ORIGINAL ARTICLE

Relating carbon and energy intensity of best-performing retailers with policy, strategy and building practice

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Abstract Retail stores are amongst the building typologies with the highest carbon (CI) and energy intensities (EI). However, previous studies have only explored best practice EI of food and non-food retailers, without identifying best practice CI threshold values. This paper presents a five-step analysis of CI and EI amongst the highest revenue retailers, benchmarking best and worst performing CI and EI retailers, analysing their nationality, performing a content analysis on their CSR reports and comparing results in terms of differentiation policies, strategies and building practices that can lead to increased environmental performance. Combined CI and EI best practice threshold values were found simultaneously under 346 kWh/m^2/y and 115 kg CO$_2$eq/m^2/y for food retailers and under 146 kWh/m^2/y and 70 kg CO$_2$eq/m^2/y for non-food retailers. In terms of policy, best-performing retailers shared a strong top-down management commitment towards sustainability across all business areas ($p = 0.04$) and an increased use of referential reporting standards, particularly of GRI standards ($p = 0.05$) and of the GHG protocol ($p = 0.01$). In terms of strategy, they established ambitious energy goals, such becoming 100% supplied by renewable energy ($p = 0.05$) or carbon neutral by 2020. As for building practice, LED and photovoltaic technology were the most popular high-performance solutions, but only the use of natural refrigerants ($p = 0.001$) and gas transfer to CO$_2$ ($p = 0.0007$) were related to best-performing practice. The variability of CI and EI found in this study shows that it is already possible to reduce the retail sector's contribution to global GHG emissions considerably. The proposed best practice CI and EI reference levels, linked to corporate policy, strategy and building practice, are useful new tools for retail energy-management, which can further promote sustainability in retail buildings, thus allowing a deeper understanding of how to decarbonize the retail building sector.

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Introduction

The building sector is responsible for about 40% of the total energy consumption and 36% of CO$_2$ emissions in Europe; out of these, the contribution of retail stores in the total CO$_2$ emissions of the building stock is about 9% (Building Performance Institute Europe 2011).

Additionally, retail stores have one of the highest energy intensities (EI)—500 to 1.000 kWh/m^2/y—especially when refrigeration systems are used (Schönberger et al. 2013). Likewise, retailers' carbon intensity (CI) is quite high in terms of direct greenhouse gas (GHG) emissions and even higher in terms of indirect GHG emissions—a factor of 7 for its supply chain and a factor of 3 for its products' end life. Retailers' overall carbon footprint is thus a substantial problem requiring a comprehensive sustainability-driven management solution (ENDS Carbon—University of Edinburgh Business School 2009).

The retail sector controls and acts as the gatekeeper for goods and services consumers are offered and, as such, it can influence behaviour and consumption patterns (The Conservation Foundation of Greater Toronto 2006). Because of its broad reach, the retail sector has the potential to affect society in a way that not many other industries can. Corporately, retailers can define environmentally oriented policies for themselves and for suppliers, and at the store level, they can showcase sustainable built stores and educate consumers. The retail sector is also in a key position in the construction industry as it can influence the supply stream of materials and technologies used in this sector (U.S. Department of Energy 2008). For instance, the energy policies of large purchasers of energy efficient equipment, such as the retailers, can push the market towards the development of more efficient equipment. Likewise, vendors also try to move their customers up the value-chain and sell better quality, energy-efficient equipment. As retail is a highly concentrated industry in terms of ownership and sales (The Conservation Foundation of Greater Toronto 2006), there is an easier best practice communication across all players in the industry. The similarities between companies make lessons learned from best-performing retailers easily transferred to competitors or other commercial units.

International regulation is also pushing retailers into energy and carbon efficiency, namely due to the Paris Agreement (United Nations 2015) or the Energy Performance of Buildings Directive (EPBD) (European Parliament 2018). In fact, according to the EPBD, commercial buildings need to become 70–80% more energy-efficient, and all new buildings must be nearly zero energy buildings (nZEBs) by 2020. nZEB is a building that has a very high energy performance and where the nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby (European Union 2016). A management culture based both on legal requirements and voluntary obligations is transversal for retailers. Therefore, what sets best-performing retailers apart from the others should be based on higher levels of ambition in terms of energy strategy and internalization of sustainability principles across all business areas, leading to different results in terms of environmental performance. Likewise, the consistency with which high-performance sustainable building solutions are used across retailers' property portfolio is reflected in lower EI and CI and using them sporadically will fail in terms of achieving the best environmental performance. Hence, a holistic approach based on the role of corporate culture and social responsibility play in achieving low CI and EI is suggested here as a key to mitigating climate change impacts related to the retail industry effectively.

Previous studies identified best practices to promote energy-efficiency in food and non-food retail stores (Galvez-Martos et al. 2013; Schönberger et al. 2013; Tassou et al. 2011), as well as carbon savings, mostly from an energy efficiency viewpoint (Fieldson and Rai 2009; Jenkins 2008; Jiang and Keith Tovey 2009; Spyrou et al. 2014). Other studies assessed corporate barriers and drivers for energy and carbon efficiency (Christina et al. 2015; Dixon-O'Mara and Ryan 2018; Sullivan and Gouldson 2013). Also, other studies have focused on policy and strategy challenges to address climate change with regard to the building stock (Carballo-Penela and Castromán-Diz 2015; Sebi et al. 2019). However, the current knowledge about what constitutes best practice amongst retailers in terms of policy, strategy and building practice to reduce EI, but more particularly CI, as well as what differentiates "best-performing" from conventional retailers (e.g. retailers with best practice CI and EI within the sector) is extremely limited. Thus, it is necessary to hypothesise about what best practice thresholds for retailers could be in terms of EI and CI, and what differentiating corporate policies, strategies and building practices contribute most to best-performing retailers' increased environmental performance.

This study is innovative by relating best practice CI and EI and best-performing retailers' policy, strategy and building practice. Two specific questions were tested in the present study: (i) What can be considered as best practice CI and EI within the retail sector? and (ii) What is the policy, strategy and building practice of the best-performing retailers that leads to a better

environmental performance? In order to answer these questions, we define our understanding of policy, strategy and energy-related building practice for the present study (each of these key-concepts represents an own body of research, which out of the scope of the present paper to analyse).

Policies are formal rules of an organization that help standardize decision-making. Policy can be defined as a plan of what to do that has been agreed to officially by a business organization or a government. The political context for retailer's climate change action has been set mainly by the Paris Agreement (which provided an international framework for climate change policy, centred on the premise of holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels), by the Montreal Protocol (which set to phaseout hydrofluorocarbon emissions by 2036) and at the European level, by the EPBD and the Energy Efficiency Directive (European Parliament 2018), promoting the improvement of the energy performance of buildings. Nonstate actors, especially those with an important carbon footprint like corporate retail, can contribute significantly to countries' ability to mitigate emissions by pursuing ambitious climate action. By peaking and reducing emissions as soon as possible and by operating energy-efficient buildings with natural refrigerants, retailers can help to meet the government's decarbonising goals and avoid the worst impacts of climate change (Levin and Rich 2017).

In parallel, strategy requires a comprehensive plan, made to accomplish the organizational goals. It is a game plan, chosen to achieve the organisational objectives, gain the trust of customers, attain competitive advantage and acquire a better market position. In particular, environmental proactive management practices are commonly associated with benefits such as waste minimization, reducing environmental risks, energy use and material needs (Carballo-Penela and Castromán-Diz 2015).

Additionally, practice is the organised way in which an individual or a group carries out a particular activity. Building practice refers to the building solutions chosen by retailers to achieve energy strategy goals whereas best practice refers to a method or technique that has been generally accepted as superior to any alternatives because it produces results that are superior to those achieved by other means (Galvez-Martos et al. 2013).

