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Comparative Analysis of Energy Intensity and Profitability in Emerging E-Grocery Retail Models

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Abstract

The supermarkets account for approximately 3% - 4% of the electricity consumption in the industrialised countries which makes them one of the main contributors to climate change. Food retail, similarly to other energy intensive industries requires deep changes that would reduce its negative environmental footprint. Online grocery (e-grocery), recording three-digit growth globally in the times of COVID-19 pandemic, has the potential to disrupt the market and bring opportunities for energy intensity reduction.

Brick & mortar retailers adapting to this trend not only experience technical challenges with order fulfilment and last-mile logistics, but also they struggle to achieve profitability of e-grocery. Therefore, there is a need for guidance in this transformation. This thesis aims to help retailers choose the least energy intensive and profitable e-grocery configuration by comparing the emerging fulfilment models (in-store, omni store, dark store) and last-mile delivery options (click & collect, home delivery).

The scope of this thesis includes a literature and market review, where an overview of e-grocery market, logistics, technologies, energy intensity and economics is given. The review is followed by methodology explaining the tools and assumptions used for analyses. Then, energy intensity analysis is performed where energy intensity per order is calculated using CyberMart software for three fulfilment models and two delivery options. After that, the operating costs and profitability of e-grocery models is analysed. Finally, the results from analyses are discussed, concluded and recommendations for the retailers are given.

The results of this thesis suggest that e-grocery may indeed reduce energy intensity of food retail but the energy consumption has little impact on the operational costs of the e-grocers. Labour fulfilment and order delivery costs optimisation play the biggest role in achieving profitability of online retail. Thus, it is recommended that the retailers, along with the growing penetration of e-grocery, develop automated fulfilment and click & collect solutions that would reduce the operational costs and allow for an incremental, yet future-proof adaptation to the e-grocery revolution.

Sammanfattning

Stormarknaderna står för cirka 3% - 4% av elförbrukningen i de industrialiserade länderna, vilket gör dem till en av de främsta orsakerna till klimatförändringarna. Livsmedelsbutiker kräver, på liknande sätt som andra energikrävande industrier, stora förändringar som kan minska dess negativa miljöpåverkan. E-handel av livsmedel, som har registrerat tresiffrig tillväxt globalt under tiderna för COVID-19-pandemin, har potential att störa marknaden och ge möjligheter till minskning av energiintensitet.

Traditionell verksamhet som anpassar sig till denna trend upplever inte bara tekniska utmaningar med orderhantering och leverans till slutkund, utan de kämpar också för att uppnå lönsamhet. Därför finns det behov av vägledning i denna omvandling. Denna avhandling syftar till att hjälpa återförsäljare att välja de minst energikrävande och lönsamma alternativen för e-handel av livsmedel genom att jämföra de nya modellerna för orderhantering (in-store, omni store, dark store) och leveransalternativ till slutkund (click & collect, hemleverans).

Avhandlingen omfattar en litteratur- och marknadsstudie, där en överblick ges över e-handel av livsmedel, logistik, teknik, energiintensitet och ekonomi. Studien följs av ett avsnitt om metodik som förklarar verktyg och antaganden som används för analysen. Därefter utförs en analys av energiintensitet där energiintensitet per order beräknas med hjälp av programvaran CyberMart för tre modeller för orderhantering och två leveransalternativ. Därefter analyseras driftskostnaderna och lönsamheten för modeller för e-handel av livsmedel. Slutligen diskuteras resultaten från analyserna och rekommendationerna till detaljhandlarna presenteras.

Resultaten av denna avhandling tyder på att e-handel av livsmedel verkligen kan minska energianvändningen i livsmedelsindustrin men energiförbrukningen har liten inverkan på driftskostnaderna för e-handlarna. Att optimera arbetet för orderhantering och kostnaden för leverans spelar störst roll för att uppnå lönsamhet för e-handeln. Det rekommenderas därför att detaljhandlarna, tillsammans med den växande andelen av e-handel, utvecklar automatiserad lösningar för orderhantering och click & collect som skulle minska driftskostnaderna och möjliggöra en stegvis, men ändå framtidssäker anpassning till e-handeln av livsmedel.

Preface

The idea for this master thesis project was born during the Energy Efficiency Hackathon in Berlin in March 2019. I had a chance to work there in an interdisciplinary team of 9 master students on a challenge provided by Danfoss, a global manufacturer of components for refrigeration, air conditioning and heating. With the aim of designing the *Energy Efficient Supermarket of Tomorrow*, we proposed a vending machine style refrigerated cabinet that would save electricity and inform customers about the origins and sustainability of the products. As a winning team we were invited by Danfoss to present the solution in their headquarters in Denmark and we were given a chance to continue developing the project in a form of an internship.

This opportunity appealed to me and during Autumn 2019 we prepared a master thesis proposal together with Danfoss and KTH, planned internship objectives and activities. In February 2020 I moved to Sønderborg in Denmark, a town next to Danfoss HQ in Nordborg. In the beginning of my thesis I had to validate the assumptions made during the hackathon by conducting a market research, literature review and interviews with experts. Thanks to Danfoss I had an opportunity to visit the biggest food retail exhibition in Europe: Euroshop that was held in Düsseldorf on 16-20 February 2020. The preliminary research made me realise that the strongest trend in food retail is related to the shift from offline to online shopping. This is why I decided to dive deep into the topic of energy intensity and profitability of online grocery.

Soon after Euroshop, the topic of my research became more relevant than ever. The global outbreak of COVID-19 pandemic accelerated the growth of the online grocery segment and all retailers had to adapt quickly. Although the interest in my research increased among the stakeholders, many retailers were too occupied with their own problems to engage in the project and provide empirical data. One of my supervisors at Danfoss once said: *You are trying to explain the outcomes of the storm being in the middle of the storm.* This is indeed how I felt and despite a number of shortcomings it caused for my research, that was a very exciting adventure for me. I hope this project will set the ground for further research in the online grocery field.

Acknowledgements

First of all, I would like to extend my gratitude to my industrial supervisors at Danfoss: Hans Ole Matthiesen, Global Segment Director and Henry Steffensen, Strategic Marketing Director of Food Retail. Both Hans and Henry gave me continuous support, sincere interest in my research and helped me to disseminate my findings. In those difficult times Hans helped me immensely with reaching out to the stakeholders around the world and always encouraged me to think globally. Henry introduced me to the world of marketing with a series of training sessions and he turned out to be the best guide of Danfoss and Danish culture I could imagine (he even borrowed me his own bike to move around Sønderborg!).

I would also like to thank my academic supervisor Samer Sawalha, professor at KTH Royal Institute of Technology in Stockholm for his guidance through the whole process of this master thesis research. Samer helped me to keep my research objectives clearly defined and prevent my project from the scope creep. At the same time, from the very beginning Samer was very open-minded about the topic of my research which helped me release creativity and the feeling of ownership. Moreover, I would like to acknowledge Jaime Arias, professor at KTH who trained me to use CyberMart software which he developed and which I used as the primary tool for energy analysis. I would also like to recognize Sotiris Thanasoulas, PhD candidate for his help in arranging distance based sessions and his constructive feedback.

Finally, I would like to thank all my colleagues, fellow interns at Danfoss, my classmates from InnoEnergy SELECT programme, my girlfriend, friends and family for their interest, understanding and keeping fingers crossed for the successful defence and submission of the project report.

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Definitions

Brick-and-mortar store (B&M): a conventional physical store that offers its products and services to its customers face-to-face [1].

Dark store: sometimes also referred to as dotcom centre or online fulfilment centre is a facility that is optimised to fulfil online orders to end customers, inaccessible to customers [2].

Customer fulfilment centre (CFC): a physical location from which a third-party logistics (3PL) provider (also known as a fulfilment provider) fulfills customer orders for ecommerce retailers (e.g. grocers) [3].

Distribution centre (DC): a large warehouse used to store goods delivered by suppliers and then shipped to retailers or wholesalers. The goods are most commonly stored in intermodal containers or pallets. It's size ranges from 5,000 m^2 to 300,000 m^2 [4].

E-grocery/online grocery: refers to the business models in food retail in which customers find and order groceries using online platforms [5].

Energy intensity: sometimes also referred to as *specific energy consumption*, is the energy consumed per unit of reference, e.g. area of a building [6], products manufactured or service delivered to the customer [7].

Micro fulfilment centre (MFC): a small-scale, highly automated warehouse facility in an accessible urban location that is close to the end-consumer [8].

Omnichannel (OC): an emerging trend in retail that aims to coordinate processes and technologies across supply and sales channels, such as offline and online channels [9].

Omni-store (OS): a concept of a store integrating offline and online fulfilment under one roof [10], [11].

Order fulfilment: a process which encompasses all activities from the moment a consumer makes an online purchase until the product is delivered to the consumer [12].

Stock keeping unit (SKU): a unique type of item for sale and all its attributes which distinguish this item from others, usually marked with an identifier, e.g. barcode [13].

1 Introduction

1.1 Thesis context

The supermarkets account for approximately 3% - 4% of the electricity consumption in the industrialised countries [14], [15] which makes them one of the main contributors to climate change. The development of new refrigeration and heating technologies for many years have been incrementally improving the energy efficiency of supermarkets but the dynamic growth of e-commerce will soon disrupt the food retail market with unknown impact on its energy intensity.

Online retail is well established globally for the non-food products but only now it makes its entrance to the groceries, recording three-digit market growth globally in the times of COVID-19 pandemic. The retailers are trying to adapt to this growth by building out their omnichannel capabilities: an integration of offline and online retail models. This integration is associated with changes of the store layout, infrastructure and supply chain.

At the time of writing this report, food retailers are still in the exploration phase, experimenting with different omnichannel models: in-store fulfilment, dark stores, micro fulfilment centres, etc. Because of that, comprehensive multidisciplinary research should support their choices to ensure that the e-commerce revolution will not only help retailers increase their revenues but also decrease their energy consumption and footprint on the environment.

1.2 Thesis statement

The growth of e-commerce is changing the design, infrastructure and supply chain of the supermarkets. If implemented properly, online fulfilment can decrease the energy intensity of the food retail. Moreover, decreasing the energy consumption can significantly help the e-grocers achieve higher profitability.

1.3 Thesis objective

The objective of this thesis is to validate the aforementioned statements and give recommendations to the retailers on how to reduce energy intensity and operating costs of e-grocery. This will be done by market & literature review, modelling and analysing the energy intensity and profitability of three main e-grocery concepts.

The report will also provide insights and comments on the costs, user experience and footprint of the analysed concepts in a broader context of supply chain and end-user delivery. This will be done to ensure the relevance of this study to the priorities in decision making of the retailers.

2 Literature & market review

2.1 E-grocery market outlook

There are two types of e-commerce retailers: pure players and omnichannel retailers. Pure players are the companies which sell products only online, while omnichannel means that the retailer uses both online and offline channels to increase the sales. The omnichannel trend has influenced both B&M stores and online shops to develop partnerships, as the shift to omnichannel requires new competencies. As presented in figure 4, the omnichannel retailers are expected to dominate the online grocery market in 2024 with 82.2% of sales, while pure players (1st party and 3rd party combined) will have a share of only 17.8% of the online grocery market [16].

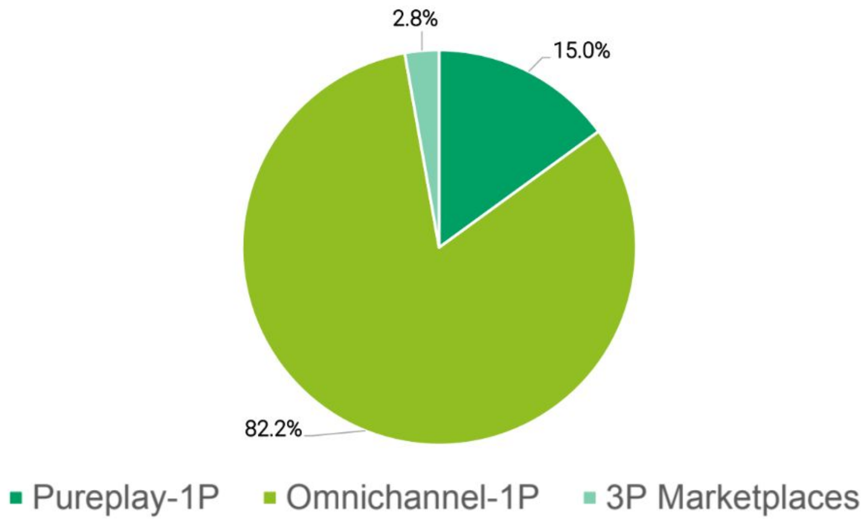

Figure 1: Global Grocery Online Sales by Segment (%) in 2024 [16]

Online sales account for approximately 3.7% of the edible grocery sales globally, vs the cross category average of 20%. There are several reasons for slow adoption of e-commerce by the grocery sector. First, consumers are used to picking the fresh products and evaluating their quality with their own senses [17], while online grocery assumes someone else picking for the customers. Moreover, order fulfilment of groceries is far more complex and expensive than for any other product category [18]. Products must be kept at different temperatures, many of them are perishable, they differ in size, weight and fragility.

Nevertheless, Edge by Ascential (food retail consultancy) in 2019 named the edible groceries the fastest growing segment in online retail with CAGR (compound annual growth rate) forecasted to be 13% over the following 5 years [16]. No one would have imagined that the expected total e-grocery annual sales growth of 84% would be achieved within less than one year.

The outbreak of COVID-19 pandemic has had a major influence on the market outlook for e-commerce in food retail. In 2020 the governments around the world introduced many restrictions with regards to shopping and movement of citizens. Although even in the peak of the pandemic B&M stores remained open for the public, many countries set limits on the number of customers that could be in the store at the same time. As the demand for food does not drop, this resulted in queues in front of the supermarkets. Moreover, the shopping experience itself became a nuisance due to the requirements of wearing face masks and rubber gloves in some countries [19]. Some customers, especially the high-risk groups (people with underlying health conditions, elderly or pregnant women) preferred to stay at home for safety reasons. The decrease of offline shoppers around the world can be observed on the map in figure 2. The map compares the number of visitors at grocery and pharmacy stores before the beginning of the pandemic (January 2020) and the day 30th March 2020. During pandemic months the offline grocery shoppers number in the U.S. dropped on average by 15% [20].

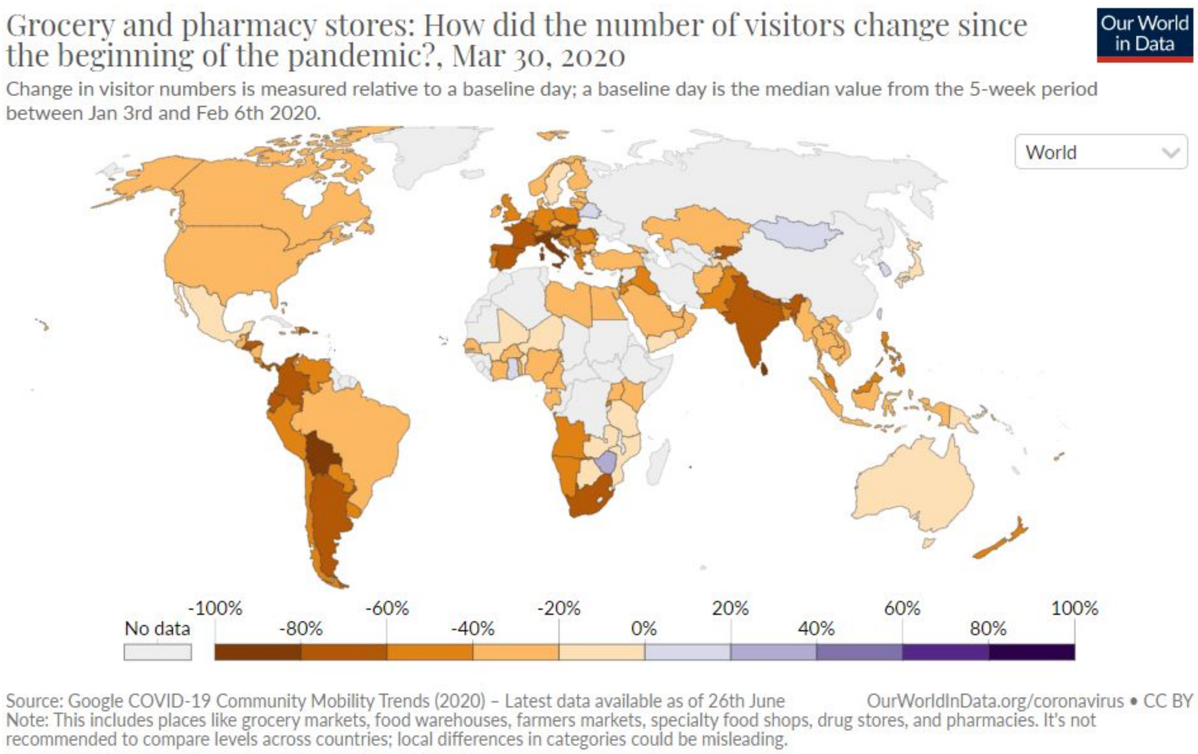

Figure 2: Change in visitors number at grocery and pharmacy stores around the world [21]

All these factors encouraged the customers to look for alternatives to conventional grocery shopping. E-commerce turned out to be the answer to many of these constraints: it allowed for lower risk and hassle-free shopping. Because of that, retailers that had managed to build e-grocery capabilities before the pandemic outbreak scored a 3-digit growth of online sales in the climax of the pandemic (March, April 2020) [22]. For many customers that was the first time they shopped online. Many of them will return to conventional supermarkets after COVID-19 pandemic but a considerable share of customers are expected to keep using digital channels for regular or occasional shopping.

