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THE CHALLENGE OF A SUSTAINABLE E-COMMERCE SUPPLY CHAIN

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ABSTRACT

The rapid rise of e-commerce in recent years challenges companies to cope with unprecedented parcel volumes and also to comply with their sustainability goals. In the literature exists a variety of recommendations for sustainable measures along the supply chain. The aim of this thesis was to demonstrate the extent to which sustainable warehousing measures are used in practice and whether these are sufficient for environmental protection. A qualitative research approach was chosen, including a case study of a leading logistics company. The results showed that the emissions of the increasing global transport activities cannot yet be compensated by the sustainability efforts of today. Low business incentives and high complexity of sustainability practices are obstacles. Ultimately, a sustainable trend reversal can only succeed if technological progress is not only used to expand e-commerce business models but also to design innovative, cost-effective, and simple-to-implement solutions in the future.

Keywords: Sustainability; E-commerce; GHG-emissions; Green Warehousing; Electromobility

INDEX

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

B2B - Business to business

B2C - Business to customer

C2B - Customer to business

C2C - Customer to customer

CO2 - Carbon dioxide

E-commerce - Electronic commerce

GHG - Greenhouse gases

HVAC - Heating, ventilation, and air conditioning

LCIA - Life cycle impact assessment

LEED - Leadership in Energy and Environmental Design

LPG - Liquefied petroleum gas

LSCM - Logistics and supply chain management

UPS - United Parcel Service of America

1 INTRODUCTION

1.1 Purpose definition

The advancing digitalization around the world is giving companies new opportunities to expand their business. This development has a particular impact on the retail sector, which has been revolutionized in recent years by the emergence of e-commerce. Forecasts predict that by the year 2022, one in five retail purchases worldwide will be made online (Lipsman, 2019). Consequently, this leads to enormous parcel volumes that must be delivered to the end consumer around the world, regardless of any distance. Here, especially logistics companies come to the fore, which have to handle these unprecedented volumes.

Alongside this challenge of avoiding bottlenecks along the supply chain, the question of sustainability is also moving into the spotlight. Global companies anchor ambitious sustainability goals in their strategies and commit themselves to the 2030 agenda for sustainable development set by the United Nations. These corporate commitments are fundamental to the future of planet earth. A variety of issues affect the e-commerce sector, with “Climate Action” and “Sustainable Cities and Communities” being of particular importance. The following understanding of the companies is crucial here. On the one hand, sustainability efforts must be targeted at the global level of transport activities. In the best case, solutions must be found which create a global climate-neutral supply chain. On the other hand, sustainable concepts must also be promoted at the local level in communities and cities to enable a liveable and climate-friendly life through the use of modern technology (United Nations, 2021).

However, the legitimate question arises: how realistically are these goals? How can companies reduce their greenhouse gas (GHG) emissions and achieve their goals despite increasing capacity demands and transport activities? This paper will revolve around this core question, with the main focus on finding sustainable answers in the area of warehousing. Warehouses are among the largest emitters of corporate emissions but at the same time offer sufficient research material for a sustainable design. In order to establish a reasonable link to the practices implemented in reality, a case study will be conducted with the logistics service provider United Parcel Service.

1.2 Research objectives

Based on this, the following research objective was determined:

Analyzing the relationship between the increasing demands of e-commerce and minimizing the carbon footprint.

The term carbon footprint is used as a measure of carbon dioxide emissions caused by the operational activities of a company (Cambridge Dictionary, 2021). The opportunities to reduce the carbon footprint along the supply chain are vast. However, in terms of scope, the main focus of this paper will be on the sustainable design of warehouses.

1.3 Research questions

The following research question is answered:

How can logistics companies minimize their carbon footprint despite the increasing volume of e-commerce parcels?

This main question is accompanied by three sub-questions, which were set up to answer the research question progressively.

Research Sub-question 1:

To what extent does the e-commerce boom influence the capacity utilization of logistics companies and danger their sustainability goals?

Research Sub-question 2:

What technologies are used at warehouses to reduce energy demand and pollutant emissions?

Research Sub-question 3:

To what extent does current technology in warehouses provide charging infrastructure for electric fleets?

1.3 Scope of the research

Although the first online purchase was made in the year 1994 (Eder, 2019), this study refers to the period from which the e-commerce sector began to play a relevant role in the retail sector. Meaningful data can be found from 2013 onwards. The end of the study period is strongly dependent on the available data. Complete data can be found up to the year 2017, whereby forecasts are also taken into account for the years above.

The entire e-commerce supply chain consists of numerous stages. These can differentiate depending on the respective sector and the selected logistics model of the company. It also implies that there is a variety of warehouse types. In this paper, the focus is on parcel hubs, sorting centers, and parcel delivery centers, which hardly differ from each other in their design. These are mainly operated by logistics companies and serve the purpose of fast delivery of goods to other businesses or to the end consumer.

The scope of the research includes all activities within the warehouse that contribute significantly to the company's carbon footprint and can be investigated from a sustainability perspective. On the one hand, the energy-intensive systems of lighting; heating, ventilation & air conditioning systems (HVAC); and material handling equipment are covered. On the other hand, the possibility of setting up charging infrastructures for electric vehicle fleets, which have a central role in electromobility, will also be discussed. Under this topic, it should be mentioned that further processes of e-mobility which go beyond the operation area of the warehouse are not in the focus of this work.

Furthermore, it should be noted that the company examined later in the case study, United Parcel Service, is an internationally operating enterprise with a globally distributed supply chain. In order not to go beyond the scope of this work, it was decided to concentrate on the two major markets of the company: the USA and Europe.

2 PRESENTATION OF THE CONTEXT

The chapter serves to conceptualize the research objective with the help of theoretical models and recommendations from the literature. It will be used as the content basis for the elaboration of the case study and help to classify the findings.

2.1 E-commerce as B2C and B2B

Electronic commerce (e-commerce) describes a business model that enables individuals and companies to buy and sell products and services over the Internet (Bloomenthal, 2020). The possibilities of information technology in the form of online shopping and electronic payment transactions simplify the interactions between the seller and the buyer. Burt and Sparks (2003) express these activities as a unification of information flows, capital flows, business flows, and logistical activities. This unification creates two main advantages benefits. Firstly, the buyer's comfort level increases and secondly, the seller manages to identify new sales channels around the world, which might create a competitive advantage over its rivals (Torabi, Hassini, & Jeihoonian, 2015).

The sector is expanding rapidly around the world, in both developed as well as emerging economies, and is seen as an important pillar for the development of the entire global economy (Barenji, Wang, Li, & Guerra-Zubiaga, 2019). Mainly, it can be explained by the advancing internet access and adoption worldwide, so that the number of digital buyers is increasing significantly every year, reaching the milestone of more than 2 billion by the year 2020 (Coppola, 2021).

Figure 1 illustrates the development of the sales volume of the e-commerce sector from 2017 to 2023 worldwide, partly as estimated forecasts. The industry is expected to exceed $6.5 trillion in sales by 2023, representing an increase of over 2.7 times since 2017. Although annual growth is declining year after year, the share of e-commerce purchases in the overall retail sector is steadily growing. By 2022, one in five retail purchases will be made online (Lipsman, 2019).

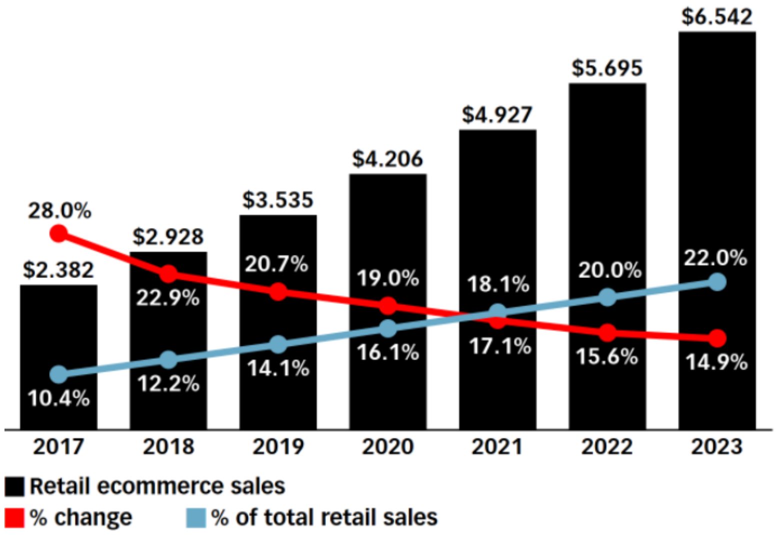


Figure 1. Retail e-commerce sales worldwide, 2017-2023, trillions.
Source: *(Lipsman, 2019)*

However, this tremendous growth in just a few years can only be cushioned if the modernization process in the logistics industry is accomplished. Investigations along the supply chain of global companies revealed that a bottleneck in delivery fulfillment might have a negative impact on the customer's online purchasing experience and thus also on the e-commerce sector (Bask, Merisalo-Rantanen, & Tuunanen, 2014). To meet these challenges, it is estimated that about 40% of the total product price is caused by logistics alone. This shows the significance of logistics and supply chain management (LSCM) for the e-commerce industry (Yu, Wang, Zhong, & Huang, 2017).

The entire e-commerce process is usually divided into three main stages. In the first step, the ordered products are distributed from the manufacturers' warehouses to the e-commerce company's hubs and distribution centers. In those, the second step of order fulfillment is carried out. Here, the products are sorted, picked, and packed. The last step describes the delivery of the products from the distribution center to the end customer (Barenji et al., 2019). This simplified process can be found in Figure 2, which was created by the e-commerce company Alibaba.

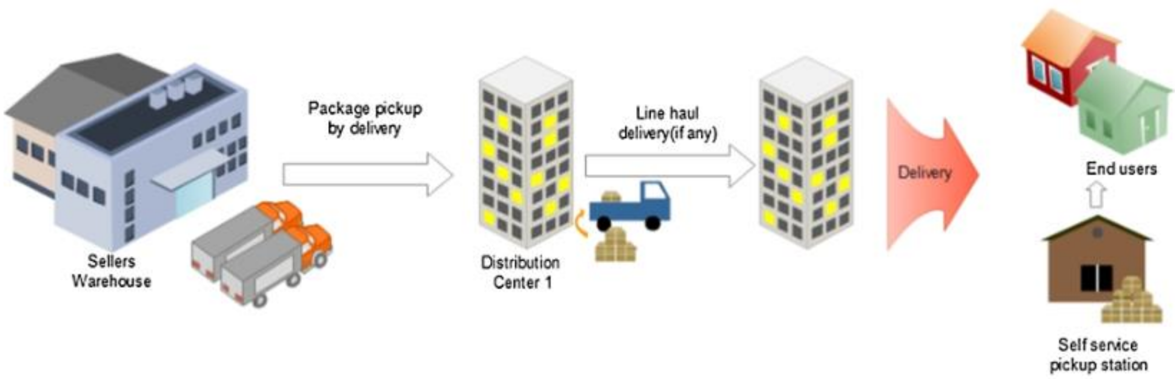


Figure 2: E-Commerce process

Source: *(Barenji, Wang, Li, & Guerra-Zubiaga, 2019)*

The relevant market segments for e-commerce are business to business (B2B) and business to customer (B2C) transactions. The customer-to-customer (C2C) and customer-to-business (C2B) models occupy a secondary role in e-commerce (Bloomenthal, 2020) and are not considered in this work.

