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The energy efficiency of corporate real estate assets

The role of energy management for corporate environmental performance

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Abstract

Purpose – On the basis of corporate wholesale and hypermarket stores, this study aims to investigate the relationship between energy consumption, physical building characteristics and operational sales performance and the impact of energy management on the corporate environmental performance.

Design/methodology/approach – A very unique dataset of METRO GROUP over 19 European countries is analyzed in a sophisticated econometric approach for the timeframe from January 2011 until December 2014. Multiple regression models are applied for the panel, to explain the electricity consumption of the corporate assets on a monthly basis and the total energy consumption on an annual basis. Using Generalized Additive Models, to model nonlinear covariate effects, the authors decompose the response variables into the implicit contribution of building characteristics, operational sales performance and energy management attributes, under control of the outdoor weather conditions and spatial–temporal effects.

Findings – METRO GROUP's wholesale and hypermarket stores prove significant reductions in electricity and total energy consumption over the analyzed timeframe. Due to the implemented energy consumption and carbon emission reduction targets, the influence of the energy management measures, such as the identification of stores associated with the lowest energy performance, was found to contribute toward a more efficient corporate environmental performance.

Originality/value – In the context of corporate responsibility/sustainability of wholesale, hypermarket and retail corporations, the energy efficiency and reduction of carbon emissions from corporates' real estate assets is of emerging interest. Besides the insights about the energy efficiency of

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corporate real estate assets, the role of the energy management, contributing to a more efficient corporate environmental performance, is not yet investigated for a large European wholesale and hypermarket portfolio.

Keywords Energy efficiency, Carbon emissions, Corporate energy management, Corporate real estate management (CREM), Multiple regression, Wholesale and retail stores

Paper type Research paper

1. Introduction

Given that the generation of energy is still highly reliant on fossil energy sources, the carbon emissions associated with consumption of electricity remain at a substantial high level. For instance, in Germany, the electricity production in 2014 was based on coal sources at 43.2 per cent and on natural gas and petrol fuel at 10.9 per cent (BDEW, 2015). With approximately three million buildings, the non-residential building sector accounts for only 15 per cent of the existing building stock in Germany, but for more than 30 per cent of total energy consumption and carbon emissions (Dena, 2015).

Commercial real estate and especially corporate real estate assets in the wholesale and hypermarket sector have significant greenhouse gas (GHG) externalities, due to the high carbon emissions associated with energy consumption for store operations in big-boxes.

Because wholesale and hypermarket buildings account for a large portion of energy consumption and carbon emissions for the operating corporations, the related costs of operations are subject to certain key business considerations. Thus, corporations have started to implement energy and carbon emission reduction strategies. On the one hand, the aim is to achieve savings from energy conservation and thereby increase the operational profitability from the sales business – even more when profit margins are lowering. On the other hand, investing in energy efficiency is intended to show customers and society an appropriate environmental practice for leveraging on corporate sustainability for the corporate brand.

Reducing the energy consumed in corporate real estate assets is of emerging interest with respect to the sustainability strategy of wholesale, hypermarket and retail corporations. For them, it is important to engage in sustainability, due to their reputation and high customer visibility. However, in the absence of significant pricing allocation, industry pressure to account for and disclose carbon emissions has increased over the past years (World Bank Group, 2015; CDP, 2014).

In this context, industry leaders have set up corporate energy management organizations, to operationalize ambitious energy- and emission-reduction targets, which affect store profitability positively through reducing operational expenses.

Using the example of METRO GROUP, this study explores the energy efficiency measures of corporate real estate assets within a specific asset class. The research investigates the level of energy consumption and carbon emission reduction, together with realized cost savings, and relation to the operational performance. With regard to the role of corporate energy management, the study analyzes the contribution to a more efficient corporate environmental performance. Finally, the study concludes with a scenario of how corporate real estate assets might be affected in the event of having carbon emission pricing in place.

The remainder of the study is as follows: Section 2 provides the empirical framework and insights from related research, while Section 3 introduces the case study for corporate real estate assets of METRO GROUP. This is followed by the underlying working hypotheses of this research (Section 4). The characteristics of the dataset are explained in Section 5, followed by a sophisticated econometric methodology in Section 6. Section 7 presents the results and Section 8 provides a reflection on the hypotheses and concludes with recommendations for further research.

2. Empirical framework

2.1 Energy and electricity consumption

Retail buildings are associated with the highest energy consumption in the commercial building sector. In the UK and Spain, they are attributed with 22 per cent and in the USA, even with 32 per cent of total commercial building energy consumption (Lombard *et al.*, 2008). For the food retail sector in Germany, a total energy consumption of 14.1 TWh was estimated for 2009 (IFEU *et al.*, 2011).

Energy consumption and emissions from wholesale, hypermarket and retail stores depend on building size and age; store format; the operational business with product mix; customer frequency and technical equipment, applied to refrigeration, heating, ventilation and air conditioning (HVAC); artificial lighting, information technology (IT) and sales systems, restaurants and further equipment for the preparation and display of products.

For supermarkets and hypermarkets in the UK, a study by Spyrou *et al.* (2014) showed that, with increasing store size, the energy consumption per square meter decreases. Also, Tassou *et al.* (2011) explain a decline in the energy consumption per square meter with increasing building (sales floor) area, up to a certain level.

For the thermo-physical, but even more so, the technical status of the premises, the building envelope and equipment, referring to newly constructed buildings compared to older buildings and retro-fitted stores might be different between the stores and sales formats, but also within a particular sales line. For Walmart, Kahn and Kok (2014b) found evidence that more recently constructed stores have lower electricity consumption than older buildings. They argue that the quality of the stores is held constant, whereas the energy efficiency of equipment in the store is improved with decreased energy use intensity in newly constructed stores.

Store formats exhibit major differences in size, and in the proportion of particular functions in the buildings, e.g. the share between food and non-food sales and storage areas, the proportion of cooled and refrigerated areas or heated and non-heated storage areas. In wholesale and hypermarket stores, a portion of the non-food sales area can also be associated with higher levels of energy consumption, e.g. electronic products such as high electricity-consuming TV walls.

Retail food stores in the UK, with formats ranging from convenience stores to hypermarkets, display a wide variability of energy intensity, even within stores of the same retail chain (Tassou *et al.*, 2011). Referring to Spyrou *et al.* (2014), the intensity in energy consumption *between* different wholesale, hypermarket and retail building formats is expected to be different, but comparatively similar *within* the same format categories. For a sample of Walmart stores across California, Kahn and Kok (2014a) found only little store-to-store variation in energy consumption and suggest that Walmart standardizes the construction and operation of the energy performance of its stores, with high importance being accorded to centralized management practices.

The impact of store operations on energy consumption is correlated with the opening hours of the store, and with the number of customers passing entrance doors, affecting the indoor temperature with heat gains or cooling losses and the refrigeration load, when selecting cooled or frozen food. The intensity of energy consumption is therefore highly dependent on the sales productivity, measured by the stores turnover figures. The TESCO-funded research of Spyrou *et al.* (2014) designed a regression model to predict the annual electricity demand, which proved that the sales productivity has the second highest explanatory and predictive power, after the sales floor area (SFA).

The proportion of total energy consumption was found to have a split of approximately 80 per cent for electricity and 20 per cent for heating energy consumption in the UK hypermarkets, and more than 70 per cent for electricity consumption in supermarkets (Spyrou *et al.*, 2014; Tassou *et al.*, 2011). Actual energy consumption in the German food retailing business accounts to 36 per cent for refrigeration, 30 per cent for heating, 20 per cent for lighting, 8 per cent for cooling and 6 per cent for other uses (IFEU *et al.*, 2011). The difference between wholesale or hypermarket stores, selling fresh and frozen food, and other retail buildings is almost completely attributable to the refrigeration technology used for food retailing (Braun *et al.*, 2014; IFEU *et al.*, 2011).

Refrigeration was found to have the largest share of 29 per cent of total electricity consumption in the UK hypermarkets (Tassou *et al.*, 2011). For smaller-sized supermarkets, the electricity consumed for food refrigeration was observed even to have a share of over 50 per cent (Ge and Tassou, 2011). Beside the local outdoor weather and indoor temperature and humidity conditions, the intensity of electricity consumption for the refrigeration load depends on customers when removing products and refilling by staff (Tassou *et al.*, 2011).

HVAC systems in stores, which provide thermal comfort to customers and staff, account for 5-9 per cent and lighting for 17-23 per cent of total electricity consumption (Spyrou *et al.*, 2014; Tassou *et al.*, 2011). Other services and equipment in stores, such as bakery and preparation, customer restaurants, elevators or escalators and offices, also account for a reasonable percentage of the total electricity consumption.

Interaction between the HVAC system and the refrigeration units in the building is crucial for energy savings. Depending on the outdoor weather conditions, both systems could support each other when cooling is needed in the summer months with high loads of energy, but also operate antagonistically to each other through heating the sales floor while simultaneously refrigerating parts of the sales floor and cold storage rooms.

For a multi-national store portfolio, differences between the individual countries also need to be considered. On the one hand, customer behavior is changing, on the other hand, different regulatory regimes, such as in the pricing of energy between countries, will have an impact on energy consumption. For instance, Walmart's electricity consumption was found to be lower with respect to the higher-priced utilities in California (Kahn and Kok, 2014a).

2.2 Carbon emissions

Due to significant GHG externalities associated with energy consumption, the building sector is regarded as having a large potential for reducing global carbon emissions from the durable building stock (WBCSD, 2015). In the USA, the retail sector accounts for the second largest amount of CO_2 emissions in the entire commercial sector of the US economy (Sullivan and Gouldson, 2014; RILA, 2012), when emissions from buildings, and also for the total supply chain, with distribution to the stores and delivery to the customers, are considered.

A recent calculation for the retail sector in Germany estimated an annual energy consumption of 46 TWh associated with CO_2 emissions of 18 million tons (HDE, 2013). Anticipating a potential mid-term efficiency realization of 8.8 TWh/a, future energy savings in the German retail sector have been predicted with a margin of 19 per cent compared to 2011 (IFEU *et al.*, 2011).