Table 1 summarises the growth of key online grocery market indicators in the U.S. (basket size, number of orders, number of customers, frequency, repeat order intent) based on market surveys conducted by Brick & Click consultancy before and after COVID-19 pandemic [23]. Between August 2019 and May 2020 there was a growth in the monthly e-grocery sales of 504%. In the same time, the number of customers with intent of repeating online orders decreased from 74% to 56%. This indicates that approximately 24 million customers in the U.S. will keep shopping groceries online after the pandemic, which means a growth in customers number of around 140% and a growth of sales of almost 300% when compared with the period before pandemic.

Table 1: Online grocery delivery & pickup market in the U.S. before and after COVID-19 [23]

	August 2019	**March 2020**	**April 2020**	**May 2020**
Spend (Average per order)	$72	$82	$85	$90
Orders (Past 30 days)	16.1 million	46.9 million	62.5 million	73.5 million
Customers (active during last 30 days)	13.1 million	39.5 million	40.0 million	43.0 million
Frequency (monthly average/customer)	1.0	1.2	1.6	1.7
Repeat order intent	78%	47%	50%	56%
Online grocery monthly sales	$1.2 billion	$4.0 billion	$5.3 billion	$6.6 billion
Total grocery monthly sales	$57.7 billion	$73.7 billion	$64.0 billion	$62.8 billion

As presented in figure 3, online grocery in the U.S. increased its share from 2.08% in August 2019 to 10.48% in May 2020. 10% share of e-grocery sales is often referred to as a penetration which requires major improvements of the order fulfilment and delivery logistics [24]. Therefore, many retailers are expected to invest in e-grocery capabilities very soon and research in this field may be useful in their decision making process.

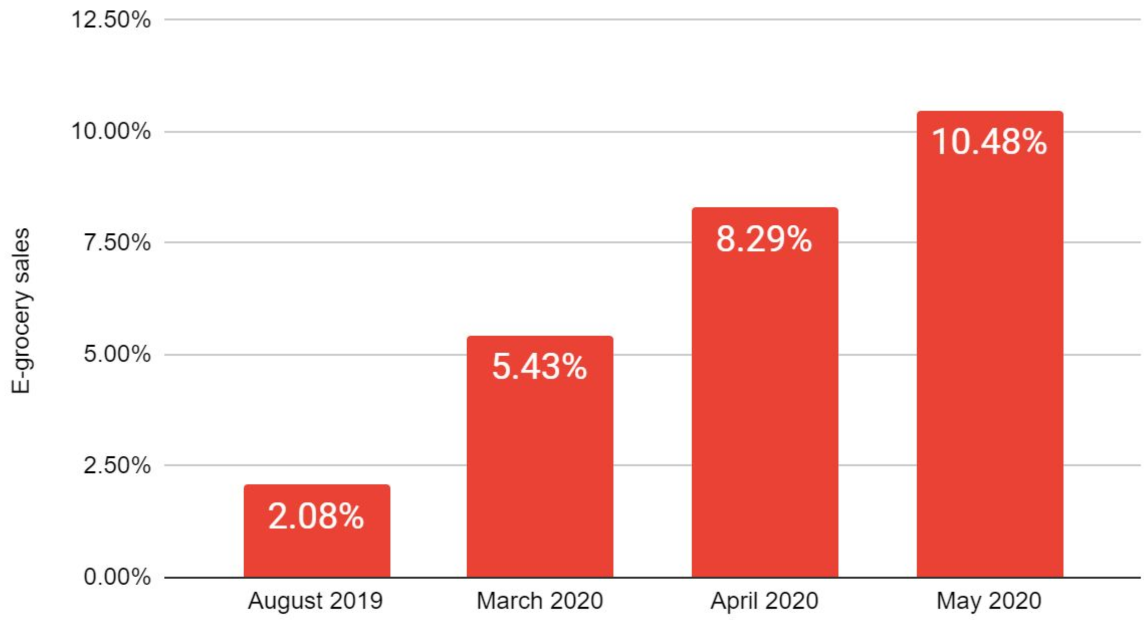

Figure 3: E-grocery share in food retail sales in the U.S. [25] [26]

2.2 Logistics network structure

The logistics network of online food retail can be segmented into distribution, order fulfilment and end-user delivery. The differences between conventional retail and e-commerce go across all steps of the network, with the order fulfilment and end-user delivery being the most distinct. The network presented in figure 4 is further explained in the following subchapters.

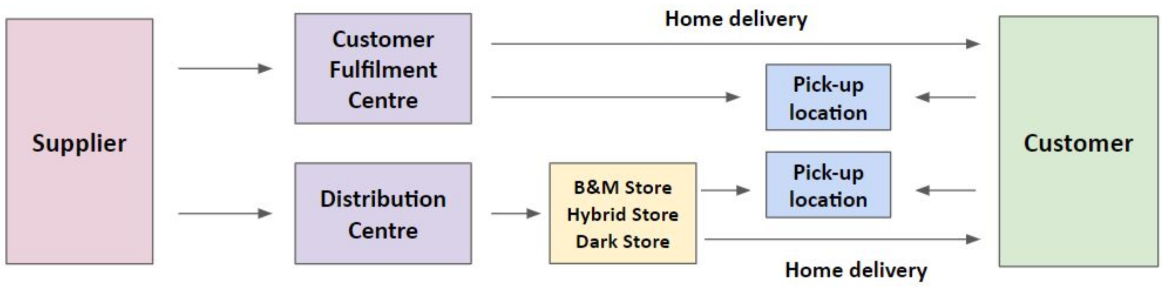

Figure 4: Conceptual presentation of e-grocery logistics network

2.2.1 Distribution

There are two most common types of distribution: two-tier and three-tier:

- In a **two-tier** distribution system the groceries are transported from suppliers to the customer fulfilment centre and there they are unpacked to customer packs, fulfilled and prepared to be dispatched.
- In a **three-tier** distribution there is one more step: once the groceries arrive at the distribution centre they are unpacked to transportation packs and shipped to the retailers who fulfill the online orders and prepare to be dispatched.

2.2.2 Order fulfilment

The food retailers fulfill their online orders using various models. The three main types distinguished in this thesis are: conventional brick-and-mortar (B&M) store, dark store and a hybrid of the two, hereinafter referred to as *omni-store*.

In conventional **brick-and-mortar stores** the online orders are fulfilled in-store, which means that the *offline* customers and fulfilment employees share the same retail area. In this case the replenishment of the goods (and the corresponding supply chain) does not differ from the store without any online orders. The convenience for end-customers is the guiding principle in the design of B&M stores.

In **dark stores** all online orders are fulfilled by the employees in the area inaccessible by the end-customers. The dark store is either operated by only manual labour or with the use of automation, e.g. goods to people stations to increase the operational efficiency. The main design principles of the centre is the speed of order fulfilment. Similarly to B&M stores, dark stores can differ in size from 1,000 m^2 (micro fulfilment centres located close to the end users) to 30,000 m^2 (customer fulfilment centres placed on the outskirts of the cities).

The **omni-stores** are conventional supermarkets that have been equipped with automated micro fulfilment centres on the back of the store to combine the benefits of both models. Depending on the concept, either all online orders are fulfilled from the back of the store or some goods (e.g. perishables) are picked in-store. The retailers retrofit their supermarkets into omnistores in partnership with automated fulfilment companies like Takeoff Technologies (Sedano's, Albertsons, Ahold Delhaize), Dematic (Meijer), Alert Innovation (Walmart) and Fabric.

Figure 5: Omnichannel store types: B&M (left), Omni Store (centre) and Dark Store (right)

2.2.3 End-user delivery

The online orders that have been fulfilled by the retailer can be either picked up by the customers in store or delivered to their home.

The **buy online, pick-up in store (BOPIS)** option allows the customers to buy their groceries with the use of a mobile app or a website and then collect the order from the physical store. The stores offer different ways of handing the groceries to their customers (figure 6). The order can be picked up either at a dedicated counter, at the unmanned grocery locker or by curbside pick-up at the parking next to the store.

Figure 6: BOPIS options - dedicated counter (left), lockers (centre) and curbside pick-up (right)

The **home delivery** is performed by the store employees or a third party delivery company. The delivery can be attended (the groceries are handed to the hands of the customer) or unattended (the order is left in a locker or fridge at customers' house or in the neighbourhood).

Three main factors that influence the choice of delivery model are: convenience for the customer, the time and cost of delivery. Naturally, the BOPIS model skips the last mile delivery shifting the delivery costs on the customers. Home delivery is considered to be more convenient to the customers but it is more costly and often takes longer time than if the customer picked the order by themselves.

2.3 Technological aspects of e-grocery

2.3.1 Refrigeration

Refrigeration in food retail is essential to store some **perishable goods**, i.e. products in which quality deteriorates with time due to environmental conditions like temperature. These goods include dairy products, meat, fish, seafood, fruit and vegetables.

Perishables need to be kept at a specific temperature throughout the journey from supplier to the end customer ("farm to fork"). Depending on the product type, 4 temperature zones can be distinguished (table 2).

Table 2: Temperature zones in food retail

Type	Frozen	Chilled	Fresh	Ambient
Temperature	-18°C / -25°C	-2°C / +4°C	+6 / +16 °C	≈ +20 °C
Examples	frozen fruit, vegetables, meat, poultry, fish	meat products, fresh meat, fresh fish, dairy, some types of fruit	fruit and vegetables	canned goods, dried goods, etc.

If at any point of the cold chain the perishable goods are exposed to inappropriate conditions, they might pose a threat to the health of end customers. To monitor the cold chain, Hazard analysis and critical control points (HACCP) approach is used around the world [27]. The temperature controls are performed by all actors of the cold chain who must be able to prove that the goods were kept in the right conditions to the third party companies or relevant authorities. Traditionally manual measurements with a thermometer have been done by the employees, recently this process becomes more automated with the use of wireless temperature-monitoring technologies, notably RFID - radio frequency identification tags and QR codes.

Storing perishables in the right temperature relies on a proper **refrigeration system** in the warehouse or supermarket. There are three main types of refrigerators systems [15]:

a) **Stand-alone** (self-contained, plug-in): the display cases (0,1 - 2,0 kW) in the supermarkets have an integrated refrigeration system, extracting condenser heat into the sales area;
b) **Condensing units**: simple system (5.0 - 25.0 kW) with one or two compressors and a condenser on the roof or small machine room, usually used in convenience stores and smaller supermarkets;
c) **Centralised** (multiplex): large (20.0 - 1000.0 kW), complex systems with a central unit located in a machine room.

There are multiple types of centralised systems (direct, indirect) with a number of refrigerants (HFCs, ammonia, CO_2). The configuration depends on the size, geolocation of the store (climate), safety requirements and many others. The decision factors specific for refrigeration systems in e-commerce outlets are the following:

a) **Presence of customers in the fulfilment area:** if the facility where e-fulfilment is performed is also open for customers, the safety measures are more strict and some refrigerants (e.g. ammonia) cannot be used.
b) **Urbanisation of the neighbourhood**: in some metropolitan areas permanent presence of an authorised operator is required if ammonia is used as refrigerant [15], [28].
c) **Level of automation**: the more automated and optimised fulfilment, the higher likelihood of choosing cold storage instead of refrigerated cabinets. The fulfilment machines can operate in cold temperatures while humans cannot spend too much time in cold.
d) **Delivery method**: in e-commerce the product must be kept in the right temperature until it is delivered to the customer which requires e.g. additional cold storage for pick-up stations.

These factors are further discussed later in the report.

2.3.2 Fulfilment automation

Order fulfilment is one of the main cost drivers for e-grocery. While in conventional food retail it is done by the customers, e-commerce requires the retailers to do it themselves or outsource it. Due to the fact that warehouses have different functional requirements than commercial spaces, online fulfilment efficiency can be improved with the use of automation technologies. Credit Suisse in their 2017 report distinguished four levels of automation summarised in figure 7. The retailers can choose from the least costly manual fulfilment improvements ($500k - $1M) to the most expensive fully automated solutions ($40+ M).

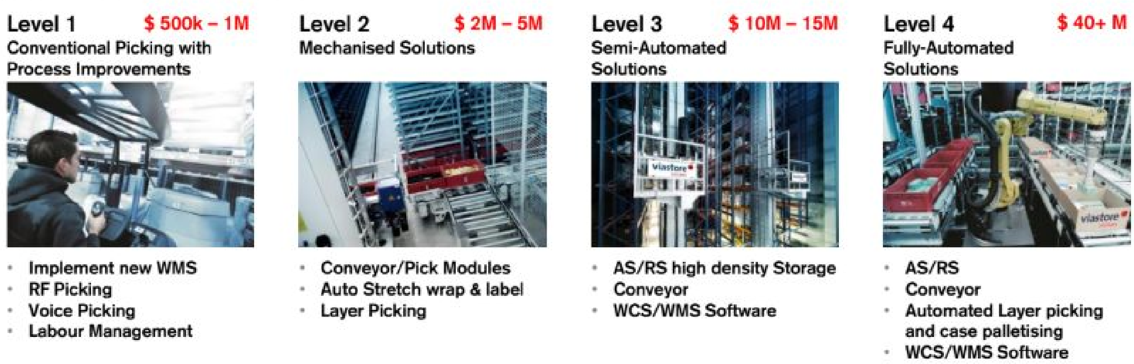

Figure 7: Levels of automation in grocery fulfilment [29]

Fulfilment solutions can also be divided into three categories, depending on their application:

- **Manual picking support/scanning technologies**: radio frequency identification (RFID), barcode scanning, pick-to-light and visual logistics solutions help to find, register and track inventory items in real life. Tracking reduces order fulfilment errors and allows to optimise the purchases.
- **Automated picking/loading solutions:** conveyor belts, automated storage and retrieval system (AS/RS), autonomous guided vehicles (AGV) and shuttles help to achieve better loading/unloading and picking performance. This reduces fulfilment time and labour costs.
- **Warehouse control/management system software and online portals:** incorporating the data obtained from the customer portal into warehouse management system allows for optimisation of the product offering and logistics operations.

2.3.3 Grocery delivery

In all cases of end-user delivery the final consolidation of the order from different temperature zones is performed by the employee right before handing the groceries to the customer or by the customer collecting the order from the self-service pick-up location. Before the consolidation can be made, the products need to be kept in proper temperature zones. Two types of end-delivery temperature control solutions can be distinguished:

- **Active:** refrigerated trucks and lockers are equipped with standalone refrigeration units to maintain the right temperature during storage and delivery of online orders.
- **Passive:** insulated bags, styrofoam boxes and dry ice are used to keep the low temperature of delivered perishable products. Passive solutions are suitable for short storage time. Depending on the delivery procedure, some boxes are disposable (parcel left at customer doorstep) while the others can be used multiple times (when the order is delivered to the hands of the customer or if the customers return the box when they make another order).