The concept of B2C in e-commerce refers to the transactions that take place on business websites directly between the company and the end customer. Here, the customer selects and orders the product and, if applicable, pays for it online. After the company receives the order, the product is sent to the customer (Yu et al., 2017). The prerequisites for the success of this business model include high-quality customer service, large-scale advertising campaigns to reach a wide range of digital buyers, and extensive investments in both software and hardware to handle the orders without delays (Nica, 2015).

While the B2C business model only involves the final transaction of selling the finished product to the end customer, the company typically has a much higher volume of transactions along their supply chain in the B2B space. These are commercial transactions with other companies to purchase sub-components of their products or raw materials (Kenton, 2021).

2.2 E-commerce logistics and supply chain management

The development of e-commerce in both business models poses considerable challenges for the LSCM. Thus, modern logistics has the important role of providing sufficient capacities to avoid bottlenecks along the supply chain while at the same time reducing distribution costs and increasing the efficiency of the material flow. These demanding requirements have contributed significantly to the development of more ingenious logistics technologies (Yu et al., 2017). According to the literature, the respective business has the choice between the logistics models of self-support, outsourcing, and joint (hybrid) distribution mode (Zheng, Zhang, & Song, 2020).

2.2.1 Self-support model

Particularly companies that attach high importance to customer service quality within their last-mile build up their own logistics network from storage to delivery. There are three categories of e-commerce enterprises that choose this model, based on Xianglian and Hua (2013) . Either they are financially strong companies with enormous volumes or traditional large manufacturers or e-commerce wholesalers (Xianglian & Hua, 2013). By avoiding external companies, the e-commerce firm gains two main advantages. On the one hand, it is more likely to harmonize its supply chain operations and maintain control over the whole delivery process (Fugate, Sahin, & Mentzer, 2006). All internal departments within the supply chain network have no conflict of interest regarding the common goal of a smooth supply chain. On the other hand, this model has a high stability. Delivery problems can be solved directly within the company without relying on the information flow from external companies. The overall delivery processes are more reliable and traceable (Xianglian & Hua, 2013).

However, the construction of such a system requires enormous resources. Large financial investments are needed for the entire logistics area, for example, the procurement of vehicles and the development of a commissioning system. In terms of e-commerce companies, which in many cases offer their products in multiple countries, this can result in low profits and capital shortages (Damme & Amstel, 1996). Furthermore, the self-support model involves a high number of employees with professional logistic capabilities in order to build an extensive distribution network. Since this activity is usually beyond the core competence of existing employees, it creates additional challenges for the company (Xianglian & Hua, 2013).

2.2.2 Outsourcing model

The concept of the third-party distribution mode, also known as contract logistics, describes the outsourcing of resource management tasks to external companies. This can include supply chain planning, warehousing, inventory management, product distribution and transportation, or invoice collection (Zheng et al., 2020). Some large examples of third-party companies are Kuehne+Nagel, DHL, United Parcel Service, and Exel. These established companies possess many years of experience within their line of business and offer cost-effective as well as customized solutions for their clientele (Grant, 2019).

Thus, they play a relevant role for e-commerce companies as their service can bypass the operational burden of a self-support model in particular (Xiao, Xia, & Zhang, 2014). No costly investments in setting up an infrastructure are needed and the company can mainly focus on its core competencies to enhance its competitiveness (Grant, 2019). Moreover, outsourcing allows e-commerce companies to significantly reduce fixed asset investments such as warehouses, land, information technology, and parcel conveyors. This can enable the turnover rate of capital to benefit (Yu et al., 2017). Furthermore, the respective specialization and expertise of each logistics company, coupled with the deployment of logistically advanced technologies, guarantee an efficient delivery worldwide (Xianglian & Hua, 2013).

Nevertheless, this model also has drawbacks. By transferring logistic activities to external partners, the seller loses control to a certain extent over sections within its logistic chain (Huang Lau & Zhang, 2006). Customer service, which is crucial to the success of the e-commerce model, must be regarded critically. By delegating responsibility for the delivery to the end customer, the third-party company may fail to meet customer demands. Insufficient efficiency in handling customer complaints or failures in the delivery may negatively impact customer satisfaction. Although this is outside the responsibility of the e-commerce company, it may in turn have a damaging effect on it (Yu et al., 2017).

2.2.3 Joint (hybrid) distribution mode

The cross-logistic model is a hybrid of the systems described above. It refers to the process of several companies entering into strategic alliances in the form of long-term joint cooperation. The aim is to jointly pursue certain logistical objectives (Xianglian & Hua, 2013). This type of cooperation has become popular in recent years, as it allows to minimize the risk of individual companies, to generate synergies between actions, and to trade more efficiently the fluctuations between supply and demand (Leitner, Meizer, Prochazka, & Sihn, 2011).

Nevertheless, as the number of participants increases so does the complexity of managing the network. Due to this difficulty, this model is simply not feasible for many companies (Zheng, Zhang, & Song, 2020).

2.3 Warehousing in the e-commerce era

A large part of the operations within the LSCM takes place in warehouses. As in the entire supply chain, the effects of the booming e-commerce industry are also noticeable here so that the requirements on the warehouses have become more sophisticated. The diversity of companies involved in the e-commerce sector and consequently the diversity of their logistical requirements not only demand more space. Moreover, it also implies organizational and functional transformations of warehouses (Dembinska, 2016). This transformation can be seen in the emergence of various types of warehouses.

2.3.1 Types of warehouses

The first type is the mega e-fulfillment center, usually used by retailers, in which goods are stored and commissioned at the article level. These facilities often operate around the clock and have an extensive storage area, ranging from 500,000 m2 to 1,000,000 m2 (Robinson, 2014).

The second category includes parcel hubs and sorting centers. Here the sorting and commissioning of individual orders take place. Orders are bundled according to their postal code and then forwarded to smaller parcel centers (Robinson, 2014). Within the delivery network, these are the focal point for supplying local parcel delivery centers and are equipped with highly automated sorting systems (Dembinska, 2016).

Compared to parcel hubs and sorting centers, the third category in the form of parcel delivery centers is available in larger quantities. In most cases, these are located on the outskirts of large cities or densely populated areas and responsible for the last mile delivery (Dembinska, 2016).

Depending on the area of operation of the respective e-commerce company, own return processing centers and dot.com warehouses for food fulfillment can also be installed along the supply chain (Dembinska, 2016).

The focus of this thesis is primarily on the categories of parcel hubs/sorting centers and the smaller parcel delivery centers, as the company investigated in the case study has warehouses in each of these categories.

2.3.2 Characteristics of e-commerce warehousing

While the various warehouses perform different operations within the supply chain, they all must comply with the characteristics of e-commerce. Typically, these are as follows:

The first characteristic is a low order quantity of private customers, who often include only a few products in their order. For example, at Amazon Germany, the average order quantity is only 1.6 items (Boysen, Stephan, & Weidinger, 2019). The characteristic of a low number of items in an individual order is typically accompanied by a large range of products offered. The reason is that e-commerce sellers enjoy the advantage of offering products online on the website which do not initially require costly storage space in stores. This also results in the possibility of offering a wide assortment of niche products which account for a much larger share of sales in e-commerce than in bricks-and-mortar retail (Brynjolfsson, Hu, & Smith, 2003). Furthermore, many e-commerce sellers guarantee next-day or even same-day deliveries. This can lead to time-critical commissioning orders and significantly increase the pressure on warehouse operations (Yaman, Karasan, & Kara, 2012). The last characteristic to be mentioned is the fluctuation of parcel volumes, especially in the B2C segment, over the course of the year. Seasonal effects can influence the volatility of parcel volumes so that scalable warehouse capacities are needed to flexibly respond to the workload (Boysen, De Koster, & Weidinger, 2018).

2.3.3 Environmental impact of warehouse buildings

Although it is well documented in the literature that the most effective way to minimize the carbon footprint of a company is to reduce emissions in all steps of the supply chain, most of the research seems to focus mainly on transport activities (Schaltegger & Burrit, 2014). The concentration might be justified by the fact that global transport activities are attributed to be one of the main contributors of greenhouse emissions in recent decades, with a yearly output of 2,500 mega-tonnes of carbon emissions (World Economic Forum, 2009). Additionally, these activities are listed by Piecyk and McKinnon (2009) as the largest single source of emission in the global supply chain, accounting for an estimated share of 14% of the total greenhouse emissions worldwide (Stern, 2007).

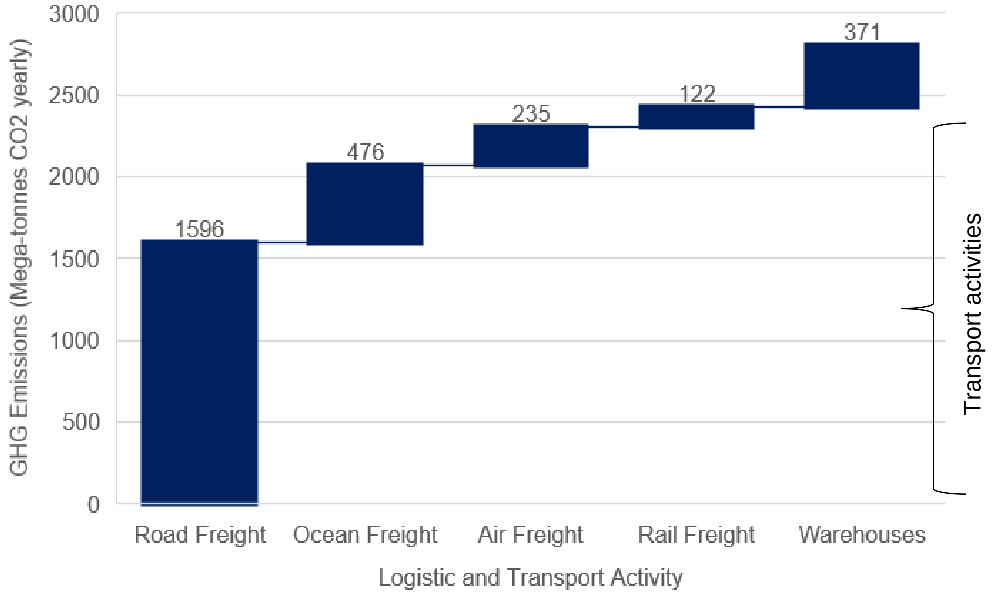


Figure 3. GHG emissions in logistics and transport activities

Source: Adapted from *(World Economic Forum, 2009)*

In addition to transportation, the emission impact of warehouses has to be regarded as a decisive factor as well. It contributes 13% of the total supply chain emissions or around 371 mega-tonnes of carbon dioxide (CO2) emissions yearly (World Economic Forum, 2009). In this context lightning, HVAC systems, and material handling equipment require closer attention.

Based on this, there are several studies regarding the potential savings of emissions within warehouses. While the World Economic Forum report (2019) indicates a potential reduction of 16%, the study conducted by Ries, Grosse, and Fichtinger (2016) provides a more extreme outcome. In this investigation, the researchers set up several scenarios to examine how varying factors such as warehouse size, technology, and building equipment (lighting, insulation, and emission intensity) affect the aggregated CO2 emissions. In their results, it becomes clear that in the case of constant space requirements, improvements in building equipment and the use of less carbon-intensive energy resources can reduce emissions by up to 10%. If it is even possible to lower the required floor space and achieve a high degree of automation, a further reduction of up to 26% is possible. However, without any reduction measures and increasing space requirements in warehouses, emissions could increase between 20% and up to 60% until the year 2025, depending on the respective operational technology (Ries et al., 2016).