Gouldson and Sullivan (2014) argue that among retail supermarket chains, a competitive environment not only exists in terms of customers and sales turnover, but also in the reduction of consumed energy and carbon emissions set by industry peer pressure. They report from TESCO that the strategy to reduce carbon emissions in cooperation with suppliers puts pressure on other retailers to follow this strategy (Gouldson and Sullivan, 2014). Furthermore, the real estate investment market also puts pressure on these assets, with regard to the socially responsible investment strategies of institutional investors (Cajias and Bienert, 2011; Cajias *et al.*, 2011; Kerscher and Schaefers, 2015).

Over the past years, many large corporations started voluntarily to disclose information about their carbon emissions. In 2012, over 80 per cent of the largest 500 corporations in the world reported this information to the Carbon Disclosure Project (CDP, 2012). In 2014, at least 150 companies used an internal carbon price, ranging from US$6 to 89 per ton of CO_2 emissions (CDP, 2014).

2.3 Corporate energy management

Spyrou *et al.* (2014) explain that managing and minimizing energy consumption is an important opportunity for both business competitiveness and national CO_2 emission targets. When analyzing Walmart, Kahn and Kok (2014a) argue that corporation size and centralization of management play key roles in determining an indicator of a corporate's environmental performance. Because costs associated with energy consumption directly affect the operational profitability of wholesale and hypermarket stores, corporates set up energy management organizations, to establish and operationalize ambitious energy- and emission-reduction targets.

From the mid-2000s, the UK retailers started to focus on specific reduction targets for carbon emissions per unit of store floor area, or to build new and more efficient buildings, compared to older peers. Based on observations by Sullivan and Gouldson (2014), the UK retailers have achieved reductions in their energy- and carbon-emission intensity by between 2.5 and 5.5 per cent per year over the period from 2007 to 2011.

In the USA, Walmart set the target to reduce its carbon emissions from existing facilities by 20 per cent in 2011, compared to 2005. In 2010, they announced their intention to reduce 20 million tons of carbon emissions from the global supply chain by the end of 2015 (Walmart, 2015a), which they exceeded by eliminating 28.2 million tons. However, Walmart does not disclose its total energy consumption (GreenBiz, 2015). In contrast, some operators do not set emission reduction targets at all, for example, US-based Costco Wholesale, or do not publish them, such as US-based Safeway and Germany-based Aldi and Lidl discount stores.

In their research results, Kahn and Kok (2014a) found no difference in consumption among leased vs owned Walmart stores, suggesting that central energy management acts to negate any initial conditions, such that leased assets are inherently inefficient.

Spyrou *et al.* (2014) argue that from an organizational management point of view, the identification of stores that have undergone significant changes in the performance for no apparent reason, is the starting point for ensuring an efficient performance of the building stock.

2.4 Profitability of energy savings

Energy efficiency measures in the wholesale and hypermarket sector may pay off, once they are introduced in the operational business. Investments in more efficient sales areas might be reasonable to obtain bottom-line savings. An additive investment in energy-efficient equipment for permanent future capital savings might turn out to have higher economic impact on profitability than entail an increase in sales turnover in the short-run.

The role of energy management in wholesale and retail corporations has been highlighted, due to smaller profit margins and energy cost savings leveraging on the profit margins of corporations. Reporting on Walmart's success with its energy efficiency initiative, The Guardian (2011) comments that energy efficiency helps retailers to compensate for lower profit margins. As the retail sector becomes even more competitive, lower profit margins induce companies to invest in strategies that can both reduce energy consumption costs and maximize profits (The Guardian, 2011). For the UK, energy consumption costs in the food retail sector are significantly affecting profitability, as the operating margins have been observed at a generally low average of 4.2 per cent in 2005 (Spyrou *et al.*, 2014). A recent study of the major 250 sales lines in Germany revealed actual energy costs with a margin between 1.3 and 1.7 per cent of the total annual net sales turnover. Considering that the average profit margin of those retailers is 1.5 per cent, the annual energy costs turn out to be equivalent to approximately 100 per cent of the profit (Dena, 2015).

The example of French-based Carrefour makes clear that the annual investment of €30mn on its energy efficiency programs is small, compared to the worldwide revenues of €90 billion (only 0.03 per cent), but accounts for 3 per cent of its net profit. However, compared to the money invested, retailers may be able to gain reasonable dividends from the investment by installing energy-efficient lighting systems, attaching freezer doors and automated information and communication systems (The Guardian, 2011). With regard to the investment budget of top USA and UK retailers in low-carbon technologies and financial support for renewable energy, Sullivan and Gouldson (2014) conclude that there are relatively narrow cost–benefit ratios, if retailers expect paybacks of less than three years for most investments. The energy management of Walmart aims for a three-year payback on its investments in energy efficiency (The New York Times, 2012).

The profitability of energy-saving measures becomes particularly obvious when looking at the extensive research and existing body of literature on the relationship between daylighting and increased retail sales. For Walmart stores equipped with natural lighting, in only half of the store, the day-lighted area was found to have significant higher sales per square foot than the artificially lighted area, also when compared to the equivalent departments in other non-day lighted stores (Fedrizzi and Rogers, 2002).

For large corporations, it was observed that it is relatively possible to allocate their investments to improving the efficiency of their durable building stock, compared to owners who operate only one or a few stores. Therefore, industrial concentration can enable higher levels of energy efficiency through economies of scale. In the case of Walmart, the size, capital market access without liquidity constraints and management expertise enable professional cost minimization (Kahn and Kok, 2014a).

Considering the investment allocation in energy efficiency, human capital plays a key role for success in corporate energy management. An on-site manager, as well as staff training, may influence the use-intensity of equipment, which depends on store performance (Kahn and Kok, 2014a, Bloom *et al.*, 2011). Sullivan and Gouldson (2014) argue that, in the course of corporate action, retail companies have engaged with their employees on energy and carbon management, by establishing awareness and education campaigns, creating store-specific energy-reduction plans and providing rewards and incentives for good performance.

3. Energy consumption and carbon emissions of METRO GROUP

For a wholesale and hypermarket corporate such as METRO GROUP, store operations with energy consumption for refrigeration, HVAC, lighting, IT and others are a major driver of carbon emissions. Beside the strategy of mere costs savings from reduced consumption of electricity and fossil fuels, the corporation set up a corporate responsibility and sustainability agenda, so as to introduce voluntary commitments with regard to the limits and future saving targets of energy consumption and carbon emissions.

This strategy follows the argumentation according to which corporations in the retail sector have a high public profile, thus facing pressure to promote sustainable consumption in general. Accordingly, they act as "translators" of the sustainability disclosure to customers (Lehner, 2015). Jones *et al.* (2014) observed that major retail corporations increasingly recognize the importance of publicly reporting on the impact of their activities via annual corporate social responsibility or sustainability reports (CSR). METRO GROUP introduced a corporate reporting system, taking carbon accounting and further activities into account, based on standards from the following:

- Global Reporting Initiative (GRI);
- UN Global Compact (UNGC);
- Dow Jones Sustainability Index (DJSI);
- Carbon Disclosure Project (CDP)/CDP Water Disclosure; and
- Forest Footprint Disclosure.

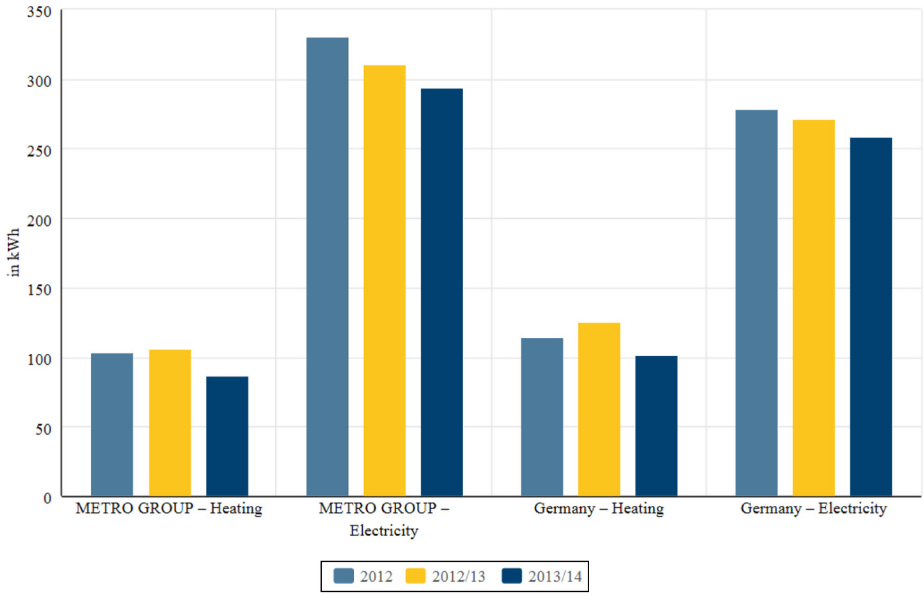
Furthermore, when rating agencies evaluate the business model of a corporate in the wholesale and retail industry, they anticipate the view of the business "through the eye of the customer". For this reason, the attitude toward sustainability, operationalized in a sustainability agenda, yields a direct impact in financial dimensions on the corporate's overall investment grade.

METRO GROUP implemented a centralized energy management division in the course of corporate responsibility activities, with the mission of contributing to energy conservation and the reduction of carbon emissions. The main target for the corporate is set at an overall reduction of CO_2 emissions per square meter SFA of 20 per cent until 2020, based on emissions in 2011. To achieve its 2020 targets, the corporation set several objectives on the baseline of 2011, for example:

- reduction of CO_2 emissions from electricity consumption by 21 per cent;
- reduction of CO_2 emissions from heating energy consumption by 10 per cent; and
- reduction of CO_2 emissions from refrigeration agents by 29 per cent.

For the corporate's total electricity consumption, a decrease of 37 kWh/m^2/a (−11 per cent) was reported between the end of the financial year in December 2012 and September 2014 (end of the financial year from October 2013 until end of September 2014, after a change in the financial year basis). Within the same timeframe, the total heating energy consumption was metered at a decline of −15 per cent (Figure 1).