2.4 Energy intensity of e-grocery

Food retail, due to the perishable nature of the products, is much more energy intensive than retail of non-perishable products. Most perishables must be refrigerated, not only inside the store but on every step of the journey from the supplier to the customer. In the three-tier distribution system e-commerce influences the cold chain on two levels: order fulfilment and delivery. This paragraph aims to analyse available research on energy intensity (specific energy consumption) of both components and draw initial conclusions on the potential influence of e-commerce on the footprint of the whole food retail.

2.4.1 Energy intensity of order fulfilment

Typically energy intensity of the buildings is measured by energy consumption per unit area. The structure of the energy consumption depends on the functions and requirements that the building needs to fulfill. On average, grocery stores consume 1.5 - 2.5 times more energy per area than other types of shops. In Norway the energy intensity of supermarkets is reported to be 460 kWh/m^2, while for other retail categories it is 200-220 kWh/m^2 [30]. In Sweden the average intensity of supermarkets is 400 kWh/m^2 while for other commercial buildings is less than 265 kWh/m^2 [31].

As online food retail is most widely adopted in the U.S., this country deserves a closer look. Every six years in the U.S. a countrywide Commercial Buildings Energy Consumption Survey (CBECS) is conducted by the Energy Information Administration. The microdata from this survey has been aggregated for this report and presented in figure 8. Three building types have been chosen for comparison: grocery stores (a sample of 48 stores with an average area of 3,500 m^2), refrigerated warehouses (a sample of 21 facilities with an average area of 17,000 m^2) and general retail stores (a sample of 294 non-grocery stores with an average area of 4,000 m^2) [32].

The most energy intensive building type in the analysed dataset is grocery store (565.5 kWh/m^2). It consumes over twice more energy per area than non-grocery retail (250.5 kWh/m^2). Refrigerated warehouses analysed in the dataset (357.0 kWh/m^2) consume 37% less energy than the grocery stores. Refrigeration is the main differentiator in the energy intensity of aforementioned building types, accounting for around 300 kWh/m^2 of grocery stores and 220 kWh/m^2 of refrigerated warehouses.

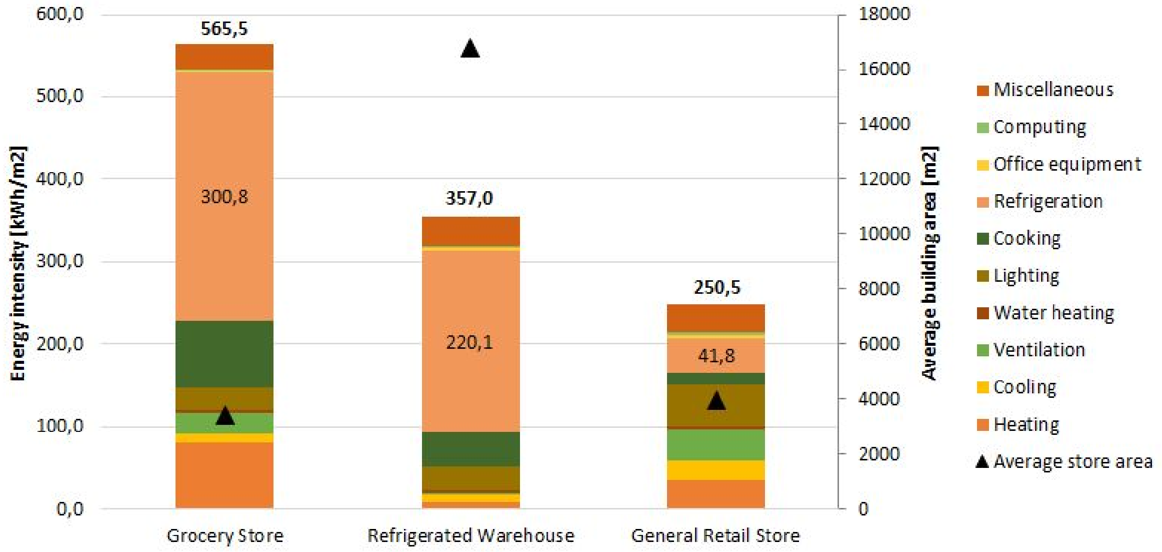

Figure 8: Average energy intensity of buildings in the U.S. in 2012 [32]

The energy consumption for refrigeration in grocery stores of the analysed sample accounts for more than half of the final energy consumption, whereas energy consumption structure in general retail stores is more balanced, with refrigeration, lighting, ventilation and heating as the biggest contributors (figure 9). The main difference in the energy use structure between grocery stores and refrigerated warehouses is heating: in the refrigerated warehouses it is almost negligible. This is due to the fact that a big share of the warehouses area works as a cold room, with heating only reserved for the administration offices.

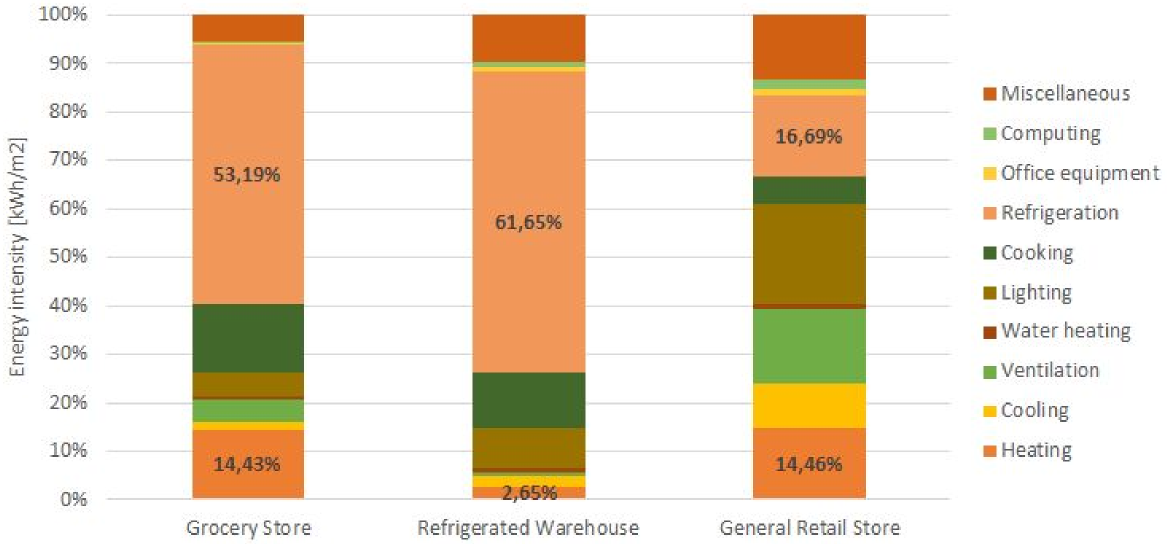

Figure 9: Energy intensity structure of buildings in the U.S. in 2012 [32]

Considering their size, it can be assumed that refrigerated warehouses in the dataset have similar energy characteristics to large customer fulfilment centres. The warehouses in general have a bigger number of SKUs per square meter as they can be stacked almost to the ceiling of the building. Thus, an initial conclusion can be drawn here that fulfilment of online orders at warehouses can be less energy intensive than retail at brick & mortar stores but only under one condition: online fulfilment facilities continuously replace the offline retail infrastructure, rather than supplement it. This assumption may not be realistic. According to market analyses [16], in the foreseeable future the two retail types will coexist (omnichannel). This issue is analysed further in the next chapters.

2.4.2 Energy intensity of grocery delivery

The last mile of online delivery is often seen as the most inefficient part of the supply chain [33]. The customers are dispersed on a large area and they usually require fast delivery which prevents the retailers from optimizing delivery routes. Still, compared to picking the orders in-store (BOPIS) or conventional in-store shopping, home delivery can be less energy intensive. This is due to a shorter distance that the delivery trucks have to cover to fulfill the orders as opposed to the customers driving their cars themselves (figure 10).

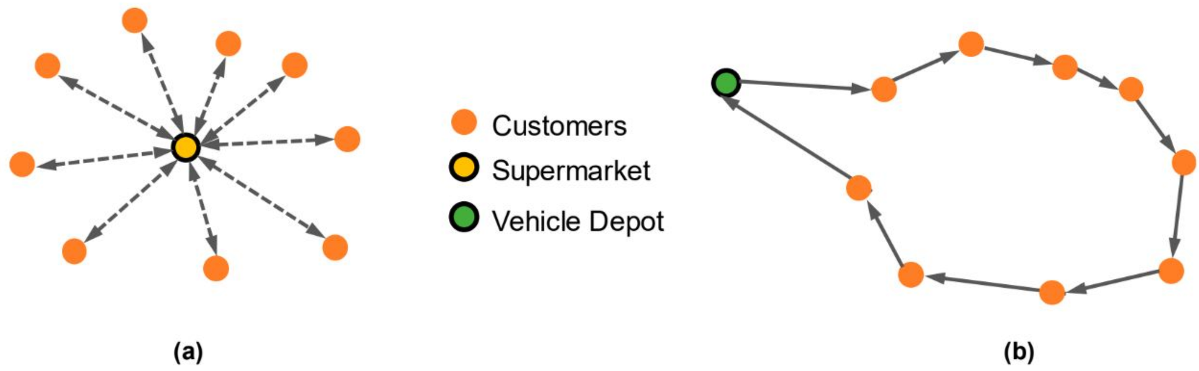

Figure 10: Customer Trips to the Supermarket (a) and Delivery Vehicle Round Tour (b) [34]

Although research that has been performed on this topic is mostly theoretical and not fully conclusive, there is an indication that home delivery can indeed reduce the environmental footprint of food retail [35]. The researchers argue that several factors determine the potential of home delivery in the reduction of energy intensity, e.g.:

- Number of products ordered;
- Success of first delivery;
- Electrification of fleet (impact presented on figure 11).

Figure 11 shows the impact of vehicle type on the final energy consumption of grocery delivery. ICECV are internal combustion engine customer vehicles, ICEFV are internal combustion engine fleet vehicles and FEV are fleet electric vehicles. Both ICE fleet vehicles and electric fleet vehicles offer significant savings on energy consumption: 74% and 92% respectively, when compared to ICE vehicles used by customers.

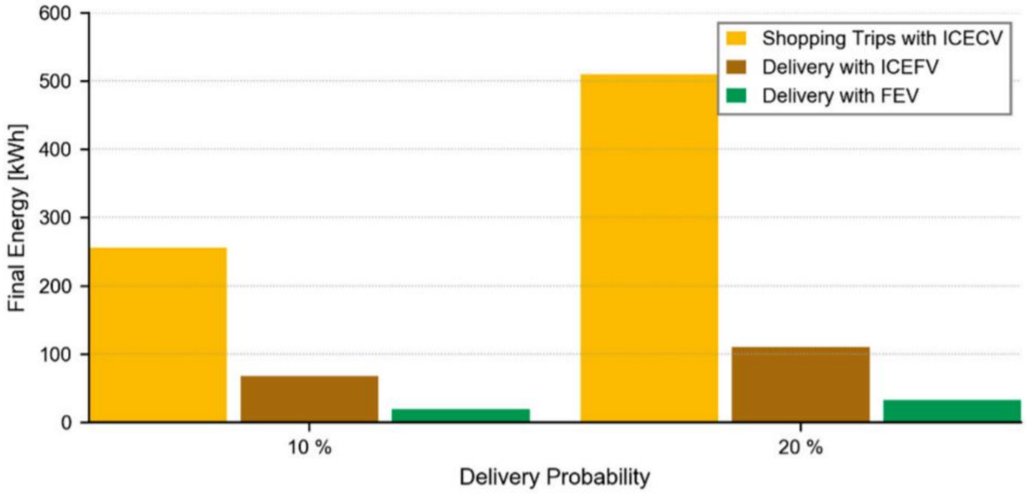

Figure 11: Energy intensity of grocery delivery for different drive types of delivery vehicles [34]

Besides fuel consumption, home delivery of perishable products require special measures to ensure food safety which also increase energy intensity. In order to maintain the right temperature during the transport, the trucks have to be equipped with refrigeration units or the packaging must be properly insulated/filled with dry ice. Further research is needed to calculate the impact of these measures on the energy intensity. In case of end customers picking up the groceries from the store these measures are not required, as it is in customers' interest how they handle the transport. However, retailers have to ensure that the orders are waiting in a suitable refrigerated locker which also consumes additional energy.

2.5 Economical feasibility of e-grocery

In a report published by consultancy company Credit Suisse the economics of online retail are analysed [36]. Seven configurations are compared: 5 fulfilment options and 2 delivery options. Apart from the three fulfilment types presented in chapter 2.2.2., two other options are considered.

3rd party delivery is very similar to in-store fulfilment, except that the employees picking and delivering orders are not working for the retailers. The retailers also use the online platform of the 3rd party company to sell the products. Such a model is popular in the U.S. (Instacart). Although the profit and loss analysis presented in figure 12 suggests that this retail option is the most profitable (22%), in reality the retailers have to share this profit with the 3rd party delivery companies [37]. It is reported that Instacart generates a net profit of approximately 2.0%, not without adding markups on some products offered on the platform. Still, this option is attractive to many retailers, as it allows them to capture the share of the growing e-grocery market without major investments in digital transformation and own fulfilment capabilities. On the other hand, analysts argue that this might be a dead end for the retailers who are giving up control of the customer relationship (and perhaps more importantly, their data) [36]. Therefore, it is recommended that with the growing penetration of e-grocery retailers should look for a more long-term strategy, e.g. investments in fulfilment automation.

Another option broadly discussed in the Credit Suisse report is a customer fulfilment centre (CFC) that is the core of a 2-tier distribution system. Thanks to omitting one level of distribution, one line of costs (around 4%) is eliminated. Moreover, highly automated CFCs can reduce the labour fulfilment costs significantly. On the other hand, such centres are very big (>30,000 m^2) and usually located far from the end-customers which increases the last-mile logistic costs. Another important factor not taken into account in the analysis is significantly higher amortisation and depreciation, due to large investments in the state-of-the-art automated solutions, e.g. robots operating on hive grid as in the newest generation Asda and Ocado warehouses [36]. According to Ocado financial statements, their amortisation and depreciation account for around 5.7% of the total costs [38], while for the offline retailers these costs are usually close to 2%. Moreover, such a solution is a better fit for experienced pure players or third party fulfilment companies rather than offline retailers who are incrementally joining the e-grocery race.

On the side of last-mile logistics, click & collect option offers higher profitability than home delivery (delivery costs lower by 7 percentage points). In this case the delivery costs are shifted on the customers who have to pick their order from the store themselves. Click & collect offers an interesting tradeoff between the convenience and costs that attracted many customers and retailers worldwide. Interestingly, last-mile delivery option popularity highly depends on the country, with home delivery as the most prevalent option in the UK and click & collect dominating the e-grocery in France [36].

Picking methodology	In-store	Dark store	Hybrid	3rd-party	Centralised	In-store	Centralised
Delivery location:	Home	Home	Home	Home	Home	C&C	C&C
Industry leader	Tesco	Tesco	Peapod	Instacart	Ocado	Leclerc	Amazon
Gross margin: £90 basket	**27%**	**27%**	**27%**	**27%**	**27%**	**25%**	**25%**
Costs:		**Cost savings relative to in-store picking + home delivery**					
Distribution to store	-4%	0%	0%	0%	4%	0%	4%
Merchandising	-2%	1%	1%	0%	1%	0%	1%
Stock loss / shrinkage	-1%	0%	0%	0%	0%	0%	0%
Payment charges	-1%	0%	0%	0%	0%	0%	0%
Picking	-9%	2%	2%	9%	5%	0%	5%
Delivery logistics	-9%	-1%	-1%	9%	-2%	7%	5%
Digital marketing	-1%	0%	0%	1%	0%	0%	0%
Web IT	0%	0%	0%	0%	0%	0%	0%
Customer services / CRM	-3%	0%	0%	3%	0%	0%	0%
Savings vs. Store Pick	-	2%	2%	22%	8%	7%	14%
Total direct costs	-29%	-26%	-27%	-6%	-21%	-22%	-14%
Direct P&L per basket	**-1%**	**1%**	**1%**	**21%**	**6%**	**3%**	**11%**

Source: Kurt Salmon, Credit Suisse research

Figure 12: Overall cost comparison of various picking and delivery methodologies [36]

Although 3rd party fulfilment and customer fulfilment centres are interesting examples of handling online grocery orders, they are a good business primarily for the 3rd parties and pure players. The focus of this thesis are the in-house fulfilment types that allow offline retailers to build up their own e-grocery capabilities: in-store fulfilment, omni store and dark store.

