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# Green 3PL Warehousing

A case study of how Kuehne Nagel Sweden's warehousing operations can become green.

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# Abstract

The thesis aims to analyze how the 3PL industry can become more sustainable in its warehousing operations. The thesis presents several factors that affect a 3PL warehouse's environmental impact through a qualitative case report. The results are based on interviews with relevant persons working within or in connection to 3PL warehousing. These interviews are analyzed in combination with a theoretical framework to ultimately answering the research questions. The conclusion structures a framework for Swedish 3PL-actors to consider when shaping their sustainable warehouses. Factors affecting a warehouse's energy efficiency are investigated to identify which areas are of higher importance to reduce the environmental impact of the warehousing operations. Also, the thesis explores the possibilities of self-producing solar energy, revealing the current pros and cons of producing renewable energy and presenting two different approaches for developing solar energy production plants. Additionally, the future of energy storage is explored to draw a picture of where the market is today and why energy storage should be considered for all modern warehouses.


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**Key words**: Green Warehousing, Green Energy, Energy Efficiency, Energy Management, Solar Energy, Energy Storage, Vehicle-2-Grid, Fast Charging, Electric Vehicles, eTrucks

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*Best regards,*
*Kevin Storgärd*

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# 1. Introduction

*The introduction chapter gives the reader the necessary background knowledge of the subject and basic understanding. Also, there is a problem discussion rendering a picture of why the research is needed, followed by the purpose and research question. Lastly, there are delimitations to the study and an overview of how the thesis is structured.*

## 1.1 Background

Companies worldwide have to collaborate with external parties to strengthen their competitive advantages to the market and the intense competition (G. Wang, Dou, Zhu, & Zhou, 2015). Interorganizational collaboration can be done through partial partnerships and entirely outsourcing functions or business units of a company to be operated by the external party. Logistics has received increased attention from companies globally, as logistics processes are critical to a company’s success (Raut, Kharat, Kamble, & Kumar, 2018). To strengthen competencies, companies can therefore decide to outsource their logistical function to a third-party logistics provider, commonly and hereafter abbreviated to “3PL”, to access said 3PLs expertise and customer service. Transportation, warehousing, distribution, and fulfillment are functions that often are outsourced. While one 3PL can provide one or multiple aspects, one company could also decide to have numerous 3PLs simultaneously. Outsourcing logistics has positive effects on reducing costs, increasing customer care, and strengthening competitive advantages (Aguezzoul, 2014). Extending on cost reduction, when outsourcing the logistics function, there is a decrease in otherwise extensive investments, an increase in flexibility, and also a higher focus on core competencies within the organization, which ultimately gives an increase in efficiency (Göl & Çatay, 2007; J.-J. Wang, Wang, Liu, & Chen, 2015).

However, modern supply chain managers have to consider further considerations than business performance as environmental impact grows in importance (Zhu, Sarkis, & Lai, 2008). Logistics play an imperative role in green supply chain management (Zailani, Amran, & Jumadi, 2011). Research estimates that the logistics industry is responsible for around ten percent of global energy usage and greenhouse gas (GHG) annually (Marchant & Baker, 2012), estimations made excluding transport operations. Thus, the “greening” of supply chains has grown a vital part of any business as it implies revolutionary changes to the logistics industry (Zhu et al., 2008). The demand for more advanced and environmentally responsible logistic services has led 3PLs to seriously reinvestigate their operations to decrease their environmental impact (Evangelista, 2014; World Economic Forum, 2009). Furthermore, changing services to lessen the environmental impact is positive for most organizations as customers recognize the effort favorably (Piecyk & Björklund, 2015). Therefore, many modern 3PLs adapt strategies and current practices to increase environmental efficiency, now integrating a sustainable perspective in all activities (Zailani et al., 2011). Also, since 3PL's primary function for their customers is to orchestrate their supply chain, and thus its environmental impact, having the expertise and capabilities of managing green supply chains grows critical for all 3PLs (Anttonen, Halme, Houtbeckers, & Nurkka, 2013). Exploring these environmental issues can result in business opportunities is crucial for any 3PL to identify and establish sustainable best practice logistical activities (Raut et al., 2018).