In progressing towards the emission targets for 2020, METRO GROUP's accounting and reporting standard is based on the Greenhouse Gas Protocol (2004) with three different scopes (Table I).



Source: METRO GROUP corporate responsibility report (2013/2014)

Figure 1. Electricity and heating energy consumption per square meter of METRO GROUP

Table I. Carbon emissions in tons CO_2 (CO_2 equivalents) of METRO GROUP

Reference year	2011	2012	2012/2013	2013/2014	Reduction (2011 baseline) (%)
Scope 1 – direct GHG emissions	1,084,509	1,132,693	1,068,706	1,015,157	*−6.4*
Scope 2 – indirect GHG emissions	2,432,102	2,379,478	2,068,787	1,803,799	*−25.8*
Scope 3 – other indirect GHG emissions	7,064,278	7,001,010	6,309,475	6,278,003	*−11.1*
Total GHG emissions	10,580,889	10,513,181	9,446,967	9,096,959	*−14.0*

Source: METRO GROUP corporate responsibility report 2013/2014

The annual emission status is recorded by METRO GROUP's Carbon Intelligence System, which captures the consumption data for the wholesale and hypermarkets. The reduction achievements over the past years result mainly from reduced electricity consumption in the stores. However, METRO GROUP no longer considers effects from changes in the portfolio and total store space over the course of the emission reporting (Figure 2).

At first glance, the comparison of overall CO_2 emission volumes per square meter of METRO GROUP shows significant differences between the portfolios in Western and Eastern Europe. On the one hand, further reduction in Western Europe seems difficult, due to the relatively low emission level already achieved. On the other hand, Eastern Europe seems to provide enormous saving potential, since emissions declined by more than 25 per cent between 2012 and September 2014.

4. Working hypotheses

With reference to the outlined empirical framework of related research referring to various studies and the specific energy consumption and carbon emissions of METRO GROUP, the following working hypotheses provide the framework for the empirical analysis of the corporate real estate assets of METRO GROUP:

H1. Due to the regulatory framework with continuously increasing energy efficiency requirements for new construction in the European Union and technological innovations (LED etc.), newer buildings show significantly lower energy consumption than their less recently constructed peers, all else equal.

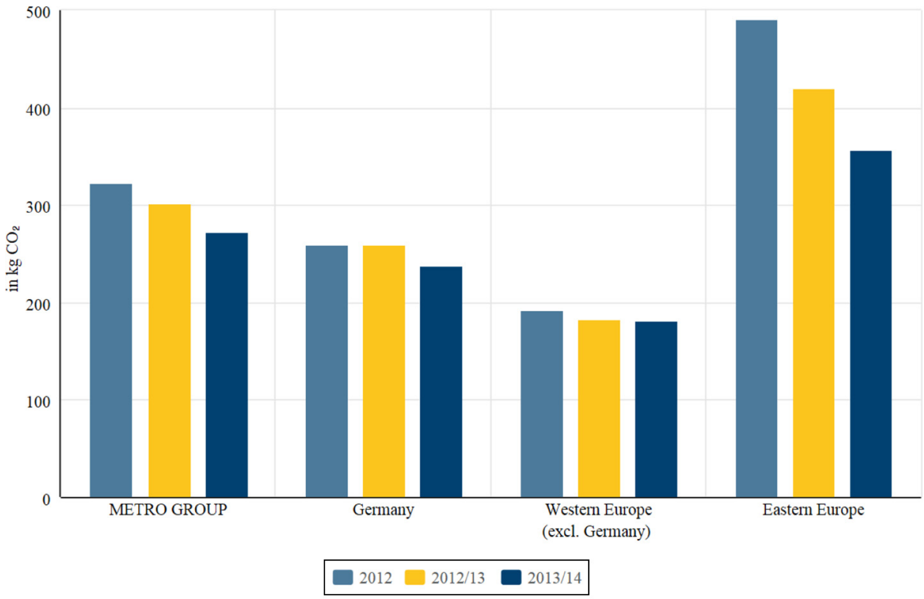


Figure 2. GHGs per square meter of METRO GROUP

Source: METRO GROUP corporate responsibility report (2013/2014)

H2. Revitalization of wholesale and hypermarket stores provides substantial energy-savings potential.

H3. The intensity of energy consumption of different wholesale and hypermarket formats is expected to differ *between* format categories, but to be comparatively similar *within* the same-format categories. The customized corporate building formats as "build to suit" allow only limited store-to-store variation in energy consumption. Large observations show lower per square meter consumption (economies of scale).

H4. Annual variation in energy consumption in the stores over time is highly correlated with the influence of outdoor weather conditions, and also the operational sales business (with seasonal peaks in consumption).

H5. With regard to centralized energy management, the ownership status of the assets (owned vs leased), in combination with the rental contract basis ("triple net"), does not prove differences in energy consumption.

H6. With regard to the physical building characteristics and technical operations, the identification of stores that have a significantly lower performance provides leverage on the total portfolio efficiency for achieving the corporate environmental performance targets ("low-hanging fruits").

H7. Energy consumption "on-site" might be influenced more intensively in country organizations, provided with an responsible energy manager (human capital) at the country level, than in countries without an own energy manager. Therefore, energy managers are allocated to counties with sufficient energy-savings potential. Thus, economies of scale provide an incentive to economize on energy consumption, when human capital yields higher profitability from energy savings.

H8. In the absence of any direct carbon pricing today, energy conservation with cost savings directly affecting the operational profitability of stores, turns out to be a promising driver. For METRO GROUP, the operating energy costs of the stores monetize to an amount within the range of the annualized profit margin from the operational sales business. For corporate energy management, the corporate real estate assets prove to be a key driver for leveraging on profitability and lowering carbon emissions.

H9. Energy consumption, especially electricity consumption, is highly correlated with sales productivity and store performance (EBIT). Therefore, it is a key challenge for corporate management to decouple high and increasing sales productivity from related energy consumption, toward a more efficient corporate environmental performance.

5. Dataset

The very unique dataset, applied in this study, relies on several sources provided by METRO AG and METRO PROPERTIES Holding GmbH. It allows for the novel approach, to introduce energy in terms of electricity and heating consumption, physical building characteristics and key performance figures from the sales business. In particular, the sales productivity with turnover per square meter is expected to indirectly represent usage intensity or footfall on store level. For the timeframe from January 2011 until December 2014, the dataset from METRO GROUP covers electricity consumption on a monthly basis and heating energy with the annual consumption. The dataset provides the possibility to analyze the electricity and heating energy consumption – with potential reductions – in a panel over the observation period. Due to the structure of the dataset, the contained variables have differences in the time-related occurrence:

(1) Time-constant variables:
   - store ID;
   - country;
   - sales line company;
   - sales line building format;
   - construction year;
   - revitalization year;
   - gross floor area (GFA);
   - sales floor area (SFA);
   - ownership status (leased vs owned); and
   - heating production type (gas, oil and district heating).
(2) Time-varying variables on annual basis (variation between years):
   - building age;
   - electricity consumption in kWh/m^2/a;
   - heating energy consumption in kWh/m^2/a;
   - total energy consumption in kWh/m^2/a (electricity and heating consumption);
   - total heating degree days (HDD) p.a.;
   - total cooling degree days (CDD) p.a.;
   - electricity price in €/m^2/a;
   - sales productivity (turnover in €/m^2/a); and
   - store-EBIT in €/m^2/a.
(3) Time-varying variables on monthly basis (variation between months):
   - electricity consumption in kWh/m^2 per month; and
   - HDD and CDD per month.

The dataset contains 781 wholesale and hypermarket buildings of METRO GROUP in 19 European countries. The hypermarket portfolio of the sales line “Real” is located only throughout Germany with a total of 300 stores. The total number of stores located in Germany amounts to 407 stores, of which 56 account for the sales line “METRO Cash & Carry” and 51 for “Cash & Carry Schaper”.

The European portfolio, except the German stores, contains only wholesale stores of the sales lines METRO or Metro Cash & Carry (MCC). It covers 374 wholesale stores with different building formats, of which the most are located in France (92), Italy (47), Spain/Portugal (45), Poland (30), Romania (26) and Turkey (24).

The different store formats of MCC wholesale and Real hypermarkets in terms of SFA are shown in Table II.

While heating energy consumption is only available on an annual basis, the total energy consumption (electricity plus heating energy consumption) was aggregated on an annual basis for the full timeframe. To control for the local outdoor weather conditions and temperature-elasticity of energy consumption and in reference to the structure of the database, the number of HDD and CDD are introduced on a monthly and an annual basis. Both HDD and CDD are calculated on the computation basis of 65°F (equal to 18.3°C), obtained from the database of Weather Underground (wunderground.com). The monthly figures for electricity consumption were combined with the monthly total of HDD and CDD to a sample with 37,488 observations (i.e. 781 stores over four years, observed on 12 months within each year).

Table III provides the descriptive statistics of the applied metric variables for energy consumption, physical building characteristics and sales business performance. With regard to confidentiality, the absolute figures of key performance indicators from the operational sales business remain undisclosed in this study.

Considering the mean values of annual electricity and heating consumption, a share of 75.7 per cent for electricity and 24.3 per cent for heating energy turns out in relation to the total energy consumption p.a. The buildings are, on average, almost 20 years old, with a range of 0 until even more than 50 years. The SFA-to-GFA ratio with an average of 71 per cent is in line with the expectation, as well as the number of floors of the big-box premises, ranging between 1 and 2 on average.

An analysis of the energy consumption of the wholesale and hypermarkets in each year of the timeframe indicates significant reductions in the electricity, as well as in the total consumption per square meter from 2011 to 2014 on average (Table IV). When comparing the total sample ($n = 781$) to a sub-sample, containing only those observations, attributed with a revitalization in the past ($n = 195$), a difference in the average age of the buildings of more than 10 years is observable. These results are corresponding to the construction year. Because revitalization is related to higher building age, the results for electricity and total consumption show significantly lower mean and median values in comparison to those of the total sample in each single year. The difference in electricity consumption seems to be most responsible for the decline in the total consumption of both samples, whereas the realized savings in heating energy consumption seem to be marginal. At first glance, this corresponds to *H2*, suggesting that the energy efficiency of equipment is improved in stores with revitalization, whereas the (thermo-physical) quality of the building remains unchanged.