CI and EI best practice reference levels for both food and non-food retailers were presented here as benchmarking tools for more efficient carbon and energy corporate management. The carbon footprint of retail stores can be minimized either by reducing EI or CI (or both); hence, these two parameters are analysed simultaneously. According to our study, achieving best practice reference levels across the retail industry would allow reducing EI by 50% and CI by 60%, which represents a significant potential for improving the energy performance in retail buildings. The present best practice CI and EI reference levels empower decision-makers to rank their stores in terms of energy and carbon efficiency, providing at the same time targets for energy and carbon management. Differentiating policies, strategies and building practice like those presented here are also expected to support retailers' decision-making process to increase the environmental performance.

Materials and methods

A qualitative comparison was performed regarding best and worst practice retailers in terms of policy, startegy and building practice, ranked according to their carbon intensity (CI) and energy intensity (EI). Five main steps were considered for this analysis.

In step 1 (CI and EI benchmarking), the context for EI and CI ranking was formulated, following the methodology of Ferreira et al. (2018a, 2018b). Here, the EI and CI of the stores of the 250 highest revenue retailers were analysed based on publicly available data from the fiscal year 2016 (Deloitte and Stores Media 2016), to establish best practice reference levels for these two variables. Outliers were identified with the interquartile range and removed as to reduce error in the dataset. CI was expressed as the total kilogramme emissions of carbon-dioxide equivalent per unit of m^2 of gross floor sales area per year (kg CO_2eq/m^2/y), according to the GHG Protocol methodology for scopes 1 (all direct GHG emissions including stationary combustion for comfort heating and fugitive emissions from refrigerant systems) and scope 2 (all indirect GHG emissions from the consumption of purchased electricity, heat or steam) (WRI and WBCSD 2016). EI was expressed as the total final energy consumption in kWh per unit of m^2 of gross floor sales area per year (kWh/m^2/y). The initial 250 retailers' sample was reduced to those retailers that presented EI or CI data (39% of the initial sample). Even

though some retailers had a mixed typology of store formats in their business portfolio, they were characterized as food or non-food retailers according to the predominant number of stores in each format. In addition, retailers were analysed into food or non-food categories, because of the significant EI/CI differences caused by refrigeration systems. The energy consumption profile of food retailers was characterised by a high demand of electricity for refrigeration, which included hypermarkets, supermarkets, discount stores, convenience stores and cash & carry stores (Galvez-Martos et al. 2013). The non-food category included primarily home improvement stores, drug stores/pharmacies, department stores, furniture/decoration stores, household appliances/electronics stores, auto-shops and office supplies stores. CI data were collected from 37 food retailers (which provided 39 entries) and from 35 non-food retailers (which provided 38 entries), and EI data were collected from 34 food retailers (which provided 56 entries for EI) and from 25 non-food retailers (which provided 35 entries for EI). The term "entries" refers to aggregated EI or CI data for either a retailer's overall performance, or for a retailers' brand or country of operation. EI and CI data were published in Data in Brief article (Ferreira et al. 2018a, 2018b). CI was reported less frequently by retailers than EI (particularly for non-food retailers); hence, the different counts between CI and EI. Each retailer of the analysed sample presented aggregated data for an average 3.120 stores and 5.5 million m^2 of total sales area. The fact that the analysed retailers operate in all major markets (USA, Eurozone, UK, Japan and other emerging markets), have a revenue of at least 3 billion US$ and employ on average over 100.000 workers each are also indicators of the representativeness of the sample. In addition, most screened retailers (90%) followed the Global Reporting Initiative (GRI) standards or resorted to third-party certifications to validate their EI and CI data.

The benchmarking of retailers' EI and CI was used as a tool for comparing environmental performance and identifying improvement opportunities (Stapenhurst 2009). Fundamentally, the value of benchmark stands in comparing one's business processes and performance metrics to industry's best practices, in the quest for increased performance (Wireman 2004). As no official definition of best practice benchmarks existed within the retail sector (Galvez-Martos et al. 2013), the methodology proposed by Ferreira et al. (2018a, 2018b) to set best performance benchmarks is based on previous works developed for other sectors (de Fátima Castro et al. 2015) and defined the threshold of the 25% best-performing retailers within the sector, as the best practice both for EI and CI. Hence, best-performing food and non-food retailers were identified applying the mathematical operation first quartile (Q1), which set them at the upper limit of the first quartile, equivalent to the boundary of the 25% lowest values. Based on the same methodology, the mathematical operation fourth quartile (Q4) was used to define the benchmark for the worst performing food and non-food retailers, which has been set at the upper limit of the fourth quartile, equivalent to the boundary of the 75% highest values.

In step 2 (desk research) and for each identified best and worst performing retailers, policy, strategy and building practice data were searched by the authors online, mainly in sustainability or CSR reports. Only the most recent (dating from 2016) and available sustainability/CSR retailers' reports were considered as to compare the most updated data. To ensure permanent access to the data that support the presented results, all internet references cited in our study were compiled in a data repository (Ferreira (2018) in the References).

In step 3 (data screening and organization), data were organized in different tables for food retailers and one for non-food retailers, according to the variables policy, strategy and building practice. Two sample strategies were selected: maximum variation sampling and deviant case sampling (Suri 2011). Data organization was made the following way: CSR/sustainability reports were searched for recurring themes, which were recorded under each variable's table, to identify core consistencies and meanings (i.e. patterns) (Miles and Huberman 1994; Patton 2002). These patterns were then sorted into categories, according to internal heterogeneity (the extent to which the data belonging in a certain category hold together) and external heterogeneity (the extent to which differences in amongst categories are clear). They were also validated by all authors to be reasonably inclusive of the analysed data as to cover our research questions. Hence, for each variable, data were organized according to the most general category that could embrace each of the identified listed measures. Only measures that were referenced by more than 10% of best-performing retailers were included in the presented tables. In total, 31 best-performing retailers were analysed (18 food retailers and 13 non-food retailers) against 27 worst performing retailers (17 food retailers and 10 non-food retailers). Nevertheless, the original grids used to code all data were compiled in a data repository

(Santos Ferreira (2019) in References). The data retrieved for the variable "policy" was organized in Table 2 under the categories: "CSR Principles and Policy", "United Nations' Partnerships", "Sustainability Indexes", "Certification Systems" and "Reporting Standards". The data retrieved for the variable "strategy", was organized in Table 3 under the categories: "Goal setting and reporting", "Support management's systems" and "Green building". The data retrieved for the variable "building practice", data were organized in Table 4 under the categories: "Envelope", "HVAC systems", "Refrigeration systems", "Lighting", "Renewable energy sources" and "Water management".

In step 4 (nationality analysis), the nationality analysis of the sampled retailers was performed, as to infer the impact of local culture in each analysed variable (policy, strategy and building practice). The geographical provenance of the sampled retailers was attributed according to their country of origin, despite the fact that most of the analysed retailers operate stores in more than one country. Hence, most of the analysed retailers were European (48%), followed by North American (33%) and Asian (10%). The remaining analysed retailers were African (4%) Australian (2%) and South American (2%) (Fig. 1). Within Europe, 28% of retailers were from

Germany (7%), France (8%) and the UK (13%), whereas in North America 28% of retailers were from the USA