Last year, global 3PL-company Kuehne+Nagel announced their new sustainability program, Net Zero Carbon. The program entails that the company will become net-zero carbon in all organizational legs by the year 2030 (Kuehne+Nagel, 2020a). The program includes their warehousing operations. Therefore, this thesis is written in collaboration with Kuehne+Nagel’s Swedish Contract Logistics organization to investigate what measures are essential for their warehousing operation towards reaching carbon neutrality.

## 1.2 Problem Discussion

As presented above, the world is becoming increasingly aware of their environmental impact in different facets of our lives. Dr. Detlef Trefzger, Kuehne+Nagel’s CEO, states that “Consumers drive the change, companies make it happen” (Kuehne+Nagel, 2020b) when discussing their new sustainability commitment. Increased consumer awareness puts stricter demands towards businesses practices and operations, which have a domino effect on companies demanding their suppliers to also fulfill earlier unprecedented sustainability goals. The increased “new” measurements have forced most industries to completely rethink their prior work as they now have to include the sustainability perspective throughout their business model. A large part of most businesses is logistics, or supply chain management, which stands for around ten percent of global GHG emissions (Marchant & Baker, 2012); thus, a “greening” of the logistics industry could have an extensive impact on the environment. Customers no longer accept dirty supply chains, and therefore 3PL companies have to adjust their operations to supply a green service (Evangelista, 2014).

The 3PL industry is arguably challenging to transform into a green industry, as the transport sector still omits immense volumes of GHG. However, measures are made to reduce the environmental impact in multiple ways throughout the whole industry. Sustainable transports, energy efficiency measures, recyclable packaging materials, responsible sourcing of materials, and carbon offsets are measures currently implemented to reduce the environmental impact. Warehousing is a natural part of any supply chain, but there exists little knowledge of what a green warehouse entails. Marchant and Baker (2012) propose a strategy for reducing the environmental impact of warehousing that involves reductions in energy intensity and incorporating renewable energy. This study will further explore energy efficiency to identify which measures are more critical than others to increase a 3PL warehouse's energy efficiency. Moreover, there exists little literature on the subject of local production of renewable energy in connection to logistics facilities. Therefore, the study will further investigate energy efficiency and local production of renewable energy and how these two aspects together can facilitate green 3PL warehousing in a Swedish context.

## 1.3 Purpose

The purpose of this study is to analyze how the 3PL industry can become more sustainable. The purpose will explore in the context of Kuehne+Nagel's operations in the Swedish market. The study will give special attention to energy efficiency in warehouse operations and how warehouse facilities can produce, sell, and store renewable energy.

## 1.4 Research Questions

- How can a 3PL adapt its warehousing operations to maximize energy efficiency?
- How can sustainable energy management systems work in warehousing?
- To what extent can a warehouse become self-sufficient in sustainable energy?
- Can energy storage become a viable part of a warehouse's energy system?

The research serves to answer multiple questions, which are all different in how they are constructed. The questions are structured differently, thus creating a dilemma where the questions do not have the same pre-conditions to be answered using one comprehensive method. Therefore, the following paragraphs explain how the author decided to answer each question, given the prerequisites identified after researching the theoretical framework that this thesis is built upon.

The first question is '*How can a 3PL adapt their warehousing operations to maximize energy efficiency?'*, touching upon a topic with prior literature directly relatable to any actor aiming to increase energy efficiency in any warehouse. The question is, however, directed to 3PLs specifically, thus demanding further anchoring in empiric evidence. Therefore, the answer to this question will be identified by analyzing primary and secondary sources found in the theoretical framework and empirical findings.

The remaining three questions are common in their theme, though they are necessary to break them apart into separate questions to answer them comprehensively and not be too general. Nevertheless, the questions will be answered by analyzing the empirical findings as existing literature does not cover the topic well enough. The questions, therefore, have to be examined primarily through primary sources, i.e., the empirical findings, and then supported or challenged by the collected secondary sources. Interviews with experienced persons will be critical to answering these questions. The interviewees do not necessarily work within 3PL warehousing, though their companies will connect to the topic and become relevant in finding answers.