Sales floor area (SFA) in m^2	Minimum	Mean	Maximum	n
MCC formats (wholesale)				
Classic	8,959	14,213	34,295	110
Junior	5,128	8,263	13,835	193
Eco	2,071	3,696	11,305	127
Schaper (METRO Gastro)	1,980	3,389	6,680	51
Real hypermarket formats (retail)				
Hypermarket (standalone)	2,691	6,750	14,322	257
Center (retailpark)	3,543	7,069	13,910	43

Table II. Store formats of MCC and real hypermarkets

Descriptive statistics	Minimum	1st quarter	Median	Mean	3rd quarter	Maximum
Electricity consumption in kWh/m^2/month	1.2	15.7	19.4	20.0	23.6	49.3
Electricity consumption in kWh/m^2/a	21.2	191.5	234.4	240.2	282.6	904.2
Heating consumption in kWh/m^2/a	1.4	41.3	67.5	77.1	97.8	984.8
Total energy consumption in kWh/m^2/a	73.8	254.0	304.0	317.3	366.3	1,006.0
Number of heating degree days (HDD)/month	0	117	352	414	681	1,465
Number of cooling degree days (CDD)/month	0	0	0	37	32	700
Number of heating degree days (HDD)/a	46	4,380	5,288	4,970	5,893	10,490
Number of cooling degree days (CDD)/a	0	173	246	440	474	2,874
Construction year building	1960	1984	1996	1993	2002	2011
Building age	0.0	10.0	16.0	19.5	28.0	54.0
Gross floor area (GFA) in m^2	2,700	5,951	10,180	11,030	14,420	42,240
Sales floor area (SFA) in m^2	1,980	4,780	6,947	7,477	9,269	34,295
SFA to GFA ratio	0.25	0.63	0.69	0.71	0.79	1.00
Number of floors	1.00	1.00	1.00	1.47	2.00	5.00
Sales productivity in €/m^2/a			Not disclosed			
Store-EBIT in €/m^2/a			Not disclosed			
Store-EBIT profit margin			Not disclosed			
Electricity price €/m^2/a			Not disclosed			
Total energy price €/m^2/a			Not disclosed			

Table III. Descriptive statistics for corporate real estate sample of METRO GROUP

A look at the panel on monthly basis (Figure 3) shows the amplitude and variation in the electricity consumption in annual cycles over the timeframe for the different store formats. Culmination of seasonal peaks in consumption is significant each year in months July and August. While analyzing the electricity without consideration of the heating energy consumption, the peaks in the summer months are not surprising with higher electricity consumption for refrigerating and cooling loads than in months with lower outside temperature, as assumed in *H4*.

While the smoothing curves (splines) indicate the monthly consumption per square meter on average (blue line), the hypermarket format as standalone (named "SB-Warenhaus") offers the largest range in the monthly electricity consumption with an average oscillating around 20 kWh/m^2/month. However, the Center format indicates slightly lower variation but higher consumption above 20 kWh/m^2/month on average. For wholesale, the Eco format shows the highest variation between the stores and the highest consumption on average, which is significant above the oscillating levels of the other wholesale formats. Surprisingly, the Classic format appears with relatively low consumption on average but old buildings – compared to the Junior and Eco formats with higher consumption but much newer buildings. The Schaper format remains with the lowest consumption on an average over the timeframe.

Table IV. Energy consumption in total sample and revitalization sub-sample

Descriptive statistics	Total sample (n = 781) Minimum	1st quarter	Median	Mean	3rd quarter	Maximum	Revitalization sample (n = 195) Minimum	1st quarter	Median	Mean	3rd quarter	Maximum
Construction year building	1960	1984	1996	1993	2002	2011	1960	1972	1979	1982	1993	2010
Building age 2011	0	9	15	*18*	27	51	1	18	32	*29*	39	51
Building age 2012	1	10	16	*19*	28	52	2	19	33	*30*	40	52
Building age 2013	2	11	17	*20*	29	53	3	20	34	*31*	41	53
Building age 2014	3	12	18	*21*	30	54	4	21	35	*32*	42	54
Electricity consumption in kWh/m^2 2011	46.0	205.1	250.5	*253.4*	300.8	508.0	46.0	196.7	233.7	*240.5*	277.2	422.7
Electricity consumption in kWh/m^2 2012	48.6	198.9	240.6	*245.2*	287.6	528.2	48.6	189.7	224.9	*231.1*	266.8	436.3
Electricity consumption in kWh/m^2 2013	23.1	188.3	228.4	*234.3*	274.5	519.6	23.1	179.3	208.6	*218.8*	255.3	423.7
Electricity consumption in kWh/m^2 2014	21.2	179.2	220.2	*227.9*	266.4	904.2	21.2	166.4	196.3	*209.5*	249.2	400.5
Relative reduction from 2011 to 2014 (%)				*10.1*						*12.9*		
Total energy consumption in kWh/m^2 2011	80.5	267.4	318.2	*332.5*	388.3	912.2	123.8	260.3	298.4	*315.7*	358.7	912.2
Total energy consumption in kWh/m^2 2012	73.8	262.0	314.2	*325.1*	372.0	919.1	115.1	253.5	291.3	*304.1*	337.8	919.1
Total energy consumption in kWh/m^2 2013	79.8	252.7	300.4	*315.9*	361.6	837.1	116.0	240.8	274.8	*291.1*	326.3	837.1
Total energy consumption in kWh/m^2 2014	114.0	235.5	280.9	*295.5*	342.3	1006.0	116.1	221.8	256.8	*272.8*	307.5	1006.0
Relative reduction from 2011 to 2014 (%)				*11.1*						*13.6*		

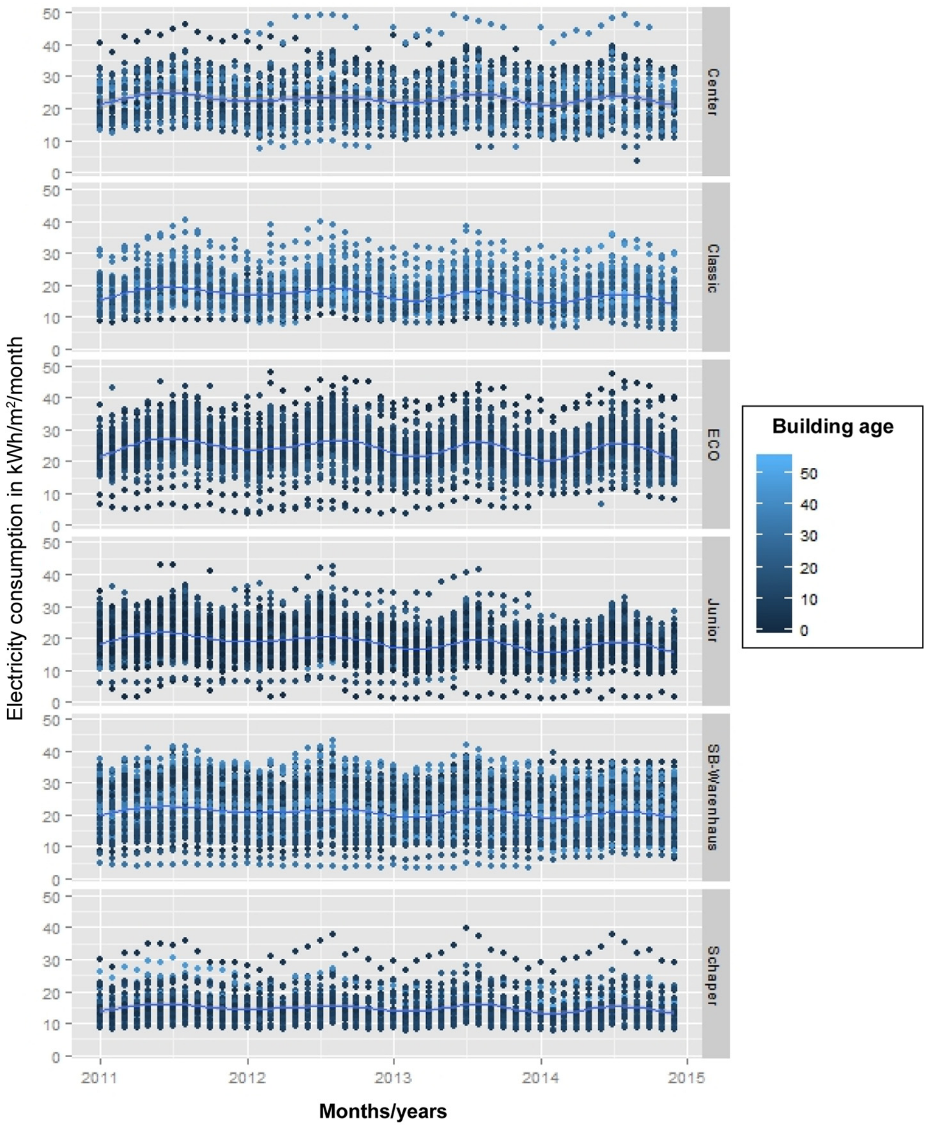


Figure 3.
Electricity consumption of different store formats

By trend, these results are in line with the expectation of different electricity consumption intensities between the formats, but comparative similarity within the same-format categories according to *H3*. This indicates evidence that customized corporate building formats as "build to suit" and energy management measures with reduction targets allow only limited store-to-store variation.

Over the timeframe, the splines for five categories of the SFA denote a decline in the consumption by trend when assuming a linear development. The splines illustrate correlation between the electricity consumption and the SFA. Higher SFA is, by trend, attributed to relatively lower electricity consumption per square meter, which proves for the existence of economies of scale described also in *H3* (Figure 4).

Introducing turnover figures (€/m^2/a) with six categories of intensity as splines to the panel, the expected correlation between higher sales productivity and increased electricity consumption turns out significantly among the three categories representing higher turnover figures. This meets the expectation when hypothesizing high correlation between electricity consumption and sales productivity in *H9* (Figure 5).

