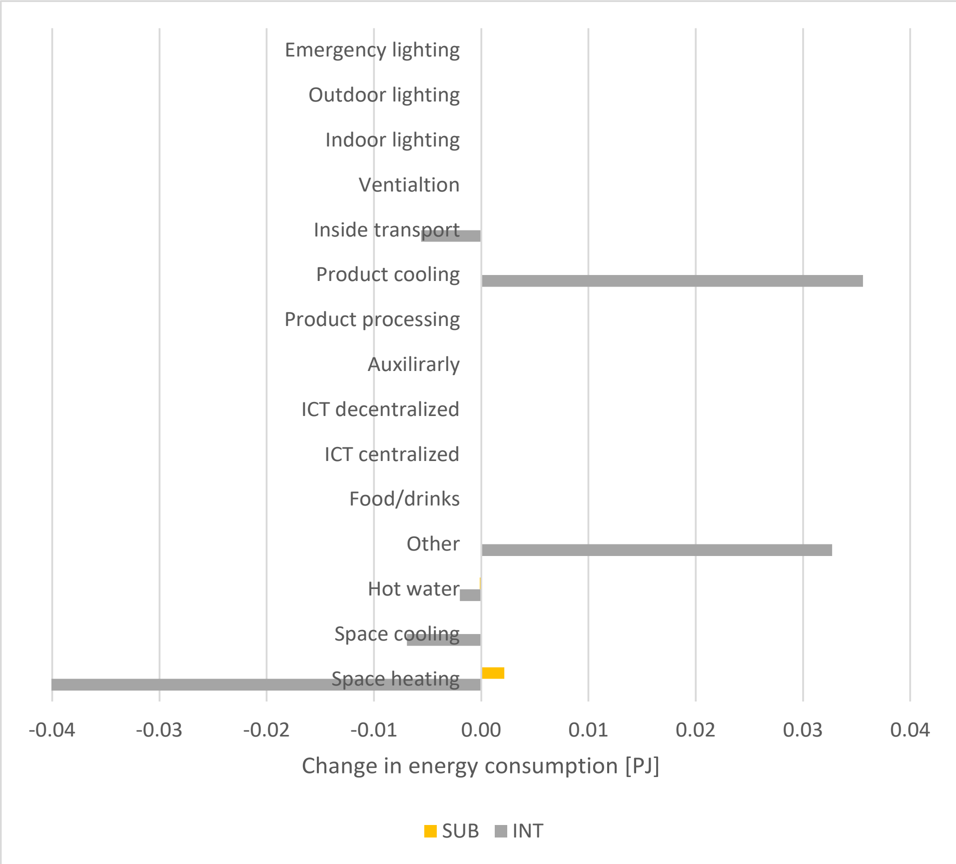

Figure 56. Sensitivity analysis energy applications of supermarkets

This has led to uncertainty in the actual change in intensity for the applications, emergency lighting, outdoor lighting, other, product cooling, hot water, auxiliary equipment, and space heating. The change in the most dominant applications was further analysed in the sensitivity analysis. This resulted in the conclusion that the decrease in product cooling and space heating is robust but would be less than assumed. The decrease in the energy application other is not a robust result.

5.4 E: Drivers and barrier evaluation

Although a downward trend is observed in the energy consumption in the retail sector, it must be concluded that the climate neutrality target of 2050 is still out of reach. Therefore, s*ub- question 3: 'What are perceived drivers and barriers to energy saving in the sub-sectors?'* is answered to gain more insight in energy savings.

5.4.1 Driver evaluation

The perceived drivers, of economics, policy and corporate responsibility are discussed and described in Table 26.

Firstly, economic incentives are perceived to be the main motivation for energy saving in supermarkets (AN8, AN11). This is induced by the extremely competitive market they operate in. This results in frequent upgrades and renovations. Most supermarkets have a fixed cycle for commercial, small adjustments and renovations (AN8, AN11). Namely, four years after opening, the commercial side is upgraded, after six years, a large renovation takes place, again after seven years a commercial upgrade is performed (AN8). After 10 years the supermarket is completely renovated. This enables frequent upgrade of appliances and installations, like product cooling, indoor lighting, bake-off ovens (idem/INNAX). A recent development is the implementation of heat exchangers in product cooling, to provide space heating. Depending on the level of insulation of the supermarket, some additional heating is necessary. However, it has made the renovated supermarkets independent of the NG connection (AN8, AN11, INNAX). This trend is also recognized in the trend analysis, where the NG consumption is decreasing steadily.

Secondly, some introduced policy has induced energy savings in the sector. The EML, and to some extent, Eco-Design is mentioned as drivers of energy savings, especially targeting the 'quick wins' (AN1, AN4, AN2). For instance, preventing the operation of climatic appliances at night by applying time management on ventilation and heating. The EML targets shops with a minimum energy consumption, this can therefore not be considered a driver for most of the small NF shops. In a survey by Panteia it is found that of the shops 'only' 50% has implemented efficient lighting (2020). Furthermore, some limitations of the EML are also experienced by supermarkets. For instance, due to the use of waste heat, renovated supermarkets have little incentive to replace the product cooling by more efficient ones (AN8, AN11). However, this is still prescribed in the EML. A more holistic approach to interplaying energy applications would be useful (AN8). The Eco-Design sets minimum standards for appliances, such as kitchen appliances, laptops, and computers. This could be a driver for NF shops. Hence, less relevant for supermarkets as they do not buy the minimum but carefully consider the economically optimal option. Another directive, the EPBD has proven to be successful in terms of reducing climatic heating demand (AN4). This is also recognized in the trend analysis, especially in relation to the NG consumption.

Thirdly, corporate responsibility is also a driver, especially for supermarkets (AN6). As shown by the voluntary agreement of the CBL, to improve the energy efficiency yearly by 2% (AN8, AN11). Some supermarkets are profiling themselves very clearly in the field of energy neutrality, like Lidl (Lidl, 2018). Also, being 'gas free', like Lidl accomplished already in 2018 (Lidl, 2018).

Especially for the smaller NF shop it is concluded that there are few drivers noticed (AN9, AN10). These are also the shops where older equipment is still present, like manually set space heating and cooling, and TL lighting (AN9, AN10). However, it is also observed that those shops overall have a lower potential for saving, as the energy consumption is induced mostly by space heating and indoor lighting.

Table 26. Perceived drivers toward energy savings in the retail sector

Driver	Sector	Remarks
Economic incentive	Supermarkets	Supermarkets exist due to cost efficiency (AN11, *AN8*). Affects, product cooling, heat transition, and indoor lighting.
Policy: EML	Large NF shops, supermarkets	Leads to quick wins, e.g., by time management reducing night consumption. (AN1, AN4, AN2)
Policy: Eco-Design	NF Shops	AN1, AN4, AN2
Policy: building directive (EPBD)	Both	Renovations and new build (AN4)
Corporate responsibility	Supermarkets	Lidl energy neutral. Profiling (AN6).
		Voluntary agreement: CLB 2% energy efficiency (*AN8*, AN11)

5.4.2 Barrier evaluation

The perceived economic barriers, split incentive, organizational barriers, bounded rationality, knowledge gaps, and technical barriers are further analysed below and described in Table 27.

Firstly, the economic barriers are discussed. The investment capital needed for measures like insulation, upgraded space heating, and lighting replacement is a limitation to NF shops (AN6). The shops are more focused on survival (idem). This is also reinforced by the fact that for large renovation, shops need to close for a period, during which no revenues can be generated (AN3). Another barrier is the discouragement experienced due to a decreasing energy tax for higher energy consumption (AN1, AN11). This provides companies with little incentive to establish energy savings.

Another barrier is the split incentive between renter and owner. According to Panteia (2020). Only 44% of the shop owners is also the 'object' owner. When investment cycles of the shop owner and asset owner do not align, renovations cannot optimally be utilized (AN3, AN8, AN1). An example brought forward in an interview is the dependency of supermarkets on the investment of the asset owner, which is encountered when applying the regeneration of heat for product cooling (AN8). Only when a high standard of insulation is applied (e.g., Rc >4), additional heating is not necessary. In fact, when less is insulation is applied, the supermarket must invest in a heating installation. Another aspect of the split incentive is missing insights in the energy savings resulting from a renovation (AN8). When this is not known, the investor and shop owner find it difficult to quantify the gains from a renovation in terms of energy saving. As a result, less or only the guaranteed measures are taken, like solar energy (idem). Besides the benefits, also challenges arise with the costs of renovation. This is enhanced by the heterogeneity of construction types in the service sector, which makes experiences with insulation less transferable (AN4). Therefore, better insulation than filling up the cavity wall, is costly.

Some organizational barriers are also perceived. Most shops are rented out solely by the building envelope, referred to as casco rental (AN3). This implies that no installations e.g., for space heating, cooling, or ventilation are present. Due to the uncertainty related to the shop's existence, and short lease periods, owners are not incentivized to install the most efficient and (often) more expensive equipment (AN3). This also induces suboptimal resource use, since most climatic installations have a longer lifespan than the rental agreement. When the appliances are present, they are also not replaced frequently in small shops, since they are not motivated or obligated to do so, i.e., as they are not included in the EML (AN9, AN10). Besides energy savings, other environmental topics are of importance too, creating an organizational barrier, due to the need for prioritization. Environmental concerns such as child labour (AN6), circularity (AN6), and resource use, like paper (SG) are brought forward. These interviewees highlight that the shops owners are concerned with the environment but do not necessarily focus only on energy saving alone.

Bounded rationality covers the barrier that the energy costs are just a marginal cost compared to other production costs (AN6, AN1). This leads to naturally less attention for energy costs and therefore energy savings. This is relevant for NF shops.

Some technical limitations cannot be overlooked, as they are perceived as crucial factors by some of the interviewees. These barriers are more applicable to the current situation, compared to the period 2010 to 2019. First, the lack of skilled technical employees is an increasing problem. The heat transition is putting additional pressure on the demand for installers and technicians. This also leads to increased costs of renovations (*AN11*, AN7). Which are also induced by higher costs of many raw materials, like wood (Cristea, 2022). Another technical obstacle is the full electricity grid (*AN11*). This hampers the further deployment of solar panels in some parts of the Netherlands (idem).