Furthermore, the study shows that although the warehouse emissions are only a minor contributor, in comparison to the overall transport emissions, neglecting this aspect would offset the reduction measures in other transport areas. Thus, the consideration of the environmental impact of warehouses within the supply chain seems indispensable (Ries et al., 2016).

2.4 Green Warehousing

After having demonstrated the need for more sustainable warehouses, this chapter examines in more detail the extent to which companies can implement measures within these to reduce their carbon footprint. Many contributions to the concept of “Green Warehousing” can be found in the literature in this regard.

Under the term "Green Warehousing”, the researcher Akandere (2016, p. 10) understands a “cluster of technological and organizational solutions designed for the efficiency of warehouse processes by maintaining the highest social standards and minimizing the effect on nature in terms of financial efficiency”. “Green warehousing” concepts refer to a variety of categories. In this thesis, the focus is on the energy-intensive areas of lightning, HVAC systems, and material handling equipment. From the author's point of view, these are the most relevant factors for the types of warehouses used in the company under investigation. For this reason, these categories will now be examined progressively with the help of the existing literature.

2.4.1 Energy savings in warehouses

So far, little research has been done on how the energy costs or energy consumption rates of warehouse operations are composed. The reason for this deficit is obvious: The multitude of different types of buildings, the different usage, and the different operations make it problematic to set a standard and a benchmark (Marchant, 2015).

Despite the uncertainty of data, the UK government`s "Energy Efficiency Best Practice Code" has developed a breakdown showing the distribution of energy consumption in warehouses. Figure 4 illustrates where warehouses need the most energy and therefore, in which areas are the greatest potential for savings. Many dimensions must be considered here. The computed data refers to a typical 15,000m2 ambient warehouse (Carbon Trust, 2019). An ambient warehouse is a facility built to operate with materials that require a dry environment and room temperature (KBD, 2021). With regard to the company examined in the case study, which mostly operates distribution centers, this data evaluation by Carbon Trust may not be completely applicable. Here, a high share of material handling equipment of the total energy demand can be expected due to parcel conveyors and other transport systems. Nevertheless, the breakdown provides a good indication.

By far, the largest energy consumption within the warehouse is accounted to the lighting, responsible for 71% of the total energy demand (warehouse and office). The entire area of heating also contributes a considerable amount, with a share of 17% (space heating and hot water) (Carbon Trust, 2019). Consequently, companies should promote alternative solutions in these areas in particular.

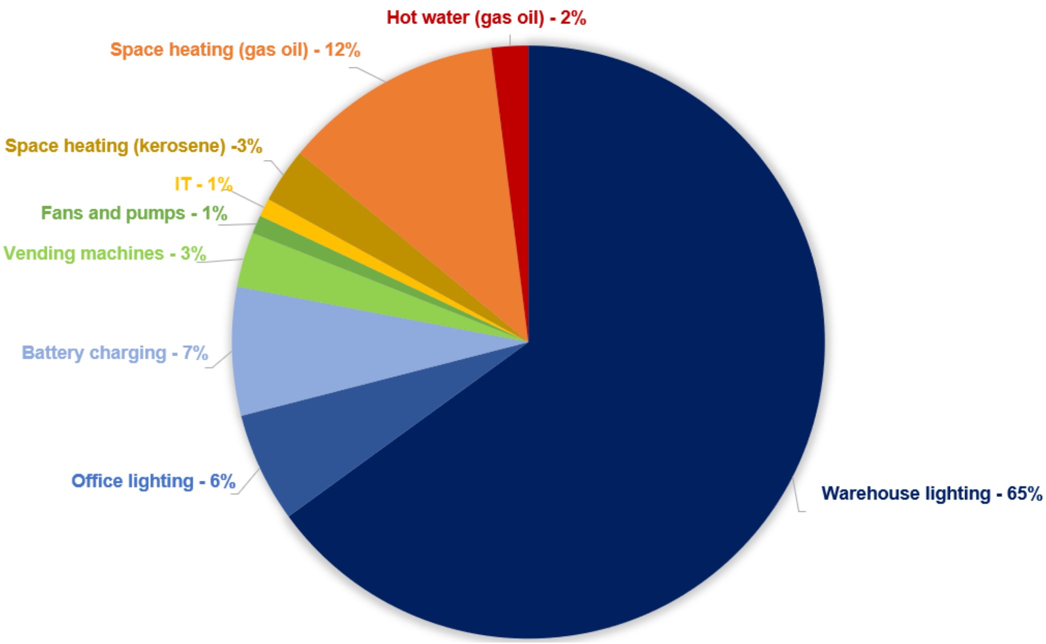


Figure 4: Typical percentage breakdown by energy use, based on 15,000m2 ambient warehouse

Source: Adapted from *(Carbon Trust, 2019)*

2.4.2 Lighting systems

A high-quality exposure system is very important for the execution of the operations inside the warehouse and guarantees the safety of the workers. Nevertheless, many companies still continue to rely on ineffective solutions nowadays.

Firstly, the Carbon Trust guide suggests a very banal sounding yet effective measure: turning off the exposure in unoccupied areas of the warehouse. For instance, this is the case in areas where seasonal products or unused transport vehicles are stored. This measure is complemented by the implementation of automatic lighting sensors, which detect the occupancy status of the respective area. The modern sensor recognizes the presence of a vehicle or person and switches on the lighting. After a certain period of absence, the light turns off automatically. By wisely installing these sensors, savings of up to 30% of the total lighting costs could be achieved, depending on the structure and operations of the warehouse (Carbon Trust, 2019).

Secondly, another promising measure is the maximum utilization of daylight. Again, the respective warehouse circumstances play a decisive role such as building orientation, building height, and daylight hours. To achieve optimal use, it is essential to choose the ideal light entry point. Relevant factors are the landscape and the weather conditions of the location. In addition, the selection of bright walls and ceilings helps to distribute the sunlight inside (Waqas Amjed & Harrison, 2013). Regarding the fluctuation of daylight hours throughout the year, it is recommended to deploy daylight sensors to precisely control between artificial and natural lighting. By coupling these sensors with dimmers, a variable level of artificial light can be provided depending on the available daylight. Thus, the optimal level for the operations can be ensured (Carbon Trust, 2019).

Further saving potential can be achieved by the correct choice of the lamp type and the ballast for switching the lighting on and off. Therefore, numerous factors should be considered in the decision: the operation to be conducted within the area, the average life of the lamp with simultaneous consideration of accessibility for replacement, the expected switching frequency, and the start-up and re-ignition rates of the lamp types (Marchant, 2015).

Table 1 illustrates the most suitable types of lamps for each area of the warehouse.

Table 1. Recommended lamp types for areas in warehouses.

Area	Type of operations	Recommended lamp type
Internal	Office space	Triphosphor tubular fluorescent, compact fluorescent, low voltage tungsten halogen
	Operational area (storage, production, distribution, etc.)	Triphosphor tubular fluorescent, metal halide, pressure sodium, emergency directional LED

External	Lighting of the outdoor area	Metal halide, high-pressure sodium

Source: *(Marchant, 2015)*

Regardless of this detailed listing, companies that are still using incandescent lamps in their warehouses are advised to replace them with LEDs or fluorescent lamps. This change alone can result in a reduction of lighting energy of 80% to 90%, which in turn means a reduction in emissions of 20% to 34% for an average warehouse (Ries et al., 2016). Furthermore, it is emphasized that significant errors may also occur when installing high-power LED lamps. If the lamps are not adequately maintained and inefficiently placed without prismatic glasses, this can severely reduce the desired energy savings, as the number of lamps or the power of these would have to be increased (Marchant, 2015).

2.4.3 Heating, ventilation, and air conditioning

Figure 4 illustrates that temperature regulation within the warehouse accounts for approximately 17% of the total energy demand. A responsible approach to the temperature setting within the building is essential, as a reduction or increase in temperature by 1 degree Celsius will either reduce or increase energy costs by 10% (Waqas Amjed & Harrison, 2013).

Many factors determine the ideal temperature setting. First and foremost, the temperature must be regulated to ensure that the handled products remain in a satisfactory condition (Waqas Amjed & Harrison, 2013). In addition, it must also be guaranteed that the operating personnel is provided with a pleasant atmosphere according to its physical activity. However, many other structural factors play a role in the configuration of the respective heating system in the buildings. These include the construction material of the exterior walls, the thermal mass and the volume of the building, the prevailing climate, the number of sunshine hours per day, and the thermal gain emanating from material handling equipment such as conveyors or forklifts (Marchant, 2015).

The “Code of Conduct” of the Carbon Trust report (2019) advises a minimum temperature of 16 degrees Celsius in the operational areas of the warehouse. If high physical exertion is required, this temperature indication can also drop to 13 degrees Celsius. Consequently, in warehouses that mainly perform the function of distribution and the turnover rate of items is relatively high, rather cooler temperatures are recommended for the well-being of employees. However, if it is a warehouse with mainly pure bulk storage and few interactions, temperatures of 10 degrees Celsius are sufficient (Carbon Trust, 2019).

Table 2. Usual heating systems in the warehouses.

Heating options	Short explanation	Application area	Energy effectiveness

Air rotation	Low air velocity, high airflow unit draws in cool air at floor level and blows it out at high level to the warmer air, results in constant air circulation	Entire warehouse	Very high effectiveness with little loss if well-engineered and constructed
Warm air	Direct and mostly gas-powered heating with decentralized control	Entire warehouse	High effectiveness possible if good insulation is available and positioning as well as handling is appropriate
Radiant	Local heater radiates heat, powered by electricity or gas	Local areas with a long presence of workers	High effectiveness if handling is appropriate and in optimal position for staff
Low temperature Hot water / Steam	Heat is generated by boiler and distributed through fan coil units	Entire warehouse	Low effectiveness, insulation, and control can improve performance

Source: Adapted from *(Carbon Trust, 2019)*

Once the heating system generates the desired temperature in the interior, ventilation must be used to maintain this level. In this context, large air circulation is associated with high energy costs. The laws of physics of convection matter here, in which heat transfer occurs through heat flow. Due to its relatively low density, the warm air rises to the ceiling, cools down there, and falls back to the floor (Kosky & Wise, 2013).

Especially in buildings with high ceilings, this effect is amplified and can lead to a heat loss of about 20% if no adequate method of removing heat layers is used (Warehouse&Logistic, 2014). To counteract this, the air rotation system mentioned in Table 2 is particularly suitable (Carbon Trust, 2019). It uses physical principles to smoothly circulate warm air to maintain a constant temperature. The system can distribute heat both horizontally and vertically in a fully automated manner and, when properly set, requires only minimal operator interventions. By using the trapped heat of the high air layers, the general heating system can reduce its output and immense energy savings can be achieved. In the long run, these savings will exceed the relatively high initial investment (Warehouse&Logistic, 2014).