Despite a high range in the scatter zone for the monthly observations, the splines of the three lower turnover categories remain almost close to each other within the same range (Figure 6).

A preliminary indication for the relationship between the Store-EBIT, illustrated again in the six spline categories for the classification of the EBIT-intensity, turns out with the supposed correlation between high EBIT and increased consumption in the stores (*H9*). This appears most significantly for the spline-category with highest EBIT (in €/m^2/a) and also in the scatter zone. The differentiation for the categories ranging below is less significant to almost indifferent related to the intensity of electricity consumption, as seen before for certain turnover categories.

6. Econometric approach

With regard to the structure of the dataset in terms of different time-constant and time-varying variables, a sophisticated econometric approach is designed. Considering the data available in a different time-related structure, two panel regression models were designed to explain: electricity consumption with observations available on a monthly basis and total electricity consumption on an annual basis. In the applied multiple regression models, the response variables are decomposed into the implicit contribution

Figure 4.
Electricity consumption in SFA categories

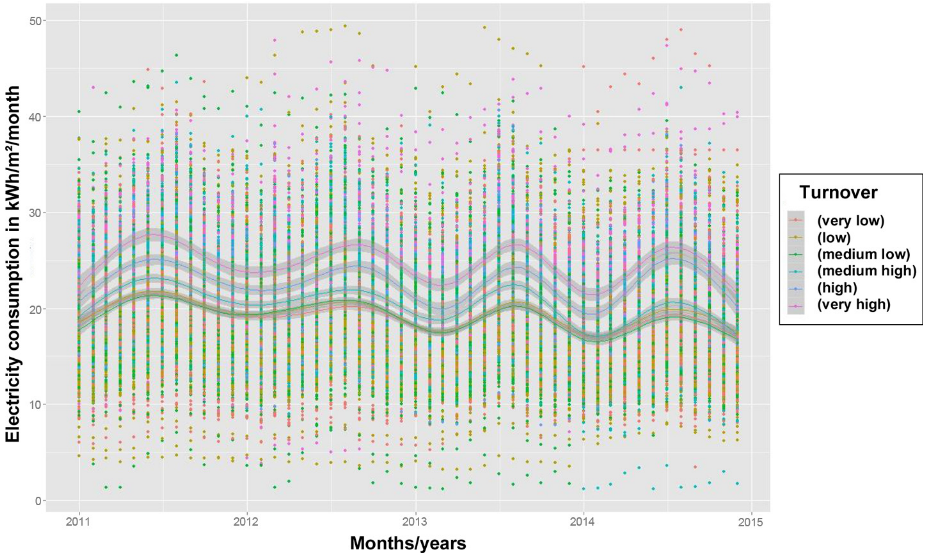


Figure 5.
Electricity consumption in turnover categories

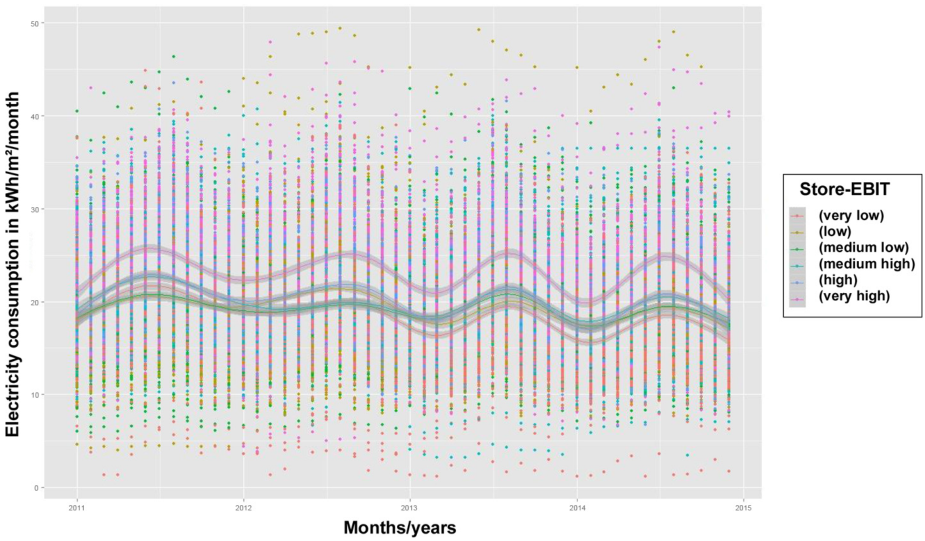


Figure 6.
Electricity consumption in EBIT categories

of the available building characteristics and the attributes related to operational sales performance, while controlling for outdoor weather conditions and locational effects from spatial heterogeneity.

In a basic model specification for the panel regression, with 37,488 observations on a monthly basis over the timeframe from January 2011 until December 2014, equation (1) is applied with electricity consumption as response y (dependent variable). The cross-sectional component can be represented by the store identifier i, with constant effects attributed to the stores, and the time-related component t, which is the month of observation of electricity consumption.

$$\mathbf{y} = \alpha + \zeta' \mathbf{X} + f(\mathbf{t}) + f(\mathbf{i}) + \varepsilon \qquad (1)$$

For total energy consumption, as response y (dependent variable) in the panel regression, equation (1) is applied the same way, but the time component t represents the year of observation of total consumption from 3,124 observations.

As the assumption of linearity in the effects of regression models often seems to be too restrictive in a real estate context (Mason and Quigley, 1996, Pace, 1998, Parmeter *et al.*, 2007, Brunauer *et al.*, 2010, 2012), it seems appropriate to use more flexible non- and semiparametric regression models. In this context, generalized additive models (GAM) are considered, as described in Wood (2006), to identify nonlinear effects for the continuous covariates. Applying GAM has the advantage of expressing the nonlinear effects in the relationship between response (dependent variable) and explanatory (independent) variables in visualized nonlinear regression splines.

In this approach, the store-specific effect is modeled by means of a random effect. For example, the effect of building age is known to be nonlinear (Fahrmeir and Tutz, 2001) and, therefore, it can be modeled by splines in an approach that penalizes over-fitting (Oelker and Tutz, 2013). Furthermore, the design of the approach allows to decompose the time effect in the regression of electricity consumption into a fixed-year effect and a nonlinear cyclical monthly effect. For total energy consumption, the time effect is only decomposed into a fixed-year effect. Additionally, and besides the store characteristics, the variation in electricity and total consumption is explained by spatial–temporal covariates (HDD, CDD), which are also modeled in a nonlinear manner.

Bearing in mind common practice in hedonic price models (Malpezzi, 2003), a logarithmical transformation of the response variables (natural logarithm of electricity consumption and total energy consumption) was applied, while expecting multiplicative effects of the building characteristics on the dependent variables. This procedure enables for the interpretation of the estimated effects as elasticities, if both sides are logarithmically transformed or semi-elasticities if the explanatory variable enters the equation in absolute values. Furthermore, this approach mitigates the problem of heteroskedasticity. The response variables (a) electricity and (b) total energy consumption, as well as the other strictly positive metric explanatory variables, are transformed logarithmically, when estimating a log-linear function with the following equation:

$$\begin{aligned}
\ln(\text{Electricity Consumption}_{i,t}) = {} & \alpha + \boldsymbol{\beta}' \,\text{Year} + \boldsymbol{\gamma}' \,\text{No. Floors}_i \\
& + \delta \,\text{Revitalization Binary}_i + \theta \,\text{Ownership Binary}_i \\
& + \boldsymbol{\kappa}' \,\text{Store Format}_i + \lambda \,\text{Problem-Store Binary}_i \\
& + \rho \,\text{F8-Country Binary}_i + \boldsymbol{\sigma}' \,\text{Country}_i + f(i) \\
& + f(\text{Month}) + f(\text{Building Age}_{i,t}) + f(\ln(\text{GFA}_i)) \\
& + f(\text{SFA Ratio}_i) + f(\ln(\text{Sales Productivity}_{i,t})) \\
& + f\left(\overline{\text{Store-EBIT}}_{i,t}\right) + f(\text{HDD}_{i,t}) + f(\text{CDD}_{i,t}) + \varepsilon_{i,t}
\end{aligned} \qquad (2)$$

In the regression of electricity consumption on the explanatory variables, a vector of coefficients is applied, containing the annual values applicable to the four years from the database. This *year* effect is introduced to the model with parametric coefficients, so as to quantify the expected electricity savings from 2011 to 2014. For the physical characteristics, the *number of floors* of the buildings is estimated with a vector of linear coefficients. The dichotomous variable, *revitalization binary*, distinguishes between observations that underwent a revitalization in the past (or not), to predict potential electricity savings associated with store revitalizations. With regard to the hypothesis, the *ownership binary* controls for differences between leased and owned stores. The *store formats* are included in a vector with the specifications mentioned in Table II, so as to control for differences between the wholesale and hypermarket formats in electricity consumption.

Over the past years, the energy management of METRO GROUP selected those stores with the weakest energy performance of the wholesale portfolio, called "Problem-Stores". In a benchmark for an average calculation, the stores with the worst 20 per cent in energy consumption per square meter SFA, were identified in 2013. Because immediate intervention measures are needed to reduce energy consumption and improve efficiency, these stores were targeted with individual reductions. In the course of the regression, a binary variable is attributed to *Problem-Stores*, to estimate the surplus consumption compared to the portfolio average.

METRO GROUP differentiates in terms of number of stores and sales activity, between eight Focus Countries and the other – less important – countries in the portfolio. Within the *F8-Countries* with higher organizational overheads, energy management is represented with a specific country manager, dedicated explicitly to energy management. Because these F8-Countries might be associated with higher consumption, but also with higher saving potential, a binary is included. To control for spatial heterogeneity, binary variables for each *country* in the portfolio are contained in a vector of coefficients for the location dummy effects.

Furthermore, the regression equation contains the store identifier *i*, with constant effects attributed to the stores, which provides a quality-adjusted identification of higher- and lower-performing stores in terms of energy efficiency. When a dataset with observations on a monthly basis is used, the electricity consumption in each month of the four years can be expressed with a *function of months* and displayed with a spline, which combines the observations into one representative spline for a "modeled year".