In step 5 (data analysis), a detailed content analysis of the information presented in best practice and worst practice retailers' sustainability/CSR reports was conducted, according to the variables "policy", "strategy" and "building practice" and following the methodology of Sullivan and Gouldson (2013). Data was searched for divergence in terms of deviant cases that did not fit the dominant identified patterns (included in Santos Ferreira (2019)), as well as rival explanations for the results (Miles and Huberman 1994; Patton 2002). To increase the rigour of data analysis, the authors have resorted to the triangulation technique, checking for their consistency with other authors' theories and data sources (see the "Discussion" section). A comparison analysis was carried out between best and worst performing retailers, based on the percentage of retailers that cited each of the listed categories' measures in their sustainability/CSR reports, in order to identify differentiating measures from best-performing retailers responsible for a higher environmental performance. In addition, the statistical test chi-square ($\chi 2$) for homogeneity of population was carried out between best and worst performing retailers, to rule out the null hypothesis (where $p < 0.05$ confirms
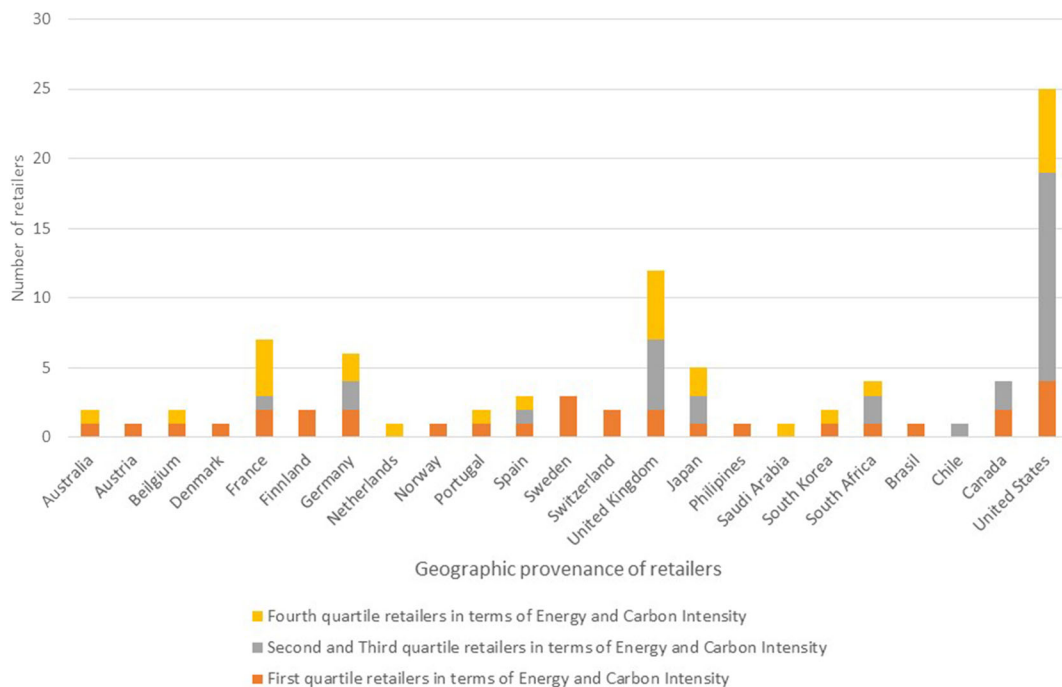
Fig. 1 Distribution of food/non-food retailers according to geographic provenance, including split within each country between first quartile (Q1), second and third quartiles (Q2 and Q3) and fourth quartile (Q4) in terms of energy and carbon intensity ($n = 89$)

that the distribution is not random, and there is a difference between best and worst performing retailers).

Results

Best-performing retailer's CI and EI

According to the sample data, CI and EI best practice reference levels for food and non-food retailers were calculated applying the statistical operation first quartile (Q1). CI best practice threshold values for food retailers are found under 115 kg CO_2eq/m^2/y and under 70 kg CO_2eq/m^2/y for non-food retailers. Best practice CI threshold values of non-food retailers are 40% less than those of food retailers (Fig. 2). CI variability for food retailers reflects a factor of 18 to 1 and for non-food retailers, a factor of 17 to 1.

EI best practice threshold values for food retailers are found under 346 kWh/m^2/y and under 146 kWh/m^2/y for non-food retailers. Hence, the best practice threshold values for non-food retailers is over half that of the food retailers (Fig. 3). EI variability for food retailers reflects a factor of 9 to 1 and for non-food retailers, a factor of 6 to 1.

Store typology average EI and CI values vary, as evidenced by the retailers that specify EI and CI according to store typology (Table 1).

Best-performing retailers' policy, strategy and building practice

The business policy, strategy and building practice of best and worst performing retailers were analysed in terms of the frequency that each listed measure was reported in these retailers' sustainability/CSR reports.

As for policy, the greatest difference between best and worst performing retailers can be found in the measure "Sustainability as part of the business strategy" and in the increased use of the "Reporting Standards" category (Table 2).

Concerning business strategy, the greatest difference between best and worst performing retailers can be found in the measure "Setting up energy objectives", which can also be indirectly observed in the measures "To be 100% supplied by renewable energy"/"To be 100% carbon neutral", as well as in the measure "Include demanding energy standards in the concept of new stores and the retrofitting of existing stores" (Table 3).

Concerning building practice, the greatest difference between best and worst performing retailers can be found in the measures "Use natural refrigerants" and "Gas transfer to CO_2" in the "Refrigeration systems" category (Table 4).

Other factors can affect EI and CI, namely CSR and local culture. Hence, a geographic analysis of Q1 and
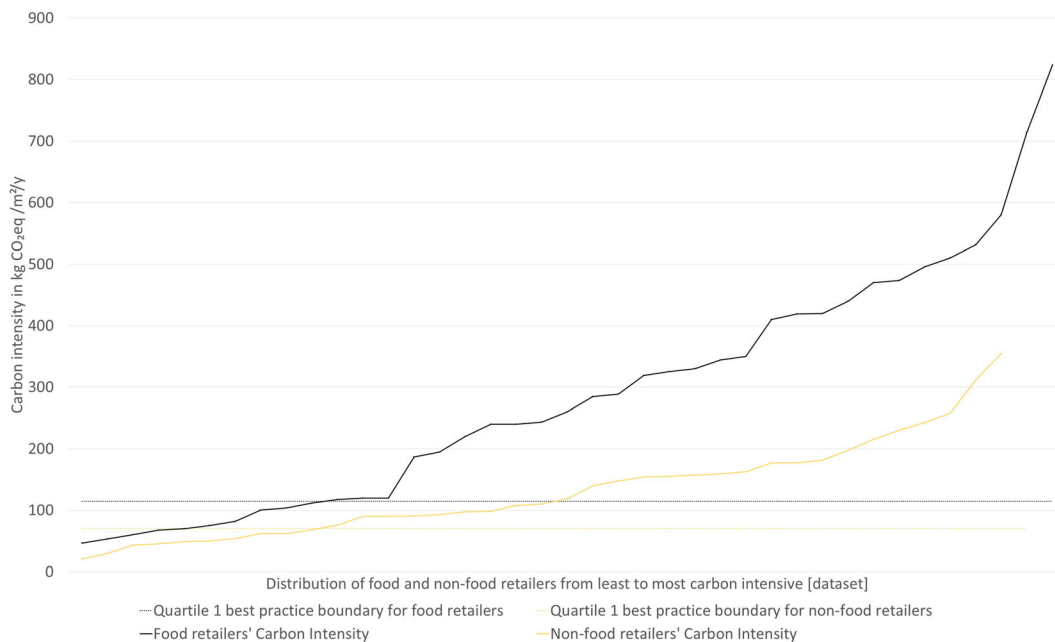
Fig. 2 Linear distribution of CI for food and non-food retailers with correspondent quartile 1 best practice boundary of each group
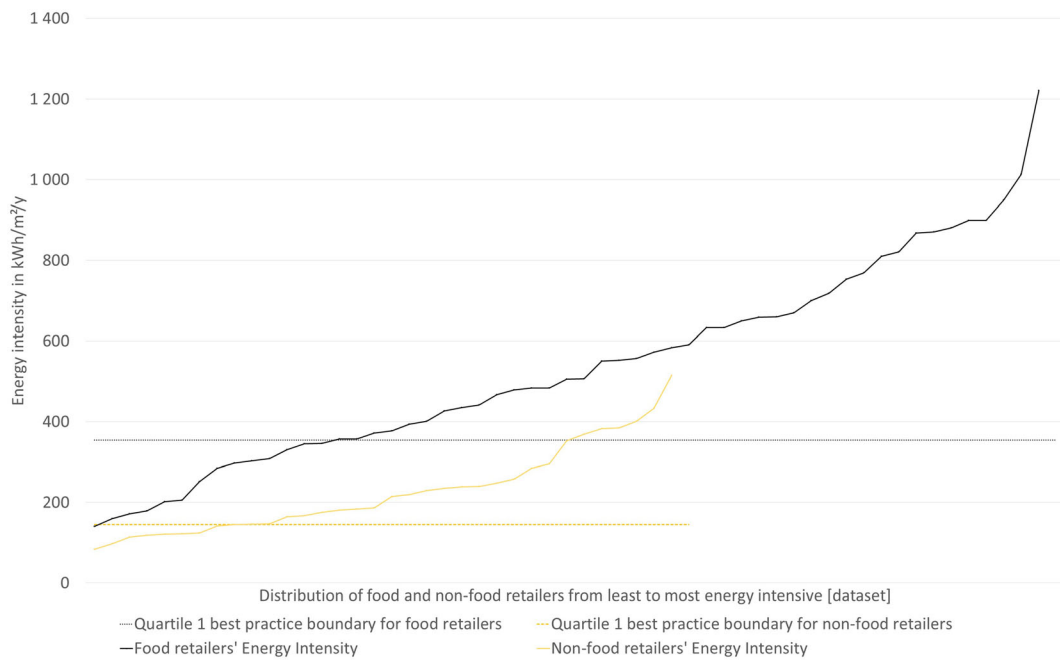
Fig. 3 Linear distribution of EI for food and non-food retailers with correspondent quartile 1 best practice boundary of each group