Furthermore, the air circulation can be affected to a considerable extent by the air draft, which may be caused by poor maintenance of the building's insulation or by long durations of open doors or windows. Neglecting this aspect can undermine the effectiveness of the measures taken and in turn increase the energy demand (Marchant, 2015). In this context, the Carbon Trust report of the year 2002 proposes additional measures. If the infrastructure of the warehouse allows it, an attempt should be made to separate it into spatial zones with different operational activities. The zones can then respectively be equipped with independent thermostats and temperature controls. For instance, there could be a spatial separation from the areas of unloading and loading vehicles. In this way, the necessary opening of gates to the outside would not affect the entire warehouse. It is further emphasized that these external gates should ideally only be opened when required and be sealed off by a maximum of appropriate insulation (Carbon Trust, 2002).

2.4.3 Mechanical handling equipment

By the term "material handling" is meant the transportation, storage, and control of raw materials and products along the supply chain. This process can begin with the procurement of raw materials, continue with the production, storage and distribution, and end with the consumption. The required equipment depends on the type of operation and can be either manual or semi-automatic, or fully automatic (MHI, 2021). Material handling equipment can be divided into four major categories. The first category includes storage equipment that stows items during the period between goods receipt and goods issue. Numerous stowage options are available depending on the characteristics of the product. Examples are shelves, pallet racks, block-stacking, sliding racks, or stacking racks. The second category consists of engineered systems that automate the movement of goods through the facility and attempt to minimize the manual effort of personnel. Examples are automated storage and retrieval systems, driverless transport systems, and the classical conveyor system. The third category includes powered vehicles that move materials around the facility and are manually operated by personnel. Classic examples are pallet trucks, forklifts, and side loaders (Bowles, 2020). The last category refers to bulk material handling systems. These typically consist of stationary machines that help workers to move larger loads, such as stacker and magnetic separators (Almasi, 2017). The primary attention of this thesis is focused on the categories of engineered systems and powered vehicles since it is assumed that most of these systems are used in parcel hubs and parcel delivery centers.

2.4.3.1 Sustainable engineered systems

Parcel conveyors move items through the entire hall to the desired location without or minimum manual intervention. Conveyors are considered to be the lifeline of the overall facility and one of the most energy-intensive components within the warehouse. Consequently, it is even more important for environmentally conscious companies to rely on energy-efficient systems. Especially the modification of the conveyor motor provides numerous ways to operate in a more energy-efficient way. For instance, an option is the implementation of motors equipped with the ability to recover used power through ultra-capacitors and release it to other devices or to the general grid. This measure can be complemented with the installation of an automatic stop control. In this case, the conveyor is stopped at times when no items are being conveyed so that the motors can be switched off during this period. Further energy savings can be achieved by deploying variable-speed drives that adjust the speed of the conveyor according to the items being moved and motor-driven rollers that can handle distribution more efficiently, in particular at nodes (CMC, 2021).

2.4.3.2 Sustainable powered vehicles

With an average share of 7-10% of the total energy costs in warehouses, the use of forklifts must also be considered from a sustainable point of view (Carbon Trust, 2019). Here, the company has the choice between 4 available systems: Electrical, liquefied petroleum gas (LPG), diesel, or fuel cell-powered forklift trucks.

Table 3. Forklift truck systems and their areas of application.

Fuel	Recommended field of use	Advantages	Disadvantages
Electric	Suitable for indoor use on a flat and even surface	Low noise, high flexibility, no emission of pollutants during operation	High acquisition cost, necessity of recharging
LPG	Suitable for indoor use, if sufficiently ventilated, as well as for outdoor use	Longer range than electric systems, low acquisition costs	Exhaust fumes and noise must be considered
Diesel	Suitable for use in outdoor areas with slopes where large power is required	Better than LPG in terms of fuel consumption, low acquisition costs	Exhaust fumes and noise limit use to certain areas
Fuel Cell	Suitable for indoor as well as outdoor use	No emission of pollutants during operation, quick refueling	Still at an early development stage, high acquisition costs

Source: Adapted from *(Carbon Trust, 2019)* and *(Engel, 2018)*

According to Marchant, comparing these systems in terms of their carbon footprint is challenging, meaning that the literature does not concur on the most environmentally friendly system. As in all comparative assessments of energy consumption, it is not sufficient to simply consider efficiency factors or CO2 emission rates during the usage (Marchant, 2015).

Rather, the environmental impact of the forklift's entire life cycle must be considered. It is starting with the procurement of raw materials, through the manufacture of the vehicle, its utilization, the procedure at the end of its service life, and ending with its compliant disposal. This process is described in the literature as life cycle impact assessment (LCIA). The most widely used application of LCIA is the well-to-wheel analysis, which uses a global perspective when comparing vehicles. Such an analysis gives an aggregate overview of resource exploitation and associated emissions, starting with the generation of the primary energy source (well) and ending with its use (wheel) (Ramachandran & Stimming, 2015). The Well-to-Wheel analysis is divisible into shorter phases: well-to-pump, in which the pump is the fuel dispenser at a refueling point; well-to-outlet, in which the outlet is the electrical supply; fuel-to-exhaust, starting with the fuel in a given vehicle and finishing with the pollutants emitted (Johnson, 2008).

However, the research conducted in the literature on the environmental impact of the forklift variants does not uniformly refer to the entire well-to-wheel life cycle. Instead, the studies focused on the environmental impact within the different sub-phases. As a result, it has not been possible to apply a uniform test standard and system boundaries to the entire life cycle (Marchant, 2015). In the studies, the forklift variants then showed different results in the various phases considered. For instance, it has been determined that LPG possesses the lowest CO_2 emission and the highest energy efficiency with 89.3% during its operation at the same time. Nonetheless, another study reported that this system requires six times more energy per operating cycle than the electric systems. Again, in another study the electric systems are rated as inefficient on a well-to-battery consideration. Ultimately, after reviewing a wide range of existing studies Johnson concludes that, in practice, the fuel carbon footprint of LPG tends to be the smallest one, followed by the electric forklift. The diesel-powered forklift truck performs the worst (Johnson, 2008). These discrepancies indicate that no clear answers can be found in the literature regarding the most environmentally friendly solution. The technologies have different benefits and drawbacks, so it is up to each company to put its own operational situation at the center of the decision-making process.

Fuel Cells offer an exciting sustainable alternative for the future but are still at a very early stage of their development. The number of truly operational forklifts using this technology is still very limited nowadays, so it is not yet a relevant alternative for the majority of companies (Johnson, 2008).

2.5 Provision of the infrastructure for switching to electrically powered vehicles

The ever-increasing appearance of electromobility is the result of efforts to use energy more efficiently. Likewise, transport operators have also recognized the future key role of electromobility in their supply chain, which will help them to sustainably convert their fleet. It is seen as a promising approach to comply with the set sustainability goals despite the demanding capacity requirements of the e-commerce. Other motivations for switching to electromobility include improving air quality in urban areas, removing the heavy dependence on fluctuating oil and gas prices as the primary fuel for the existing fleet, and responding to public pressure to act in a climate-friendly manner (Muzik, Vajnar, & Vostracky, 2018).

The entire area of electromobility within the supply chain of the e-commerce sector is enormous. However, since the scope of this thesis focuses mainly on processes within the warehouse, this chapter examines which benefits and drawbacks an implementation of an electromobility infrastructure provides. It is considered a basic prerequisite for the successful implementation of a large electric vehicle fleet.

The term electromobility infrastructure refers to the charging infrastructure and connections required for the operation of electric vehicles. It requires modern energy supply networks to ensure the provision of electricity at all times, regardless of the current demand. In other words, the objective is to guarantee a stable, secure, and practical supply (TÜV Süd, 2021). Meeting these requirements is challenging, as there can be high load peaks when many vehicles need to be recharged at the same time. These load peaks can cause the supply from the public power grid to become overloaded and inefficient. One way to avoid these difficulties is to build off-grid power systems, known as micro smart grids (Liebegott, 2017). By this term is understood the adjustment of the charging cycle of electric vehicles both to the circumstances on the public power grid and to the requirements of the vehicle park. It is seen as the solution to unlock the synergies between low-carbon mobility and the green transportation segment (IRENA, 2019).

2.5.1 Benefits of charging stations for electric-vehicle fleets

The construction of such a charging infrastructure is complex but can generate significant efficiency gains when deployed on a large scale. According to the analysis of McKinsey&Company, cost savings of 15% to 25% can be achieved compared to a similar fleet with combustion engines by 2030. Most of the financial benefit could be gained mainly from 3 activities (Bland, Gao, Noffsinger, & Siccardo, 2020).

The first activity is the sourcing of renewable electricity directly from the generator. Instead of purchasing the required electricity from the usual power grid, it is obtained from off-grid generation plants. The company has the option of setting up its own generating facilities, such as solar plants, or purchasing off-grid electricity through direct contracts with large-scale plants. In the latter case, the cost advantage is achieved through the difference between retail and wholesale prices (Bland et al., 2020).

The second activity that generates financial benefits is the provision of energy management services to the power system (IRENA, 2019). Here, energy storage batteries have a key role to play. These enable charging station infrastructure operators to purchase electricity from the power grid at off-peak times and use this stored electricity to charge their e-vehicles when electricity prices are at their highest. Conversely, charging stations can also be configured to replenish electric vehicle batteries with grid power when prices drop (Bland et al., 2020).

However, the company can also benefit the other way around as a seller of electricity during periods of high prices. The third activity describes the provision of additional grid services to the external power grid (IRENA, 2019). As a sort of "vehicle-to-grid" service, the power stored in the batteries of the electric vehicles can be sold to the power grid at times of peak demand, assuming that the utilization of the company's own fleet permits this (Bland et al., 2020).

2.5.2 Drawbacks of charging stations for electric-vehicle fleets

Nevertheless, integrating such an infrastructure into warehouses and their vehicle fleets entails very large investments at the outset with high technological complexity (IRENA, 2019).

One of the major technological challenges seems to be the development of a software that maximizes the benefits of both electricity storage and vehicle use. Numerous factors such as timetables and routes, charging frequency, vehicle servicing, and current delivery workloads must be taken into account. Depending on the individual enterprise, such IT solutions must be created differently. For participation in the regular power grid, the charging infrastructure control system must also have access to real-time pricing signals from the market. This is crucial to make timely decisions concerning the right moment to purchase or sell electricity (Bland et al., 2020).

2.6 Summary of the theoretical framework

The purpose of this chapter was to put the research objective in context with existing literature, conducted studies, and other relevant research results.

The first part served to illustrate the rapid development of the entire e-commerce retail sector. This way of retailing has become more attractive to end customers around the world in recent years, mainly due to more advanced internet access, bringing the number of digital buyers to more than two billion by 2020 (Coppola, 2021).

In the next step, it was pointed out that this development implies especially one issue for the heavyweights of e-commerce: growing logistical challenges to prevent bottlenecks along the supply chain (Yu et al., 2017). It requires modern logistics and supply chain management, whether by building a self-support model, using services of third-party companies, or in the form of a joint (hybrid) distribution model (Zheng et al., 2020). Modern logistics also implies modification in one part of the supply chain, where a large part of the operations takes place: Warehousing. Influenced by the growing e-commerce, the emergence of different types of warehouses as well as changes in the operation characteristics are taking place (Dembinska, 2016).

In addition to meeting the increasing capacity requirements, companies must also consider the environmental footprint of warehouse operations, which contribute a significant share to the carbon footprint of the entire supply chain (World Economic Forum, 2009). With this outline, the transition has been made to the concept of "Green Warehousing".