Building age is introduced as a function, to explain the effect on electricity consumption in a regression spline, as well as the two other physical characteristics, *ln(GFA)* and *SFA-Ratio*. Although the GFA accounts for the total size of a building and the intensity of energy consumption, not every part in the building necessarily has the same energy-consumption intensity. Therefore, it is common practice to account for SFA, which is introduced here with the percentage ratio of SFA to GFA, to avoid collinearity in the effects.

The performance attributes are expected to yield significant effects on the electricity consumption. The turnover figures of the stores are introduced with *ln(sales productivity)* per square meter, to consider the local impact of a store in terms of population size and catchment area, determining the number of customers, differences in purchasing power and the intensity of competition in the local market environment.

However, it stands to reason that sales productivity and EBIT are highly correlated with each other. Because it is expected that the EBIT is a suitable indicator of the cost structure (including electricity costs) at the individual store level, the EBIT is reconsidered for integration in a "cleaned" mode, from which the explanatory power of the sales productivity has been eliminated. For this reason, a "helper regression" is designed in equation (3), which contains a residual output, as the unexplained part of the regression that is used to eliminate the correlation with sales productivity (orthogonalization):

$$\text{StoreEBIT}_{i,t} = f(\text{In}(\text{Sales Productivity}_{i,t})) + \widetilde{\text{Store-EBIT}}_{i,t} \tag{3}$$

The *residual output of the Store-EBIT* contains the information not explained through the systematic part of the model from equation (3). This information, reflecting the specific cost structures in the operational sales business as an explanatory variable in the final model, ensures that the resulting effects are directly attributable to electricity consumption.

The model includes the specific *HDD* and *CDD* of the individual store locations on a monthly basis, to control for spatial heterogeneity in the outside temperature variation over the timeframe as spatial–temporal covariates. Although heating energy consumption is not considered in the regression for electricity consumption, the impact of outdoor weather conditions via HDD might be reasonable, due to additional heating-production loads (e.g. for storage premises) – based on electricity – associated with very low temperatures. CDD are included, while higher electricity consumption for refrigeration and cooling is expect with an increasing outside temperature.

For the regression of total energy consumption on an annual basis in (b), this model is applied with some differences in notation, when the spline for a nonlinear cyclical monthly effect "f(Month)" is excluded from the model. To explain the contained heating-energy consumption, a binary for the *heating production type* in the stores is introduced, controlling for different heating energy efficiency between the fuels of gas, oil and district heating systems. HDD and CDD are introduced with the annual total degree days as explanatory variable.

7. Results

First, the results of the regression for electricity consumption as response are presented here, followed by the results of the regression for total energy consumption in the next subsection.

7.1 Results for electricity consumption

The results of the log-linear regression model applied for estimating the effect of electricity consumption are summarized in Table V with parametric coefficients following equation (2), and nonlinear regression splines depicted as smoothed curves in Figure 7.

The significant coefficients indicating the intensity of electricity consumption for the calendar years quantify substantial electricity savings from 2011 to 2014. In 2012, the consumption was 3.1 per cent lower, with a further decline of 7.2 per cent in 2013, and electricity savings of almost 10 per cent in 2014, compared to electricity consumed in 2011 as a reference. With regard to Table V, in semi-logarithmic regressions, the

Table V. Parametric coefficients from regression of electricity consumption from equation (2)

Response variable: ln(electricity consumption in kWh/m^2/month)	Parametric coefficients (*t*-values)
Intercept	2.947 (66.841)***
Year 2012 (2011 = omitted)	−0.031 (−15.763)***
Year 2013 (2011 = omitted)	−0.075 (−26.914)***
Year 2014 (2011 = omitted)	−0.102 (−27.376)***
Number of floors 2 (Number of floors 1 = omitted)	0.020 (0.904)
Number of floors 3 (Number of floors 1 = omitted)	0.040 (0.798)
Number of floors 4 (Number of floors 1 = omitted)	0.294 (1.607)
Number of floors 5 (Number of floors 1 = omitted)	0.328 (1.272)
Revitalization Binary (Revitalization = 1)	−0.006 (−0.214)
Ownership Binary (owned = 1)	−0.012 (−0.408)
Classic (Hypermarket, standalone = omitted)	−0.111 (−1.964)*
Junior (Hypermarket, standalone = omitted)	−0.229 (−3.688)***
Schaper (Hypermarket, standalone = omitted)	−0.502 (−10.343)***
Eco (Hypermarket, standalone = omitted)	−0.122 (−1.820)
Center (Hypermarket, standalone = omitted)	−0.006 (−0.135)
"Problem-Store" Binary ("Problem-Store" = 1)	0.148 (4.854)***
F8-Countries Binary (F8-Countries = 1)	0.112 (2.260)*
AT (Germany = omitted)	0.083 (1.133)
BE (Germany = omitted)	0.000 (−0.001)
DK (Germany = omitted)	0.182 (1.672)
FR (Germany = omitted)	−0.029 (−0.452)
IT (Germany = omitted)	0.097 (1.662)
NL (Germany = omitted)	0.084 (1.303)
PT (Germany = omitted)	0.271 (2.924)**
ES (Germany = omitted)	0.120 (1.681)
TR (Germany = omitted)	0.060 (0.773)
BG (Germany = omitted)	0.378 (4.886)***
HR (Germany = omitted)	0.320 (3.190)**
CZ (Germany = omitted)	0.318 (4.428)***
GR (Germany = omitted)	0.270 (3.130)**
HU (Germany = omitted)	0.306 (4.163)***
PL (Germany = omitted)	0.345 (4.559)***
RO (Germany = omitted)	0.307 (5.620)***
RS (Germany = omitted)	0.300 (3.173)**
SK (Germany = omitted)	0.285 (2.773)**
R^2	0.885
Adjusted R^2	0.883
AIC-Criterion	−62,339.78
Number of observations (*n*)	37,488

Notes: Significance: ***0.001; **0.01; *0.05

percentage effect of the coefficients for binary variables is calculated as anti-logarithm of the estimated coefficients with $((\exp(\beta x) - 1) \times 100)$ in relation to the omitted reference variable (Halvorsen and Palmquist, 1980, Hardy, 1993).

These results point to significant reductions, achieved in the course of implemented reduction targets and efficiency measures of corporate energy management. Pertaining to METRO GROUP's 20 per cent reduction target of CO_2 emissions, this is an initial

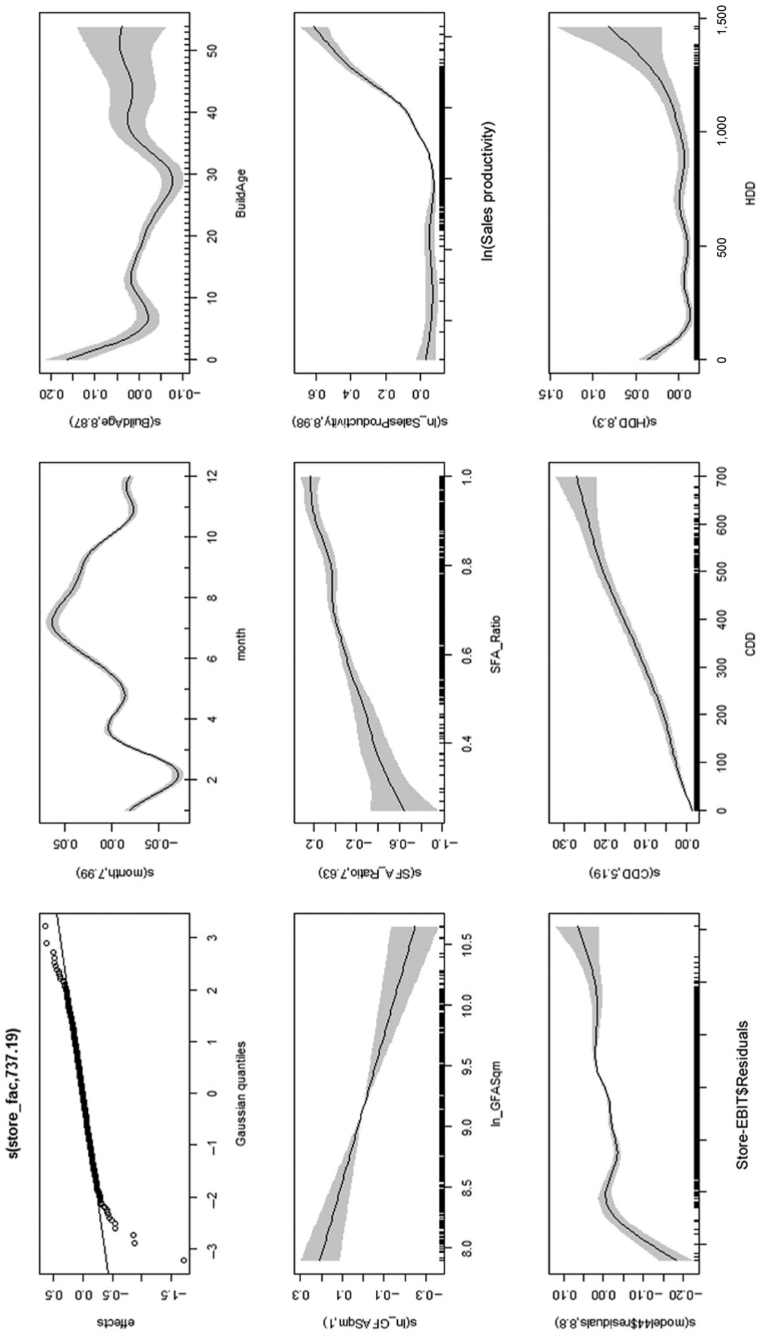


Figure 7.
Regression splines from regression for electricity consumption from equation (2)

indicator of success (corresponding to *H8*) – considering that a reduction of almost 10 per cent was realized in the four years after the target-setting baseline. Assuming significant electricity costs savings, a "conservation pay-off" from cost structures related to the operational sales business might be possible.