Q4 retailers was performed, with retailers from Scandinavian countries (Denmark, Finland, Sweden or Norway) standing out in the best-performing retailers' group (Table 5).

Discussion

The data collected on the CI and EI of the world's largest retailers have allowed to benchmark best and worst performing retailers, according to the first and third quartile statistic formulas. The factors behind CI and EI variability are concisely addressed in the subsection "Best-performing retailers' Carbon (CI) and Energy (EI) intensities", followed by the discussion of differentiating corporate measures that enable a higher environmental performance in the subsections "Best-performing retailers' energy policy", "Best-performing retailers' energy strategy" and "Best-performing retailers' building practice".

Best-performing retailers' carbon and energy intensities

CI and EI benchmarks positioned best practice energy performance under 346 kWh/m²/y and 115 kg CO_2eq/m²/y for food retailers and under 146 kWh/m²/y and

70 kg CO_2eq/m²/y for non-food retailers (Ferreira et al. 2018a, 2018b).

Results allow to conclude that both for food and non-food retailers, store typology impacts EI and CI (Table 1), as evidenced by the retailers that specify EI and CI according to store typology. In food retail, the trend is for convenience stores to have on average higher EI and CI (as they incorporate the most intense refrigeration-systems' typology per linear meter of aisle), followed by supermarkets, hypermarkets and discount stores. A third of the best-performing food retailers are hard discount stores, whereas in the worst performing group only one retailer is a hard discounter. Low CI and EI in hard discount stores may be an indicator of the necessity of this format to be competitive, as pointed out by Ochieng et al. (2014). Other reasons for low CI and EI may relate to a greater proportion of dry packaged goods versus refrigerated food in these stores, the lack of deli or hot food counters or the lack of onsite coffee shops. In addition, hard discount is a young store format, so stores are typically newer and more energy efficient. New stores with more energy-efficient equipment may give retailers an energy efficiency advantage.

In non-food retail, the trend is for department stores and apparel/footwear stores to have on average higher EI and CI and for home improvement, decoration stores and auto-shops to have the lowest EI and CI (Table 1).

Table 1 EI and CI breakdown per retail sub-type

Retail sub-type	Average energy intensity in kWh/m²/y	Average carbon intensity in kg CO₂eq/m²/y
Food retailers		
Discount stores[1]	555	226
Hypermarkets[2]	591	258
Supermarkets[3]	584	273
Convenience stores[4]	941	568
Non-food retailers		
Home improvement/DIY stores[5]	150	130
Furniture/decoration stores[6]	165	60
Auto-shops[7]	169	82
Electronics/household appliances stores[8]	212	106
Drug stores/pharmacies[9]	220	160
Department stores[10]	283	175
Apparel/footwear stores[11]	321	161

[1] Discount stores: with average surface less than 1000 m², in stand-alone buildings (usually owned) or building units (usually rented) (Galvez-Martos et al. 2013; Schönberger et al. 2013)

[2] Hypermarkets: with high sales area, low relative refrigeration load compared with food supermarkets and in stand-alone buildings, usually owned (Galvez-Martos et al. 2013; Schönberger et al. 2013)

[3] Supermarket: with high refrigeration load, surface from 1000 to 3000 m², can be in stand-alone buildings (usually owned) or building units (usually rented) (Galvez-Martos et al. 2013; Schönberger et al. 2013)

[4] Convenience stores: small stores with refrigeration of food. Building units are usually rented (Galvez-Martos et al. 2013; Schönberger et al. 2013)

[5] Home improvement/do-it-yourself (DIY) stores sell household hardware for home improvement, repair equipment, materials and garden accessories

[6] Furniture/decoration stores sell home accessories and furniture

[7] Auto-shops deal in the repair of automobiles

[8] Electronics/household appliances stores sell electronic equipment intended for everyday use;

[9] Drug stores/pharmacies sell cosmetics, toiletry items, first-aid supplies and medications

[10] Department stores sell an extensive assortment of goods, organized into separate departments

[11] Apparel/footwear stores sell clothing, footwear and accessories

This may be explained through different marketing and pricing strategies, reflecting distinct needs of each store format as how to effectively display merchandise and how to provide comfort and store ambiance for customers, which in turn will affect lighting, HVAC and equipment requirements.

In addition, it was found a tendency for store location to impact EI, as evidenced by the retailers that specified EI per retail sub-type and per country. These results suggest that EI variability within in European countries is lower than that of other continents. Nevertheless, the fact that within Europe, stores located in countries with different climate conditions, have similar EI values, points to the existence of other more important factors affecting the EI than climate conditions (Ferreira et al.

2018a, 2018b), such as location, opening hours, occupancy, staff behaviour, maintenance routines, store size, store volume, the nature of products being retailed, type, building age, equipment's efficiency (Spyrou et al. 2014) or even local government regulation or building incentives.

We also found a tendency for best-performing retailers to have less stores than worst-performing ones (36% versus 64% for food retailers and 44% versus 56% for non-food retailers). In addition, retailers with green store concepts for new buildings claim to be able to achieve 30–70% of the traditional store EI as a result of incorporating high-performance sustainable solutions (Aeon 2015; Aldi 2015; Lidl 2015), which stresses the importance energy-efficient equipment to achieve low

Table 2 Best (Q1) versus worst (Q4) performing retailers in terms of business policy

Dimension	Category	Measure	% of best-performing food retailers that apply each listed measure	% of best-performing non-food retailers that apply each listed measure	% of worst-performing food retailers that apply each listed measure	% of worst-performing non-food retailers that apply each listed measure
Policy	CSR Principles and Policy	Sustainability as part of business strategy	33	31	6	10
		Circular economy	6	23	12	0
		Environmental policy	22	54	29	10
		Sustainability policy	28	23	35	0
	United Nations' Partnerships	UN Global Compact Principles	44	23	12	10
		COP 21 Paris pledge for action	6	23	24	20
	Sustainability Indexes	WWF Environmental Rating	11	8	0	0
		Dow Jones Sustainability Index (DJSI)	17	15	24	0
	Certification Systems	BREEAM	11	8	18	10
		LEED (building design + construction)	11	15	6	60
		Other certification schemes	22	8	0	0
		ISO 14001	0	23	29	40
		ISO 50001	6	0	18	0
	Reporting Standards	Global Reporting Initiative (GRI)	83	69	53	70
		Greenhouse Gas (GHG) Emissions' Protocol	89	62	47	50
		Carbon Disclosure Project	39	77	47	40
			$n = 18$	$n = 13$	$n = 17$	$n = 10$