“Green Warehousing” has a variety of dimensions, so the next part of the chapter aimed to cover the areas relevant to the company studied later in the case study. First, the dimensions of the three most energy-demanding systems were analyzed: lighting systems, HVAC systems, and material handling equipment. Several various technologies were analyzed, assessed from a sustainable point of view, and ultimately a series of recommendations were drawn up.

While these energy-saving measures are applicable and relevant to almost all types of warehouses simultaneously, the investigated dimension of electric charging infrastructure vehicles mainly specialized on the warehouse types of logistics providers. Smart grid systems are of high complexity but will play a major role in shaping climate-neutral delivery in the future (IRENA, 2019).

The information gathered in this chapter, partially complemented with recommendations, is suitable to be used as a foundation for the case study of United Parcel Service.

3 METHODOLOGY

This chapter serves to introduce the investigated company of the case study and provides justification for its choice. Furthermore, the research methods for obtaining primary data in the form of interviews and secondary data in the form of reports are presented.

3.1 The company under consideration

The US-based company United Parcel Service (UPS) is the world's leading parcel delivery service and a provider of global supply chain solutions. It is represented in more than 220 countries and operated by 495,000 employees. The logistics company offers its customers a portfolio of the following services: shipping by land, sea, and air; distribution; contract logistics; international trade and brokerage services; insurance and customs clearance (UPS, 2021a). Now based in Sandy Springs, USA, the firm was founded in 1907 under the name “American Messenger Company” by James E. Casey. The first subsidiary outside the USA was opened in 1976 in Neuss, Germany (Lewis, 2020).

In 2020, the organization reported a global turnover of 84.6 billion US dollars, with more than half of this coming from the domestic US market. The revenue was positively impacted by the global B2C volume growth due to the strong increase in digital buyers in e-commerce, resulting in a total of 6.3 billion parcels being delivered (UPS, 2021a). The growing e-commerce sector also influenced the distribution of the company's B2B and B2C transactions. Before the emergence of this market, B2B dominated the company's daily business, while over the past few years the distribution has shifted towards B2C, which now accounts for approximately 55% of all transactions (Benzinga, 2020).

The company's strategic emphasis lies on innovative, client-oriented solutions in fast-growing sectors such as healthcare, midsize companies, and transnational trade. In doing so, the company has also firmly embedded in its strategy the responsibility of creating inclusive, resilient, and safe communities with economic equality and justice for all (UPS, 2021b).

Another pillar of the corporate strategy is the intention to create a more sustainable world. According to its own understanding, UPS is at the forefront of organizations that are tackling the challenges of sustainability in the most committed and tireless manner. It seeks to innovate in every aspect of its business and work collaboratively to meet its own sustainability goals as well as those of its partners (UPS, 2021c). In 2016, the company set 10 sustainability goals, which it aims to achieve by 2025. These relate to protecting the environment and employees, as well as strengthening the communities in which the company operates. The most important of the four environmental goals is the reduction of GHG emissions from global ground operations by 12% compared to the 2015 baseline. Moreover, the company aims to source 25% of its energy usage from sustainable energy sources, to achieve a 40% share of alternative or renewable fuels of the total fuel used on the ground, and to achieve a 25% share of alternative fuel or sustainable technology equipped vehicles of its annually purchased new vehicles (UPS, 2020).

Especially logistics service providers, such as UPS, are directly experiencing the impact of the rapid development of the e-commerce sector. Although they are considered to be one of the beneficiaries of the boom, since they act as third-party partners for the majority of the e-commerce sellers, this also implies increasing capacity requirements along their entire supply chain. Including also parcel hubs and parcel delivery centers, which are the cornerstone of an efficient distribution network. At the same time, the company is committed to making the world a more sustainable place and set high sustainability targets in 2015 (UPS, 2021c). From the perspective of the author, this combination of increased capacity requirements and a strong sustainability mindset provides an excellent basis for conducting a case study in relation to the research objective to be investigated.

Furthermore, UPS is also particularly interesting when comparing its sustainability practices with other logistics and third-party companies. In various rankings of business magazines, it is distinguished as having one of the most sustainable supply chains in the industry. The company was also able to assert itself against other heavyweights of the sector, such as DHL and FedEx, so that it can be considered as a pioneer of sustainability efforts (Boa, 2021; SupplyChain, 2013; Hepler, 2017).

3.2 Qualitative research approach

For the purpose of this work, a qualitative research approach was chosen. From the author's point of view, this was the most appropriate method to investigate the extent to which the analyzed company masters its sustainability efforts despite demanding capacity requirements. The reason is that this method enabled the exploration of the phenomenon in its context, considering multiple sources of information. As a result, the topic was not only examined through one perspective but from a variety of perspectives, uncovering different facets of the phenomenon (Baxter & Jack, 2008).

A quantitative methodology was not suitable as the data needed to answer the research question consisted largely of contextual information rather than numerical data. Thus, it was difficult to display the collected data in a measurable and scalable way. Furthermore, there was no necessity to use mathematical and statistical models to transform the collected data when deriving the results (Ahmad, Wasim, Irfan, & Gogoi, 2019).

3.2.1 Primary data through interviews

As an interview type, the so-called semi-structured interviews were selected, whereby predetermined open questions were posed to the individual interviewees. Thereby, the questions followed a semi-structured guideline, which is a systematic outline of questions and themes (DiCicco-Bloom & Crabtree, 2006). The benefit was that the interview time could be optimally used to both methodically and comprehensively explore the interviewees as well as to narrow down the topics relevant to this work (DiCicco-Bloom & Crabtree, 2006). With the condition of consent from all interview partners, which both gave, the conversations were recorded to transcribe them afterward and guarantee data completeness (Jamshed, 2014).

When selecting the interview partners, care was taken to ensure that the persons were experts with relevant experience and a certain level of expertise in the field of sustainable warehousing. It was also advantageous if they had already been working for the considered company, United Parcel Service, for several years and had an adequate overview of the current projects. It was intended to ensure that most of the sustainability projects carried out would be covered in the scope of this work. Based on these requirements, two valuable interview partners were found: The "City Logistics/ Corporate Social Responsibility /Communication Officer" Klaus Stodick and the warehouse manager Maximilian Jestädt.

Klaus Stodick has been working at United Parcel Service for 15 years, during which he worked 12 years in management positions in the "External Communication" department, including the position of the "Deputy Press Officer" in Germany. Already then, the emerging topic of sustainability in the logistics industry was communicated with the public in many dimensions. For the past three years, he has been holding the position of a "City Logistics/ Corporate Social Responsibility/ Communication Officer". Primarily he concentrates on the sustainable design of transshipment points and the last-mile delivery in cities. A current focus in his daily work is the development of charging infrastructures for electric vehicle fleets, which is of high relevance for this thesis (Stodick, 2021).

Maximilian Jestädt has been working for the company for seven years. In the last four years, he has been holding the position of a warehouse manager in three different warehouses. He is mainly responsible for ensuring that the operational processes within the parcel delivery center, from parcel receipt to delivery, run successfully. Having managed several warehouses in Germany, he has broad expertise in sustainable technology within the facilities. In addition, he is regularly involved in sustainability projects, such as the development of an electric bicycle fleet for the last mile delivery (Jestädt, 2021).

This combination of interviewees, representing both the management and the operational level of the enterprise, was chosen deliberately and provides an opportunity to explore diverse perspectives on the company's sustainability efforts.

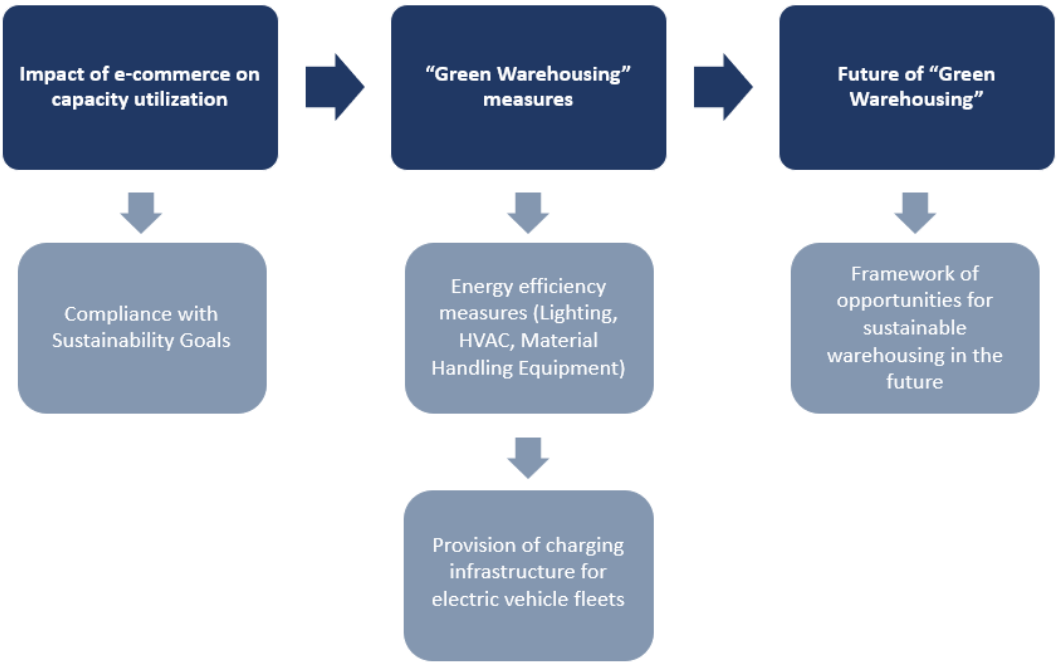


Figure 5. Applied interview guide.
Source: Own elaboration

Both interviews started with a brief introduction of the participants and a more detailed explanation of the research question to be answered. In addition, the interviewees were informed that they contribute a crucial input to the research procedure. Figure 5 illustrates the guideline on which the interviews were conducted. The guide is composed of three major categories, each containing its own subcategory/ subcategories.

The first thematic block related to the impact of the e-commerce boom on the capacity utilization of UPS. Questions were addressed about the extent to which this development pushes existing capacities within the supply chain to its limits, but also to what extent it endangers the sustainability goals. The second block of topics dealt with the company's efforts to achieve sustainable warehousing. Here, the classic areas of green warehousing such as lighting, HVAC systems, and material handling equipment were discussed. In addition, the topic of charging infrastructure for electric fleets was also addressed. In the last block, the experts shared their personal opinions if the existing sustainability measures are sufficient and which future sustainability measures will pave the way to carbon-neutral operations.

The interview leader's behavior during the interview aimed to establish a trusting and honest relationship with the interviewee. The interviewees should at all times feel free from any pressure to express their own perspectives. To achieve this, a relaxed and attentive approach was adopted and care was taken to conduct the interview at the interviewee`s preferred speed (Legard, Keegan, & Ward, 2003).

3.2.2 Secondary data collection

The information and statements collected through the interviews were complemented by secondary data. This mainly involved information from company reports, statistical databases, and business journals. Here, only data that originated from a reliable source and was still up to date in terms of its publication date was considered. One of the most valuable sources were the UPS Sustainability Progress reports, which have been published annually by the company since 2002. These reports are used to present the progress and development of the company's sustainability efforts (UPS, 2020).