The introduced differentiation for the number of floors in the buildings remains insignificant. A significant effect of floor numbers is assumed when considering installation of elevators or escalators in the wholesale and hypermarket stores. However, these attributes may not be significant in relation to the size and compactness of the building structure – and also with respect to the introduced dummies for the different store formats. It appears that the wholesale formats do consume much less energy per square meter than the omitted standalone hypermarkets as reference. For the small-sized format of Schaper, the electricity consumption is almost 40 per cent; for the Junior-Format, approximately 20 per cent; and even for the MCC-Format Classic, almost 11 per cent lower than in standalone hypermarkets. This is remarkable, given that the Classic-Format is very often attributed with escalators and elevators to a so-called "Mezzanine-Floor", whereas most of the standalone hypermarkets feature only one flat floor. Furthermore, the difference between hypermarkets in retail parks (Center) and those which are standalone, is marginal and insignificant (as proposed in *H3*).

Surprisingly, with regard to *H2* and the results of Table IV, the revitalization binary turns out to be insignificant. However, it might be the case that the revitalization attribute contained in the dataset is dedicated rather to construction measures affecting the outside and inside appearance of the stores and sales floor, but less significant for the technical status of electricity-related building and sales floor facilities and equipment.

In line with *H5* for the ownership status of the assets, no significant effect on electricity consumption is found, according to whether a store is owned by METRO GROUP or leased. The result points to the fact that METRO GROUP's reduction targets cover both owned and leased assets, so that corporate energy management is responsible for reduction measures, independent of the ownership status. Furthermore, many stores were constructed according to the customized corporate building formats as "build to suit". In the case of a later sale and lease-back of corporate assets, based on a "triple-net" contract, the insignificance appears reasonable.

For the Problem-Stores, identified by corporate energy management, the results yield a higher consumption estimate of 16 per cent, compared to the portfolio average, all else being equal. This confirms the obvious potential of the stores for higher costs savings and thus higher profitability and lower carbon emissions, following *H6*. Although each Problem-Store is targeted with individual energy reductions, this nevertheless provides a reference point for the reduction targets from a management perspective. Confronting the higher electricity consumption of the Problem-Stores with a reduction of 16 per cent to the average, might result in cost savings of €4.39/m^2/a and an assumed reduction of CO_2 emissions by 2.42 kg/m^2/a.

The binary variable for the Focus-Countries reveals higher consumption of approximately 12 per cent in reference to the non-Focus Countries. This meets the expectation of higher energy savings potential that can be realized through country-wide managers (with regard to *H7*), dedicated explicitly to energy management. The single-country binaries exhibit significantly increased electricity consumption in several – mostly Eastern European – countries. This is in line with

Figure 2 of this study and shows disproportionately high savings potential – but *a fortiori* higher pressure for reduction measures.

Figure 7 illustrates the regression splines for the covariate effects from equation (2). The y-axes can be analyzed approximately as the percentage effect on electricity consumption. A linear relationship between explanatory and response is explained, if the effective degrees of freedom (edf) are estimated at 1.0. An estimated edf higher than 1.0 displays a nonlinear function in the relationship. Within the splines, the continuous black lines are the expected effects, and the gray areas are point-wise 95 per cent confidence intervals.

In the results, the store identifier allows for the quality-adjusted identification of higher and lower performing stores, and indicates only few outliners. The function of months displayed in a combined regression spline over the "average calendar year" explains that lowest electricity consumption is observable in January, February and the beginning of March. Culmination of a seasonal peak is significant in July and August when refrigeration loads are at maximum level (*H4*). Furthermore, seasonal effects seem evident in the spline. In December, the consumption intensity is relatively high, compared to January and February, which reflects higher sales productivity prior to Christmas – usually the timeframe with the highest turnover in the business year and an increased volume of illumination. For March and April, a significant increase occurs followed by a decrease in May. First, the increase might be due to increasing outside temperatures, with higher refrigeration and cooling consumption. Second, the decrease in May seems surprising and could be interpreted as the result of a large number of public holidays and closed stores at this time of the year.

The spline for building age proves, surprisingly, to have the highest consumption in the newest stores, which is counterintuitive to *H1*. Because the consumption decreases immediately in the following, up to an age of six years, a cautious interpretation might be that new stores need a few years of operation, to achieve a relatively low consumption level. With increasing age, a slightly higher consumption follows up to an age of 12 years, after which a continuous decrease until the age of 28 is observable. The lowest consumption, around the age of 30 years might account for older stores with less complex technical standards and equipment. However, it seems to be more likely that these stores were given to an electricity or energy-related retro-fit, compared to their older peers. If this appears to be the case, the retro-fit has obviously not been attributed to a revitalization of the stores – corresponding to the result for the revitalization binary (*H2*).

In line with other research, a linear decline in electricity consumption per square meter with increasing GFA is observed. The SFA-to-GFA ratio confirms to the expectation that a higher share of SFA to GFA relates to higher consumption by trend. Hence, it is reaffirmed that SFA is the relevant parameter in terms of electricity consumption.

The spline for sales productivity indicates at first a zone of indifference associated with low levels of turnover, which is followed by an almost exponential function. From a certain point, the slight increase turns into a progressively stronger increase. This proves higher electricity consumption with increasing turnover, as hypothesized in *H9*. In a linear function, a turnover increase of 1 per cent is associated with an increase of 3.2 per cent in electricity consumption. This result suggests a key challenge for the energy management, which is to realize energy savings permanently, while simultaneously increasing sales productivity with high volumes of customers.

The residual output of equation (3) was estimated as an indicator of the cost structure in the operational sales business, with overhead costs such as for personnel and energy and utilities. After a phase, associated with the cost structure of a very low Store-EBIT, the significant effect explains that a slight rise in the cost structure is coherent by trend with higher electricity consumption up to a certain crest, confirming *H9*. From this point onwards, some indifference in the effect, followed even by a very slight decrease in consumption, can be observed. Interpreted with care, this might suggest that at stores with very high costs, certain electricity-saving measures (such as the Problem-Store reduction targets) in fact reduce operational costs as a contribution to Store-EBIT. However, for the most part, the results prove clearly that higher operational cost structures are linked to slightly higher electricity consumption.

The regression spline for CDD corresponds to the supposition in *H4* that with higher outdoor temperatures, more electricity is used for refrigeration and cooling in the stores. An increase in HDD verifies only a marginal effect on electricity consumption as expected. From 200 up to 1,000 HDD, an almost indifferent zone of the effect is followed by slightly higher consumption in stores facing more than 1,000 HDD. This suggests additional heating-production loads, based on electricity, at very low outside temperatures, e.g. for usually un-heated storage premises and the use of additional equipment. The higher consumption at lower than 200 HDD is intuitively surprising, but may account for a still relatively high refrigeration load and electricity consumed in regard to relatively high outdoor temperatures. The immediate descent with increasing HDD supports to this interpretation.

7.2 Results for total energy consumption

The results obtained in the regression model for total energy consumption following equation (2), with the explained model-specification, correspond in many ways to the results discussed before, for electricity consumption. Thus, the major differences and additional results with regard to thermo-physical- and heating-related attributes are explained below.

For total energy consumption, an annual reduction of almost 3 per cent in 2012, 5 per cent in 2013 and even 11 per cent in 2014 has been realized, with reference to the energy consumed in 2011. Again, Schaper turns out as the format of lowest energy consumption, with a 20 per cent lower consumption than in standalone hypermarkets. Surprisingly, the Eco format is found to have 16 per cent higher consumption than in those hypermarkets. For the heating production type, oil was found to have 7 per cent higher consumption than natural gas. The Problem-Stores account for 11 per cent higher consumption than the portfolio average. With regard to the results obtained for electricity consumption, this might indicate higher thermo-physical and heating efficiency in the Problem-Stores, whereas electricity consumption remains the major issue.

The binary for the focus countries reveals a significantly higher consumption of up to 60 per cent in the focus countries. Few country binaries yield lower energy consumption with reference to Germany (omitted), for France by −30 per cent, Italy by −15 per cent and Turkey by −23 per cent. The countries in Eastern Europe reconfirm the results for electricity, but some even yield higher total energy consumption than for electricity only. This suggests that beside electricity, heating energy efficiency is also weak. For the omitted reference binary of Germany, the results might point to the more restrictive building codes over the past decades, with effectively lower levels of consumption. The results are in line with the overall GHG emissions of METRO GROUP, as illustrated in Figure 2 (Table VI).

Overall, there is little variation in the covariate effects explained in the splines. Once again, the stores with a building age of around 30 years prove to have the lowest consumption. The youngest and the oldest observations are associated with significantly higher levels of energy consumed. This ambiguous result is comparable to those of Spyrou *et al.* (2014), that the construction year proved not to exert a significant influence on energy consumption. It seems that the influence of building age and related thermo-physical characteristics is only marginal compared to other factors (Figure 8).

The spline for HDD is intuitive to the assumption of higher energy consumption due to increased HDD. A comparison of the spline to the result for electricity consumption shows the significant effect when explaining total energy consumption. The spline illustrates that from a crest point onwards, no higher consumption arises, if HDD are increasing from that point onwards. This indifference in the effect might be because, despite a further increase in HDD, the heating systems do not exceed their energy use, while they have already reached the peak load.

8. Reflection, conclusion and outlook

This study investigates the relationship between energy consumption, physical building characteristics, operational sales performance and the potential impact of corporate energy management. A very unique multi-national dataset, containing big-box wholesale and hypermarket stores of METRO GROUP, is applied to a sophisticated panel regression, explaining the electricity and total energy consumption of corporate real estate assets. In this context, the research analyzes the role of corporate energy management for achieving energy conservation and contributing toward a more efficient corporate environmental performance.

The dataset with 781 stores is used twofold, in a regression for electricity consumption on a monthly basis with 37,488 observations, and for total energy consumption on an annual basis with 3,124 observations, in the timeframe from 2011 until 2014. The econometric approach is designed to explore nonlinear covariate effects between response and explanatory variables, which are depicted in regression splines.

The results prove significant electricity and total energy savings in the wholesale and hypermarkets of METRO GROUP. An exemplified pay-off calculation from lower electricity consumption achieved by 2014, is estimated with more than €3.00/m^2/a and forecasted to almost €9.00/m^2/a by 2020. In an indicative scenario, assuming pricing for the internalization of GHG externalities, the potential electricity cost saving by 2020 would be offset by almost 10 per cent due to CO_2 pricing. The applied cost of €30.00/ton CO_2 is derived from assumed "social cost" of US$32/ton of CO_2 calculated by Kahn and Kok (2014b) for the case of Walmart in California (with reference day 30 November 2015).