3 Methodology

3.1 Case study definition

This thesis project analyses a case of a food retailer, owner of a supermarket chain in Stockholm, Sweden. It is assumed that the penetration of online retail has reached 10% and the retailer has to decide which online fulfilment and delivery option to choose to ensure lowest energy intensity and highest profitability of their operation.

The retailer can choose one of three fulfilment options:

- In-store manual fulfilment with little interference into store infrastructure;
- Omni store adaptation with reduced offline sales area and highly automated micro fulfilment unit located on the back of the store;
- Dark store - new semi-automated fulfilment facility used only for handling online orders.

There are two options of last-mile logistics under consideration:

- Home delivery - the retailer organises transport of the fulfilled orders to the doorstep of the customers.
- Click & collect - the customers pick their orders from refrigerated lockers located next to the store.

The energy and profitability calculation models are developed, the results are compared, discussed and recommendations for retailers are given.

3.2 Properties of comparison

3.2.1 Energy intensity

The energy intensity of supermarkets is usually defined in the literature (e.g. [39], [40]) as the unit of energy per unit of retail area (e.g. kwh/m^2). However, online fulfilment centres differ significantly from the brick & mortar stores in terms of SKUs and total number of products per unit of area. This means that omni stores and dark stores can store and potentially sell more products per square meter than conventional supermarkets. Comparing consumption per area would not say much about the performance of fulfilment, which is one of the key factors in online retail.

Moreover, as suggested in the literature [41], [42], e-commerce has a far broader impact on the environmental footprint than just the one concerning in-store operations. Online shopping changes the logistics, introduces delivery of the products to the end customers and even gives the customers spare time that can be spent on other energy consuming activities. Although this thesis does not aim to analyse in detail each of these elements, it is essential to ensure that its results are relevant for further research on this topic.

Considering these facts, energy intensity in this thesis will be first established with a modelling software per unit of area and then translated into as energy consumed per one receipt (i.e. order) using average number of online orders fulfilled in one year (annual online sales divided by average basket size).

3.2.2 Profitability

In this thesis profitability is defined as EBIT (earnings before interest and taxes). EBIT can be also defined as the gross margin minus operating costs, amortisation and depreciation. The gross margin is defined as net sales minus costs of goods sold (COGS). Both EBIT and gross margin are expressed in percentage of net sales (basket size). Table 3 presents the full list of costs of the retailers with their definitions.

Table 3: Costs in food retail

Cost type	**Definition**
Goods	All costs incurred in bringing the goods to the retailer's distribution centre (production, processing, storage, transportation, etc.).
Distribution	Costs incurred in storage and transportation of goods from the distribution centre to the store/fulfilment facility.
Labour fulfilment	Fully loaded salaries for employees working inside the store/facility.
Home delivery	Costs of labour (drivers), fuel and fleet used for grocery delivery.
Inventory shrinkage	Costs of goods that were not sold due to theft or operational errors/inefficiencies.
Fulfilment charge	Fee put on the retailer by 3rd party fulfilment provider (e.g. automation company).
Energy	Costs of electricity, space heating and water heating.
Rental	Costs of renting the building.
Marketing	Costs of offline and digital advertising.
IT	Costs of the store website and software needed to enable online orders.
Amortisation & depreciation	Expensing the acquisition cost minus the residual value of intangible and tangible assets (e.g. store equipment) over their estimated useful life.
Other operating costs	Franchising, licenses, payment fees, insurance, etc.

3.3 Modelling tools

For the theoretical comparison of energy intensity, each online fulfilment concept has been modelled in CyberMart software. CyberMart is a programme developed by Jaime Arias in 2005 at KTH in Stockholm [43]. It allows to compare different designs of refrigeration systems in supermarkets by calculating the energy use during one year, Total Equivalent Warming Impact and Life Cycle Cost.

Among the input data to the model there are: climate conditions, building envelope characteristics, opening hours, detailed design of refrigeration system and general HVAC system design. Cybermart has a database of the most common refrigeration equipment installed in Swedish supermarkets.

The software is fit for purpose: CyberMart has just enough functions to estimate energy intensity of three online retail types and analyse parameters of the model that have the biggest impact on efficiency of the outlets.

3.4 Assumptions for the energy calculation model

The assumptions about building envelope, HVAC, refrigeration systems and operational details were based on the information provided by industrial partner Danfoss, previous research done at KTH Royal Institute of Technology (thesis project by Eduard Lloret Font [44], doctoral thesis by Jaime Arias [43]), interviews with representatives from the food retail industry and information available online.

In order to achieve results that can be compared, it is assumed that all three buildings are in the same location (Stockholm) and have the same area (3500 m^2). This ensures that the differences in energy intensity are related to the operational properties and building characteristics of the analysed e-grocery models. The CO2 transcritical system has been selected in all three cases as the state-of-the-art refrigeration solution. It has been assumed the omni-store uses a highly automated micro fulfilment unit, the dark store is equipped with some automation solutions (conveyor system, WMS software) while the B&M store only uses manual labour without any picking improvements. The refrigeration capacity of the brick & mortar store has been assumed based on the case study by Eduard Lloret Font [45]. The refrigeration capacity of the omni-store has been calculated by scaling down the sales area and adding a cold storage area for the micro fulfilment unit as in the case of Sedano's supermarket in Miami, Florida [46]. Refrigeration capacity of the dark store has been calculated based on a scaled down layout of Asda online fulfilment centre in Nottingham, UK [47]. The general assumptions made are summarised in table 4. The full list of inputs for the Cybermart model can be found in appendix 1.

Table 4: General assumptions for the energy calculation model

			
	Store #1: Brick & Mortar	**Store #2: Omni-store**	**Store #3: Dark Store**
Location	Stockholm	Stockholm	Stockholm
Total area	3500 m^2	3500 m^2	3500 m^2
Sales area	3500 m^2	2500 m^2	0 m^2
Fulfilment area	3500 m^2	1000 m^2	3500 m^2
Fulfilment type	In-store fulfilment	Automated micro-fulfilment	Semi-automated fulfilment
Refrigeration system	CO2 Transcritical	CO2 Transcritical	CO2 Transcritical
Refrigeration capacity	MT: 160 kW LT: 29 kW	MT: 176 kW LT: 29 kW	MT: 52 kW LT: 23 kW

3.5 Assumptions for the economic analysis model

Assumptions included in the profitability analysis are based on a number of market reports and executive presentations available online. The financial figures are given in USD as most of the data come from retailers in the U.S. It is assumed that the average basket size for different fulfilment models is the same. In the case of B&M and Omni Store both online and offline sales are performed, while in a Dark Store there are only online sales. The general assumptions are summarised in table 5.

Table 5: General assumptions for the economic analysis model

	Brick & Mortar	**Omni Store**	**Dark Store**
Annual sales per customer area [$/m^2]	$6,770	$6,770	$0
Annual sales per fulfilment area [$/m^2]	$677	$30,000	$18,330
Annual sales [$]	$26,000,000	$47,000,000	$64,000,000
Conventional basket size [$/order]	$55.0	$55.0	$55.0
Online (home delivery) basket size [$/order]	$91.0	$91.0	$91.0

The full list of assumptions for the profitability analysis can be found in appendix 2.

3.6 Assumptions for the sensitivity analysis

The e-grocery sector is changing very rapidly and there are several variables (table 6) that may influence the choice of online fulfilment solutions in the future. The sensitivity analysis is conducted for profitability of food retail in order to identify possible areas of increasing net margins by the retailers. The sensitivity analysis of energy intensity is not conducted, since it would require complex calculations which are not within the scope of this research.

Table 6: Sensitivity analysis variables

Analysis	**Variable**	**Values**
Profitability	**Energy intensity**:	-50%/-25%/0%/+50%/+100%
	Delivery costs:	-30%/-15%/0%/+15%/+30%
	Wages:	-30%/-15%/0%/+15%/+30%

4 Energy intensity analysis

The output of energy calculation performed in CyberMart includes hourly power loads of the systems presented in table 7. The data is obtained for an average year. The annual energy intensity per unit area has been calculated by total hourly loads from all systems and subtracting the energy recovered.

Table 7: Output hourly data from CyberMart

Category	**Property**
Indoor/outdoor climate	Indoor temperature, outdoor temperature, relative humidity
Heating	Heat recovered from ventilation, heat recovered from refrigeration, heat from district heating, total heating loads
Air Conditioning	Cold recovered from ventilation, air conditioning, total air conditioning loads
Refrigeration	Medium temperature (MT) compressors, low temperature (LT) compressors, MT condensers, LT condensers, MT refrigeration loads, LT refrigeration loads, total compressors, total energy consumption for refrigeration
Lighting	Total lighting loads
Equipment	Total loads of electrical equipment
Ventilation	Total ventilation loads

4.1 Refrigeration and heating loads

The daily medium temperature refrigeration loads are plotted in figure 13. The MT loads in brick & mortar and omni stores show high sensitivity to outdoor air temperature, with higher loads during warmer days. The omni store has a similar number of MT refrigerated cabinets as the brick & mortar store but it has a bigger cold storage capacity, thus the loads have similar trend but they are approximately 13 kW (300 kWh daily) higher in the omni store. The medium temperature refrigeration loads in the dark store are approximately twice lower than in the brick & mortar and omni store. Dark store MT loads have a very low sensitivity to outdoor temperatures, mainly due to the fact that cold rooms are used instead of refrigerated cabinets. Refrigerated cabinets are in general more susceptible to outdoor conditions (temperature, humidity) due to frequent loading and customers opening doors [48]. However, in case of online fulfilment the cold rooms are entered much more often than in offline retail where they are accessed primarily during store replenishment. Unfortunately, this operational detail cannot be modelled with the use of CyberMart therefore there is an uncertainty embedded in the results of refrigeration loads calculation.

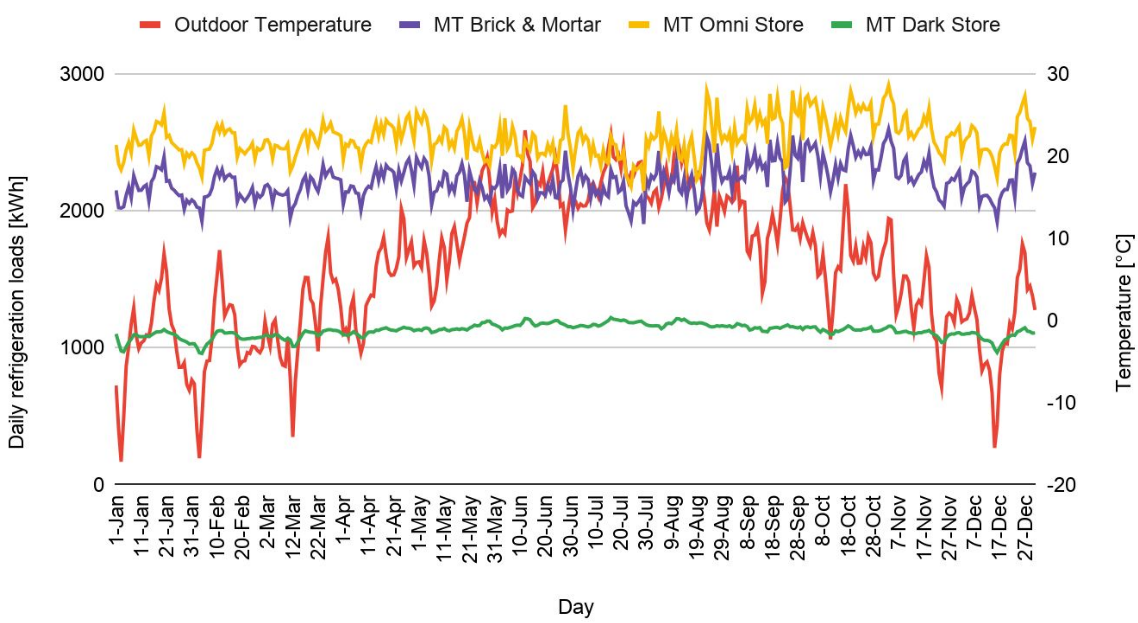

Figure 13: Daily medium temperature refrigeration loads in e-grocery fulfilment

The low temperature refrigeration daily loads are characterised by a similar trend in all three store types (figure 14). The LT loads in the brick & mortar and omni stores are approximately 4-5 times lower than the MT loads, while in the dark store the LT loads are around 2-3 times lower than MT loads. All three retail types use a combination of cold rooms and refrigerated cabinets. Even though the dark store has the highest fraction of cold storage capacity, it is currently not possible to perform online fulfilment with the use of cold rooms only, due to the working conditions requirements (employees cannot spend too much time in the freezing temperatures) and technical constraints (frequent opening of low temperature storage would increase the amount of frost building up on the refrigeration equipment). Thus, dark stores also have several LT refrigerated cabinets to enable manual fulfilment.

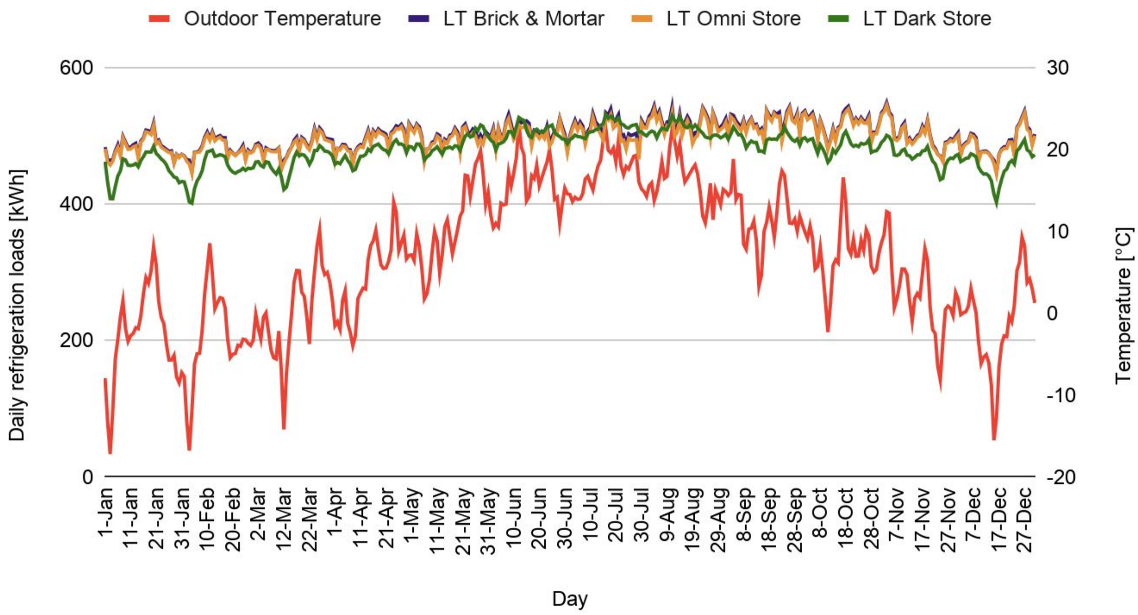

Figure 14: Daily low temperature refrigeration loads in e-grocery fulfilment

It is assumed in the model that all retail types use heat recovery from ventilation (rotary heat exchanger) and refrigeration (heat from condensers). In all cases the heat recovery is sufficient to cover almost all heating needs of the buildings with the heat recovery from refrigeration covering approximately 90% of the demands. An example of monthly heating loads balance is presented on figure 15.