3.3 Quality criteria of qualitative research

Quality categories are of importance for qualitative research, as they guarantee the credibility of the results obtained. Only if certain criteria are met, the academic value of the work will be acknowledged in the scientific community (Strübing, Hirschhauer, Ayaß, Krähnke, & Scheffer, 2018). Within qualitative research, there are still no standardized quality criteria in the literature. However, three quality criteria frequently appear in the literature and are considered in this work: Transparency, inter-subjectivity, and scope. From the author`s point of view, the thesis adherence to these criteria (Genau, 2020).

The criterion of transparency was fulfilled because the entire process of qualitative research was documented and presented in a transparent way. This included a clear, explicit, and open justification and description of the research question as well as of the applied research procedures (Mey, Vock, & Ruppel, 2020).

In addition, the evaluated results were presented plausibly and sufficient room for interpretation was offered to external persons. It was guaranteed that the derived results would not be influenced to an excessive degree by the subjectivity of the author (Genau, 2020). Thus, the second criterion of intersubjectivity has also been achieved.

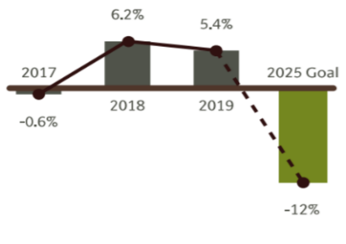
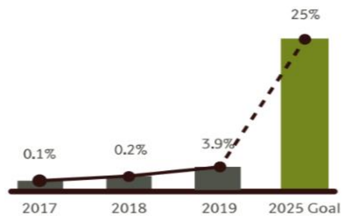
The criterion of scope addresses the extent to which the results of the qualitative research, despite its smaller number of samples compared to the quantitative research, allow a generalization (Mey, Vock, & Ruppel, 2020). Although this paper involves only a single case study, with UPS a company was chosen that takes a leading, if not the leading, role in the logistics industry concerning sustainability. It can be assumed that its measures and efforts represent a current framework of possibilities and therefore are also applicable to the entire industry.

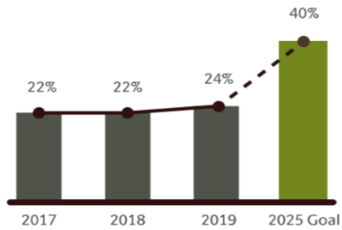
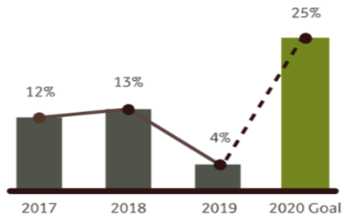
4 RESULTS

In this chapter, the derived results from the interviews and other qualitative research methods are provided. The practices of the company are presented in relation to the respective sub-research question and the connection with the literature is drawn.

The significance of a sustainable supply chain plays a major role in UPS's corporate strategy. Both interview partners confirmed that they have increasingly been involved in sustainability projects in their personal work in recent years. According to warehouse manager Jestädt (2021), the reason behind this intensification of efforts is mainly due to the sustainability goals set in 2016. Among other sustainability goals related to social impact and employees, the environmental efforts focus on four objectives to be achieved by 2020 and 2025.

Table 4. Environmental goals at UPS.

Sustainability goals for 2020/25 with baseline 2015	Current progress
12% reduction of GHG emissions from global ground operations by 2025	
25% renewable energy by 2025	

40% share of alternative and renewable fuels of the total fuel used on the ground by 2025	
25% share of alternative fuel or sustainable technology equipped vehicles of its annually purchased new vehicles by 2020	

Source: Adapted from *(UPS, 2020)*

The developments shown in Table 4 demonstrate that the objectives are progressing at different speeds. Good advances can be seen with the third objective in particular, namely that 40% of all vehicles should be powered by alternative and sustainable fuels by 2025. Although the share has only increased by a few percentage points in recent years, it had already reached 24% by 2019. In contrast, the other three targets are developing rather sluggishly. For instance, instead of a reduction in GHG emissions from ground operations compared to the baseline in 2015, there was an overall increase of 5.4% in 2019 (UPS, 2020). In the following, the reasons for this partly stagnation in achieving the objectives will be discussed.

4.1 Influence of e-commerce on capacity utilization and sustainability goals

Sustainability Manager Stodick (2021) identifies the rapid growth of the e-commerce sector as one of the main reasons why the fulfillment of the sustainability goals is stuttering in some cases. Especially the B2C sector has grown extremely and led to an exorbitant increase in parcel volumes in recent years (Stodick, 2021).

UPS attributes this rise primarily to consumers becoming more familiar and comfortable with making purchases from their smartphones, which already accounted for 30% of all online purchases in 2014. The ability to make purchases on the go, regardless of time and place, is transforming the entire retail market. Retailers' business models and supply chains need to adapt accordingly, including the logistics industry. Before the e-commerce era, the majority of the UPS` services were attributable to the B2B sector, the original area of expertise. Due to the change in the sectors, the characteristics of the delivery have changed to some extent. The parcels are lighter in weight, the shipping frequency is shorter, and the delivery locations are much more distributed (UPS, 2015). When confronted with possible challenges associated with this development, Stodick (2021) replied that UPS is able to deal with the changed package characteristics as well as with the increasing volumes. Important solutions are the optimal bundling of packages and an optimized utilization ratio of vehicles, which in the best case should be at least 90% (Stodick, 2021).

Table 5. Comparison of annual worldwide parcel volume growth and GHG emissions by UPS from 2013 to 2017.

	2013	**2014**	**2015**	**2016**	**2017**
Annual worldwide parcel volume growth in percent	+5,8%	+4,3%	+5,2%	+9,2%	+11,4%
GHG Emissions by UPS in CO2e metric tonnes (figures in thousands)	12,598	12,870	13,011	13,263	13,792

Source: Adapted from *(Mazareanu, 2020)* and *(UPS, 2018)*

To examine the impact of the increasing number of packages on the fulfillment of sustainability goals, a comparison with the company's GHG emissions since the start of the e-commerce era is useful. The period under review starts in 2013 and ends in 2017, as this is the only period in which complete data could be found. The data is shown in table 5.

While UPS did not publish any company-specific data regarding package volumes, the package volumes can be reflected in the global growth figures. In the years from 2012 to 2015, the annual growth was stable at a level of 4.3%-5.8%. However, afterward there were two consecutive years of enormous growth leaps. In 2016, there were 9.2% more packages, while in 2017 there was the biggest spike with an annual growth of 11.4%.

UPS's GHG emissions have also steadily increased from the beginning to the end of the study period. While emissions were at a level of 12.598 CO2e metric tonnes in 2013, they jumped to 13.792 CO2e metric tonnes in 2017. The largest annual rise can be seen between the years 2016 and 2017 with 529 CO2e metric tonnes, which is a percentage increase of 3.99%.

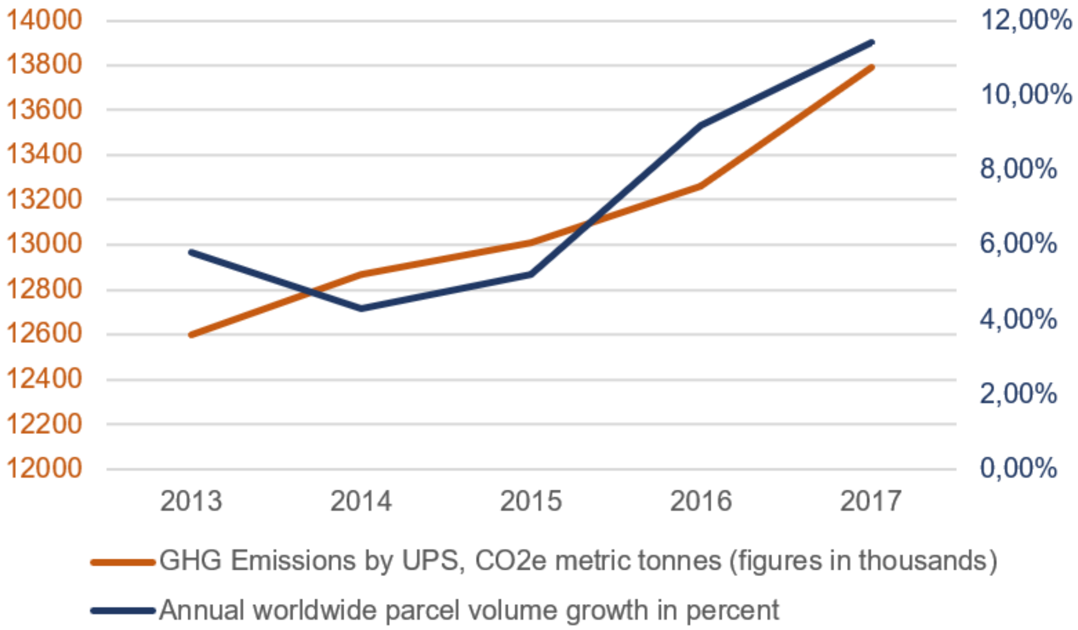


Figure 6. Relationship between global package volume and GHG emissions of UPS.
Source: Adapted from *(Mazareanu, 2020)* and *(UPS, 2018)*

In order to illustrate the development of both comparative variables in a clear manner, the data were summarized in Figure 6. The similarity of the two curves suggests that there is a correlation. While both initially increase only slightly or even decrease slightly in the years 2013 to 2015, the line for both variables rises sharply from 2015 onward. The high point for both curves is reached in 2017. From this observation can be deduced that the increasing demand of the e-commerce sector has a recognizable impact on the GHG emissions of UPS. Consequently, the fulfillment of the sustainability goal of reducing GHG emissions from ground operations by 12% by 2025 is also made more problematic.

4.2 Green Warehousing of UPS

The company offers its services to almost every location in the world so that it operates over 2,500 warehouses worldwide with a total of 28.6 million square feet of automated facilities (UPS, 2020). Almost all of these facilities fall into the warehousing category of parcel delivery centers, while the company has only 12 hubs around the world. Their operation allows resources to be centralized in a small number of locations while still taking advantage of the smaller distribution channels. With five hubs, most of the hubs are located in the USA (Smyth, 2020).

The importance of sustainable warehousing becomes visible when examining the composition of the company's total GHG emissions, which can be seen in table 6. The company reports four emission sources: airline fuel, vehicle fuel, facility fuel for heating, and facility electricity. By far the largest emissions are emitted by the company's private airline fleet as it contributes more than half of all emissions in any given year. The second-largest share is attributable to the company's vehicle fleet. It is noticeable that emissions from both sources have risen steadily in recent years. In comparison with the emission allocation of the Carbon Trust Report of 2019 presented in the second chapter, which refers to the entire global logistics industry, this weighting is thus different. While in the global transport sector, almost 2/3 of the emissions are attributable to road transport, at UPS the figure is only 1/3. This demonstrates the specialization of the company in air freight.

With regard to the warehouses, which are the focus of this work, the emissions are divided into the categories facility fuel (heat) and facility electricity. It can be seen that the largest part of emissions is caused by electricity consumption and only a smaller part by the heating systems. On the positive side, it is noticeable that the share of warehouse emissions in total emissions is decreasing over the years. While this value was 8.34% in 2013, it decreased to 7.04% in 2017.

Overall, the company succeeded in significantly reducing emissions of the facilities despite increasing package volumes. After an initial rise of 7.14% of emissions in 2014 compared to 2013, the company gradually minimized emissions. In 2017, an annual reduction of 7.83% was achieved despite an enormous growth of parcel volumes within this year. It can be deduced that the measures implemented by UPS have had an effect.

The following section will examine which technologies the company relies on in its warehouses to drive this positive development.