Table 3 Best (Q1) versus worst (Q4) performing retailers in terms of business strategy

Dimension	Category	Measure	% of best-performing food retailers that apply each listed measure	% of best-performing non-food retailers that apply each listed measure	% of worst-performing food retailers that apply each listed measure	% of worst-performing non-food retailers that apply each listed measure
Strategy	Goal setting and reporting	To be 100% supplied by renewable energy	6	31	0	0
		To be 100% carbon neutral	17	15	0	20
		Independency from grid energy	17	0	0	0
		Setting up energy objectives	78	0	29	30
		Establish sustainability targets	28	38	24	10
		Results/kpi monitoring	44	38	24	40
		Report on progress	22	15	12	10
		Energy management system	28	8	41	40
		GHG emissions management	11	0	6	0
		Energy guidelines	6	15	12	0
		Staff training	72	69	59	40
		Energy audits	28	0	6	0
		Corporate sustainability tools	17	0	6	0
	Green buildings	Development of Carbon Neutral or Green Stores Concepts	50	46	35	40
		Include demanding energy standards in the concept of new stores and the retrofitting of existing stores	33	31	0	0
		Low impact building materials	44	15	0	0
		Recyclable building materials	28	15	0	0
		Recharging stations for electric vehicles	0	0	6	0
		Rolling out according to best practice	11	8	12	30
		Implement energy savings in distribution centres	0	15	0	0
			$n = 18$	$n = 13$	$n = 17$	$n = 10$

Table 4 Best (Q1) versus worst (Q4) performing retailers in terms of building practice

Dimension	Category	Measure	% of best-performing food retailers that apply each listed measure	% of best-performing non-food retailers that apply each listed measure	% of worst-performing food retailers that apply each listed measure	% of worst-performing non-food retailers that apply each listed measure
Building practice	Envelope	Optimize envelope insulation	28	31	24	30
		Change to more efficient glazing	11	8	6	30
	HVAC systems	Retrofit/optimize the design of HVAC systems	6	23	0	50
		Variable speed fans	22	8	18	0
		HVAC automation	22	38	12	10
	Refrigeration systems	Use natural refrigerants	61	0	6	0
		Ammonia based refrigeration	11	0	6	0
		CO_2 based refrigeration	33	0	35	0
		Hydrocarbon refrigeration	17	0	6	0
		Glycol and water refrigeration system	11	0	6	0
		Propane refrigeration system	11	0	0	0
		Gas transfer to CO_2	22	0	18	0
		Gas transfer to $CO_2 + CO_2$–based refrigeration	50	0	0	0
		Covering display cases	6	0	0	0
		Glass doors	39	0	47	0
		LED light in cabinets	11	0	0	0
		Air curtains	11	0	0	0
	Lighting	Occupancy sensors, dimming, time control	17	15	18	40
		Daylight harvesting	22	38	47	10
		Light on demand	28	15	6	10
		Efficient equipment	39	46	35	40
		LED	72	77	41	80
		High efficiency lamps	17	31	24	20
	Renewable energy sources	Biomass-fired boilers	22	15	18	0
		Wind turbines	17	31	24	10
		PV panels	61	69	65	30
		Purchase of available 'green' electricity	28	54	41	40
		Carbon offsetting	11	15	12	50

Table 4 (continued)

Dimension	Category	Measure	% of best-performing food retailers that apply each listed measure	% of best-performing non-food retailers that apply each listed measure	% of worst-performing food retailers that apply each listed measure	% of worst-performing non-food retailers that apply each listed measure
	Water management	Rainwater harvesting	6	15	29	10
		Landscape integration	28	15	6	40
		Green roofs	22	0	12	0
		Installing flow restrictors in taps	6	15	35	50
			n = 18	n = 13	n = 17	n = 10

EI. Some retailers specified the EI of traditional stores versus the EI of new, more energy-efficient ones, such as Rewe (950 vs 500 kWh/m^2/y) (Rewe 2017) or Edeka (357 vs 104 kWh/m^2/y) (Edeka 2016). Other retailers have specified the reductions on the energy consumption they are able to achieve by introducing energy efficient technology in new or refurbished stores, such as Lidl (claiming energy savings of 40% overall) (Lidl 2015) or Aldi (claiming energy savings of 30% overall) (Aldi 2015). Newer stores, utilizing newer equipment (and lighting) are inherently more energy efficient, as demonstrated by these retailers. In fact, Lidl claims 40% of energy savings when using LED lighting and an additional 30–40% when using low-energy refrigeration systems, coupled with glass doors on cabinets.

Other factors that affect EI include the price and availability of local electricity generation and local culture (Ferreira et al. 2018a, 2018b). In fact, corporate culture and social responsibility must also impact CI and EI, as most of the best-performing retailers are from countries with leading climate change performance (Burck et al. 2019): Switzerland, Denmark, Finland, Sweden or Norway. Indeed, there are no retailers from these nationalities in the worst performing retailers' group (Table 4). By analysing the compared nationality percentage of best-performing retailers versus worst performing retailers, it is possible to suggest that policy at national and international levels play a role at pushing retailers into energy and carbon efficiency, namely in the decarbonizing strategies and goals set by retailers. Nevertheless, it is rather retailers' CSR approach that is a differentiating factor in terms of energy and carbon performance—the differences of energy and GHG emissions' reduction goals within European retailers with a common legislative framework, are evidence of such. The differences of EI and CI performance within European countries with a common legislative framework are further evidence of such. Likewise, developing countries like Brazil and Philippines ranking amongst best-performing retailers also attest to the role of CSR in environmental performance.

CI variability was greater than that of EI, particularly for non-food retailers, which is consistent with the findings of Schönberger et al. (2013), placing the carbon footprint of retail companies as highly dependent on electricity use—60% for food retailers and higher for non-food retailers, due to the absence of refrigeration systems (Schönberger et al. 2013). Carbon intensity is thus affected mostly by the carbon content of purchased

Table 5 Nationality prevalence of best and worst-performing retailers

	Q1 food retailers			Q1 nonfood retailers			% of Q1 retailers from the same country within sample
	Best-performing in terms of CI	Best-performing in terms of EI	Best-performing in terms of both EI and CI	Best-performing in terms of CI	Best-performing in terms of EI	Best-performing in terms of both EI and CI	
Australia	1						50
Austria	1						100
Beilgium	1	1					50
Brazil							100
Canada		1		2			50
Denmark					1		100
France						1	100
Finnland			2				29
Germany	2	2					33
Japan				1			20
Netherlands							
Norway	1	1					100
Philipines		1					100
Portugal		1					50
Saudi Arabia							
South Africa	1						25
South Korea			1				50
Spain		1					33
Sweden		1		2			100
Switzerland	2						100
UK				2			17
USA				1	2	1	16

	Q4 food retailers			Q4 nonfood retailers			% of Q1 retailers from the same country within sample
	Worst-performing in terms of CI	Worst-performing in terms of EI	Worst-performing in terms of both EI and CI	Worst-performing in terms of CI	Worst-performing in terms of EI	Worst-performing in terms of both EI and CI	
Australia	1						50
Austria							
Beilgium	1						50
Brazil							
Canada							
Denmark							
France	3	1					
Finnland			1				0
Germany	1						33

Table 5 (continued)

	Worst-performing in terms of CI	Worst-performing in terms of EI	Worst-performing in terms of both EI and CI	Q4 nonfood retailers	Worst-performing in terms of CI	Worst-performing in terms of EI	Worst-performing in terms of both EI and CI	% of Q1 retailers from the same country within sample
Japan	1							40
Netherlands			1					
Norway								
Philipines								
Portugal			1					50
Saudi Arabia		1						
South Africa							1	25
South Korea		1						50
Spain		1						33
Sweden								
Switzerland								
UK			3		1		1	42
USA					4	1	1	24

electricity in the countries in which a retailer is active. Low carbon energy, mainly when not generated on-site by the retailers but evidenced from guarantees of origin, may thus impact CI results. However, as no retailer has specified CI per retail per country, the exact impact of the energy mix in CI variability remains to be determined. In general terms, CI variability is a result of the energy-efficiency strategies to minimize the consumption of energy and of the energy's production source (fossil vs. renewable energy). For food retailers, it also results from unintentional refrigeration systems' fugitive emissions (ENDS Carbon—University of Edinburgh Business School 2009). Therefore, the variability found in the present study both for CI and EI values supports the theory that, in order to decrease retailers' carbon footprint, EI reduction should first be addressed (Schönberger et al. 2013).