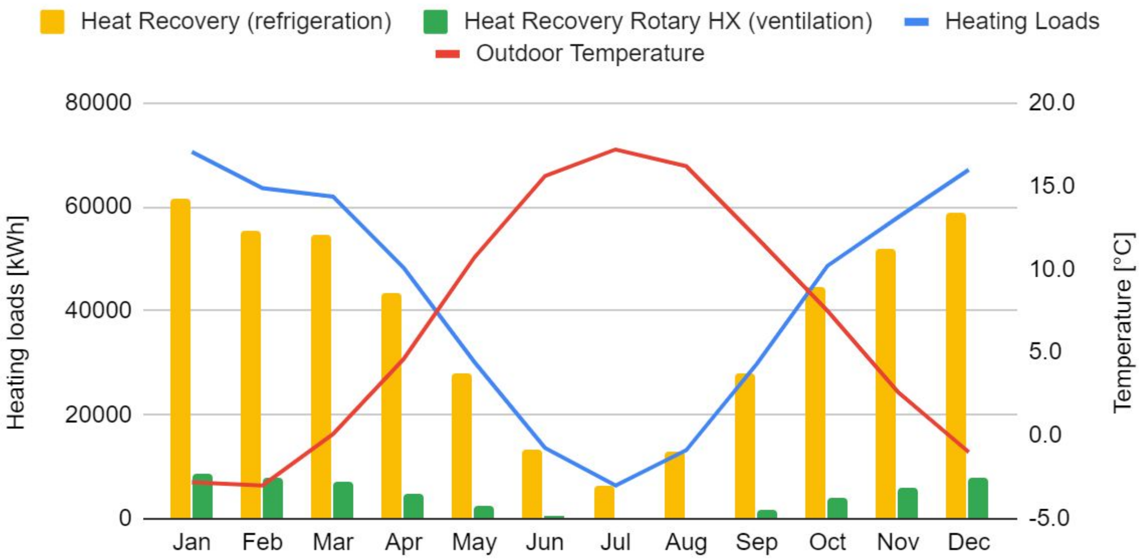

Figure 15: Monthly heating loads and heat recovery in a Brick & Mortar store

Although heat recovery reduces the energy consumption on heating to almost zero, it increases the electrical energy consumption of the refrigeration system. In such case CO2 transcritical system changes its operation from floating condensing mode (condensing temperature follows the ambient temperature to a minimum condensing level) to heat recovery mode, when the condensing temperature is increased to provide the proper temperature for the heating system [49]. Because of that CO2 system operates with a lower refrigeration COP and consumes more energy. A comparison of refrigeration/heating systems with and without heat recovery is presented in figure 16. The seasonal performance factor (SPF) of heat recovery in brick & mortar and omni stores equals 3.85 and 3.87 respectively, while for the dark store it is lower: 2.79.

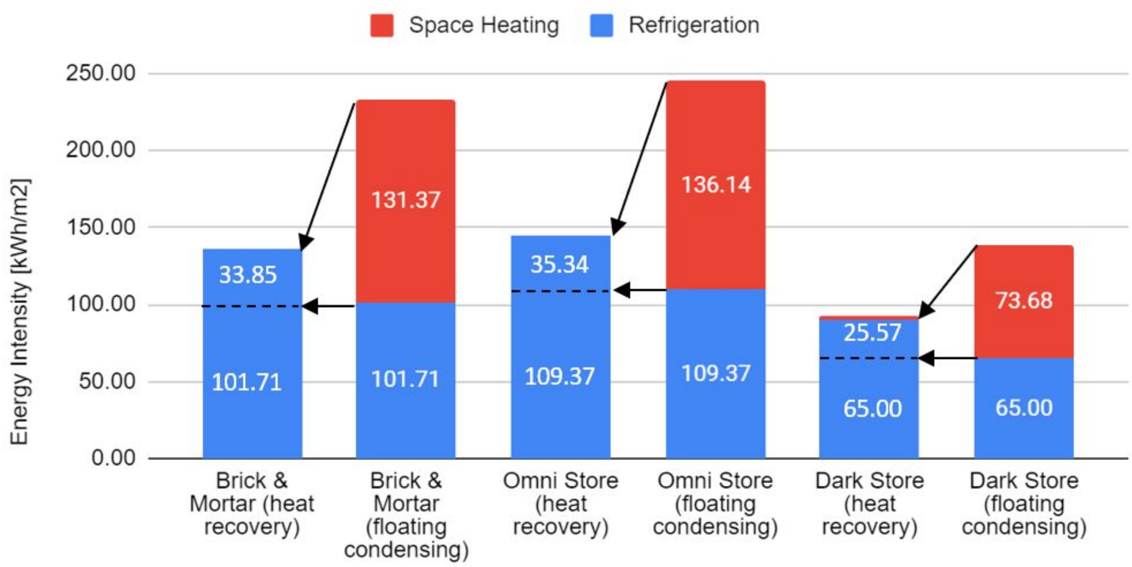

Figure 16: Specific electrical energy use for refrigeration and heating in e-grocery fulfilment

4.2 Energy intensity of online fulfilment

As presented in figure 17, the online fulfilment in a dark store is characterised by the smallest energy intensity per unit area. It is approximately 43% lower than fulfilment in both brick & mortar and omni stores. The reduction in energy intensity is due to:

- Use of cold rooms instead of refrigerated cabinets. Lower capacity is required to refrigerate the same volume of products if properly insulated cold rooms are used and accessed only by employees.
- Use of natural light through skylights. Dark stores are usually standalone warehouses with high ceilings and as such, they can make use of natural light more efficiently than supermarkets having lower ceilings [50]. Moreover, conventional supermarket buildings sometimes have more than one floor, which prevents skylights.
- Lower occupancy than in the supermarket. There are only employees in the dark store and thus, the ventilation loads are smaller.
- No plug-in cabinets. Thanks to the optimisation of space most of the refrigeration can be done with the use of cold rooms instead of inefficient plug-ins.

The omni store has a similar overall energy intensity to the conventional brick & mortar store but its consumption structure differs slightly. The use of additional automated micro fulfilment in omni stores increases energy consumption on equipment and adds medium temperature refrigeration capacity (bigger cold storage). In the same time it replaces half of the plug-in cabinets and reduces ventilation loads, thanks to lower occupancy in the fulfilment area.

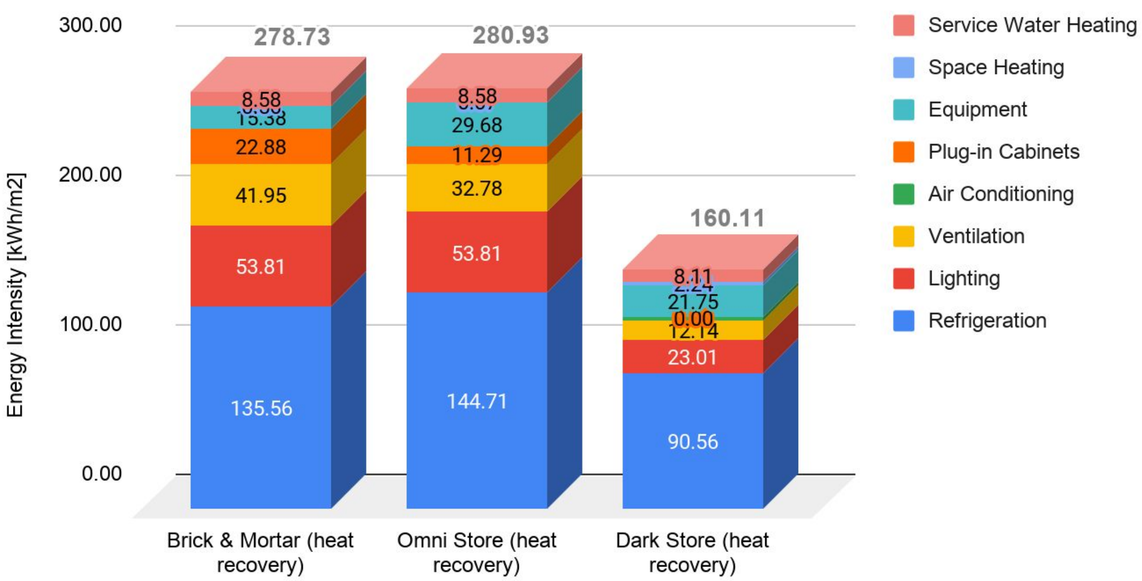

Figure 17: Energy intensity of e-grocery fulfilment per unit area

As explained in Chapter 3.2, the energy intensity results per unit area are translated into energy intensity per order with the use of average sales per unit area and average basket size. Such translation reveals how intensive e-grocery is, taking into account higher density and turnover of product stock for online fulfilment models. The main difference in the results is visible for the omni store model, which is almost 63% less energy intensive per order than the conventional retail as presented in figure 18. The main reason for such significant change is the difference in average annual sales per unit area: omni stores can sell approximately 80% more products than the regular stores (own calculation based on [51]). Dark stores are more approximately 65% less energy intensive and in-store fulfilment is just slightly less energy intensive (6%) than offline retail.

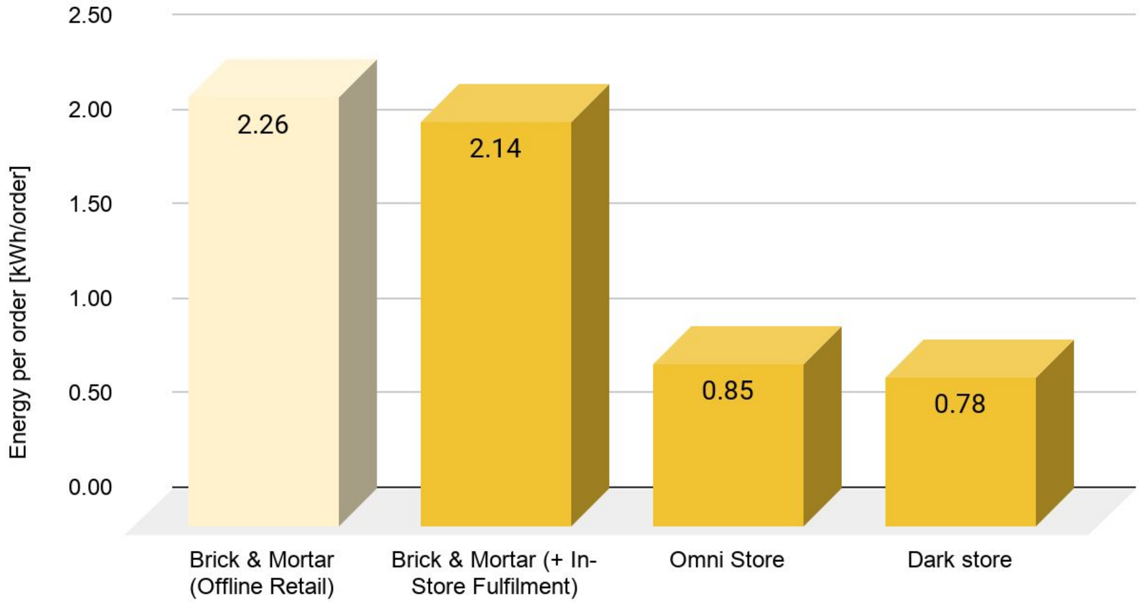

Figure 18: Energy intensity of e-grocery fulfilment per order

4.3 Energy intensity of last-mile logistics

The energy intensity analysis of the last-mile logistics is based on research performed by Hardi and Wagner [34] on the case of e-grocery in one district of Munich, Germany. The researchers assume that in a scenario of 10% e-grocery penetration the distance that has to be covered by motorised vehicles is significantly lower when the orders are delivered home rather than when the customers come to the store to collect their grocery themselves. The assumptions made in that research are summarised in table 8.

Table 8: Assumptions for the e-grocery last-mile logistics [34]

	Conventional / Click & Collect	**Home Delivery**
Urban density [inhabitants/km^2]	18,100	18,100
E-grocery penetration	10%	10%
Sample number of orders	832	832
Total distance travelled with vehicles [km]	388	91.8
Vehicle energy consumption [kWh/100km]	65.8	73.6

Dividing the result of aforementioned analysis by the number of orders delivered, energy intensity per order has been obtained. This allows to utilise the results by Hardi & Wagner in the framework proposed in this thesis. In addition to fuel consumption, two more energy consuming processes are proposed to be included in the analysis. First, in case of home delivery, the products must be kept in the right temperature which requires the use of refrigerated trucks, or more commonly, dry ice placed in the insulated boxes. It has been assumed that 1kg of dry ice is needed per order. The production of 1kg of dry ice (frozen CO2) requires approximately 0.05 kWh using industrial pelletiser [52]. In the case of click & collect option, refrigerated lockers are the most common way to keep the orders cold until the customers pick them up. Assuming that the average collection slot lasts 4 hours [53], the energy consumed by a refrigerated locker equals approximately 0.15 kWh per order. In summary, the click & collect is the most energy intensive last-mile option per order and home delivery consumes the least energy per order (figure 19).

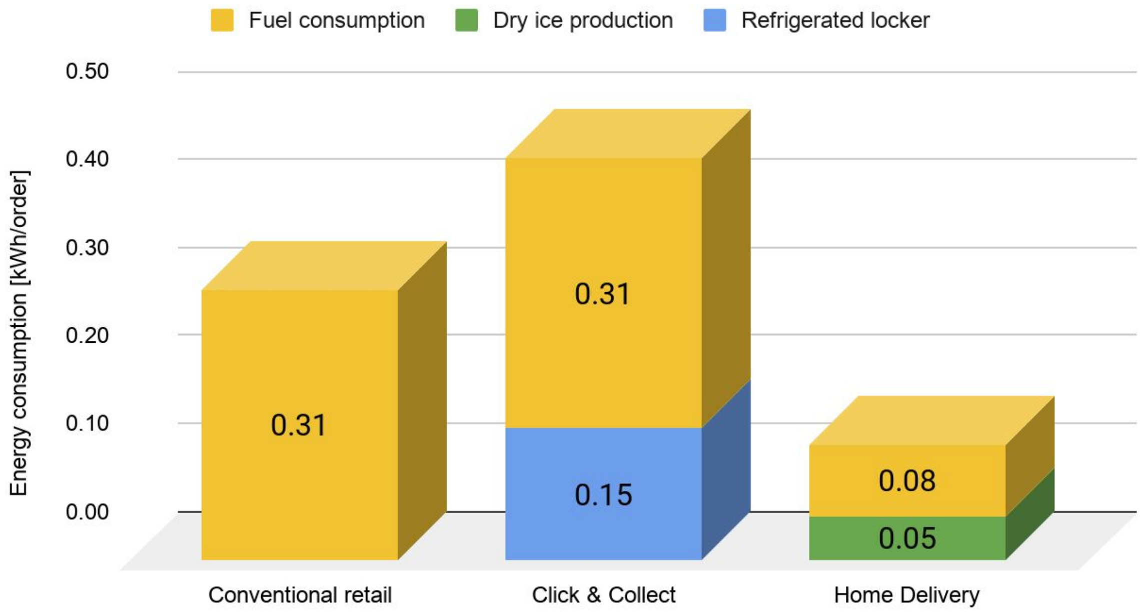

Figure 19: Energy intensity of e-grocery with click & collect

4.4 Energy intensity of online retail

Summing up the results from energy intensity analysis of online fulfilment and last-mile logistics, the energy intensity of online retail is obtained. These results indicate how much energy is used from the moment food products are delivered to the grocery store until the moment when the order is delivered to the customer's home. The energy intensity is expressed in kWh per one order and it is irrespective of the source and payer of this energy (e.g. for click & collect option it is the customer who pays for the fuel used to get the product delivered).

In the case of click & collect delivery and fulfilment using omni store or dark store, the energy intensity per order is approximately 50% lower than conventional retail or click & collect with in-store online fulfilment (figure 20). Although in-store fulfilment alone has a slightly lower energy intensity than offline retail (5% lower), the last mile logistics have a higher footprint due to additional refrigeration needs in click & collect lockers (50% higher).

Figure 20: Energy intensity of e-grocery with click & collect

The energy intensity of online retail with home delivery is lower than conventional retail in all types of fulfilment (figure 21). In-store fulfilment allows for savings of around 12%, omni store fulfilment has 62% lower energy intensity than offline retail, while in dark stores it is more than 64% lower.

Figure 21: Energy intensity of e-grocery with home delivery

The above results confirm the first thesis statement: *if implemented properly, online fulfilment can decrease the energy intensity of the food retail.* Highest energy savings can be obtained when automated fulfilment is used and the products are delivered to the customers with delivery trucks.

The validity of the energy intensity results depends on several important factors that should be taken into account when applying the proposed model for specific cases:

a) Geographical location - the climate zone influences heating, air conditioning and refrigeration loads.
b) Refrigeration/heating system configuration - there are various types of refrigeration/heating systems as well as strategies for their operation which influence the energy efficiency.
c) E-grocery penetration - the higher penetration of e-grocery the more optimised stores can be for fulfilment performance which influences energy intensity of both fulfilment and last mile logistics.
d) Sales density - the more orders can be sold per unit area, the lower energy intensity of online fulfilment. Sales density depends on how fast the products are moving and the number of products that can be stacked per unit area.
e) Population density - urban areas are characterised by shorter average distances from the store to the customer, reducing the energy intensity for last-mile logistics. Higher density also allows for better optimisation of home delivery routes.