Table 27. Perceived barriers toward energy savings in the retail sector

Barrier	Experienced by	Remarks
Economic	Both	Energy tax decreases with higher consumption (AN1, AN11)
		Investment capital. NF more focused on survival (AN6)
Split incentive ***Landlord-tenant problem***	Both	Alignment renovations (AN8, AN3, AN1)
		Insight saving after measures and rent increase (AN8). E.g., heterogeneity with insulation is large challenge for service sector (AN4)
Organizational barrier ***Low priority of energy issues***	Both	Short term rental & casco rental (AN6)
		Replacement appliances not so often for NF (AN7, AN10, AN9)
		Other topics besides energy: child labour (AN6), circularity (AN6), resource use (AN10)
Bounded rationality *Energy costs are minor compared to other costs of production*	NF	For NF (AN1)
Knowledge *Gap between market and retail*	Supermarkets	Supermarkets: large savings not known how to gain (*AN8*, AN11)
Technical limitations	Both	Electricity grid at full capacity (AN11)
		Lack of technical employees (AN7, AN11)

To conclude, many barriers for energy saving measures are perceived in the sector, whereas the drivers are lacking especially in the NF shop sector. It is observed that the energy savings were not high on the agenda for NF shops, until the recent development in energy prices.

6. Discussion

In the discussion the results of this study are interpreted considering earlier research, and limitations of the methodology and the studied dataset are discussed. Finally, suggestions are made for further research.

6.1 Interpretation

This study has sought to gain more insight in historical trends in energy consumption and the drivers of change in consumption. Although interpretation of the available data challenging, an overall decrease in energy intensity is observed for supermarkets and for NF shops. This decrease was stronger for NF shops. The overall observed energy consumption in this study is in line with trends in the overall service sector which has shown a 7% decrease in total energy consumption (Figure 1) (CBS, 2021).

The decomposition analysis reveals that the dominant factor in the overall decrease in energy consumption is the the intensity decrease, followed by temperature change. Both the NF shops and supermarket show a decrease in energy consumption when leaving out the factor of temperature change. This decrease is however greater for NF. The floor area of both NF and supermarkets has in turn increased, leading to an increase in energy consumption. The increase in activity and a decrease in energy savings, reflected in energy intensity are recognized in the Dutch service sector in the Odysee-Mure decomposition tool, which is based on economic indicators (Enerdata, 2022). This tool also accounted for behavioural changes and productivity, which have not been considered in this study. The tool finds that especially productivity, reflected as the value added per employee, has increased largely, leading to a decrease in overall energy consumption. Additionally, Mairet & Decellas (2009) found that in the French service sector, the economic growth was the largest driver of an increase in energy consumption. The studied period of 2010 until 2019 did not include an (economic) crisis, but it cannot be excluded that economic drivers have influenced the energy consumption.

Further drivers of change were broken down based on energy applications. Only the robust energy functions could be interpreted to this aspect. It was found that space heating and indoor lighting have decreased for NF shops. Overall, this is in line with an evaluation study of the EML that estimated 12% electricity and 15% NG for retail building energy savings (Wetzels, Menkveld & Oliveira, 2021). For supermarkets, the largest intensity decrease is shown for space heating and product cooling. This too is line with findings of CBL who observed that 24% overall efficiency was reached in supermarkets between 2010 and 2020, due to a focus on product cooling and becoming 'NG free' (CBL, 2020). The increase in product processing, namely bake-off, is allocated to the changes 'concept' of the supermarkets.

In chapter 5.4, perceived drivers and barriers for energy savings were evaluated. It was found that the split incentive was a hurdle as well as limited investment capital. This is in line with earlier research by van Eijk et al. (2021). In similar fashion, rented space, investment costs, and other investment priorities were found to be the most relevant barriers for the adoption of efficient lighting, insulation, heating replacement, and optimization of heating system operations in a study on the non-residential German sector (Olsthoorn Schleich & Hirzel, 2017). Additionally, they discussed that the lifespan of a measure might be another determining factor in implementation. This was not found in this research. With regards to drivers, earlier research concludes that energy audits would be able to overcome information asymmetry in the split incentive. Also, an energy manager was found to be a driver (Olsthoorn Schleich & Hirzel, 2017). Although energy audits are performed in large Dutch retail, they have not been indicated as a driver in this study. This could be due to the limited number of interviews that were performed.

6.2 Limitations

6.2.1 Data limitations

The availability of data, in line with limited insights into energy consumption, has been a matter that requires attention too. Firstly, data of the floor area for supermarkets varies between sources. There is a discrepancy observed of three million m^2 of total floor area between the data of 2019 from the 2010 to 2019 dataset and 2020 from the 2020-2021 dataset (CBS, 2021*a*.; CBS, 2022). Additionally, the share of 'constructed after 2010' is underestimated in this research, based on the sample. Furthermore, the data of Retaildashboard (CBS, 2018) provides a slightly higher energy consumption in general than the outcome in this study. Secondly, data for NF from the CBS Buildingmatrix gives an assumed overestimation of the floor area of NF shops, suggesting a sensitivity issue. Data on this is, however, only available for the year 2018 and can therefore not be assessed for other years. In total, the weighed conclusion is made that the results for NF shops cannot be interpreted in absolute terms, but only in relative terms, and that uncertainty remains about the total energy consumption of both sub-sectors. Which is partly induced by the bottom-up methodology of energy consumption, as also applied in the Retaildashboard.

A study of this nature is sensitive to assumptions made for each energy application. It should therefore be noted that for the energy applications in 2010, a reference from the year 2007 was used from a study by Meijer & Verweij (2009). Additionally, the methodology in that study was not transparent, which leads to uncertainty about results and underlying assumptions. For example, the observed reversed substitution effect for hot water might be a result of underlying assumption. This is unlikely but cannot be validated due to limited data for this finding. Furthermore, the research is sensitive to the assumptions made for the determination of each energy application. As for NF shops, the observed decrease in ICT centralized, auxiliary equipment, emergency lighting, and space cooling was not expected. The increase in transport, and other is also not expected. The change in the most dominant applications was further analysed in the sensitivity analysis. This has led to unrobust results for the energy applications other for supermarkets and ventilation and other for NF shops. The observed changes for the energy applications ICT centralized, auxiliary equipment, emergency lighting was not robust for both sub-sectors, but was not further studied due limited expected effect on the overall results.

To paint a coherent picture of the situation of 2019, the most adequate data is required for every single energy application. For some applications, however, data more recent than from the year 2000 was not available. For instance, the yielded energy intensity for food and drinks is likely to be higher than realistic as efficiency has been improved over the years. Furthermore, the fit factor with respect to the allocation of energy applications for supermarkets and NF reference shops for bottom-up electricity intensity ranged between 80% and 105%. The decision was therefore made to make alterations in categories indoor lighting and other, though these alterations are sensitive to interpretation. And as indoor lighting has a major impact on electricity consumption, the assumptions affect the results significantly. For instance, a difference of 15 W/m^2 in installed capacity, representing LED versus Tl lighting, makes a 36 kWh/m^2 impact on the final electricity consumption. For NF shops, this would be about $1/3^{rd}$ of the electricity consumption. Furthermore, the 'Energy label' dataset of the shops were not differentiated per shop type. As there is a clear difference between supermarkets and NF shops, an underestimation can be made of the efficiency of supermarket installations as these are not isolated from NF installations. In turn, the efficiency of NF shop installations can be overestimated. These are relevant notes to clarify the role of applications such as ventilation and space cooling, of which the outcomes were also associated with uncertainty, as shown in the sensitivity analysis.

To make a more complete overview of the Dutch retail sector in the future, the omission of shopping malls and specialty stores like bakeries should be solved. Especially bakeries add to the NG consumption given their production process and could provide valuable insights in the heat transition. For shopping malls, the floor area was too uncertain given the limited data to include this category. The CBS Microdata sample does not include them either.

A more complete sample size will make future research more robust too. An example is the exclusion of inactive 'objects' for 2019 in the energy intensity sample. This exclusion represents itself when, for instance, a building is transformed from a shop to an office. In this case, the energy intensity for that building before its transformation is excluded, effectively leading to a loss of valuable data. This is also recognized in the large sample (i.e., 102%) compared to the population of supermarkets 'constructed after 2010'.

Lastly, this study would be more complete if data was available about solar thermal and district heat in the retail sector (Panteia, 2020). The shares of all-electric are extrapolated to the entire population. This leads to a slight overestimation of all-electric shop and, and possibly, to an underestimation of the total energy consumption.

Overall, future research would benefit from greater data availability; both in numbers as well as in completeness and uniformity. Not only is this an issue for the retail sector's insight in energy consumption and acting on it, but it also slows down research on this topic. This effectively maintains a status quo of unfamiliarity which must be breached by actively gathering more information and doing it in a centralised fashion to prevent fragmentation of data and incorrect categorisation.

6.2.2 Methodological limitations

The accuracy of this and future research can be enhanced by making several improvements on the methodology applied in this study. First, the energy intensity demonstrated is the weighted average of all shops in the sample set. However, the heterogeneity of the sector has a right skewed distribution for energy intensity. Thus, due to the large variation in energy intensity, the average not necessarily reflect the variation in energy consumption. Especially for NF shops, further disaggregation in shop types might provide more insights in the overall change in consumption and the driving forces of changes.

Secondly, no temperature correction was applied for electricity although significant shares all-electric were found. This leads to an unfair comparison of the substitution effect. Additionally, a relative HDD method was applied with reference year 2019 which makes this research difficult to compare to other studies. Furthermore, no cooling correction was applied. Particularly, Hekkenberg (2009) observed a 0.5% increase in total electricity consumption for each degree change in outside temperature. This effect would have been interesting to quantify given the increasing outside temperature.

Thirdly, this study leaves out the effect of emerging wase heat utilization in supermarkets. This development makes the analysis of energy applications less suitable for supermarkets, and less complete as it does not paint the complete picture. Quantification of this relatively innovative technology is not available yet and could therefore not be included in this study. The effect of waste heat utilization in supermarkets assumingly leads to a decrease in energy demand, and an attribution of energy flows must be applied. Interestingly, this could also be relevant for space cooling in supermarkets, which is most likely already, passively happening in spaces where products are cooled. Another factor of split energy applications is on-site produced energy. It is argued that the self-consumed electricity will mostly be consumed in summer. An attribution method should be developed to account for this too.