Table 6. GHG emissions by source of UPS in CO2e metric tonnes.

Source of GHG Emission	**2013**	**2014**	**2015**	**2016**	**2017**
Total	12,598	12,870	13,011	13,263	13,792
Airline Fuel	7,160	7,195	7,375	7,720	8,190
Vehicle Fuel	4,387	4,549	4,587	4,496	4,631
Facility Fuel (Heat)	223	256	235	216	226
Facility Electricity	828	870	814	831	745
% share of facility emissions of total emissions	8,34%	8,75%	8,06%	7,89%	7,04%
Annual % change of facility emissions	-	+7,14%	-6,84%	-0,19%	-7,83%

Source: Adapted from *(UPS, 2018)*

4.2.1 Current practices in the warehouses

From UPS's perspective, the operations within the warehouses offer great possibilities to lower energy consumption and thus also GHG emissions. Therefore, the company has decided to establish best practices that are considered in the building of new facilities and in the renovation of existing facilities (UPS, 2018). The aim is to obtain a Leadership in Energy and Environmental Design (LEED) certification for the buildings. The LEED rating system, which is awarded by the U.S. Green Building Council, is a voluntary standard for sustainable buildings. Receiving such a certificate reflects the incentive of a company for efficient and sustainable building design (Lane, 2012). Facilities are assessed on various aspects, including sustainable utilization of resources, high energy efficiency, and sustainable indoor environment (JOC.com, 2012). At the present time, 18 UPS facilities meet the high standards of this green-building certificate (UPS, 2020). The areas of lighting, HVAC systems, and material handling equipment discussed in this paper also fall under these evaluation points.

Table 7 shows the technologies used by UPS in the warehouses and relates them to the theory discussed in Chapter 2. Most of the information was gathered by the warehouse manager Jestädt (2021).

Table 7. Connection of UPS's warehousing measures with theoretical models.

Energy Systems	Handling in UPS facilities	Reference to theory
Lightning	Complete LED conversion, used in all areas of the warehouse	2.5.1.1 Lighting systems Ries, Grosse, & Fichtinger, 2016
	Deployment of light sensors only outdoors, not indoors	2.5.1.1 Lighting systems Carbon Trust, 2019
	Utilization of daylight through windows in the center of the gable roof	2.5.1.1 Lighting systems Waqas Amjed & Harrison, 2013
Heating, cooling & ventilation	No temperature specification, employees should feel comfortable during their activities	2.5.1.2 Warehouse Heating, Cooling & Ventilation Carbon Trust, 2019
	Gas-fired radiators heat the entire warehouse, placed next to outdoor docking bays	2.5.1.2 Warehouse Heating, Cooling & Ventilation Carbon Trust, 2019
	Planned future installation of air rotation systems, but not yet implemented on a large scale	2.5.1.2 Warehouse Heating, Cooling & Ventilation Carbon Trust, 2019

Material handling equipment	Control of the speed of the parcel conveyor belts	2.4.3.1 Sustainable engineered systems CMC, 2021
	Shunting vehicles, mainly 12-tonne trucks operated with diesel fuel	2.5.3.2 Sustainable powered vehicles Engel, 2018
	Forklifts powered mainly by gas	2.5.3.2 Sustainable powered vehicles Engel, 2018
	Deployment of electric pallet trucks	2.5.3.2 Sustainable powered vehicles Engel, 2018

Source: Own elaboration

UPS implements a variety of technologies that have been recommended in the literature. These include the complete switch away from incandescent bulbs to LED lighting systems, which is supported by the use of light sensors. However, such sensors are only used in external areas, as the entire warehouse is used for operational purposes and must therefore also be illuminated. In addition, the company also follows the proposal of providing a large part of the required light within the warehouses by flooding in daylight. The company achieves this by glazing the center of the gable roof. This can be opened and closed automatically so that the air quality can also be better controlled (Jestädt, 2021). Contrary to theoretical recommendations, the company foregoes the use of daylight sensors, which automatically find the right balance between daylight and illumination. The recommended use of different types of lamps in different operating areas was also not followed.

When asked about the temperature setting indoors, the warehouse manager (Jestädt, 2021) replied that there is no temperature specification. The most important factor is that the employees feel comfortable during their physical exertions. For heating the entire facility, the company uses permanently installed gas-fired radiators distributed throughout the hall. The heating automatically switches on when certain temperature limits are reached. This heating option of the “warm air” is also recommended in the literature, as it is highly effective when handled correctly. UPS also takes care to ensure effective insulation throughout the building. Not yet implemented but in the planning phase is the installation of air rotation systems in a wide range of facilities. These systems are intended to provide optimal ventilation and air circulation in the summer (Jestädt, 2021).

The parcel conveyor belt plays an essential role in the warehouses of UPS. Depending on the parcel volume the system has to deal with, it can throttle and increase the running speed. In larger hubs this works via sensors, while in smaller parcel centers the speed is set manually. However, the background of this system is not necessarily of sustainable nature, rather it fulfills the purpose of facilitating the work of the employees. The powered vehicles used at UPS consist mainly of shunting vehicles, forklift trucks, and electronic ants. Shunting vehicles have the function of transporting the swap bodies to the gates of the warehouses. For this purpose, UPS relies on 12-tonne trucks that run on diesel. Although diesel-powered trucks are not the most environmentally friendly type of fuel, these are best suited for the operation carried out. Diesel vehicles have great power and operate without problems outdoors. In most parcel centers, the use of electrically powered pallet trucks is sufficient, so no forklifts are needed. Only in large hubs and sorting centers gas-powered forklifts are deployed. According to the warehouse manager (Jestädt, 2021), electric forklifts or fuel cell-powered forklifts do not yet play a role.

4.2.2 Future Green Warehousing projects

In addition to the current warehousing practices, UPS is working on designing the warehouses of the future. A number of these projects are related to reducing water consumption. One example is the construction of the Atlanta (USA) facility in 2018. The facility operates a system that recycles and uses water to wash vehicles. This innovative system can save approximately 7.6 million liters of water annually. The facility in Paris (France), which was built in 2020, also collects rainwater in barrels and uses it for the same purpose. UPS is looking into the feasibility of this system for other facilities in the future (UPS, 2020). However, Stodick emphasized that the question of business viability is a major factor in the decision-making process. Setting up such a system is usually not economical in practice (Stodick, 2021).

Furthermore, the company is putting a lot of effort into building up its own power generation for renewable energy. The company's own solar systems are expected to play a key role here, as these should also guarantee a sufficient power supply for charging electric vehicles. One prototype is the warehouse in Visalia, USA, which was built in 2020. The entire electricity demand of the facility is covered by the supply of the in-house solar system. It is intended to provide the impetus for a completely climate-neutral facility (UPS, 2020). According to Stodick, many facilities already have solar systems, especially in the USA it is becoming more and more common. The problem of an extensive expansion of solar energy is, as in the point above, the profitability. Many of the buildings are several decades old and retrofitting them with solar systems involves high financial outlays (Stodick, 2021). Nonetheless, the company will need to make major developments in this area if it wants to achieve its 2025 target. This requires that at least 25% of all electricity used in the facilities is generated by sustainable sources (UPS, 2020).

4.3 Provision of charging infrastructure for electric vehicle fleets

In the overall context of environmental protection, it can be assumed that electromobility is one of the most relevant pillars of UPS's sustainability strategy. It relates to three of the four environmental sustainability targets the company has set itself: a 12% reduction in emissions from ground operations, a 40% share of alternative and sustainable fuels throughout the entire fleet, and 25% of all new vehicles purchased each year equipped with sustainable technology. The objectives are based on the company's belief that the logistics market will make a considerable breakthrough in the electrification of mobility in the next decade. Further technological advances of battery systems and increasing ranges combined with decreasing costs will make the adaptation of electric fleets attractive and indispensable (UPS, 2018).

Presently, the company operates more than 10,300 vehicles worldwide that are powered by alternative fuels or advanced technology. By comparison, the logistics company's entire fleet consists of 125,000 vans, cars, tractors, and motorbikes (UPS, 2021d). This means a current share of vehicles powered by alternative fuels or advanced technologies of slightly more than 8%.

4.3.1 Charging infrastructure as an obstacle

In the interview, the sustainability manager (Stodick, 2021) also confirmed this promising forecast of his company regarding electrification in the future. However, he emphasized that this development is coupled with a successful expansion of charging infrastructures in the facilities, which are not yet sufficiently present in Europe and the USA.

He further explained that establishing such an infrastructure is as challenging as acquiring electric vehicles suitable for parcel delivery. At the moment, the company's electric vehicles are divided into many small fleets so that the current charging infrastructures of the warehouses are still largely sufficient. However, with the desired rise of electric vehicles in the entire fleet, the capacity demand on the charging stations and simultaneously on the local power grids will also increase. It must be ensured that the local power grids are capable of charging a high number of vehicles and supplying the other material handling equipment with sufficient power at the same time (Stodick, 2021).

According to Stodick (2021), most of the sites lack this capability at the moment. Difficulties arise because the respective local conditions prevent the supply of larger power lines to the warehouses or the local power grid does simply not have enough capacity. This already existing issue is intensified by the decision of the company to increasingly rely on the electrification of trucks with a maximum load of 7.5 tonnes. The reason behind this decision is that these trucks have a higher loading capacity than the smaller vans and can drive longer routes more efficiently. From the company's point of view, they have a higher utility and sustainability value than electric vans. However, this also implies that even more power is needed at the charging stations (Stodick, 2021).

4.3.2 Addressing the charging Issue

In 2017, UPS set itself the task of overcoming this hurdle. It joined a consortium in the UK which is working on the deployment of smart grid solutions. These solutions should enable the simultaneous charging of a large electric fleet in single warehouse facilities without expensive investments in the expansion of the local power grid (UPS, 2018). At the beginning of 2018, the breakthrough of the "Smart Electric Urban Logistics" project was achieved. According to the company, the largest functioning smart grid solution to that time was created, meaning a significant advance for electric mobility. The system enables UPS to operate 170 electric vehicles simultaneously at its central London site, up from 65 previously (UPS, 2018).