The sensitivity analysis of energy intensity to any of these factors would require complex calculations that are not within the scope of this thesis and are recommended for further research. It is also highly advisable to validate the theoretical model with empirical data collected from the emerging e-grocery retailers once more online fulfilment facilities are in place.

5 Profitability analysis

The growth of the e-commerce market throws into question the profitability of food retail. The conventional retail business model is based on the fact that the customers arrive at the stores with their own cars, fulfill the products themselves and deliver the products to their own homes. The retailers try to keep the customers as long in the store as possible to increase the value of the basket. The labour is used to replenish the store, advise customers and help them with the check-out.

When the groceries are bought online the cost structure and operation of a store is turned upside down. In this case the retailer must organise the fulfilment and delivery of the groceries, while the customer choices do not happen in the physical store but on the online platform. The retailer's facilities must excel at operational efficiency with one of the main KPIs being the speed of order fulfilment.

To stay profitable the retailers charge part of the delivery costs to the customers but at the same time, to gain share of the rapidly growing e-grocery market, they try to offer free delivery if the value of the basket is high enough. In this situation, keeping at least the same (very low) margin of 1-3% in food retail is very challenging. The B&M retailers will have to disrupt their current operation and look for ways to cut their costs. This chapter aims to analyse the profitability of three online fulfilment models and present opportunities for decreasing the costs of the retailers.

5.1 Operating costs

One major difference between retail types is the basket size (average spend per one customer). According to GlobalData survey conducted in 2017 [54], the average basket size for conventional grocery is approximately $55, for e-grocery with click & collect it equals $72, while for e-grocery with home delivery the basket size is the biggest, reaching $91. The basket size has an influence on the allocation of some costs (e.g. distribution) but it has not been proven to have influence on the overall profitability of grocery retail [55].

The biggest share of the retail costs are the costs of goods sold (COGS). COGS include all costs of production of the goods, specified in this thesis as everything that happened before the product entered the distribution centre. These costs depend on the retail type, due to a different category mix in e-grocery when compared to conventional retail. Customers buying online prefer to buy products like heavy, bulky washing powders or beverages, which have higher gross margins [56]. Therefore, the COGS in e-grocery are lower per basket than in the conventional retail. However, these costs are assumed to be the same for all three types of online fulfilment and are assumed to be insensitive to any changes in the retail infrastructure. Figure 22 presents the cost breakdown in analysed retail models with home delivery. 100% represents the basket value, i.e. the average amount of money paid by the customers ($55 for offline retail and $91 for online retail with home delivery).

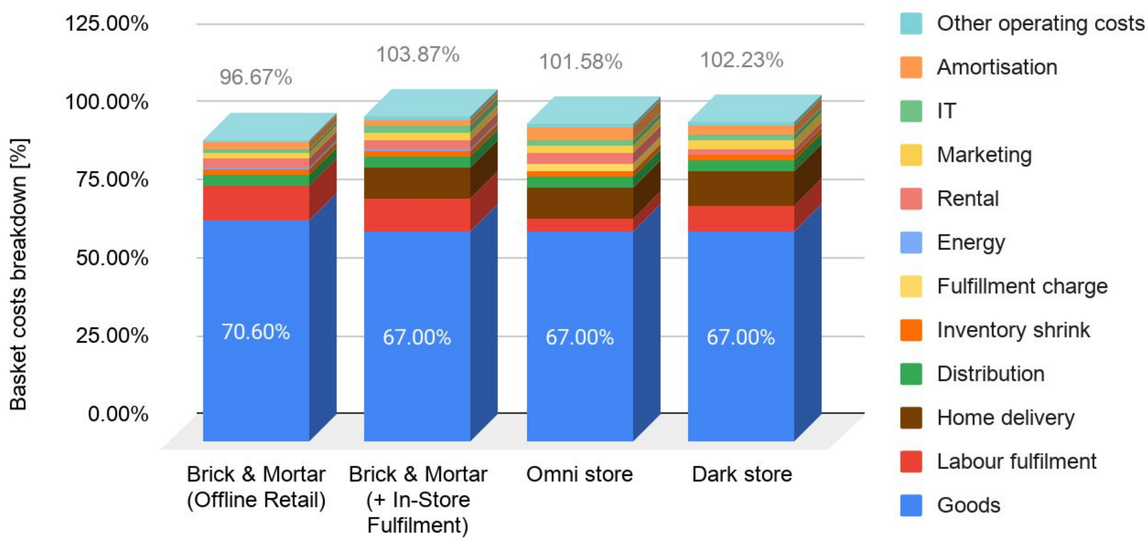

Figure 22: Basket costs breakdown of e-grocery with home delivery

After subtracting the costs of goods sold, a breakdown of operating costs is analysed. As can be seen in figure 23, the two biggest cost components in e-grocery are labour fulfilment (4%-11%) and home delivery (10%-11%). The fulfilment costs are assumed to be a function of the units processed per labour hour (UPH). Fulfilment automation increases operational efficiency of the whole facility, thus the UPH for highly automated micro fulfilment centre in omni store is the highest. High UPH means that more orders can be fulfilled every hour by one employee, so the labour costs per order decrease. The assumptions for the efficiency of automated fulfilment are based on a report by MWPVL International [51].

The average costs of delivery range between $6 - $20 [51] and depend mostly on the business model (own fleet or 3rd party), average distance between the store and the customers, penetration of e-grocery in the neighbourhood and the population density. It is assumed that the delivery costs from the dark store are slightly higher than from supermarkets, as the dark stores are usually located in a less urbanised area.

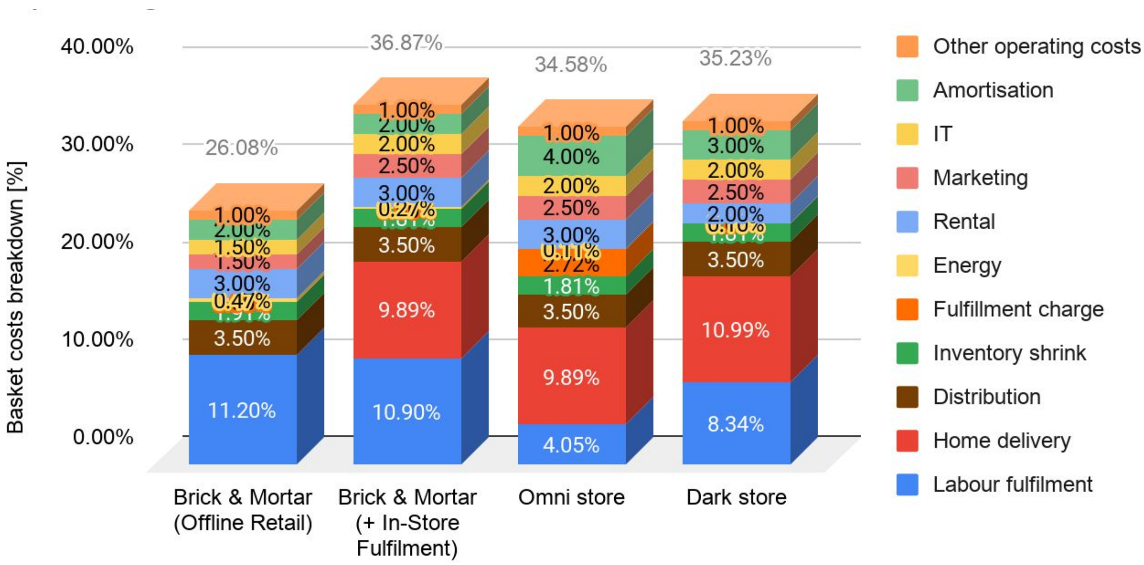

Figure 23: Operating costs breakdown of e-grocery with home delivery

The distribution cost is assumed the same (3,5%) [36] for all retail types under the scope of this research. This cost does not apply in the case of two-tier distribution, as the orders are fulfilled directly in the customer fulfilment centre. The inventory shrinkage indicates how much of the products in stock have not been sold due to inefficiencies and errors in operation (64%) and theft (36%) [57]. On average inventory shrink accounts for almost 2% of the costs per basket. Although automated fulfilment usually helps to manage the stock more efficiently, orders delivered to the customers are sometimes returned due to replacements or packaging damage. Because of that, the inventory shrink is assumed to be the same regardless of the retail type.

Energy costs are calculated based on the energy intensity of the retail types analysed in the previous chapter. Assuming average price of electricity for businesses in the U.S. ($0.114) [58], the energy costs per order range between 0.10% - 0.47% with the automated online fulfilment models at the lower end of the range. Marketing and IT costs are assumed after [58], [59] to be 1.5% each for B&M stores and slightly higher for e-grocery models which require more investments in the online platform and digital marketing.

In the case of omni store, a micro fulfilment unit is usually installed as a turnkey solution and some automation companies add a charge per unit (in this case $0.075/unit) fulfilled with their product [51]. Rental costs are established at 3% for B&M store and omni store ([16], excluding the costs of utilities), while for the dark store they are lower (2%), since dark stores can be placed in less expensive locations.

Depreciation and amortisation costs are related to the value of the equipment used by retailers [51]. High CAPEX on the automation increases the costs that need to be allocated to the omni store (4%) and dark store (3%) sales. The other costs (1%) include payment fees, taxes, insurance, licences, etc.

5.2 Profitability

High fulfilment and delivery costs drastically reduce profitability of e-grocery retail. While offline retail has a low but stable net margin of approximately 3%, profit and loss balance of all e-grocery types remain negative without any additional charges in place (figure 24).

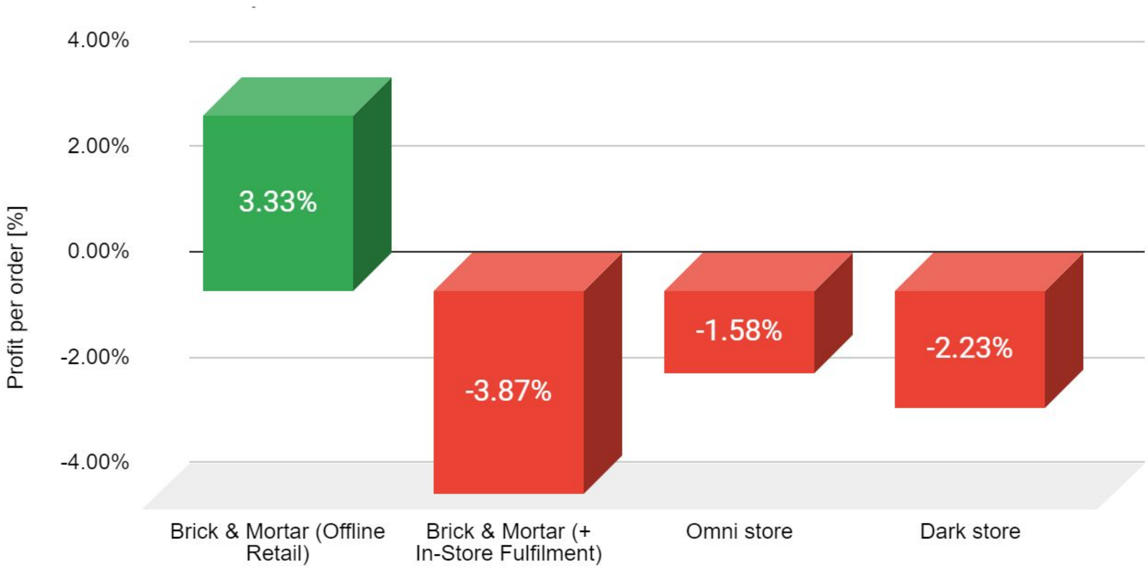

Figure 24: Profitability of e-grocery with home delivery

Although some retailers may keep such a negative balance of e-grocery sales for a certain time and still make a profit overall (e-grocery is still usually no more than 10% of the B&M sales), obviously this is not a sustainable business model. Usually the e-grocers charge the customers for the delivery, as this is the most justified premium service offered by the retailer. It has been suggested that the retailers should add a fee of 4% of the basket value [60] to achieve a profitable model. Adding such a fee to the model presented in this thesis seems to do the job (figure 25). The market review (e.g. [36]) revealed that the additional fee is usually not included in the price of the products (this discourages customers from buying online) but added as a fixed price, sometimes depending on the delivery distance. Moreover, many retailers offer free delivery on the orders above a certain basket size or they offer an annual subscription for a free delivery service [61]. In conclusion, the additional costs of e-grocery are usually borne by customers buying a small number of products.

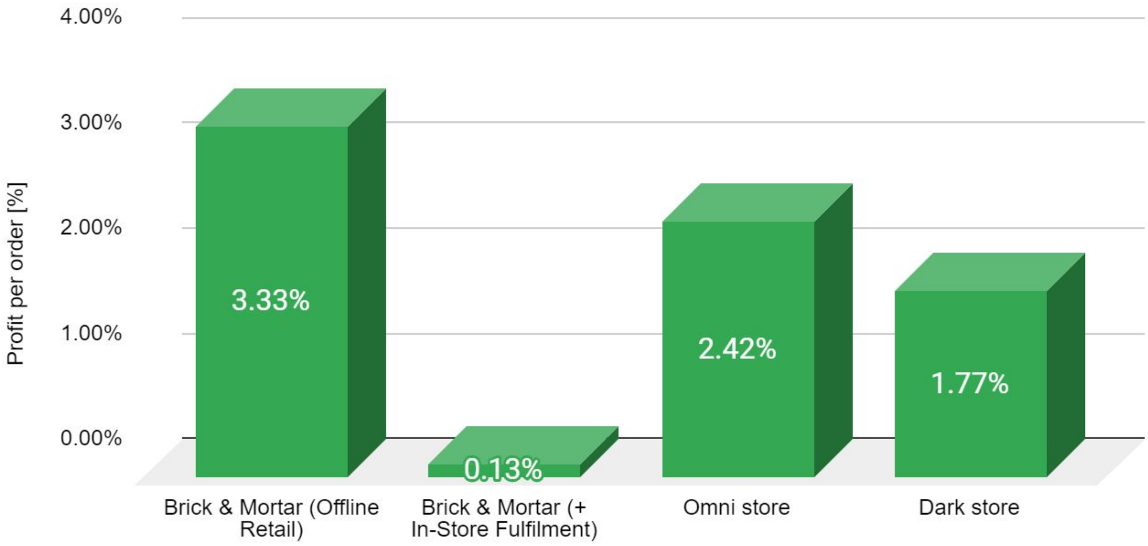

Figure 25: Profitability of e-grocery with home delivery fee (+4%)

Even with the delivery fee, the net margins of e-grocery with home delivery are very thin (0.13% - 2.42%). To evaluate potential of increasing profitability, three operating costs have been further examined in the sensitivity analysis: energy costs, labour fulfilment costs and delivery costs.

5.3 Sensitivity analysis

The sensitivity of profitability to change in energy consumption is an analysis that directly relates to the second hypothesis in this project: *decreasing energy consumption can significantly help the e-grocers achieve higher profitability*.

The energy intensity calculated in the previous chapter pertains to the supermarkets with state-of-the-art refrigeration and HVAC systems. Obviously, many stores are less energy efficient. As described in chapter 2.4.2, average energy consumption in the U.S. grocery stores equals 565 kWh/m^2 which is approximately twice higher than the result of analysis presented in this report for a brick & mortar store. This is why the sensitivity analysis assumes that the energy intensity can be up to 100% higher than concluded in the base scenario. On the other hand, there is always space for improvement in terms of energy efficiency, therefore it is also assumed that the energy intensity can be reduced by up to 50%. The results presented in figure 26 indicate that the sensitivity of profitability to changes in energy intensity is very low. Energy efficiency improvements can increase the net margin by 0.06 to 0.13 percentage point for e-grocery retail and 0.23 percentage point for offline retail. This means that energy intensity is less of a deciding factor for e-grocers when it comes to improving profitability, which proves the second statement wrong.