Fourthly, opening hours of shops change over time and it is interesting if this can be corrected for. This provides a more accurate insight in the change in efficiency of energy applications over time. Additionally, the interviewees highlight that for some shops the comparison of shop types between now and 2010 is unfair due to a change in concepts or products they offer. Especially for supermarkets, the focus on fresh products leads to a direct increase in energy consumption in the shop. This is recognized in a higher intensity for product preparation in the shop like a bake-off or a sushi corner. An increase in efficiency therefore does not necessarily lead to a decrease in energy consumption. Overall, it is thus very difficult to capture the whole heterogeneity of the retail sector in numbers and continuously working on including these factors will improve accuracy in future research.

Fifthly, in this study it was strived for to compare shops with comparable building characteristics by recognizing two construction periods. Therefore, it would have been valuable to correct for large scale renovations as these renovations blur the effect of actual energy intensity improvements of the construction period ‘constructed before and in 2010’. Furthermore, the performed analysis assumes that the energy intensity of energy applications is similar for the two construction periods in 2019. However, this is unlikely to represent the actual situation. It leads to a potential overestimation of building related applications in the construction period ‘constructed after 2010’, and potentially underestimation in ‘constructed before and in 2010’.

Lastly, regarding the evaluation of the barriers and drivers for energy savings, it would have been interesting to provide more insight in the ranking of each driver and barrier. This could have led to more specific focus in the policy recommendations. Additionally, the number of interviews was lower for NF shops than for supermarkets and the interviewees were often respondents in policy positions. A more representative group of respondents is required to formulate policy on interviews alone. Respondents that have more practical functions in shops will give a more complete view of the perceived drivers and barriers.

6.3 Further research

The interviewees perceived the DA as a valuable visualization of changes in the sector. Therefore, it is suggested that a decomposition analysis is performed more frequently in the service sector, to track drivers of change. However, the focus should be on the collection of more reliable inputs, and it is suggested to focus on a smaller sample with data of energy audits performed with the same methodology. To that extend, strategies need to be developed to allocate the energy flows of solar power and product cooling to the relevant energy applications. These insights can be used to combine a quantitative and qualitative analysis of energy saving measures in a sector.

The inclusion of economic drivers has become more relevant due to the recent developments of COVID-19 and the energy crisis. This influence of this would be interesting to study both in the quantitative as well as in the qualitative analysis. The inclusion of changes in the energy price, or value added as a driving force would be interesting to evaluate. The qualitative analysis of strategies for energy savings could be improved by spreading surveys among a larger group of shop owners, asset owner, policy makers and shop staff. This would also allow the ranking of drivers and barriers. It is suggested that policy makers consider the outcomes of these research in policy making.

Another suggestion for further research is the inclusion of other environmental indicators, like resource depletion in the analysis of changes in the sector. Especially when the replacement of installations is proposed, a life-cycle analysis can provide further insights in the overall environmental benefits of these kinds of measures.

7. Conclusion & policy recommendations

7.1 Conclusion

To conclude, first the research question '*Which trends can be identified in final energy consumption in the retail sub-sectors between 2010 and 2019 and how much did driving forces like activity change, structure change, and intensity change of energy applications contribute to the observed change in final energy consumption?'* is answered. An overall decrease in energy consumption is observed in both retail sub-sectors, which is much larger for NF shops than for supermarkets. The intensity effect and weather correction induced the largest decrease, for both sub-sectors. For NF shops, the volume effect induced a slight increase in overall consumption. For supermarkets, a substantial volume increase is observed. The sub-sectoral change was small but negative, since the construction of new shops, 'constructed after 2010', contributed to a decrease in energy consumption, shown for both sub-sectors. This is also observed for the substitution effect, due to the substitution of electricity for NG in space heating for both sub-sectors.

The decrease in intensity is explained by changes in energy applications. For supermarkets the decrease in intensity is explained by product cooling and space heating. ICT is the driving force of increase in intensity. About NF shops, indoor lighting and space heating are contributing most to the decrease. Higher intensity for food/drinks is considered a robust driver of a higher energy intensity.

Second, the research question *'What are perceived drivers and barriers to energy saving in the retail sub-sectors?'* is answered. The main drivers for supermarkets are the highly competitive market, which induces economic drivers for energy costs savings, and corporate responsibility. For large NF shops, the EML policy is a driver. It is observed that energy costs, and therefore energy savings were not high on the agenda of NF shops, until the recent increase in energy prices. Perceived barriers are the split incentive, economic barriers for investment capital, knowledge and technical limitations, like the lack of technicians.

7.2 Policy recommendations

These insights were combined to evaluate strategies for climate neutrality by 2050. Three policy recommendations are provided. It is suggested to set-up a pilot study to gain more insight in the energy savings gained by investments in energy saving measures. Additionally, extensive collaboration is suggested. The influence of higher energy prices could have a twofold effect, and developments on the longer-term are unknown, therefore, it is suggested to provide a quantitative target in the service sector regarding final energy consumption to provide guidelines along the way to climate neutrality by 2050. These suggestions are elaborated further below.

7.2.1 Pilot projects

A first strategy is to gain more insight in the costs and benefits of energy saving measures by laying out extensive pilot projects. These pilot projects can help to overcome several barriers, namely the split incentive, the knowledge barrier, and can provide overall insight in energy consumption by application in the retail sector. It also helps to evaluate the effectiveness of policies, in terms of energy savings. The continuous monitoring can be performed with energy audits and smart metering. This should be performed for multiple type of shops, to overcome the heterogeneity in the sector. The results should be communicated to the retail sector, e.g., on a platform.

Several field of energy saving are suggested for the pilot projects. Namely, the building envelope related measures like applying and comparing several types of inside, and outside insulation. No consensus was found on the influence of the behaviour of staff among the interviews. Therefore, this is an interesting pilot case too. For instance, the impact of closing of all doors, to create separate climatic areas was perceived as an opportunity (AN7). For small NF shops, the influence of behaviour of staff is perceived as larger due to less automated appliances (e.g., space heating and cooling) (AN9, AN10). Here, the effects of a smart metering, a switch to centrally managed energy systems, or clear settings of the climatic appliances, can be quantified. For supermarkets, more insight can be gained for the use of waste heat from ovens, as shown in Figure 57. Among the interviewees there was a lack of consensus on this potential and applicability.

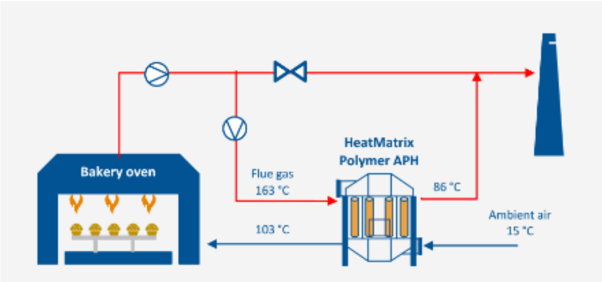

Figure 57. Schematic potential of utilization of waste heat of ovens (Heatmatrix, 2021)

Some synergies are expected in terms of collaboration between renter and owner. Due to less knowledge gaps, it can be easier to plan renovation and agree on the economic costs and benefits. These insights also help to overcome the lack of knowledge and heterogeneity in terms of the building envelope in the service sector.

7.2.2 Collaboration

Another strategy to enhance the energy savings is to improve the collaboration between stakeholders. This recommendation includes both national as well as the EU level. To this extent, the NF shops can learn from the supermarket sector. Dutch supermarkets are already committed to setting targets regarding energy efficiency and committing to becoming 'gas-free'. However, it is also perceived that this collaboration can be enhanced, one of the barriers that needs to overcome is that energy consumption is still viewed as a 'business secret' (AN8). Collaboration in the NF shop sector could be established due to the retail chains under which most shops operate.

A strategy which is in line with collaboration of retail chains, is the sharing of knowledge on an EU scale. This could be done by platforms and working groups. Some countries are taking stringent measures to prepare for the coming winter. When these measures and practical implications are shared, other retailers can learn from this. In France, the supermarkets are frontrunners in terms of intended energy savings, as they have proposed to take the following measures. Collaboration of retail chains within the EU can help to overcome the organizational barrier. Furthermore, some European retails are considering shorter opening times this winter (Naudu, 2022). Collecting data on the effectiveness of these kind of measures can provide valuable insight to other retail. The energy saving measures that will be implemented in France are:

1. Turn off marketing outdoor lighting, outside opening hours. Which used to be on for another hour (van Oosbree, 2022)
2. Reduce indoor lighting at night by 50 % (van Oosbree, 2022)
3. Reduce indoor lighting during opening hours by 30%, where possible (van Oosbree, 2022)
4. Turn of ventilation at night (van Oosbree, 2022)
5. Limit indoor temperature to 17 °C in winter (van Oosbree, 2022)
6. Carrefour and grid operator agreed to reduce store electricity consumption at peak hours (Naudu, 2022)

7.2.3 Target

At last, the recent high energy prices have shifted attention to energy consumption. On the one hand, this can help to address drivers and overcome barriers like ‘bounded rationality’ and could influence economic decision making. Since the payback period is shorter if the savings are larger. On the other hand, it also leads to increased costs, possibly leading to lower investment capital. To establish and provide certainty for long-term energy saving efforts, a proposed strategy is to set the ‘Climate Neutrality’ target for the retail sector by 2050. If found necessary, this can be guided by ‘reachable’ annual savings percentage target. The target that will be established for 2050 needs to be clarified on the type of energy consumption, total energy intensity is suggested. Additionally, the selected floor area and the exclusion of on-site renewable energy production.

Not all barriers are overcome by these strategies, especially the technical barriers are of importance, and these barriers go beyond the retail sector. Therefore, it is suggested that external factors should be considered in future strategies for energy savings. A more holistic approach is needed to establish the challenging pathway to climate neutrality in the service sector.

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Appendix

1. Annex A: Detailed method energy application

1.1 Building related

The building related bottom-up approximation of energy by application is explained in the following paragraphs.