With regard to the hypothesis from the empirical framework of this study, the results prove no evidence for higher energy efficiency of more recent wholesale and hypermarket stores (*H1*). In particular, the relatively new stores in Eastern Europe,

Table VI. Parametric coefficients from regression of total energy consumption from equation (2)

Response variable: ln(Total energy consumption in kWh/m^2/month)	Parametric coefficients (*t*-values)
Intercept	5.295 (101.129)***
Year 2012 (2011 = omitted)	−0.026 (−15.853)***
Year 2013 (2011 = omitted)	−0.055 (−21.904)***
Year 2014 (2011 = omitted)	−0.115 (−35.660)***
Number of floors 2 (Number floors 1 = omitted)	0.011 (0.401)
Number of floors 3 (Number floors 1 = omitted)	−0.007 (−0.121)
Number of floors 4 (Number floors 1 = omitted)	0.190 (1.118)
Number of floors 5 (Number floors 1 = omitted)	0.245 (1.017)
Revitalization Binary (revitalization = 1)	0.032 (1.167)
Ownership Binary (owned = 1)	0.039 (1.392)
Classic (Hypermarket, standalone = omitted)	0.034 (0.622)
Junior (Hypermarket, standalone = omitted)	−0.005 (−0.080)
Schaper (Hypermarket, standalone = omitted)	−0.229 (−5.178)***
Eco (Hypermarket, standalone = omitted)	0.147 (2.351)*
Center (Hypermarket, standalone = omitted)	−0.077 (−1.794)
Oil heating (gas = omitted)	0.069 (2.172)*
District heating eating (gas = omitted)	0.041 (1.234)
"Problem-Store" Binary ("Problem-Store" = 1)	0.108 (3.805)***
F8-Countries Binary (F8-Countries = 1)	0.481 (10.449)***
AT (Germany = omitted)	0.371 (5.478)***
BE (Germany = omitted)	0.263 (3.438)***
DK (Germany = omitted)	0.240 (2.335)*
FR (Germany = omitted)	−0.354 (−5.994)***
IT (Germany = omitted)	−0.167 (−3.102)**
NL (Germany = omitted)	0.287 (4.889)***
PT (Germany = omitted)	0.084 (0.976)
ES (Germany = omitted)	−0.042 (−0.648)
TR (Germany = omitted)	−0.267 (−3.681)***
BG (Germany = omitted)	0.450 (6.210)***
HR (Germany = omitted)	0.444 (4.754)***
CZ (Germany = omitted)	0.488 (7.264)***
GR (Germany = omitted)	0.473 (5.894)***
HU (Germany = omitted)	0.441 (6.535)***
PL (Germany = omitted)	0.090 (1.258)
RO (Germany = omitted)	0.449 (7.854)***
RS (Germany = omitted)	0.415 (4.727)***
SK (Germany = omitted)	0.488 (5.154)***
R^2	0.937
Adjusted R^2	0.936
AIC-Criterion	−90,885.02
Number of observations (*n*)	3124

Notes: Significance: ***0.001; **0.01; *0.05

show higher consumption, on average. It is concluded that the influence of building age is only marginal, compared to other factors, such as the technical facilities and equipment used. This corresponds to the results obtained for revitalization (*H2*). Whereas the sub-portfolio with stores which have undergone revitalization yields lower consumption on average, the insignificant effect obtained in the regression might

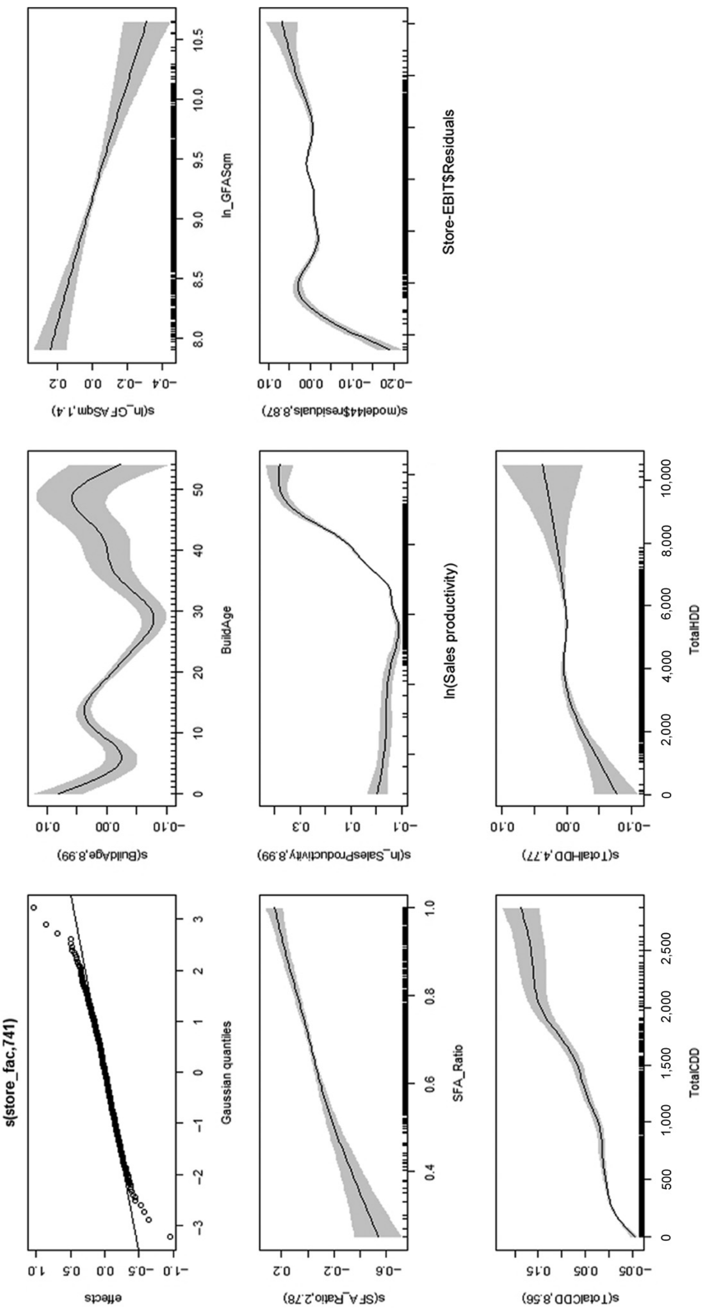


Figure 8.
Regression splines from regression for total energy consumption from equation (2)

suggest that revitalization is attributed more to construction measures for the appearance of the stores, but less to energy-consuming technical equipment.

A comparison of the electricity consumption between the different sales line and store formats (*H3*) revealed annual consumption cycles, with relatively similar store-to-store variation for the same formats, and higher variation among different formats. Hypermarkets are identified as having significantly higher consumption on average, as well as with greater variation between single stores. This implies the impact of the customized corporate building formats as "build to suit", and the influence of centralized energy management.

The summer months were found to be associated with the highest electricity, as well as total energy consumption, due to the highest refrigeration and cooling loads. January and February are observed as being the months of lowest consumption. Beside the outdoor and indoor temperature impact, seasonal effects of the operational sales business are also displayed in the regression outcome (*H4*).

Due to the customized building formats and centralized energy management, which apply both to owned and leased stores, in combination with the "triple-net" rental contract basis, no significant difference in the energy consumption of owned and leased stores is investigated (*H5*).

The identification of "Problem-Stores", in terms of energy efficiency from energy management, provides a reference point with regard to achieving individual reduction targets for the stores (*H6*). The reduction of electricity consumption by 16 per cent in the Problem-Stores, compared to the average of the MCC wholesale portfolio, is followed by cost savings of €4.39/m^2/a and an assumed reduction of CO_2 emissions of 2.42 kg/m^2/a.

The six METRO GROUP Focus-Countries, included in the study dataset, are identified as associated with significantly higher electricity and total energy consumption, thus having the highest energy saving potential (*H7*). Considering the number of stores in the countries and the size of the local organizations – with their own energy manager at the country level – these countries are advised, to take advantage of existing economies of scale for economizing on energy consumption, so that human capital gains higher profitability from savings.

This suggests that – besides the reduction of carbon emissions – continuous energy conservation with cost savings is also a promising driver for operational store profitability. From the dataset, electricity costs are revealed of 0.55 per cent and total energy costs with 0.73 per cent of annual turnover per square meter. *H8*, proposing annual operating energy costs approximately in the range of the annualized profit margin from the operational sales business (Dena, 2014), is not confirmed, as the total energy costs amount to a margin of not even 50 per cent of annual turnover. Notwithstanding, the corporate real estate assets of METRO GROUP will provide leverage on store profitability, if further cost savings can be realized from lower consumption in the course of attempting to achieve the energy reduction targets.

For the most part, the results prove clearly that higher operational cost structures are linked to slightly higher energy consumption. Energy consumption and related costs are highly correlated with sales productivity and store performance (EBIT). This constitutes a key challenge, namely, to realize energy savings permanently towards a more efficient corporate environmental performance, while retaining or increasing sales productivity with high volumes of customers (*H9*).

The research outlined in this study explores the energy efficiency of corporate real estate assets and the key role of corporate energy management. However, for the tested wholesale and hypermarket store portfolio of METRO GROUP, the cost structure of corporate energy management is not part of this study. In this regard, the current cost-benefit analysis provides an opportunity for future research in related studies.

Furthermore, besides the energy manager in Focus-Countries, the extent of human capital engaged in energy savings and corporate environmental performance is not analyzed in this study and is thus another avenue for further research, especially in the field of behavioral real estate. In this regard, the study recommends raising the awareness of (real estate asset) management and staff, with regard to energy efficiency and environmental issues for higher corporate environmental performance. Highlighting the role of wholesale and hypermarkets as a transmission mechanism for sustainability issues, as anticipated by customers, might support to this objective.

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