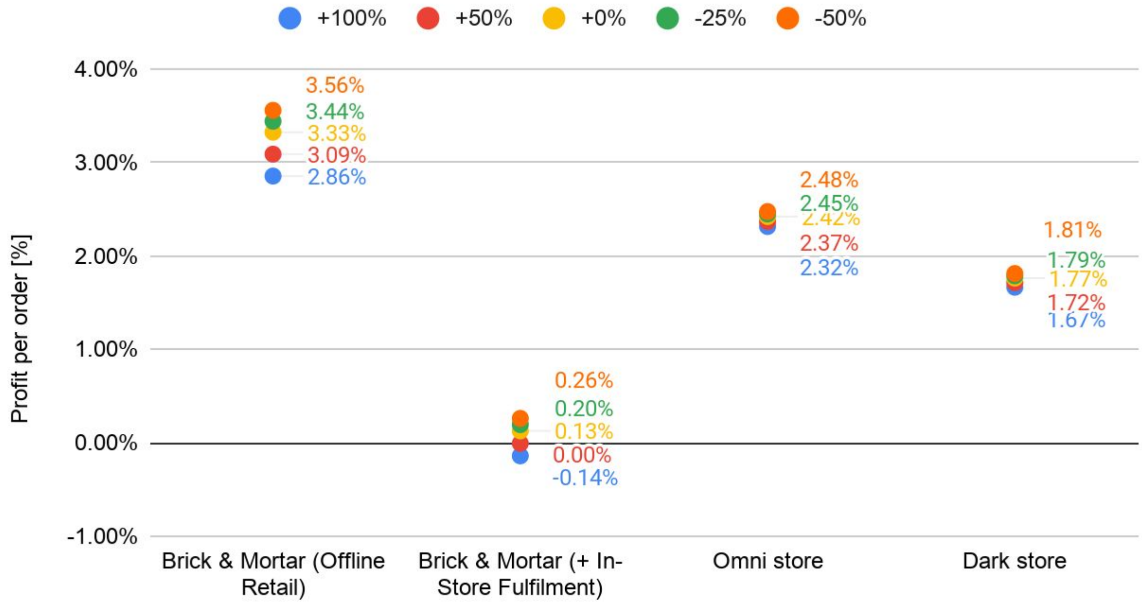

Figure 26: Sensitivity of e-grocery profitability to energy intensity

Much higher impact on the profitability can be found when analysing the fulfilment costs. It has been assumed that the labour fulfilment costs in other countries can be 30% higher or lower when compared to the U.S. As can be seen on figure 27, the profitability is most sensitive to the labour costs in the manual online fulfilment, while the more automated retail is characterised by a small sensitivity to change in wages. This is why the grocery retail, similarly to other labour intensive sectors, will adopt automation much faster in highly developed countries where the salaries are high. In less developed countries the incentive is smaller, therefore manual fulfilment can be more prevalent.

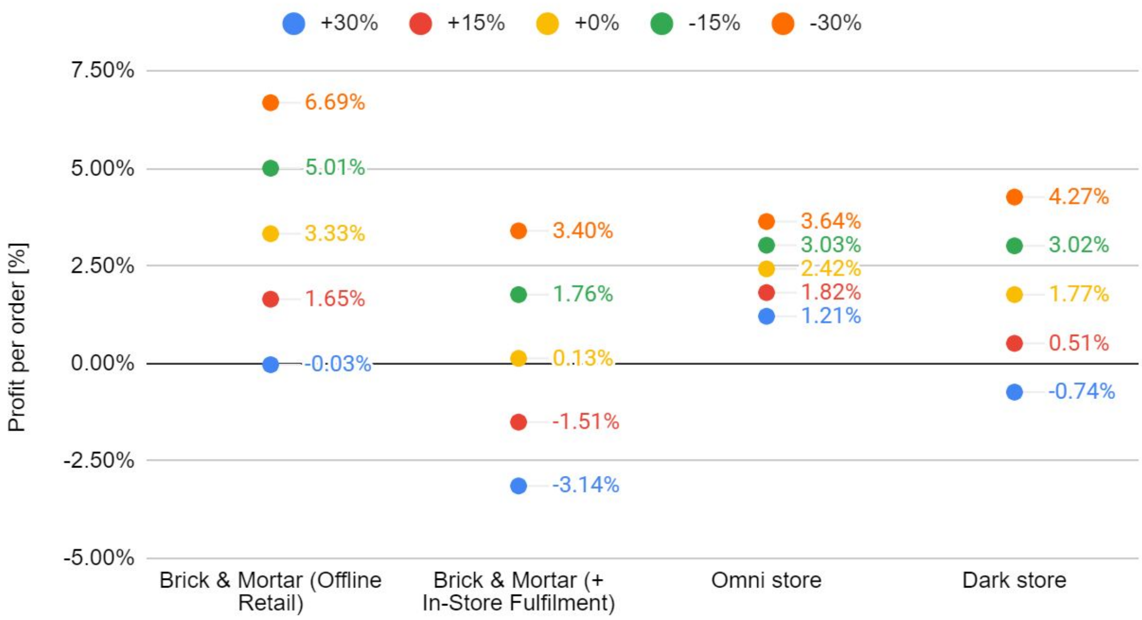

Figure 27: Sensitivity of e-grocery profitability to fulfilment costs

The home delivery costs include salaries of the drivers, fuel consumption and amortisation of the car fleet. These costs mostly depend on the average distance between the store and the customer but also on the fuel efficiency of the fleet (e.g. electric vs. internal combustion engine vehicles [34]). Since these relations have several variables, this analysis has been simplified to indicate the sensitivity to overall changes of the delivery costs. In all cases of e-grocery, profitability increases by approximately 3 percentage points when the delivery costs are reduced by 30% (figure 28). This is why many retailers also offer the click & collect option, where the delivery costs incurred on the customers are significantly lower (depending on the location of the click & collect station) [62].

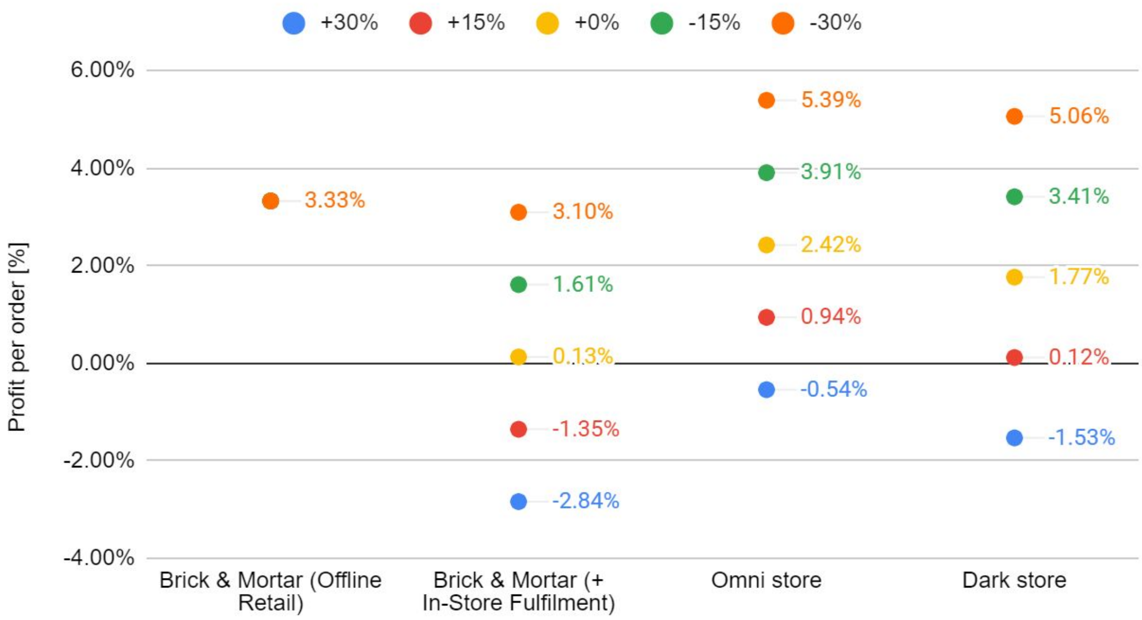

Figure 28: Sensitivity of e-grocery profitability to last mile logistics costs

6 Discussions

6.1 E-grocery as the way to reduce energy intensity of food retail

The results of this research suggest that energy intensity of online food retail is significantly less energy intensive than the conventional retail, provided it is done with the use of automated fulfilment. This stays true under one important condition that the retailers replace their current conventional facilities with e-grocery centres. In some cases the reality is different, as the retailers build up their online fulfilment capabilities in addition to existing infrastructure, providing the customers with omnichannel experience but at a cost of higher energy and carbon footprint.

To achieve a lower energy footprint of the chain of stores, it is advisable to build up the e-commerce capacity incrementally, replacing the existing supermarkets with fulfilment centres or adapting them to allow for more efficient packing (automated micro fulfilment). Due to higher sales density per unit area one fulfilment centre can replace several supermarkets. The highest reduction of energy intensity will be possible once a critical mass of online orders is achieved, allowing for more optimised home delivery routes and better coverage of neighbourhoods with urban fulfilment centres.

6.2 Constraints for uptake of e-grocery

The above considerations imply that a high uptake of e-grocery is desirable on the sustainability standpoint. There are several factors hampering growth of this sector though.

The main constraint is the questionable profitability of the fulfilment and home delivery. Without automation the operational costs of manual fulfilment are very high, especially in countries with high minimum wages. Aside from the profitability issues, there are technical obstacles preventing e-commerce from disrupting the food retail like it did for most other retail sectors. Most of them are connected with different temperature requirements for the perishable products [63]. In case of online orders the products have to be kept in different temperatures up until they are delivered to the customer or the customer collects them. This requires an innovative approach to packaging and last-mile logistics. Currently the reusable packaging is often damaged or thrown to trash. The delivery companies struggle to deliver the groceries at the right temperature. Fresh produce tends to freeze while ice cream tends to melt during transportation. Moreover, the orders delivered to the end customer are often not complete or some of the products are replaced. One of the reasons are the mistakes of the employees that are packaging the groceries. Another one, mostly relevant to in-store fulfilment, is the discrepancy between the online and offline stock of the store.

When it comes to refrigeration, the online fulfilment requires even easier access to the products when compared to the conventional retail area, due the higher speed of goods pickup by the employees. To allow for easier and faster pickup, the refrigerated products are usually kept in cold rooms. In the case of automated MFCs the fulfilment shuttles enter the cold rooms with product racks through air curtains. So far, no MFC company offers automated fulfilment of frozen goods. The companies claim it is very difficult to maintain the low enough temperature and at the same time high accessibility to the enclosed refrigerated space. One other challenge that prevents the stores from full automation of their fulfilment centres is the size constraint. Some goods are too bulky to be stored in customer units on the racks, therefore they need to be picked manually.

6.3 Business opportunities

The above constraints open many opportunities for new businesses and innovation. The retailers need support in planning the shift to online retail which is a good news for consultancy companies specialised in this sector. Automation companies will be another benefactor of the upcoming growth, as they are major enablers of higher fulfilment efficiency. The e-grocery requires a digital transformation of traditional retailers and quite often they outsource companies specialised in e-commerce to help them in this shift.

The investments in fulfilment solutions usually are accompanied by update or introduction of warehouse management systems, giving opportunities for growth of software companies. The other players that have already gained significance are 3rd party fulfilment companies, e.g. Instacart in the U.S. Their model so far has been popular but mainly due to the fact that e-grocery has not achieved high enough penetration for the retailers to run their own fulfilment service.

In terms of refrigeration, cold storage is the technology that will most probably see investments and technical advancements. This may be a window of opportunity for industrial storage OEMs to grow their businesses and a signal for typical refrigerated cabinet manufacturers to watch out for the market shift. Multiple opportunities arise in the refrigerated storage last-mile delivery business. The technical constraints call for innovation in packaging, grocery click & collect lockers, refrigerated vans and new logistic models.

6.4 Limitations and recommendations for future research

The scope of this research is limited to theoretical energy and profitability models with assumptions based on expert knowledge from conducted interviews. This approach is due to insufficient empirical data from the retailers. First, some fulfilment concepts discussed in this thesis (e.g. automated micro-fulfilment) are novel and there are only several facilities operational in the world for longer than 1 year. Secondly, the retailers preferred to keep their operational data (energy consumption, margins) confidential. Thirdly, this thesis was completed during the COVID-19 pandemic and many companies were occupied with implementing e-grocery capabilities. This resulted in a very limited bandwidth to engage in research projects.

It is recommended to follow up this research after the COVID-19 pandemic to validate models presented in this thesis with empirical data from more retailers and further discuss the possibilities of driving down energy intensity of grocery online fulfilment and its costs. It is also recommended to conduct research focused on finding optimal refrigeration systems for automated fulfilment facilities, as well as hybrids of conventional retail and micro fulfilment.

Another area where further research is needed is the economical feasibility of store automation. There are multiple levels of automation that can be chosen by the retailers and it is important to give recommendations of the decision factors that should be taken into account.

There is also little research available on the energy intensity of last mile e-grocery delivery. A simulation in various urban densities would help retailers to optimise their operations with regards to transportation.

7 Conclusions & Recommendations

The initial research hypotheses stated that online fulfilment can decrease the energy intensity of food retail and that this reduction is an essential factor in improving profitability of online fulfilment. The first hypothesis proves to be true: automated fulfilment and home delivery of the grocery orders drive down the energy intensity of food retail per order by 60-70%.

The second hypothesis is proved to be wrong. Although the profitability of e-grocery is a real issue, energy costs account just for a small share of the total retailer costs (0.1% - 0.5%). There are other costs that have a far bigger impact on profitability: labour (4% - 11% of the total costs) and delivery (10% - 11% of the total costs).

Therefore, the primary conclusion of this thesis is that e-grocery supported with automated fulfilment reduces energy intensity of the food retail and that the retailers need to drive down their operational costs to increase penetration of e-commerce. There are several recommendations for the retailers on how to achieve it.

First of all, the level of engagement of retailers in e-commerce should be based on a solid market research with regards to the demand of the customers for online services. Although in the times of COVID-19 pandemic e-grocery penetration rose dramatically (500% in the U.S. between August 2019 and May 2020), it is not certain how many customers will keep buying food online after the pandemic. Thus, it is recommended that the fulfilment capabilities should be developed incrementally, i.e. by equipping the existing supermarkets with micro fulfilment solutions. It is generally advisable to turn to alternative ways of fulfilment (other than in-store fulfilment) when the e-grocery reaches 10% of the total sales for a retailer [24].

Secondly, the well-being and user experience of brick & mortar shoppers should not be put at risk. The prevalent in-store fulfilment (both performed by store employees and third party pickers) seems to be a temporary solution that decreases the level of service for the offline retail customers and is characterised by very high labour costs. The retailers are recommended to divide the retail space into conventional sales area and fulfilment area, either in the same building or separate buildings so that the employees do not bother the customers. With the use of automation, a separate fulfilment area is far more efficient than manual picking which reduces the labour costs and increases profitability of e-grocery.

Fulfilment automation has another unquestionable advantage of increasing the density of products per unit area thanks to stacking of the totes to the heights normally out of reach for the human. This increases the sales per unit area and helps reduce labour fulfilment costs, boosting profitability of e-grocery. Coupled with cold storage solutions (instead of refrigerated cabinets), automated fulfilment can also greatly reduce energy intensity per order.

To drive down the energy intensity of e-grocery even further, fulfilment facilities should be located closer to the end customers. This would cut down the fuel consumed for last-mile logistics. In the first stage of e-grocery adaptation it is advisable to choose click & collect delivery option since it reduces the perceived costs for the customers and allows for higher profitability of the retailers. Once e-grocery achieves high penetration, home delivery should be prioritised in order to further lower the energy intensity of food retail.