1.1.1 Hot water

The following approach is used to calculate the hot water demand.

The hot water demand is approximated by the NTA 8800. Which assumes a net hot water demand of 1,4 kWh/m^2 (NTA 8800, 2020). For hot water, a correction for losses in the storage tank need to be included. A loss of 25% is associated to storage tank of 30 L (CE, 2021). This represents the loss of a one-person household. For commercial uses, it can be expected that the losses are slightly lower, since showers require the largest storage, however, no data could be found on that. The resulting heat demand is 1.75 kWh/m^2.

Based on the installed tap water boilers, it can be calculated what the required energy from NG and electricity is.

For simplicity, only differentiation between gas and electrical boilers is made. This results in hot water production for 73% with an electric boiler and 27% with a gas boiler (EPA Input W/E, 2019). From the theoretical dataset it is known 20% is fuelled by high efficiency boilers (HR/CW). Therefore, the efficiency of that boilers is taken as representative for all gas boilers. In reality, the efficiency would be slightly lower. The efficiency of boilers is used to calculate the energy requirement, see Equation 26. The efficiencies are shown in *Table 28*.

Equation 26

$$\eta = \frac{E_{useful}}{E_{total}}$$

Table 28. Efficiency and share of hot water installations

Type boiler	Efficiency (η) (CE, n.d.)	Share shops (S)
Electrical boiler	95%	73%
HR gas boiler	90%	27%

The electricity and NG consumption can then be calculated with Equation 27, which is shown for electricity. For the purpose of unit transformation, the lower heating value (LHV) of 31.65 MJ/m^3 NG is used, as preferred at TNO.

Equation 27

$$Q_{electric} = (Q_{total} * S_{el.boiler}) \,/\, \eta_{el.boiler}$$

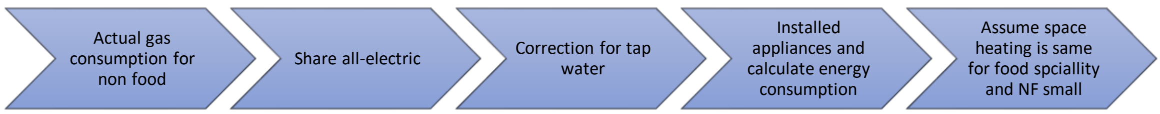
This results in the following energy consumption, which is assumed to be constant for all reference buildings. It could be argued that food shops consume more hot water for production and cleaning. Due to missing data, this is not accounted for.

Table 29. Intermediate results hot water

	Net heat demand [kWh/m²]	Including losses [kWh/ m²]	Electricity [kWh/ m²]	NG [kWh/ m²]	NG [m³/ m²]	Energy consumption [kWh/m²]
Shop	1.4	1.75	1.34	0.53	0.06	1.90

1.1.2 Space heating

The space heating is calculated based on the actual NG consumption for shops non-food, which are connected to the NG grid. It is assumed that all shops with NG connection use NG for space heating. A correction for the hot water production with NG is made. The supermarkets were found to have a lower NG consumption compared to non-food shops and are therefore expected to do no product processing with NG.



The share of all-electric shops is calculated from the sample for each reference building.

Equation 28

$$S_{all-electric} = 1 - \frac{Valid\ N_{NG\ in\ 2019}}{Valid\ N_{electricity\ in\ 2019}}$$

This yields the table below.

Table 30. Share all-electric

Shop type	Share all-electric
NF small	9,68%
NF large	7,45%
NF average	9,09%
Supermarket	25,65%

The NG consumption for space heating is calculated by subtrackting the tap water NG demand from the NG intensity. To determine the space heating electricity demand, it is assumed that all all-electric shops are heated with a heat pump. The efficiency of the gasboiler needs to be determined to estimate the heat demand for the all-electric shops.

Since it is unknown which type of gas boiler is installed, the efficiency needs to be calculated, to determine the heat demand for HP.

Equation 29.

$$\eta_{gasboilerl,j} = \left(Q_{NG,j} - Q_{NG,TW}\right) * \left(\frac{1 - S_{all-electric,j}}{Q_{NG,j} - Q_{NG,HW}}\right)$$

$\eta_{gasboilel}$	Efficiency reference building, *j*
S_i	Share of all-electric *i*
Q_{NG}	NG intensity for NG connected shops
$Q_{gas,HW}$	Gas intensity for hot water

This is needed to determine the gross energy requirement for heating with a boiler or a heat pump.

Equation 30.

$$Q_{boiler} = Q_{NG,j} - Q_{NG,HW}$$

Equation 31.

$$Q_{HP} = \frac{Q_{boiler}}{\eta_{gas\ boiler,j} * S_{boiler}} * \frac{S_{all-electric}}{\eta_{HP}}$$

This yields an average efficiency for the gas boilers of:

Table 31. Calculated efficiencies for gas boilers

Reference building	Calculated efficiency NG boiler
Non-food Small	90%
Non-food Large	93%
Non-food Average	91%
Supermarket	74%

Which is in line with expected efficiencies:

Table 32. Efficiency heating systems (NTA, 2019, p. 303_305; Milieucentraal, n.d.)

Type	Efficiency	Assumption
conventional boiler	75%	
VR (improved efficiency)	80%	
HR 107 (high efficiency)	95%	
Heat pump	2.3	Supply temperature between 35 and 55 C. Heat pump on outside air. Average COP is 2,3. From table 9.27 NTA 8800 2019

The gross heat demand for boilers and HP is then calculated with Equation 31. In the table below the results are presented. The space heating for small shops is assumed equal for non-food and food shops. The total NG consumption for shops with NG connection is corrected for all the shops, including the all-electric ones, as calculated above. The space heating demand is expressed in NG and electricity, which are both needed to heat an 'average' shop.

Table 33. Energy requirement for space heating

	NG connected	NG average all shops	El (kWh/m²)	
			Boiler	HP
Non-food small	10.15	9.16	80.04	3.73
Non-food large	7.39	6.84	59.63	2.09
Non-food average	9.40	8.55	74.62	3.24
Supermarket	7.33	5.45	47.41	7.11

1.1.3 Auxiliary equipment

Auxiliary energy is needed for the heating and cooling systems in a building. For heating and cooling these values are estimated separately and corrected for the number of shops with space cooling. The intensities for offices are assumed to resemble the intensities of shops. All shops are assumed to have the same intensity.

Table 34. auxiliary equipment (INNAX, 2022)

Circulator type	Electricity intensity [kWh/m²]	Share cooling
Heating	1.5	
Cooling	1.1	45%
All shops	1.99	

1.1.4 Ventilation

The ventilation requirements are dependent on the type of building and its energetic performance. The requirement is dependent on the heating, cooling, seams and cracks in the building (source). Since this is complicated to model, and data availability is limited, a standardized formula is used, which is:

Equation 32.

$$P_{shaft} = \frac{U_{v,min} * c_{sys} * A_i}{1000}$$

(NEN 2916, 2004 p.80)

Where (NEN 2916, p. 80)

P_{eff}	Standard effective capacity [kW]
c_{sys}	Dependent on the installed appliances [(W.s)/dm³]
$u_{v;m}$	Air supply by mechanical ventilation [dm³/(s.m²)]
A_i	Floor area [m²]

The effective standard capacity is calculated by

Equation 33.

$$P_{eff} = rf * \frac{f_{time} * P_{shaft}}{\eta}$$

(NEN 2916, 2004, p. 82)

The energy consumption for ventilation is calculated by

Equation 34.

$$E = f_v * 8760 * \frac{P_{eff}}{A_i}$$

Table 35. Other input values ventilation

Variable	Value	Assumption	*Source*
f_time	1	Reduction factor for type of ventilator. Assumed is no time management.	*NEN2916, 2004, p. 83*
rf	0.8	Reduction factor for over dimensioning of ventilator	*NEN2916, 2004*
f_fraction	0.3	Fraction of time the ventilator is in operation	*NEN2916, 2004 p. 51*
$u_{v;m}$	0.35	Ventilation air flow rate as prescribed in Building Order for a shop (Bouwbesluit) 2012	NTA 8800, 2020 p. 449

Table 36. Efficiency shaft motor, installed after 2004 (NTA 8800, p.493)

Shaft power (kW)	Efficiency
<1	70%
1 to 2	75%
2 to 4	80%
4 to 10	85%
10 to 30	87.25%
30 to 60	90%
60 to 120	92.5%
≥120	95%

Table 37. Constant values for c_sys

		c_{sys} [W.s/dm^3] (NEN 2916, 2004)	**Share of shops with ventilation (W/E, 2022)**
A1	**Natural ventilation**		**73%**
C1	Mechanical exhaust	1.2	62%
B1	Mechanical supply	2	4%
D1 and D2	Other	3	34%
Weighted average		1.85	

For each reference shop type, it is estimated whether they have installed ventilation, which results in the table below. It can be noted that only using the building code as input to the calculations yields a simplified and most likely underestimated energy intensity. The values are lower than the intensities found by Meijer & Verweij (2009).

Table 38. Energy intensity of ventilation

Reference building	Share ventilation	EI (kWh/m^2)
Supermarket	100%	1.94
tot non food	18%	0.35
Non-food Small	7%	0.14
Non-food Large	47%	0.92

1.1.5 Space cooling

For the reference buildings, the theoretical calculations as presented in the document 'Uniforme Maatlat' by the ECW (2021) are used. For that purpose, the floor area, construction period, heat loss area and the window area need to be assigned to the reference buildings. The floor area, construction period and heat loss are taken from the CBS. The window area is based on the BENG reference buildings, shop size S (DGMR, 2018). Assumptions for the ventilation type per reference buildings are based on expert insight at TNO, for the small shops natural ventilation (A) is assumed. For the large shops the C1, mechanical exhaust fan is assumed. The shape factor and the cooling demand are then calculated in the 'Unfiorme maatlat' for a shop.