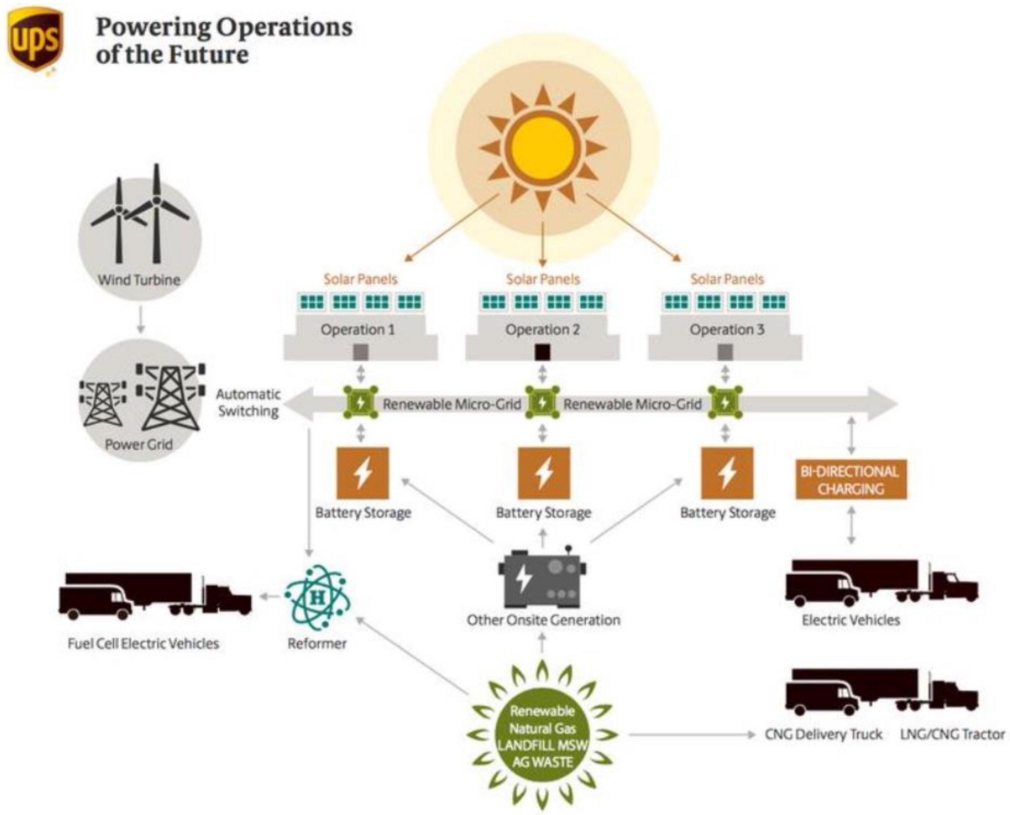


Figure 7. UPS smart grid and onsite energy storage solution.
Source: *(Smart Energy Decisions, 2018)*

Figure 7 illustrates the mode of operation: The smart grid's central server is networked with the grid power supply, the on-site energy storage system, and each individual charging point. By distributing the charging process of the electric fleet over the whole night, the smart system manages to maintain an uninterrupted power supply to the operational systems in the building (lights, conveyor belts, etc.). Additionally, it ensures that all vehicles are fully charged by the time they are used in the morning but never exceed the maximum available power of the network (UPS, 2018).

Another key element of this system is the so-called “onsite energy storage batteries”, which together with the smart grid technology might be the game-changer. The batteries are able to store the energy generated locally by solar energy or other energy generation systems and release it when needed. At the moment, new batteries are deployed, but the company is also working on solutions to use second-life batteries from vehicles (Mandel, 2018).

Stodick is convinced that this technology will play an important role in the extension of electromobility. Although the system still needs to be further developed, it will be a common practice in the logistics industry of the future (Stodick, 2021).

4.3.3 Link with theory

The system developed by the Smart Electric Urban Logistics initiative is widely similar to the models already discussed in the literature. The combination of an intelligent smart grid system, onsite energy production, and storage batteries enables UPS not only to increase the number of electric vehicles but also to generate further financial benefits (IRENA, 2019).

One option is to provide an energy management service for the power grid. Depending on market conditions, UPS can act as both a buyer and a seller of electricity. During off-peak periods when market prices are low, the company purchases electricity, stores it in storage batteries and utilizes it to recharge its fleet when needed. Conversely, when prices in the electricity market are higher, UPS can sell its stored energy back into the market. This can be done, for example, through vehicle-to-grid solutions as explained in chapter 2 (IRENA, 2019; Bland et al., 2020).

Stodick (2021) also confirms this future possibility but emphasizes that at the current time, the technology developed is still at an early stage. For the time being, the priority is to implement the charging infrastructure in the facilities across the board and in a timely manner. However, he personally assumes that it will take at least 5 more years until new technological findings enable a general standardisation of the system (Stodick, 2021).

5 CONCLUSIONS

This chapter illustrates to what extent the sub-research questions and the main question posed at the beginning can be answered by the research done, what practical contribution this work provides, which international approach it offers, but also which limitations must be mentioned.

5.1 Answers to the sub-questions

Research sub-question 1: To what extent does the e-commerce boom influence the capacity utilization of logistics companies and danger their sustainability goals?

The relevance of the e-commerce sector to the retail sector as a whole is growing as a result of the ongoing digitalization around the world. Breaking the 2 billion digital buyers milestone demonstrates the huge opportunities available to e-commerce sellers. This is accompanied by enormous financial gains for companies involved in the supply chain. However, there is also a downside to this development. The global transport of goods is increasing significantly and leading to higher emissions.

The results of the UPS study, which as a logistics company can be listed as one of the main players in e-commerce logistics, illustrate this extent. The company's distribution network remains capable of coping with increasing capacity requirements without the need for large-scale investments. Process optimizations seem to be sufficient. However, a different picture emerges with regard to emissions. In 2017, the year in which the e-commerce sector experienced its largest annual sales growth of 28% and the growth of the total global package volume was also 11.4%, the company had to record its largest GHG emissions to date (UPS, 2018). The findings suggest a clear correlation between the increasing parcel volumes and the increasing emissions of the logistics company. In particular, airfreight saw a huge rise, pointing to an ever more interconnected world regardless of distance.

As a consequence, UPS faces a major challenge in meeting its sustainability goals, such as the desired 12% reduction in GHG emissions from global ground operations by 2025. Although UPS has been awarded for its sustainability efforts in many rankings and can be considered a pioneer, it is running into difficulties in this regard. It can be assumed that other companies in the logistics industry are also in a similar situation and have to rethink their approach to emissions reduction.

Research sub-question 2:

What technologies are used at warehouses to reduce energy demand and pollutant emissions?

Warehouses emit approximately 371 megatons of CO2 annually, which represents 13% of total supply chain emissions. This is a significant contribution when compared to other logistics activities such as rail freight (122 megatons of CO2), air freight (235), or even ocean freight (476). Considering also the rising forecasts regarding the further development of emissions, the necessity of sustainability measures becomes clear.

Indeed, it seems that logistics companies such as UPS have understood the need for action to some degree. A great number of the recommendations from the literature for achieving sustainable warehousing can be observed in the company's facilities. Sustainable technologies have been applied in all three energy-intensive areas of the warehouse: lighting, HVAC systems, and material handling equipment. Probably the most energy-saving measures taken by UPS were the switch from incandescent lamps to full LED lighting, as well as the installation of glass roofs to optimize the use of daylight. In addition, the company relies on efficient heating systems and a high degree of insulation of the buildings. In terms of material equipment handling, the company also strives to use sustainable systems in line with the current state of technology.

The evaluation of the emissions data has proven that the efforts made in recent years are paying off. Between the period 2013 to 2017, greenhouse gas emissions from warehouse operations declined from 1051 to 971 tonnes of CO2. This corresponds to a reduction of approximately 7.6% (UPS, 2018). This is a remarkable development considering the increasing parcel volumes during this period.

Nevertheless, the warehouses are still far from being nearly climate-neutral facilities. Promising opportunities in the areas of parcel conveyors, air rotation systems, water conversation, and solar installations are being missed. The reason for the partial omission or hesitation in implementing emission savings could be the lack of economic efficiency. Retrofitting the buildings, some of which are decades old, is costly and the sustainable measures are not always monetarily profitable. This is an obstacle that affects not only UPS but the entire logistics industry.

Research sub-question 3:

To what extent does current technology in warehouses provide charging infrastructure for electric fleets?

A far greater divergence between the theoretical models and their implementation in practice can be observed in this research question. The literature extensively explains how a smart grid solution for solving the current problems in setting up the charging infrastructure could look like and what benefits it could bring. Although this topic is already of great importance for the deployment of electric mobility today, it is surprising that so far few to no implementations of such models can be found on the logistics market.

According to its own statements, UPS is one of the first companies to have ventured into a project of this magnitude. By joining forces with scientists and universities, the "Smart Electric Urban Logistics" project has succeeded in developing a functioning network of intelligent smart grid systems, onsite energy production, and storage batteries. If the company now manages to reduce the complexity of this system and to minimize the costs of installation, thus making it suitable for general use in parcel centers, this would be an enormous step towards electromobility. UPS could come much closer to meeting its sustainability goals in the short term while putting significant pressure on its competitors in the industry.

5.2 Answer to the main research question

How can logistics companies minimize their carbon footprint despite the increasing volume of e-commerce parcels?

The e-commerce revolution in the retail sector has changed supply chain operations around the world. Long delivery distances are becoming less relevant and the volume of parcels is rising to new record highs every year. To the advantage of sellers and end customers, to the detriment of the environment. The UPS case study clearly shows the negative impact of increasing global transport on the carbon footprint of the companies involved. The objectives set in connection with the commitment to the sustainable development goals 2030 of the United Nations are in danger of failing.

However, there is hope by looking at the solutions offered by technological progress. The area of warehousing plays a decisive role. Besides the enormous potential for saving emissions in the classic energy-intensive areas, the charging infrastructure for electric vehicles lays the foundation for the climate-neutral delivery of parcels. Apparently, it will still take some time until standardized smart grid solutions are available that can be implemented in a large number of warehouses at a low financial cost. The project driven by UPS can be seen as a promising prototype and contribute greatly to future research in this field.

Ultimately, in answering the research question, it must be stated that companies can only compensate increasing emissions by realizing any possible emission-saving opportunity, no matter how small, within their supply chain. As pointed out in the literature, single measures are not sufficient, rather a combination of various sustainability measures is necessary. In this context, the possibilities of technological progress should not only be used for the development of successful e-commerce business models but also for the development of innovative sustainability measures at the same time. Cost-effective, standardized, and thus simple-to-implement solutions are needed to minimize the carbon footprint of the supply chain across the globe.

5.3 Practical contribution

The practical contribution of the thesis is that it examines the extent to which the recommended technologies and measures from the literature are feasible for companies up to the present day. Thus, in the second chapter, this theory was first presented and then in the fourth chapter compared with the practices of the company under study.

The aim was to identify not only current sustainability measures but also to define the challenges that companies are facing in practice. In other words, what hinders companies from turning their existing sustainability drive into actual practice. Additionally, promising projects that might have a lasting impact on the future direction of the industry were considered. The results of this work can not only be applied to traditional logistics companies such as UPS but are also applicable to general retailers with globally developed supply chains.

For this analysis, the globally active U.S. company United Parcel Service of America, Inc. was selected. As a global leader in the logistics industry and as a company that is primarily experiencing the impact of the e-commerce boom, it was well suited to investigate the set research objectives. The assumption was made that the emission impacts of e-commerce and the existing sustainability practices within the warehouses of UPS reflect, to some extent, the logistics industry as a whole.

5.4 International aspect

The logistics service provider UPS, as well as the majority of the e-commerce companies involved, operate internationally. Their supply chains have many distribution channels and cross a large number of countries. Environmental protection can only be successful if measures are implemented across countries and companies understand the global scope of their supply chain. Therefore, the research questions were always tried to be answered from a global perspective.

5.5 Limitation

Nevertheless, the work is also subject to limitations. Firstly, it must be mentioned that the interviewees may not have been capable of covering all measures and projects within the company completely with their knowledge. The company owns a too large number of facilities, which also have different technological statuses due to their varying ages. However, it can be assumed that the most relevant projects for environmental protection were in the field of knowledge of the experts.

Secondly, no complete data on the GHG emissions of UPS from the year 2018 could be found, as these were not published. Thus, the effect of the Covid 19 pandemic on e-commerce and its consequences on pollutant emissions could not be considered in this work. It can be assumed that the forecasts used in the work, which were made before the pandemic, may now deviate to some extent.

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