To mitigate scope 1 GHG direct emissions, namely stationary combustion for comfort heating, food retailers can recover waste heat from the refrigeration cycle, hence suppressing the need for additional store heating. To address fugitive emissions resulting from the unintentional release of GHG from refrigerant systems, retailers can invest in gas leakage detection and improved maintenance in HVAC and refrigeration systems. The later can minimize food retailers' carbon footprint by up to 30% (Schönberger et al. 2013). Gas transfer to CO_2 in refrigeration systems also ranks high for European food retailers, because of its impact on the company's overall carbon footprint. In addition, to mitigate scope 2 GHG indirect emissions from the consumption of purchased electricity, retailers can invest in the on-site production of renewable energy, in the purchase of green energy or in offsetting methods. Energy efficiency solutions minimising energy consumption are the first step to decrease emissions from the electrification process. Thus, to achieve significant CI and EI reductions, a multidimensional corporate approach needs to be considered, integrating several materiality issues in business policy, strategy and building practice.

Best-performing retailers' energy policy

When comparing best with worst performing retailers in terms of energy policy, the greatest difference can be found in the measure "Sustainability as part of the business strategy", reported by 33% and 31% best-performing food and non-food retailers respectively against 6% and 10% worst performing food and non-

food retailers respectively. The results show that integrating sustainability as part of the business strategy has a positive effect on best-performing food retailers ($p = 0.04$). Best-performing retailers that integrate sustainability as a part of their business strategy invoke for such improved business resilience, cost reduction across the value chain, brand differentiation or social responsibility towards the environment, which is analogous to the findings of Galvez-Martos et al. (2013). This also attests the findings of Testa et al. (2017), according to whom a firm's "greening" strategic profile plays a role in setting them apart from competitors. In best-performing non-food retailers, there was a positive effect regarding the adoption of an environmental policy ($p = 0.03$). Contrary, no important differences between best and worst performing food retailers were found in the measures "environmental policy", often associated with an environmental management system (EMS). This can be explained by the different level of corporate internalization of the environmental management system in terms of strategies and daily operational procedures between best or worst performing retailers, therefore, leading to different results in terms of environmental performance. According to Testa et al. (2017), deeper internalization of an environmental management system can be achieved with wider and more frequent employee involvement or higher integration with other management and operational tools, as is the case of the best-performing retailers in the present study, in relation to staff training, energy audits and development of corporate sustainability tools (see the "Best-performing retailers' energy strategy" section).

Similarly, the results show that worst performing food and non-food retailers report increased use of the ISO 14001 certification. In fact, for worst-performing food retailers, there was a positive effect regarding the adoption of ISO 14001 ($p = 0.01$), suggesting that adopting a meta-standard does not necessarily lead to a better environmental performance. Voluntary standards emerged as global regulatory mechanisms to address sustainability, quality, health and safety in organizations (Tuczek et al. 2018). This proves that a mimetic strategy with the purpose of being compliant with a standard—as that potentially led by worst performing retailers—will fail in terms of achieving the same result as a best-performing competitor (Testa et al. 2017). The same is also likely true for the use of ISO 50001: only one best-performing food retailer has mentioned the use of this standard, against three worst performing food retailers.

Additionally, two best-performing retailers have issued Energy Policy statements that do not mention this norm. The fact that retailers are not commenting on the use of ISO 50001 in their sustainability/CSR reports is not an irrefutable proof that they do not use the standard (although evidence does not support the opposite hypothesis either). In fact, most best-performing retailers (68%) mention the use of an energy management system (e.g., a system that monitors and adjusts the energy consumption of stores), coupled with energy goal setting and monitoring, which may hint at the possibility of retailers to resort to ISO 50001 as a more structured framework for operational energy management.

No relevant differences were found concerning sustainability indexes (namely the Dow Jones Sustainability Index) between best and worst performing food and non-food retailers. Sustainability Indexes are another way of promoting environmental, social and governance (ESG) issues in the retail industry, tracking companies with strong sustainability profiles (MSCI 2017). In fact, investors are attracted to sustainability for its superior risk-return profiles and because sustainability stands for informed and disciplined management (Choi and Gray 2008).

A management culture based both on legal requirements and voluntary obligations is transversal to best and worst performing retailers as a way of incurring some goodwill with consumers (Richman and Simpson 2016), as well as partnerships with Non-Government Organizations (NGOs). Both best-performing food and non-food retailers adhere to the UN Global Compact Principles (44% and 23% best-performing food and non-food retailers respectively vs 12% and 10% worst-performing food and non-food retailers respectively), with a positive effect ($p = 0.03$) for best-performing food retailers. Opposite, there are no important differences in the adherence to the COP 21 Paris Pledge for Action by either best or worst-performing food and non-food retailers. Whereas the UN Global Compact provided a framework for improving the analysis of ESG issues in corporate investments, the COP 21 Paris Pledge for Action invited signatories to support the objectives of the Paris Agreement. The use of reporting standards is largely reported by retailers, with best-performing food retailers adhering more than worst performing ones (83% vs 53% for GRI standards and 88% vs 47% for the GHG Protocol). In fact, there was a positive effect regarding the adoption of GRI standards ($p = 0.05$) and of the GHG Protocol ($p = 0.01$) for best-performing food retailers. This attests

to best-performing food retailers' effort to bring consistency and transparency on energy accounting tools, as to reduce limitations in calculation methodologies concerning data comparability. In addition, voluntary standards tend to signal positive environmental performance and deter companies from greenwashing (Hahn and Luelfs 2014; Kim and Lyon 2015; Parguel et al. 2011). GRI reporting standards, followed by most best-performing retailers, help to overcome greenwashing tendencies by reporting both positive and negative aspects of sustainability performance (Hahn and Luelfs 2014).

Voluntary green building certification systems have become increasingly popular as a means for achieving sustainability in the built environment (Borgstein et al. 2016) and of mitigating the negative impacts associated with construction (Shi et al. 2016). About half of the studied retailers reported the use of a Green Building Certification System, usually chosen according to retailers' geographic provenance. BREEAM, as a European certification system, was chosen uniquely by European retailers. Besides, European retailers report the use of other national building certification schemes, such as Germany's Sustainable Building Council (DGNB), France's Haute Qualité Environnementale (HQE), Switzerland's Sustainable Construction Standards (SNBS) or Sweden's Green Building Council (SGBC). In addition, there was a positive effect regarding the adoption of other green building certification systems ($p = 0.04$) for best-performing food retailers. In contrast, LEED, as an American certification system, was chosen by all American retailers, by four European retailers and by one Asian retailer. Hence, LEED was the most popular green building certification system, reported both by best (26%) and worst (66%) performing retailers overall. Differences seem to exist in the approach of best-performing retailers to green building design, as only they include demanding energy standards in the concept of new stores and the retrofitting of existing stores (see the "Best-performing retailers' energy strategy" section). The fact that LEED appears to have been used mainly by retailers in the worst-performing retailers—with a positive effect ($p = 0.03$) for worst-performing non-food retailers—could suggest they are greenwashing, as LEED certifications, may only have been achieved in few stores and not replicated across retailers' property portfolio. It could also reflect more on other factors, such as the carbon intensity of US electricity and the large summer-winter temperature difference in continental USA, than on

voluntary actions. Since the number of certified green stores stands as a key performance indicator of environmental management, their percentage in retailers' portfolio is expected to increase.