Table 39. Space cooling input (DGMR, 2018; ECW, 2021; CBS microdata, 2022)

Reference building	Area [m^2]	Window ratio	A_{loss} /Area	Construction period	Shape factor [W/m^2 K]	Assumption	Cooling demand [kWh/ m^2]
Supermarket	1326		0.70	1986	0.95	C1	19.7
Non-food average	459		0.78	1941	2.65	C1	13.2
Non-food small	280		0.79	1934	2.65	A	12.7
Non-food large	949		0.75	1960	2.65	C1	14.4

Since it is known that not all shops full the cooling demand, a correction is performed for the share of cooled shops. This is based on the theoretical dataset, which states that 45% of the shops has no installed space cooling device. In this dataset, mobile air conditioners are not included.

Table 40. Space cooling appliances (W/E adviseurs, 2022)

Adjusted categories	Share of total
None, unknown, negligible	45%
Compression	52.8%
Free cooling	2.6%
Total	

Table 41. Assumed efficiency space cooling

Type	COP	Assumptions	Source
Compression	3.75	Average of 3 and 4.5	Israëls, Stofberg & Kuijpers-van Gaalen (2020)
Free cooling	13	Average of groundwater and ground heat exchange	Israëls, Stofberg & Kuijpers-van Gaalen (2020).

It is assumed that the space cooling is applicable to the large shops and the small shops do not have installed cooling appliances, as shown in Table 39. When cooling is assumed present, the shares of Table 40 are applied. This yields the following table.

Table 42. Energy intensity space cooling

	Energy consumption cooling [kWh/m^2]			
	Supermarket	Small NF	Large NF	NF
Compression	5.01		3.66	0.89
Free cooling	0.07		0.05	0.01
Total	**5.08**		**3.71**	**0.09**

1.1.6 Indoor lighting

Indoor lighting in shops is used for product lighting and 'head lighting' (also called, horizontal lighting or loopverlichting). The lighting produced by the refrigerators is not included in indoor lighting and is counted towards product cooling.

In the annual monitoring research by Panteia (2020), a survey among shops results in a sample size of about 190 shops. This research shows that 62% of the shops has efficient LED lighting and 38% uses regular Tl lighting (Panteia, 2020). Based on the capacity and the hours, the energy consumption is calculated, see Equation 35 below and

Table 43, assumptions for the capacity of indoor lighting are shown.

Equation 35.

$$E = P * t * cf$$

E	Energy consumption [kWh]
P	Capacity [kW]
t	Operating time [h]
cf	Capacity factor [0-1]

Table 43. Indoor lighting capacity and assumptions

	Capacity [W/m²]	Assumptions	Source
Supermarket			
Low efficiency	30	Standard is 30 W/m²	NTA 8800, 2020
High efficiency	17.5	High efficiency lighting with LED for shops is between 15 – 20 W/m²	Neprom, 2014
Non food			
Low efficiency	27.5	Values found in practice for buildings with higher roofs, average of 20 to 35 W/m².	Neprom, 2014
High efficiency	17.5	High efficiency lighting with LED for shops is between 15 – 20 W/m². Average taken.	
Garden shops	6	Garden shops with additional daylight	

The operating time is based on the standard value for shops of ISSO (2010), which are 2400 hours. The NTA 8800 (2020), assumes a considerably higher figure, namely maximum 3100 hours per year. For the reference buildings it seems that this number is relatively high, assuming 6 opening days a week, it comes down to 10 hours per day. Therefore, the 2400 hours are assumed. Only for supermarkets, longer opening times are assumed, namely 10 hours opened from Monday to Saturday, and on Sunday 6 hours. This results in 3441 hours per year. However, due to higher application of smart technologies in supermarkets, a correction for a lower capacity factor is incorporated (Anonymous, 2022). The correction factor is adjusted according to the daylight, 60% by dusk, and 30% after sunset (Interact, 2018). Overall, an 80% CF is taken for supermarkets (Stimular, 2022). For garden shops, significantly less lighting is used due to the large windows. The lighting intensity for shops non-food is therefore corrected for the share of garden shops. Which yield the table below.

Table 44. Energy intensity for indoor lighting

	Energy intensity [kWh/m²]			
	Supermarket	NF	NF small	Large NF
Total	61	48	51	41

1.1.7 Emergency lighting

Emergency lighting energy consumption is published by ECT ISSO (2022), for shops. It includes escape route lighting and indication. This total 0.6 kWh/m² for all shop types.

1.1.8 Solar PV

The self-consumption of electricity should be added to the electricity consumption as known by the CBS, to determine the total electricity consumption. However, this data is not available. Only the feed-in and theoretical production are known. The theoretical production is the average for all shops, being 0.12 kWh/m^2 calculated with the NTA methodology (based on Nuiten, 2020). Which implies a peak capacity based on the material and installation year (NTA 8800, 2020). The CBS provides the feed-in electricity but emphasizes that this is only accurate for large electricity consumers, due to challenges in the electricity bill registration for small consumers, experienced by electricity companies (Sipma, 2021).

If is found that the average theoretical production is lower than feed-in electricity for supermarkets and is therefore not representative. Therefore, the assumption is made that the feed-in electricity equals the self-consumption.

Table 45. Solar PV energy production in 2019 (CBS microdata, 2022)

		Weighted average Theoretical energy production PV (NTA method) [kWh/m²]	**Weighted average Feed-in [kWh/m²]**	**Self-consumption [kWh/m²]**	**Self-consumption [MJ/m²]**
Sup	<= 2010	0.03	0.00002	0.03	0.12
Sup	>2010	0.43	0.00088	0.43	1.54
Sup	Total_Sample	0.10	0.00017	0.10	0.36
Sup	Total_Population				0.17
NF	<= 2010	0.08		0.08	0.30
NF	>2010	0	0	0	
NF	Total_Sample	0.08		0.08	0.28
NF	Total_Population				0.29

1.2 User related

1.2.1 Outdoor lighting

Outdoor lighting is based on assumptions for the number of lamps and operating time. A lamp is assumed to have the following characteristics, see Table 46. For each reference building, an assumption is made for the number of lamps, see Table 47. With the basic energy intensity equation, the consumption is calculated. Lighting for marketing purposes is not included, due to data availability. This implies that the actual outdoor lighting intensity might be higher.

Table 46. Assumptions outdoor lighting

	Value	**Assumption**	**Source**
Capacity	65 W	Outdoor lamp	Bedrijfsverlichting, 2022
Operating time	4100 hours	Equal to public outdoor lighting	Ledlichtnederland, 2021

Yearly energy consumption	267 kWh		

Equation 36

$$EI = \frac{E}{A}$$

E	*Energy consumption [kWh]*
A	*Floor area for each reference building [m²]*
EI	*Energy intensity in [kWh/m²]*

Table 47. Energy consumption outdoor lighting

	Supermarket	NF	Non-food small	Non-food large
Number of lamps	10	4.9	10	3
Energy consumption [kWh/ m²]	1.95	2.94	2.92	2.96

1.2.2 ICT decentralized

This category covers various types of electronic devices like computers. First a collection of various devices and their energy consumption is presented. Afterwards, for each category it is determined how many are present in each reference building.

NF is calculated as weighted average based on number of shops for large and small NF shops.

Table 48. ICT energy consumption

	Energy consumption [kwh/year]	Assumption	Source
Computer	123.5	Includes computer, monitor, mouse and keyboard	Maya-Drysdale et al., 2018
Laptop	27.7	Notebook	Maya-Drysdale et al., 2018
Monitor	86.52	Tco 2005 Data 17-inch LCD	IVF, 2007
Cash register	27.7	Assume same as laptop	
Copy machine	780	Running 430 hours, ‘stand-by’ 1.900 hours; ‘off 6.400 hours from 2007	Freitas, 2007

Table 49. Number of ICT devices per reference building and resulting energy intensity

Appliances per reference building			**Energy intensity (kWh/m²)**			
	Small	Large	Supermarket	NF	Small NF	Large NF
Computer	1	4	0	0	0	1
Laptop	5	10	0	0	0	0

Monitor	4	4	0	1	1	0
Cash register	2	10	0	0	0	0
Copying machine	1	1	1	2	2	1
Total			1.6	3.1	3.3	2.4

1.2.3 ICT centralized

Shops need servers to offer Wi-Fi connection to their customers, run a webshop, the cash register (ITbases, n.d.). It runs day and night, 8760 hours (SenterNovem, 2007). For a shop smaller than 10 thousand m^2, the capacity of a patch room is measured at 1.5 W/m^2 (Tebodin, 2007). Based on estimations to which an ICT server room applies, the following energy intensity is calculated.

Table 50. ICT centralized energy intensity

	Share of shops with ICT centralized	Energy intensity [kWh/m^2]
Supermarket	100%	13.14
NF	6%	0.8
NF small	7%	1.0
NF large	3%	0.3

1.2.4 Food and drink facility

For food and facilities in stores three types of energy consumption are recognized. Firstly, machines for soda, snacks and coffee. Secondly, a basic kitchen for the staff. Thirdly, appliances needed to run a lunchroom. It is assumed that every shop has a staff kitchen. For soda machines and the restaurant area it is determined per shop whether it is applicable, see Table 51.**Error! Reference source not found.**

Table 51. Applicability soda and snack machines

	Share soda/snack
tot nonfood	10%
Small	0%
Large	39%

Vending machines

The energy consumption for vending machines is approximated at:

Table 52. Vending machine energy consumption

	Energy consumption [kWh/year]	Assumption	Source
Coffee machine	1100	machine installed after 2005	Stimular, n.d.
Soda machine	1547	7 °C temperature and best available technology	EC, 2019
Snack machine	2070	3 °C temperature and best available technology	EC, 2019

Table 53. Vending machines energy intensity

	Energy intensity [kWh/m^2]			
Coffee machine	Supermarket	NF	NF small	NF large
Soda machine	7.64	0.56	0.01	1.00
Snack machine		0.86		1.58
Total machines	7.64	1.42	0.01	2.58

Basic kitchen

For a small kitchen for the staff of a shop, the basic appliances considered are described below. One kitchen is assumed per shop type. The total energy is divided over the floor area of each shop type.

Table 54. Energy consumption for a basic staff kitchen

	Energy consumption [kWh/year]	Operating time	Assumption	Source
Refrigerator	120	8760	A refrigerator, including a freezer. With energy label B.	Milieucentraal, n.d.
Microwave	95			SenterNovem, 2007
Dishwasher	305		Data from 2000	SenterNovem, 2007
Coffee machine	79		Applicable to hospitality. Data from 2000	SenterNovem, 2007
Kettle	33		Applicable to hospitality. Data from 2000	SenterNovem, 2007
Total	**632**			

Lunch corner

A lunch corner includes the energy consumption as described in Table 55.