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9 Appendices

Appendix 1: Assumptions for Cybermart Model

	Section	Property	Brick & Mortar Store	Omni-Store	Dark Store
Building Envelope	Dimensions	Length [m]	70	70	90
		Width [m]	50	50	39
		Height [m]	6	6	8
		Sale Area [m2]	2500	1500	0
	Wall 1	Area [m2]	420	420	720
		Direction	S	S	S
		Side	Outside	Outside	Outside
		Construction	Medium	Medium	Medium
		Window Area [m2]	20	20	254
		Window Type	Double glass, glass only	Double glass, glass only	Double glass, glass only
		Window Shield	No	No	No
	Wall 2	Area [m2]	300	300	312
		Direction	E	E	E
		Side	Outside	Outside	Outside
		Construction	Medium	Medium	Medium
		Window Area [m2]	20	20	0
		Window Type	Double glass, glass only	Double glass, glass only	Double glass, glass only
		Window Shield	No	No	No
	Wall 3	Area [m2]	420	420	720
		Direction	N	N	N
		Side	Outside	Outside	Outside
		Construction	Medium	Medium	Medium
		Window Area [m2]	20	12	0
		Window Type	Double glass, glass only	Double glass, glass only	Double glass, glass only
		Window Shield	No	No	No
	Wall 4	Area [m2]	300	300	312
		Direction	W	W	W
		Side	Outside	Outside	Outside
		Construction	Medium	Medium	Medium
		Window Area [m2]	12	12	0
		Window Type	Double glass, glass only	Double glass, glass only	Double glass, glass only
		Window Shield	No	No	No
	Roof	Side	Outside	Outside	Outside
		Construction	Medium	Medium	Medium

	Floor	Side	Outside	Outside	Outside
		Construction	Medium	Medium	Medium
		Edge Insulation	No	No	No

Ventilation	Heat Recovery	Heat Recovery	Recirculated Air and Rotary Heat Exchanger	Recirculated Air and Rotary Heat Exchanger	Recirculated Air and Rotary Heat Exchanger
		Recirculate only when close	Yes	Yes	Yes
		Efficiency of rotary heat exchanger	0.7	0.7	0.7
	Open	Winter volume flow [m3]	32000	25000	10000
		Summer volume flow [m3]	32000	25000	10000
		Pressure drop [Pa]	300	300	300
	Close	Winter volume flow [m3]	16000	12500	5000
		Summer volume flow [m3]	16000	12500	5000
		Pressure drop [Pa]	300	300	300
	Daily profile	8.00h - 11.00h	100%	100%	100%
		11.00h - 14.00h	100%	100%	100%
		14.00h - 17.00h	100%	100%	100%
		17.00h - 19.00h	100%	100%	100%
		19.00h - 21.00h	100%	100%	100%
	Infiltration	Open air change	0.3	0.3	0.3
		Close air change	0.1	0.1	0.1
		Entrance air change	5	5	5
Heat sources	Lighting	Open [W/m2]	10	10	5
		Close [W/m2]	1	1	1
	Equipments	Power open [W]	10000	20000	20000
		Power close [W]	1000	1000	1000
		Water production open [gr/h]	1000	1000	1000
		Water production close [gr/h]	500	500	500
	Service water heating	Service water heating [l/day]	1500	1500	1500
	Plug in cabinets	Heat dissipated MT [W]	8000	4000	0
		Compressor Power MT [W]	8000	4000	0
		Heat dissipated LT [W]	5000	2500	0
		Compressor Power LT [W]	5000	2500	0

Heat sour	Occupants	Monday	50%	100%	100%
		Tuesday	50%	100%	100%
		Wednesday	70%	100%	100%

ces		Thursday	60%	100%	100%
		Friday	90%	100%	100%
		Saturday	100%	100%	100%
		Sunday	70%	70%	0%
		Maximum occupants per day	2000	1000	150
		8.00h - 11.00h	15%	15%	33%
		11.00h - 14.00h	30%	30%	33%
		14.00h - 17.00h	15%	15%	34%
		17.00h - 19.00h	30%	30%	0%
		19.00h - 21.00h	10%	10%	0%
		21.00h - 8.00h	0%	0%	0%
Opening hours	**Opening hours**	Monday - Friday open	08:00	08:00	09:00
		Monday - Friday close	21:00	21:00	17:00
		Saturday open	08:00	08:00	09:00
		Saturday close	21:00	21:00	17:00
		Sunday open	10:00	10:00	09:00
		Sunday close	21:00	21:00	16:00
HVAC	**General**	Heating	Yes	Yes	Yes
		Heat Recovery Condensers	Yes	Yes	Yes
		Floating Condensing	No	No	No
		Air Conditioning	Yes	Yes	Yes
	Heating	Source	District Heating	District Heating	District Heating
		Price [kr/kWh]	0.77	0.77	0.77
		Max. Heat Capacity [kW]	150	150	150
		Sala	No	No	No
	Air conditioning	Type	Chiller	Chiller	Chiller
		Max. Cooling Capacity [kW]	30	30	30
	Supermarket temperature	Winter open	21	21	21
		Winter close	16	16	16
		Summer open	21	21	21
		Summer close	21	21	21
	Control	End winter	14	14	14
		Start summer	19	19	19
	Electricity price	Electricity price [kr/kWh]	0.7	0.7	0.7
	Heat Recovery	Condenser Cooler Fluid Temperature After Condenser	38	38	38
	Water	Temperature In [°C]	5	5	5
		Temperature Out [°C]	10	10	10

Refrigeration	**System Design**	Type	CO2 Transcritical	CO2 Transcritical	CO2 Transcritical
		Refrigerant	CO2	CO2	CO2
		Compressor MT	Reciprocating Bitzer	Reciprocating Bitzer	Reciprocating Bitzer
		Dry cooling fluid MT	Propylene glycol	Propylene glycol	Propylene glycol
		Brine MT	Propylene glycol	Propylene glycol	Propylene glycol
		Night cover cabinets MT	Yes	Yes	Yes
		Dry cooling fluid LT	Propylene glycol	Propylene glycol	Propylene glycol
		Brine LT	Carbon Dioxide	Carbon Dioxide	Carbon Dioxide
		Compressor LT	Reciprocating Bitzer	Reciprocating Bitzer	Reciprocating Bitzer
		Night cover cabinets LT	Yes	Yes	Yes
		MT Cabinet models	3	3	1
		MT Cold storages	1	1	1
		LT Cabinet models	3	3	1
		LT Cold storages	1	1	1
	MT Cabinets 1	Model	Electrolux - EE - 2500	Electrolux - EE - 2500	-
		Capacity [kW]	3.2	3.2	-
		Number	15	10	-
		Doors	Yes	Yes	-
	MT Cabinets 2	Model	Electrolux - EE - 3750	Electrolux - EE - 3750	-
		Capacity [kW]	4.8	4.8	-
		Number	10	7	-
		Doors	Yes	Yes	-
	MT Cabinets 3	Model	Electrolux - EE - 1875	Electrolux - EE - 1875	-
		Capacity [kW]	1.9	1.9	-
		Number	15	10	-
		Doors	Yes	Yes	-
	MT Storage 1	Length [m]	10	40	40
		Breadth [m]	8	5	10
		Temperature [°C]	0	0	0
	MT Storage 2	Length [m]	15	15	-
		Breadth [m]	5	5	-
		Temperature [°C]	10	10	-
	MT Capacity	MT Capacity [kW]	**160**	**176**	**52**
	LT Cabinets 1	Model	Electrolux - UB - 3750	Electrolux - UB - 3750	Electrolux - UB - 3750
		Capacity [kW]	2.5	2.5	2.5
		Number	4	4	5

		Doors	Yes	Yes	Yes
	LT Cabinets 2	Model	Electrolux - UB - 2500	Electrolux - UB - 2500	-
		Capacity [kW]	1.16	1.16	-
		Number	4	4	-
		Doors	Yes	Yes	-
	LT Cabinets 3	Model	Electrolux - UBP - 1952	Electrolux - UBP - 1952	-
		Capacity [kW]	0.66	0.66	-
		Number	4	4	-
		Doors	Yes	Yes	-
	LT Storage	Length [m]	4	4	20
		Breadth [m]	9	9	7
		Temperature [°C]	-20	-20	-20
	LT Capacity	LT Capacity [kW]	**29**	**29**	**23**

Appendix 2: Assumptions for the profitability analysis

Parameter	Brick & Mortar (Offline Retail)	Brick & Mortar (+ In-Store Fulfilment)	Omni Store	Dark store
Customer area [m2]	3,500	3,500	2,500	0
Fulfilment area [m2]	0	3,500	1,000	3,500
Annual sales per customer area [$/m2]	$6,770	$6,770	$6,770	$0
Annual sales per fulfilment area [$/m2]	$0	$677	$30,000	$18,330
Annual sales [$]	$23,695,672	$26,065,239	$46,925,480	$64,156,575
Online sales	$0	$2,369,567	$30,000,000	$64,156,575
Conventional basket size [$/order]	$55.0	$55.0	$55.0	$55.0
Online basket size [$/order]	$91.0	$91.0	$91.0	$91.0
COGS (cost of goods sold) [$/order]	$38.83	$60.97	$60.97	$60.97
COGS (cost of goods sold) [%]	70.60%	67.00%	67.00%	67.00%
Annual conventional transactions per m2	123	123	123	0
Annual online orders per m2	0	7	330	201
UPH (units processed per labour hour) [units/hour]	0	65	175	85
Minutes to process order	0	40	15	30
Store personnel [$/order]	$6.16	$9.92	$3.69	$7.59
Store personnel [%]	11%	10.9%	4.1%	8.3%
Home delivery [$/order]	$0.0	$9.0	$9.0	$10.0
Home delivery [%]	0.0%	9.9%	9.9%	11.0%
Inventory shrink [$/order]	$1.05	$1.65	$1.65	$1.65
Inventory shrink [%]	1.91%	1.81%	1.81%	1.81%
fulfilment charge [$/order]	$0.0	$0.0	$2.5	$0.0
fulfilment charge [$/order]	0.0%	0.0%	2.7%	0.0%
Distribution [$/order]	$1.93	$3.19	$3.19	$3.19
Distribution [%]	3.50%	3.50%	3.50%	3.50%
Annual energy consumption [kWh/m2]	278.73	278.73	280.93	157.8
Energy [€/m2]	$31.78	$31.78	$32.03	$17.99
Energy [$/order]	$0.26	$0.24	$0.10	$0.09
Energy [%]	0.47%	0.27%	0.11%	0.10%
Energy per order [kWh/order]	2.26	2.14	0.85	0.78
Rental [$/order]	$1.65	$2.73	$2.73	$1.82
Rental [%]	3.00%	3.00%	3.00%	2.00%
Marketing [$/order]	$0.83	$2.28	$2.28	$2.28
Marketing [%]	1.50%	2.50%	2.50%	2.50%
IT [$/order]	$0.83	$1.82	$1.82	$1.82
IT [%]	1.50%	2.00%	2.00%	2.00%
Depreciation & amortization [$/order]	$1.10	$1.82	$3.64	$2.73
Depreciation & amortization [%]	2.00%	2.00%	4.00%	3.00%

Other operating costs [$/order]	$0.55	$0.91	$0.91	$0.91
Other operating costs [%]	1.00%	1.00%	1.00%	1.00%
Net margin [$/order]	$1.83	-$3.52	-$1.43	-$2.03
Net margin [%]	3.33%	-3.87%	-1.58%	-2.23%
Delivery charge [$/order]	$0.0	$3.6	$3.6	$3.6
Delivery charge [%]	0.00%	4.00%	4.00%	4.00%
Net margin after delivery fee [€/order]	$1.83	$0.12	$2.21	$1.61
Net margin after delivery fee [%]	3.33%	0.13%	2.42%	1.77%

Appendix 3: Retailer costs breakdown - available sources

Figure 75: Overall cost comparisons of various picking and delivery methodologies

Picking methodology	In-store	Dark store	Hybrid	3rd-party	Centralised	In-store	Centralised
Delivery location:	Home	Home	Home	Home	Home	C&C	C&C
Industry leader	Tesco	Tesco	Peapod	Instacart	Ocado	Leclerc	Amazon
Gross margin: £90 basket	27%	27%	27%	27%	27%	25%	25%
Costs:		**Cost savings relative to in-store picking + home delivery**					
Distribution to store	-4%	0%	0%	0%	4%	0%	4%
Merchandising	-2%	1%	1%	0%	1%	0%	1%
Stock loss / shrinkage	-1%	0%	0%	0%	0%	0%	0%
Payment charges	-1%	0%	0%	0%	0%	0%	0%
Picking	-9%	2%	2%	9%	5%	0%	5%
Delivery logistics	-9%	-1%	-1%	9%	-2%	7%	5%
Digital marketing	-1%	0%	0%	1%	0%	0%	0%
Web IT	0%	0%	0%	0%	0%	0%	0%
Customer services / CRM	-3%	0%	0%	3%	0%	0%	0%
Savings vs. Store Pick	-	2%	2%	22%	8%	7%	14%
Total direct costs	-29%	-26%	-27%	-6%	-21%	-22%	-14%
Direct P&L per basket	-1%	1%	1%	21%	6%	3%	11%

Source: Kurt Salmon, Credit Suisse research

Figure 2. Food Retailing Operating Costs

Total net company sales	**100.0%**
Cost of goods sold	**70.7**
Gross Margin	**29.3%**
Total payroll	**11.2%**
Employee benefits	**3.6**
Property rental	**1.8**
Depreciation & amortization	**1.4**
Utilities	**1.4**
Supplies	**1.0**
Maintenance and repairs	**0.7**
Taxes and licenses	**0.4**
Insurance	**0.3**
All other operating expenses	**4.3**
Total operating costs	**26.3%**

Note: Percentages may not add up to 100 percent due to rounding.
Source: FMI, *The Food Retailing Industry Speaks, 2008*

Table I Comparison of Streamline and a typical superstore

	Typical supermarket* (%)	Streamline (%)
Cost of goods sold	75	72
Operating costs	17	13
Distribution	4	6
Corporate overheads	3	3
Net profit (%)	1	6

Note: * Figures compiled by Smart Store, a research-and-development initiative at Andersen Consulting

Source: Macht (1996)

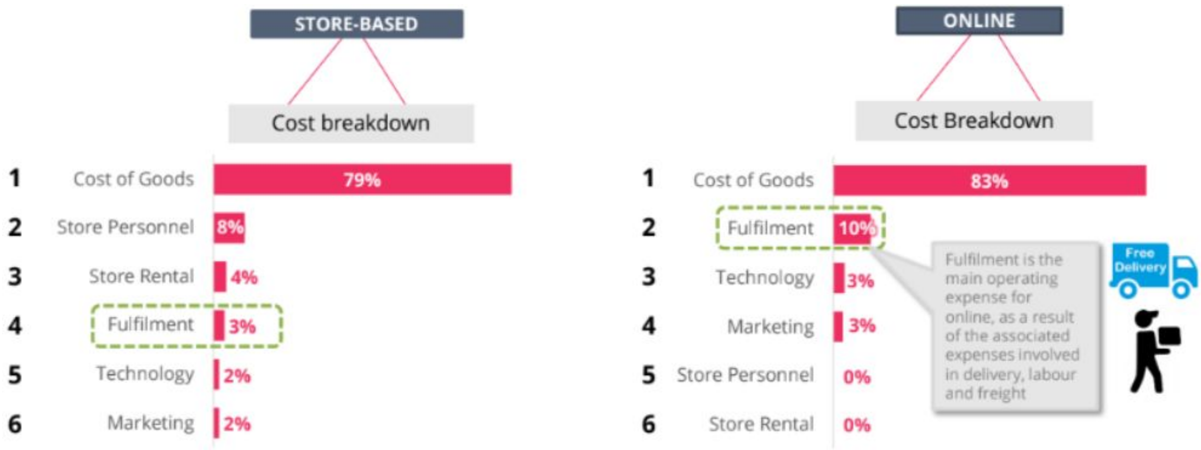
P&L comparison grocery bricks & mortar vs. pure player

	Bricks & Mortar	Pure Player
Revenue	100	100
Gross margin	30	30
Gross income	30	30
Costs total	24	26.5
Rent stores	4	0
Personnel	9	4
IT	1.5	3
Marketing	1.5	2.5
Distribution	3	12
others	5	5
EBITDA	6%	3.5%
depreciation & amortisation	2%	3%
EBIT	4%	0.5%

Source: FRC research team, indicative calculation

Table 5.2 Cost models of store and online grocery retailers: an example from the UK

	MORRISONS 52 weeks ended 1 Feb. 2014 Store:online sales = 100:0 % of sales	SAINSBURY 52 weeks to 15 Mar. 2014 Store:online sales = 95:5 % of sales	OCADO 52 weeks to 30 Nov. 2014 Store:online sales = 0:100 % of sales
Revenue	100	100	100
Cost of sales	93.9 (1)	94.2	67
Distribution costs			26.7 (2)
Employment costs	11.2	10.2	17.8
Depreciation charges—property, plant, equipment	1.9	2.2	4.2
Operating lease rentals			1
Administrative expenses	2.0 (3)	1.9	9.0 (4)
Operating profit before tax, JV & exceptional items			1.5



Source: PlanetRetail RNG

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