Business models do change and these changes can have an important influence on GHG emissions (Sullivan and Gouldson 2013). If reducing operational emissions remains a priority for all retailers (Sullivan and Gouldson 2013), customer preference, revenue growth and access to natural resources stand as additional environmental business drivers for best-performing retailers, that believe their commitment to sustainability will yield long-term economic performance to the organization.

Best-performing retailers' energy strategy

Setting up energy objectives as an energy-related business strategy was the most popular measure declared by retailers (78% in best-performing food retailers vs about 30% in worst performing food and non-food retailers). Indeed, there was a positive effect regarding this measure for both best-performing food retailers ($p = 0.004$) and worst-performing non-food retailers ($p = 0.03$). Nevertheless, best-performing retailers convey the will to consider radical changes in their business models in order to tackle climate change, such becoming 100% supplied by renewable energy (with positive effect ($p = 0.05$) for best-performing non-food retailers) or carbon neutral by 2020. Those who do not target at carbon neutrality set energy and carbon reduction goals that range from 20 up to 85%, by 2020. Drivers for energy reduction targets and strategies include climate change ethical considerations alongside rising energy prices, as pointed by Christina et al. (2015). Contrary, worst performing retailers do not share carbon neutrality goals, and the two retailers that do advocate it, either do not indicate the year to accomplish targets or push them to 2050.

There are no important differences in the reported use of energy and GHG emissions' management systems both for best and worst-performing food and non-food retailers. For food retailers, GHG emissions' management systems are important tools to decrease their carbon footprint, since 30% of it can derive from refrigeration systems' gas leakage (WRI and WBCSD 2016).

Staff training is the most reported energy management measure overall, whereas energy audits are rarely reported by worst performing food retailers, despite being an important tool to identify energy optimization areas. Additionally, the use of specific corporate sustainability tools or apps on carbon footprint has been reported by retailers as novel ways to raise environmental awareness amongst associates.

In terms of green building design, both best and worst performing food and non-food retailers develop carbon neutral or green store concepts as a way of promoting environmental concern. However, only best-performing retailers include demanding energy standards in the concept of new stores and in the retrofitting of existing stores (with positive effect for best-performing food ($p = 0.01$) and non-food retailers ($p = 0.05$)). This suggests that best-performing retailers understand the importance of a structured approach to innovation to achieve energy-efficiency and carbon neutrality, as argued by Sullivan and Gouldson (2013). The integration of low impact building materials ($p = 0.002$) and recyclable building materials ($p = 0.02$) also have a positive effect for best-performing food retailers. Additionally, soft mobility principles and of recharging stations for electric vehicles, as well as of lean principles to identify areas of wasted resources, are also trends mentioned by best-performing retailers.

In addition, best-performing retailers seem to be willing to endure higher initial construction costs, with longer payback periods, as they believe that green buildings allow lower running costs, enhance property assets and improve the wellbeing for customers and teams, which in turn may translate to a better shopping experience and increased sales. The use of low impact building materials is also reported more frequently by best-performing retailers as well as the use of recycled building materials. This corroborates the findings of Ochieng et al. (2014) and of Richman and Simpson (2016), given that best-performing retailers' initiatives to build energy-efficient stores are driven as much by business imperatives as by commitments to sustainability. Nonetheless, green building concepts are tested both by best and worst performing retailers in pilot projects. For best-performing retailers, once a technology is proven, it is immediately rolled out to other existing stores, which in turn improves the energy-efficiency of the company overall. Such may not be the case for worst performing retailers, which do not disclose the speed of this process.

Best-performing retailers' building practice

According to Schönberger et al. (2013), the average share for energy consumption for a food retailer is

50% for refrigeration, 25% for lighting, 20% for HVAC systems and 5% for electric appliances and other internal processes. For non-food retailers, the map for the energy consumption of a store depends more on business typology though lighting, HVAC systems and electric appliances and other internal processes remain the three most important energy consumption segments. Given the positive correlation between EI and CI, measures that contribute the most to environmental performance are those that allow decreasing the energy consumption of the most energy-intensive store segments (in order, refrigeration, lighting, HVAC and electric appliances and others internal processes). In addition, the most common energy-efficiency solutions reported by best and worst performing retailers are economically and environmentally driven: CO_2-based refrigeration, glass doors in frozen cabinets (exclusively for food retailers), LED lighting, efficient equipment and either photovoltaic energy produced on site or the purchase of available "green" electricity. CO_2-based refrigeration and glass doors in frozen cabinets can reduce energy consumption by 40%, whereas LED lighting systems can reduce energy consumption by 50%, when compared with fluorescent T8 lighting (CommONEnergy Project 2013a; Schönberger et al. 2013). Besides, the replacement of old rooftop units by more efficient equipment can reduce the energy consumption of HVAC systems in 20%, improving thermal conditions for customers at the same time (CommONEnergy Project 2013b). Differences were found in the higher percentage of best-performing food that reported the use of LED (72% vs 41%). For food and non-food retailers alike, the main difference was found in the use of HVAC automation (22% + 38% best-performing retailers vs 12% + 10% worst-performing retailers).

Despite this, the greatest difference between best and worst performing food retailers was found regarding the use of natural refrigerants in refrigeration systems (with a positive effect ($p = 0.001$) for best-performing food retailers). Best-performing food retailers promote gas transfer to CO_2 in existing stores systems (with a positive effect of $p = 0.0007$) and trial more alternative solutions with refrigerants with lower Global Warming Potential (GWP) than worst-performing food retailers. The use of natural refrigerants comes in line with recent regulation regarding F-gases, such as the Kigali Amendment to the Montreal Protocol, or the European Union F-Gas Regulation No 517/2014, intending at a large-scale conversion to climate-friendly technologies in new

equipment and products by 2030 (European Parliament and European Council 2014). According to data collected, it is not possible to identify the impact of new stores, with more efficient equipment (purchased after update of the F-gases regulation), in each of the retailers overall EI and CI performance. Some retailers—especially the so-called "hard discounters" have expanded their store base rapidly in recent years into many new markets, which may affect their average EI/CI. In fact, that prevalence of a third of hard discount retailers in the group of best-performing retailers points at this possibility. Nonetheless, differences in CI performance between best and worst performing retailers could be explained by the speed rate at which gas transfer to lower GWP refrigerants has occurred in existing stores, alongside with complementary fugitive GHG emissions' detection measures, such as gas leakage detection programs.

When choosing alternative refrigeration gases, retailers are opting for refrigerants with the lowest possible GWP, like CO_2 (provided local climate conditions allow it), with best-performing retailers further trialling alternative refrigeration solutions, namely Hydrocarbon, ammonia, propane and glycol and water refrigeration systems. The choices for natural refrigeration seem related to company choice and to decisions that support good EI/CI performance, instead of merely responding to legislation. Nonetheless, some retailers may not have direct control in refrigeration systems, namely, if they customarily operate out of leased property where the landlord is responsible for cooling.

Most (90%) of the best-performing retailers have equally good levels of performance in EI and CI. Exceptions to this rule are two best-performing retailers that exhibited first quartile CI levels and third quartile EI levels. This result could be explained by the use of renewable energy or by purchasing green electricity, with a relatively small investment in energy efficiency. In fact, these retailers are Canadian, which ties into the comment above about the carbon intensity of electricity, given Canada's strong reliance on hydro and nuclear energy (Natural Resources Canada 2019). In contrast, one best-performing retailer exhibited first quartile EI levels and fourth quartile CI levels, which could mean the opposite. Similarly, most worst performing retailers (52%) have equally poor levels of performance in EI and CI. Exceptions to this rule are two best-performing retailers which exhibited fourth quartile CI levels and second quartile EI levels, which could be explained by the use of fossil energy despite the use of some energy efficiency solutions.