Table 55. Lunch corner energy consumption

Energy application	Capacity [kW]	In operation (h/day)	Capacity factor	Energy consumption	Assumption	Source
Stove	3.5	0.4	0.6	307	Average of minimum and maximum capacity. Electricity fuelled.	SenterNovem, 2007
Oven	8	0.4	0.9	1051	Average of minimum and maximum capacity	SenterNovem, 2007

Hot plate			0.75	0	Average of minimum and maximum capacity	SenterNovem, 2007
Dishwasher	3.5	5	0.275	1757	New dishwasher with 230 V connection and 3.5 kW capacity. Other values from SenterNovem.	HKL horeca, n.d.; SenterNovem, 2007
Display fridge				1643	Self-service cooled counter-island. Cooling refrigerant R290. For temperature between -1 and +1 °C. and energy label C.	Carrier, 2022
Refrigerator	0.2	24	0.6	1051	Average of minimum and maximum capacity	SenterNovem, 2007
Cold storage	1.7	24	0.4	5957	Average of minimum and maximum capacity	SenterNovem, 2007
Extraction hood				15	Extraction hood for a household	Keukenloods (n.d.)
Total lunch corner				**12900**	With a correction for opening 6 instead of 7 days a week	

The reference table is used to estimate the applicability of the lunchroom, which yield the energy intensity.

Table 56. Energy intensity of a coffee/lunch corner

		Energy intensity [kwh/m2]
Supermarket		
NF	9%	2.67
Small	3%	1.37
Large	26%	3.77

The total food and drink (horeca) energy intensity is the sum of the three.

Table 57. Results of food and drink facility

	Food	**Non food**		
	supermarket	**non food**	Small	Large
Total	8.10	5.52	3.69	7.05
Staff kitchen	0.46	1.43	2.31	0.70

1.2.5 Transport

For transport, elevators and escalators are considered. This only includes the inside transport within a shop. Based on a sample of 1500 shops,

Table 59 is constructed. It is assumed that the shop has one elevator and/or escalator when applicable. The energy consumption for elevator and escalator is.

Table 58. Energy consumption for transport

	Energy consumption [kWh/jaar]	**Assumption**	**Source**

Eleva tor	550	Best practice elevator. An elevator for a small office or administrative building. With 50 operations per day.	Durand et al., 2019
Escal ator	9426	Finnish elevator in a shop in December. Extrapolated to energy consumption for a year.	Semen, 2015

Table 59. Share of elevators and escalators (CBS microdata, 2022)

	Elevator	Escalator
Supermarket	11%	6%
NF	24%	7%
Small NF	21%	8%
Large NF	26%	7%

Table 60. Energy consumption transport

	Elevator [kWh/ m²]	Escalator [kWh/ m²]	Total transport [kWh/ m²]
Supermarket	0.04	4.06	4.10
NF	0.29	4.65	4.94
Small NF	0.42	2.58	3.00
Large NF	0.16	0.74	0.90

1.2.6 Product processing

For product processing, only electric appliances are assumed. It can include frying pans, and electric ovens.

For electric product processing, the consumption of food preparation in fish mongers and butchers is considered. Therefore, the consumption of a frying pan, oven and stove are evaluated. For a supermarket, only the oven is considered for bake-off.

Table 61. Electric product preparation

	Capacity [kW]	Operating time [h/yr]	CF	Energy consumption [kWh/yr]	Assumption	Source
Frying pan	5	183	0.6	548	Assume 2 pans per shop	SenterNovem, 2007
Ovens	8	Shop specific	0.9		Supermarkets assume 4 ovens operating 4 h/day.	
Stove	3.5	146	0.6	307	Assume 1 per shop	

Based on the reference table, the following energy consumption results.

Table 62. Energy intensity electric product preparation

	Energy intensity [kWh/m²]

Supermarket	30.76

1.2.7 Product cooling

Freezers and cooling are considered separately. It is assumed that horizontal and vertical cooling are equally applicable. The estimated space in a shop is used to determine the cooling requirement. Per shop it is indicated how much cooling they require. The cooled warehouse of a supermarket is considered an industrial function and is therefore not included in the shop's energy consumption. For the NF shops, the department stores require product cooling, and therefore are included in this category.

Type of cooling	Energy consumption (kWh/year)	Operating time	Assumption	Source
Vertical refrigerator	4526	8760	Best available technology. Area : 3.3 m^2	EC, 2019
Horizontal refrigerator	2044	8760	Best available technology. Area : 2.2 m^2	EC, 2019
Average refrigerator	**6570**	8760	Best available technology. Area: 5.5 m^2	EC, 2019
Vertical freezer	9709	8760	Best available technology. Area : 3 m^2	EC, 2019
Horizontal freezer	1606	8760	Best available technology. Area : 1.4 m^2	EC, 2019
Average freezer	**11315**	8760	Best available technology. Area: 4.4 m^2	EC, 2019
Self-service counter-island	1643	8760	Self-service cooled counter-island. Cooling refrigerant R290. For temperature between -1 and +1 °C. and energy label C.	INNAX and Carrier 2022

Based on the table for reference buildings the applicability of product cooling is determined. Then, an assumption on the share of area cooled is determined. With Equation 37 the energy intensity is calculated, as presented in Table 64.

Table 63. Share of area cooled

	Supermarket
Refrigerator C_r	4%
Freezer (C_f)	2.8%
Self-service counter island ($n_{counter\text{-}island}$)	5 pieces

Equation 37.

$$E_{product\ cooling} = S_i * A_i\ * C_f * E_{freezer} + S_i * A_i\ * C_r * E_{refrigator} + E_{counter-island} * n_{counter-island}$$

Table 64. Energy intensity for product cooling

	Share of shops	**Refrigeration [kWh/m²]**	**Freezer [kWh/m²]**	**Total [kWh/m²]**
Supermarket	100%	53.79	70.72	**125**
NF	0.3%	0.14	0.20	**0.3**
Small NF	0%			
Large NF	1%	0.51	0.75	**1.3**

1.2.8 Other

Other energy application which was not captured in the prior categories are included here. Some examples are, other product preparation appliances, and security systems and air curtains (DGMR, 2021). The other category is considered a residual category, so for the final tweaking, energy can be allocated to this application.

2. Annex B: Interview questions

The interview questions for the researchers, policy

1. *Which were the most effective policies in place in the retail-sector?*
2. *What has been the effect of the past and present energy policy?*
3. *Is there incentive for shops to save energy? If so, what is it?*
4. *Is there potential for additional energy saving? Where and how can this be accomplished?*
5. *Reflect on the present energy policies, are improvements necessary?*
6. *Reflect on suggestions for policy: Maximum (fossil) energy consumption, building related or final (EU/government/DGBC)*
7. *What other future developments can be expected in the retail sector that can affect the energy consumption?*

Interview energy manager supermarket:

1. *Are you in aware of the energy consumption of your type of shop?*
2. *What is the incentive to be more sustainable and to save energy at the supermarket?*
3. *What is the energy saving target for the supermarket(s)?*
4. *Reflect on suggestions for policy: Maximum (fossil) energy consumption, building related or final (EU/government/DGBC)*
5. *Where can further energy savings be gained? How can this be established?*
6. *Discussion of various innovations in the sector.*
    i. *Which local and renewable energy resources can supermarket utilize locally, are improvements necessary?*
7. *Is the EML implemented at supermarkets? Are other policies effective?*
8. *Is additional policy necessary to reach further energy savings?*

Interviews shop employees

1. *Is the shop owner/manager aware of the energy consumption of the shop? Are you aware of it?*
2. *Has this changed since the developments of rising energy prices?*
3. *Are other environmental measures taken?*
4. *Are you motivated (by e.g., the boss) to save energy?*
5. *Are there appliances left 'on' or at 'stand-by' during the closing times?*
6. *Is there room for behavioural wins in terms of energy savings?*
7. *Which type of applications are present? Lighting, space heating, cooling?*
8. *Are you aware of energy policy for retail?*
9. *What other future developments can be expected in the retail sector that can affect the energy consumption?*

3. Annex C: Interview summaries

Short summary of the held interviews. To protect the anonymity of the interviewees, some discussed topics are left out of the summary.

3.1 Interview 1

Date: 04-07-2022
Reference: AN1
Field of expertise: researcher service sector
Discussion on current policy.

*Recognised List of Energy Efficiency Measures (EML) under de Environmental Act. The EML is updated in 2019. However, it is still too general for shops, and it is not updated frequently enough. It focuses on heating and cooling appliances, ventilation, product cooling, elevators, escalators, and product processing. One of the critics is that the monitoring and enforcement by the Environmental agency (omgevingsdienst) is not that well performed. A recent development is the 'Energy efficiency notification obligation (Informatieplicht), which obligates company to notify which measures they have taken. All measures with a payback period of less than 5 years are obligated to take.

Another criticism is that there is a minimum energy consumption, where only the companies above this level need to take EML measures. A suggestion would be to include all companies. Until now, the policy was effective to gain the quick wins.

*Casco rental. Most shops are rented without equipment. This means that the renter needs to install heating and other equipment. When a shop switches owner frequently, this is not a sustainable manner. Also, in terms of resource uses. The split incentive is the problem. If the owner of the building would invest in efficient technologies, the renter would benefit.

* Difference within retails. Small shops. When shops are located in an outdoor shopping mall (winkelplint), there is little incentive to insulate the building. The heat loss is mainly generated by open shop doors and ventilation. Supermarkets like Lidl are much further in energy neutral buildings.

*Building directive (Bouwbesluit): no longer NG grid connection requirement. Subsidies for HP and insulation are not used on a wide scale.

Improvements policy

The shops which consume less than the requirement for EML should be targeted too. The focus is now on building related energy. Gains can be achieved by better management of current energy systems.

Emission trading system: only effective if large gains can come from user related energy. This is uncertain.

Where can energy savings come from?

Good housekeeping. Energy management. The employees have little influence on the energy consumption.

Optimal versus measured energy consumption. Insight needs to be acquired with smart meters.

Other market effects?

Intermittency renewables. The emission reduction can be achieved with renewable energy sources which are variable in supply. A problem is the low flexibility in energy demand from shops. Local and small-scale storage of heat would offer some solutions. Peak shift maybe possible by shifting and/or lowering product cooling load. But influence on product's freshness should be researched.

Energy costs used to be a minor part of total annual expenses of shop, but this is changing due to recent high energy prices.

3.2 Interview 2

Date: 05-07-2022
Reference: AN2
Field of expertise: researcher service sector
Discussion on current policy.

Clear distinction between existing and new built.

*For new built there are requirements regarding insulation, epc.

*Use phase: important measure is the EML. The EML where obligated but not monitored. Until 8 years ago no monitoring or checks performed. Instead of check there is now an information obligation in an ePortal (eLoket). Another policy are the eco-design requirements. These make the producer responsible for the energetic performance of a product. Those are EU wide.

Improvements policy

Two lines of thinking exist around the focus on actual or theoretical energy consumption and savings. On the one hand commercial parties see more potential for energy savings and take actual energy consumption as more valuable indicator. They see potential for better energy management with existing installations. There has been a suggestion for a recurrent check on the climatic installations in a building. This was never executed but could be a way to overcome this type of energy spill. On the other hand, the ministry and EU are more focused on theoretical energy consumption.

Where can energy savings come from?

The largest challenge is the large variation in energy consumption. The variation and heterogeneity in energy consumption also originates from difference in size and energetic performance and type of shop. Some gains can be achieved in building related energy consumption. However, the energy requirements like formulated in Eco-Design are already quite sharp. For instance, when indoor lighting is upgraded, it needs to adhere to eco-design requirements. So, it is uncertain how much additional gains can be reached, after these 'quick wins' are implemented. .

The target for energy savings is not specific for the retail sector. For all service sector the goal to save 1 Mton local emisions. The electricity consumption is only increasing. Incentive comes from energy prices. Companies not motivated without economic incentive. This is slowly shifting (..).

Other market effects?

Next to policy there is also movement from the market. Like the DGBC. They do not want to wait for policy.

3.3 Interview 3

Date: 06-07-2022
Reference: AN3
Field of expertise: expert real estate and sustainability

Two incentives for energy savings in retail. The rising energy prices, which is mainly affecting the smaller businesses. Another incentive regards the institutional investors, which have to deal with more strict rules for their investment. Namely the EU taxonomy and the SFDR. A better project in terms of energetic performance of buildings leads to a better score and a better chance of finding investors.

The targets are now set by set by the DGBC. It is expected that also on national level, an ‘eindnorm’ will be set. This means a (theoretical) maximum energy consumption. Also, the energy labels will be rearranged. A relative energy label will be formed, only energy neutral buildings will get label A.

Energy saving potential: product cooling with waste heat. Solar panels for local energy production. No open-door policy.

Another problem is the relationship between renter and owner of the buildings. There is often some distrust. In the optimal case, the owner and renter perform a renovation at the same time. And make sure that the shop is closed for a short period.
Casco rental is currently the standard. This means that a shop is rented without equipment. With short lease contracts, it is costly to install the high end and most efficient installations. Ending the casco rental could lead to better equipment in the shops.

Good example: in France the shop owner and renter are required to make a plan to establish *30%* energy savings by 2030. If they do not, they are both violating the law.

Other market influences that can change the energy consumption are the increased demand for luxurious treatment in stores. For instance, more coffee offered. Also, more fresh products. And self-check-out counters.

3.4 Interview 4

Date: 07-07-2022
Reference: AN4
Field of expertise: researcher service sector

In the service sector, comparable less policy is active to the residential sector. In the coalition agreement additional budget for renovation of ‘social real estate’ is reserved. In the form of subsidies and directly to the built environment. So called ‘Dumava’.
Other active policy are new build codes, sport accomodiation subsidies, the energy saving duty (energiebesparingsplicht) and ecodesign. Offices are required to perform better than label C. it can be expected that some comparable requirement will come for other building types too. For house owners there is also an energy saving loan, this could work for service sector too.

Two parallel measurements for energy consumption are now presented. The DGBC has proposed an actual energy consumption maximum. The BENG2 requirements are not yet defined. The DGBC has given some direction to these national/EU wide BENG2 requirements by 2050. Since the EU will only work with the theoretical requirement is can be expected that both measurements will stay. Around 2025 the EU wants to harmonise the energy labels. This is not so beneficial for the NL since it has just implemented a new methodology, the NTA 8800.

The DGBC works with the energycompas and label class/WEII score. Suggestions for renovation or better use of the current building are given. For instance, weather dependent energy management.

The climate agreement goals for local emission are set for the whole service sector (1 Mton savings). This is focused on the natural gas use. Reaching this goal can be achieved by upgrading the worst energy labels. The electricity is becoming sustainable in a rapid pace. Therefore, policy should focus even more on NG.
The electricity price of big consumers is much lower than for households. This makes energy saving measures less attractive. The production of solar energy will be required with BENG2 requirements for some buildings. However there exist some hurdles regarding the shape and roof size of some buildings. A fair comparison needs to be made.
Which energy application have potential energy savings? The space heating could be lowered by more insulation of building. However, this is expensive, and all the buildings are different, which makes it more costly (compared to houses). The learning outcomes from renovation should be shared more openly. To tackle challenges from high rise buildings, filling of the cavities in buildings. In the operational efficiency of space heating some wins can also be achieved. For instance, a check in the settings (inregeling) of the space heating. Smart metering can also assist in checking the settings for appliances.

About 2/3 of the companies has performed their duty for the energy saving obligations. The check is improved over the years. An important upgrade is that network operators are now obliged to provide a list of companies who fulfill the minimum energy consumption requirement.

Further developments in the service sector are the increasing demand for healthcare, some digitalization, more work from home.

3.5 Interview 5

Date: 08-07-2022
Reference: AN5
Field of expertise: researcher service sector

The effectiveness of the energy saving duty has been hard to measure. It seems like less has been gained than its potential. It was already introduced about 20 years ago. Due to the higher energy price, increasingly more measures will be on the list of measures. This is dependent on the energy price that will be chosen.
Increasingly more policies are introduced. For instance, solar PV is obligated for large new buildings.

The current goal of 1 Mton emission reduction is outdated. This was based on 49% reduction target. This is now 55 or even 60%. When aiming for 60, it can be sure that 55% will be reached.

The government has been debating about a maximum energy consumption for a long time. Much time is passing by. Some choices are between implementing intermediate steps. However, this leads away from the actual goal by 2050 emission free. An intermediate step could be the ban on worst performing energy labels.

The heat transition is another point. The municipalities are in charge of giving a direction for regions regarding district heating. There is a discussion on the zero-emissions of those heat plants. Measures are taken to account for emissions. For instance, biomass is not subsidized anymore. It should be supplied by waste heat and waste combustion. It is also important to consider other uses of natural gas. For instances in bakeries for ovens. Electrification of heat is also an option. Just a s the use of green gas and hydrogen. Shops are dependent on the municipalities in this topic. There is subsidy available for heat pumps with SDE++.

The emission trading systems is also still on the table. This would also still only cover the local emissions (NG). It could be implemented for built environment and transport.

Not only increase the price. But the energy ytax on NG is increased compared to electricity.

3.6 Interview 6

Date: 11-07-2022
Reference: AN6
Field of expertise: sector representatieve

The retail is a complicated sector in terms of energy savings. Already large share has an energy label A. therefore, the sector believes more gains can be reached in the process related energy consumption. Also, a TNO study by Sipma has shown a low relation of only 3% between the energy label and the actual energy consumption. According to DGMR, the largest gains can be reached from double paned windows and insulation.
The current incentive for energy saving sin the retail is various. The EML. However, also measures are on the list which have very little impact, like the escalators. Retail chains are incentivized by MVO policy (corporate sustainability). For instance, supermarkets want to promote themselves as sustainable, like the Lidl being energy neutral. This also includes transport and material related emissions. Supermarkets are renovated every 7 years. Increasingly more attention is given to circularity in these renovations.

For NF shops there are many more issues to focus on, for instance child labour related to the production. Or the packaging of products.

In the heat transition the supermarkets are not the worry. Many have made the transition from detaching from the NG already.

The smaller shops are of large issues regarding energy savings. This is for several reasons. First of all: due to Covid19 more focus on survival then on investments and energy savings. Also, external obligations. However, the energy costs are contributing to the troubles. The split incentive is also problematic. It is unclear who has to make which investments in relation to renovations. The investors only invest in the building envelope. About half of the shops is owned, the other half is rented (rough estimates).

Evaluation existing energy policy.

The EU taxonomy impact and its relevance for the Netherlands is now investigated. Financial institutions are more motivated to give lower interest rates for sustainable investment. The risk for ‘unsustainable’ investments is increasing.

Proposed maximum actual energy consumption. This is based on the assumption of 1/3 of electricity being renewable. This has led to the goals of 80 and 150 kWh/m2. These targets are supported in the sector. Only two categories were recognized, with and without cooling. The DGBC is mainly focusing on large parties and chains. Contact with VNO and MKB Netherlands.

Where is potential for additional energy savings? Especially the inefficiency and energy management. The benchmarking of shops is helpful to identify inefficiencies. The biggest shares of energy consumption are from product cooling and product processing. The local production of solar PV creates an unfair comparison when this energy is subtracted from the total energy consumption.

It could be measured in net and gross energy consumption. Another idea is to measure chain wide. For instance, measuring energy consumption over the chains, e.g. all Albert Heijn supermarket average.

The energy label will stay since it is obligated by the EU. The focus should not only be on NG savings, but also on electricity savings. Some initiatives from investors to focus more on energy consumption are Creame and Pathways. It is becoming more common to report on the energy consumption of the investment portfolio.

Other opportunities are related to the intensifying of the product cooling with an overshoot of solar energy. This is applied at refrigeration and freezer storages, but not researched if applicable to supermarkets.

Difference between sectors who is in lead. For supermarkets it is the sector itself in combination with the investors. For smaller chains the branches are more in charge. The focus on corporate sustainability can lead to big chunks.