Energy-efficiency and CO_2-based refrigeration are the consensual priority amongst best and worst performing retailers when introducing sustainable high-performance solutions in their stores. This is above all because of the potential high energy-cost savings and because energy efficiency, as well as refrigerants with lower GWP, contribute to the reduction of GHG emissions. Additionally, best and worst performing retailers tend to invest both in passive and active sustainable building solutions, including a better-insulated envelope, daylight harvesting and more efficient glazing. In fact, the general trend is for retailers to obtain consistent improvements in energy efficiency over time, as argued by Sullivan and Gouldson (2013). In fact, the top high-performance solutions mentioned by best and worst performing retailers in the present study are in line with the findings of Sullivan and Gouldson (2013), Richman and Simpson (2016) and Ochieng et al. (2014), naming LED lighting, refrigeration and HVAC as key areas where attention is typically given by retailers to improve energy efficiency. Reducing energy demand ultimately means an increase in efficiency through a reduction in waste (Price 2010), with energy-efficiency solutions minimising energy consumption are the first step to decrease GHG emissions. Nonetheless, the fact that building solutions are used by both best and worst performing retailers points to differences in the way these solutions are incorporated across retailers' property portfolio. This could suggest that worst performing retailers are greenwashing, or just that using high-performance building solution sporadically will fail in terms of achieving the same environmental performance as best-performing retailers. Furthermore, it points to the existence of a behavioural inconsistency between 'stated' business energy efficiency and 'actual' business energy efficiency, with best EI and CI resulting also from proper attention given to property management (leasing agreements), facility management (maintenance), tenants behaviour (consumption of energy), construction management (new stores) and ownership (investments' funding and value).

The wide array of high-performance energy-efficient solutions used by best and worst performing retailers shows that there is no "silver bullet" to achieve nearly zero energy buildings (nZEBs), but rather, a combined approach of energy-efficient and low-carbon solutions, coupled with behavioural change. Other studies suggested similar strategies (Jenkins 2008; Sullivan and Gouldson 2013; Thompson 2007). Nonetheless, for large organizations with massive quantities of buildings the nZEBs do not seem to be a real target but rather increased sustainability across all the systems. This is partly due to the distribution of utilities and their infrastructure, as it is cheaper and better to pay a reasonable price for the service than it is to buy specialized materials and services that substitute for the utility service. In certain cases, regulatory requirements may even hamper the independence of buildings from the service grid.

As no single parameter is responsible for low CI or EI, an integrated design approach that takes into account climate, technology, occupant behaviour, and maintenance should be implemented to maximize energy efficiency and minimize GHG emissions (Jiang and Keith Tovey 2009; Li et al. 2014). In parallel, to decrease GHG emissions and improve carbon efficiency, food retailers can recover waste heat from the refrigeration cycle and invest in gas leakage detection and in improved maintenance in HVAC and refrigeration systems. Moreover, food and non-food retailers can invest in the on-site production of renewable energy, namely solar, in the purchase of green energy or in carbon offsetting methods. Technologies that will make a difference in the future will be those that can promote energy-efficiency and the reduction of GHG emissions, combined with passive building solutions that minimize the consumption of energy.

Limitations

Firstly, some of the retailers' data collected online could be outdated as not all retailers publish sustainability/CSR reports on a yearly basis. In addition, analysing only the most recent reports (from the fiscal year 2016) may produce different results than analysing reports from the previous 10 years.

Secondly, analysing retailers according to their country of origin may induce potential bias in the EI/CI results, as there is an inherent risk where individual retailers are consolidating their energy and carbon data from several countries in different parts of the world, with different climates, store formats and electricity sources. Likewise, the categorisation of retailers within the food/non-food group according to the predominant number of stores may also induce potential biases. Results accuracy would be sounder had data been disaggregated and reported by each country and by retail type by most retailers.

Thirdly, it is important to notice that identifying the most energy or carbon-efficient retailers through CI or

EI (particularly for food retailers) is not straightforward. This is mainly due to the considerable variation in the amount of refrigerated food that companies retailed as a proportion of their overall activity (ENDS Carbon—University of Edinburgh Business School 2009), with direct impact on their CI or EI. For future research, a more-in-depth investigation of one type of retailer (such as a supermarkets' one) could be of value.

Fourthly, best-performing retailers are qualified as those with best practice CI or EI. Even though the use of the first quartile to define the upper limit of best practice can be questioned, best practice benchmarks defined by the first quartile upper limit represent a high environmental performance level, far better than good or average performance. The same holds true for worst practice retailers, on the opposite end, defined by the lower limit of the third quartile. Nevertheless, by looking only at retailers for which data is publicly available, benchmarks could be biased as best-performing retailers may have an advantage in presenting EI or CI data, but worst-performing retailers may not. Drawing inferences from small sub-sample sizes may also potentially bias conclusions.

Lastly, the analytical categories recorded under each variable's table (policy, strategy and building practice) were agreed upon by all authors (an architect with 12 years of work experience in retail stores, an environmental engineer expert in green building certification systems, a civil engineer specialised in sustainable construction and a civil engineer specialised in buildings' refurbishment). Nonetheless, bias can derive from the selectivity of these authors in terms of data coding.

To make comparisons of EI and CI more robust, the analysis of other relevant normalizing factors, such as local climate and weather, local government regulation or incentives, is necessary in future studies. Likewise, the analysis of conventional performing retailers (from the second and third quartiles) could further stress or provide new findings to the current investigation. Further research works could also focus on the links between CI and EI and on the effect on EI and CI of specific policies, strategies or technology sets.

Conclusion

By analysing the policy, strategy and building practice of the best EI and CI performing retailers in comparison with the worst performing ones, this study set out to identify the measures that contribute most to the retailers' enhanced environmental performance like energy and carbon. Our key findings are as follows:

- Combined CI and EI best practice threshold values are found simultaneously under 346 kWh/m^2/y and 115 kg CO_2eq/m^2/y for food retailers and under 146 kWh/m^2/y and 70 kg CO_2eq/m^2/y for non-food retailers;
- In terms of policy, best-performing food retailers share a strong top-down management commitment towards sustainability across all business areas ($p = 0.04$) and an increased use of referential reporting standards, particularly of GRI standards ($p = 0.05$) and of the GHG Protocol ($p = 0.01$), suggesting that high levels of corporate internalization of the environmental management systems lead to a higher environmental performance;
- The contrapositive is also likely true: a lack of strong top-down broad commitment towards sustainability across all business areas will not yield a best performance in CI and EI: low levels of corporate internalization of the environmental management systems lead to a poorer environmental performance, evidenced by worst performing retailers' dependency on external drivers to achieve sustainability standards;
- In terms of strategy, best-performing retailers establish ambitious energy goals, such becoming 100% supplied by renewable energy ($p = 0.05$) or carbon neutral by 2020. Best-performing food ($p = 0.01$) and non-food retailers ($p = 0.05$) include demanding energy standards in the concept of new stores and existing stores;
- As for building practice, LED and photovoltaic technology are amongst the most popular high-performance sustainable solutions. Nevertheless, only the use of natural refrigerants ($p = 0.001$) and gas transfer to CO_2 ($p = 0.0007$) were related to best-performing practice;
- The variability of CI and EI found in this study demonstrates that it can be possible to reduce the retail sector's contribution to global GHG emissions considerably, which would impact decisively and positively the environmental performance of this industry.

These findings are of immediate interest and application to retailers, confirming that a higher

environmental performance is possible, in turn, attaining a more resilient, sustainable business. These findings are also of immediate interest and application to architects, engineers when considering the design and operation of new and refurbished retail stores. Our ongoing research aims to further assess the influence of isolated variables on retail EI and CI (like location, retail sub-type or building size) as well as the influence of isolated high-performance building solutions, like passive building-envelope measures, renewable-energy systems, smart-lighting and other relevant building technologies.

Compliance with ethical standards

Conflict of interest   The authors declare that they have no conflict of interest.

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