Market developments. Mixing image of more or less retail. Especially the luxuriousness is increasing. More bake off and fresh products. But digitalization and covid leads to more online ordering. However, this trend is not clearly recognized yet. Supermarkets are increasing.

3.7 Interview 7

Date: 06-07-2022
Reference: AN7
Field of expertise: energy audit expert

Expert on energy advise and 'Klim op'projects. Works with energy audit in retail. When they perform an audit, they are counting all installations and reading off the installed capacity.
A technology with much potential saving is the weather forecasting energy management from Cloud Energy Optimizers. Based on sensors in the building and weather forecast they set the comfortable heating, cooling and ventilation. This can lead to maximum 20% energy reduction. Also, the heat regeneration (WTW) of cooling systems is becoming more popular. Every 6 to 7 year the supermarket replaces their large installations.
Other energy savings come from good housekeeping. Simply keeping doors closed and lights out when someone leaves.
The problem is the technical knowledge in the Netherlands. People are less and less aware of the installations and their capabilities. Much of the equipment is still manual, which leads to large energy losses.

3.8 Interview 8

Date: 01-08-2022
Reference: AN8
Field of expertise: energy manager supermarket

Background in energy and policy. Supermarket is an extremely competitive market. This has led to supermarket not open in sharing their data. For instance, on energy consumption and energy costs. Growth is most important to supermarkets. But increasingly more attention for climate and emission reduction. The focus of jumbo is also on personal well-being.

The energy efficiency, EEI, agreements in the supermarket branch were agreed by the CBL. They have agreed on 2% increase every year, and already reached 44% by 2020 . However, while the EEI is increasing, the overall consumption is increasing too. This efficiency can give some insight in whether you have performed a measure in an effective way. It starts with a score of 100%, but this can decrease when effective measures are taken. This is done by comparing the actual consumption to the expected consumption after a measure. Up to know, a good new supermarket can score about 45%. The consumption is compensated for the cooled floor area, opening hours, number of ovens and floor area are indicators for energy consumption.

About paris proof score. The best performance of supermarkets is now 230 kWh/m2 final consumption. How to reach a paris proof score is not yet known. Except for the generation of local energy like solar PV. However, this should not be subtracted from the total consumption, since it is still consumed. Also, some discussion is related to the floor area which should be used. Most supermarkets now work with 'sales' floor area.
The lacking large penetration of solar energy is related to the rent-owner construction. Most often, the roof is owned by the asset owner. There is a split incentive between renter and owner. A popular construction is that the supermarket will rent the solar panels from the asset owner, who invests in them. It was calculated that in summer, about 1/3 of the total energy demand can be generated by solar energy if the whole roof is covered. So even the whole roof is still not enough.
The quality of the building is determining the space heating demand. If the building is of very high quality, the regeneration of waste heat from product cooling is enough to heat the building. But most often this is not the case. It is feared that the focus is too much on energy efficiency improvement of product cooling, and not on the overall energy performance of the supermarket. A lot of function have interplay.
Next to product cooling, also ovens can be used for utilization of waste heat. Same story regarding energy efficiency.

There should be more incentive for asset owners to invest or renovate the building envelope. This should not necessarily be included in policy or laws but finds way to stimulate more. The uncertainty for the asset owner is related to the limited insight in the effectiveness and energy reduction that a measure has. Therefore, it is complicated to agree on a certain rent increase after renovations. The supermarket has a fixed 'heartbeat' of upgrading. Where commercial renovations, large renovations and complete upgrade are performed with cycles of about 5 to 10 years. If this was in line with renovation pace of investor, more energy efficient gains can be accomplished.
Right now, the energy label is a very limited indicator of energy consumption, the construction period says more. How can more insight be given in energetic performance? For instance, with EEI.
To gain additional energy reduction, the concepts of supermarkets should include energy consumption from the start. For instance, smaller appliances with lower capacity.
Other energy reduction from energy regeneration and more formula and conceptual thinking. The commercial value is super important, so decreasing lighting only when it is not influencing the marketing. At the check-out some lighting reduction could be achieved. Large scale research is necessary in this field to identify further saving measures.
The switch to 'gas-free' is aimed for in supermarkets, this can be achieved during a large-scale renovation. The gas-free ambitions differ per supermarket and are often profiled.
Also, the CBL is searching how to apply the climate agreement to the supermarket branch. An absolute goal seems inevitable. But no plans yet. Supermarkets are different from other branches since they are not waiting for steps of the government. The focus is already on energy consumption, and much knowledge on energy consumption patterns. The existing goals. By 2030 CO_2 neutral, by buying certificates from sustainable energy. By 2040 paris proof with only 150 kWh/m2 energy consumption.

3.9 Interview 9

Date: 04-08-2022
Reference: AN9
Field of expertise: employee NF shop

The employee of a clothing shop. The shop is rather small, so does not need to comply to the EML. The space heating was manually arranged, just as the space cooling. This also means that dependent on the employee working during the day, the temperature was set differently. Although ensure, the employee assumes TL lighting in the shop. During the night only surveillance and one television was on. The television was the marketing. Energy saving was not a hot topic, and no one was aware of it. There was a very small staff kitchen. With some basic appliances.

3.10 Interview 10

Date: 11-08-2022
Reference: AN10
Field of expertise: employee NF shop

The employee works in a gift ship, so a small NF shop. It is also expected that this shop does not need to adhere to the EML. There is attention for environmental impact, but this is mostly related to the use of paper. Energy saving is not an important topic among the employees. The employee is not sure but expects TL lighting. At night, the lights are turned off, except for at the counter, to show that the there is nothing to steal. Some room for energy saving according to the employee would be the quicker stand-by modus of the check-out system. Also, the building is very old, so potentially gains from insulation could be achieved.

3.11 Interview 11

Date: 29-08-2022
Reference: AN11
Field of expertise: energy expert supermarkets

In the MJA1 agreements, there were already goals for supermarket energy efficiency. It was agreed to save 32% energy by 2010 compared to 1995. The municipalities and government were monitoring these goals. The first result was the day-coverage of product cooling.
An important aspect is that the energy saving collides with the business model. The relative increase of (fresh) food in supermarkets has led to more energy consumption. Without efficiency improvements, the absolute energy consumption would have increased by 40%. The comparison between then and now is complicated.
Also, the expert provides feedback on the energy balance for supermarkets. Product cooling of 40%, lighting of 20% and food processing of 10% seems in line with the expectations and experiences of the expert. However, the average supermarket does not really exist. The aldi has for instance no product preparation. And discounters have less fresh and cooled products. To this extent, the energy audits are very unreliable and would not have increased the robustness of the results.

Current incentive for energy savings.

- The CLB 2% energy efficiency increase. In 2020, a 24% increase was reached. This 2% is still worked with at supermarkets.
- The EML. Criticism, not all measures lead to energy savings. And lead away from the big chunks.

- Supermarkets exist because of their cost efficiency. So if a measure leads to cost savings, it will be implemented. Investments are made when: there is ambition, energy saving potential, and financial capabilities.
- The renovation of buildings has saving potential. When the three requirements are fulfilled, no policy is needed. Especially the financial side can be an issue.
- For shops NF, especially saving from indoor lighting. And automatization of indoor comfort.
- Most supermarkets are in old buildings. It is not clear who is addressed in terms of renovation. The government targets the user mostly.
- DGBC is now focusing on getting the asset owners on board in energy saving. They have large influence with the choices for renovations.
- Furthermore, not only do we need to reduce CO2 emissions. Also resource use, lack of skilled employees.

Ideas about the introduction of an endnorm. The setting of targets is necessary for policy. But the current target is not within reach. Also not known how this target could be reached. A lot of focus on the energy infrastructure and electricity production. If this would be done without CO2, the endnorm would be lowered. Saved energy will remain most sustainable. The targets should be realistic and year to year reachable. Consider that the supermarket is changing, and comparison with 2040 is challenging.

Electric heat in combination with regenerated heat is still necessary. Only for very well insulated buildings, with RC >4 it is possible without. The ovens also produce waste heat, but this heat is not utilized in supermarkets. Yet. Because the heat regenerators get too greasy. The server room is very limited and often not separate in a supermarket. So not expected that waste heat will be utilized.

External complications for energy transition is the full electricity grid. Feed in electricity can be fined when there is too much supply. This work dysfunctional and destimulates supermarkets. Also, subsidy was quickly finished. Also, the little energy tax that is payed by large consumers works conflicting. More consumption is currently rewarded. This should be the other way around. Also the outlook for resources is worrisome. And could induce potential crisis. A long-term vision is necessary. Helps to clarify targets too.
Also, people are skilled for the wrong job. The external influences are getting a larger hurdle for climate neutrality.

Discussion on floor area. The gross, net, building, shop and sales area are recognized.

Supermarkets are active in energy saving also because they have a prominent role in society. For NF there is little collaboration and no representative. This is need for collaboration.

4. Annex D: Split small and large NF shops

Table 65. Small & large NF shops

Energy application	Energy carrier	Energy intensity [kWh/m^2]			NG intensity (m^3/m^2)
		Small	Large	Average	Average
Space heating	Natural gas	88.67	64.47	82.13	9.34
	Electricity	9.04	6.24	8.43	
Space cooling	Electricity	0	3.71	0.90	
Hot water	Electricity	1.34	1.34	1.34	
	Natural gas	0.53	0.53	0.53	0.06
Other	Electricity	19.00	0.50	12.50	
Food/drinks	Electricity	3.69	7.05	5.52	
ICT centralized	Electricity	0.96	0.35	0.80	
ICT decentralized	Electricity	3.34	2.41	3.09	
Auxiliary	Electricity	1.99	1.99	1.99	
Inside transport	Electricity	2.58	0.74	4.65	
Ventilation	Electricity	0.14	0.92	0.35	
Indoor lighting	Electricity	51.12	40.64	48.34	
Outdoor lighting	Electricity	0.60	0.60	0.60	
Emergency lighting	Electricity	5.55	1.95	2.94	
Solar PV	Electricity	-	0.08	0.02	
Total					
	NG [Nm^3/m^2]	10.15	7.39	9.40	
	NG [kWh/m^2]	89.21	65.01	82.66	
	Electricity [kWh/m^2]	99.35	68.44	91.44	