## 1.5 Delimitations

Due to the extent of this study and the current restrictions resulting from Covid-19, some delimitations have been made. Primarily, the focus has been narrowed down to only looking at Swedish warehouses, and even more so, exploring Kuehne+Nagel Sweden's contract logistics operations in Sweden. Kuehne+Nagel is a global actor within the 3PL industry, so delimitations entail only considering warehouses run by 3PL companies. Also, most 3PLs do not own the warehouses they operate within, as they are renting the space according to their expected demand over a given amount of time. Thus, the thesis originates from a perspective of a 3PL that does not own the warehouse itself. Renting warehouse facilities is also the case for Kuehne+Nagel Sweden, as they rent all facilities. Therefore, the focus will be only on factors the 3PL has direct influence over, i.e., their daily operations and energy usage. Moreover, factors such as water management and recyclable packaging materials are also excluded from the thesis. This is mainly due to the time constraints of the thesis and maintaining a more cohesive scope.

A factor that has a significant impact on sustainability is transportations, and a 3PL can definitively affect a supply chain's environmental footprint through purchasing sustainable transports. However, customers are ultimately in charge of what type of transportations they want and whether or not they will utilize the same 3PL for that task. Therefore, the warehousing

3PL is not necessarily in control of the transportation to and from their warehouse, resulting in this thesis being focused on only the warehousing operations itself.

## 1.6 Research Structure

The layout of the research conducted follows accordingly,

1. *Introduction*. It gives the reader the necessary background knowledge of the subject and lifts why the research has been undertaken, the goal, and the research question.
2. *Methodology.* The methodological process is explained and detailed.
3. *Theoretical Framework.* Presenting relevant literature and other sources of information necessary for better grasping the research.
4. *Empirical Findings.* Primary data and information are sourced from interviews and reports.
5. *Analysis.* Literature, theoretical framework, and empirical findings are combined in analysis to answer the research question.
6. *Conclusion.* The contributions of the research and the answer to the research question are summarized, and additional suggestions for further research are presented

# 2. Methodology

*The methodology chapter will detail how the research has been conducted—starting by explaining the general research approach, followed by the research design, how data was collected, and the quality of the study.*

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## 2.1 Research Approach

This thesis explores how 3PLs can design or redesign their operations to become more environmentally sustainable. Redesigning operations means adapting the actual processes in how the company operates and adjusting processes that today waste more energy than needed and thus, make the energy consumed greener. For this thesis, a qualitative perspective is used as information, thoughts, and data are collected from a myriad of sources. The qualitative perspective is used as the data is of nominal form, meaning that it cannot be measured and therefore not be quantified, making the data qualitative (Collis & Hussey, 2014). Researching through a qualitative perspective also means that the researcher works from an interpretivist paradigm, recognizing that the "social reality" is highly subjective as it is shaped by individuals' perspectives (Collis & Hussey, 2014). The theoretical framework includes information from existing literature surrounding the research area and non-academic sources, such as company reports and articles. Also, under the theoretical framework, other cases or projects in sustainable warehousing or sustainable buildings are presented to enable further understanding of the subject. Next, within the empirical findings, all the presented sources will be primary data collected through interviews. Eventually, the thesis culminates in an analysis that combines the theoretical framework and the empirical findings. Lastly, the research questions will be answered in the thesis' conclusion and suggestions for further research.

## 2.2 Research Design

The method for conducting the research is a case study. Collis & Hussey (2014) describes case studies as a methodology for exploring a phenomenon in its natural setting while using different methods to develop in-depth knowledge. Furthermore, the case researched can differ and be a singular phenomenon, event, process, or business (Collis & Hussey, 2014). Also, considering green supply chain management research, the case study methodology is the most popular, primarily due to the difficulty in collecting empirical and secondary data (Min & Kim, 2012).

This thesis follows the case study methodology where the increased focus is on Kuehne+Nagel's operations in Sweden and their warehousing operations. There are different categories of case studies. This study will be within the category of opportunistic nature, explained by Otley and Berry (1994) as when the author has an opportunity and access to research a given business. For the sake of transparency, the author has been employed periodically by Kuehne+Nagel Sweden previously, which is how the collaboration originally started, though not within the contract logistics department. The research is also descriptive, explained by Ryan, Scapens, and Theobold (2002), as where the case is restricted to investigating current practices. Therefore, the given methodology for this case study is a combination of opportunistic and descriptive as it explores Kuehne+Nagel's current practices, making the thesis a descriptive opportunistic case study.

The research's design was shaped by the author's findings when researching for the theoretical framework. As mentioned earlier, the topic of "green warehousing" is relatively new, and limited amounts of prior literature exist. Thus, the literary research of the study helps enrichen the author's understanding of the research area and, thus, reveals the areas that require further research outside the literature. Therefore, the study's design follows the structured layout of the thesis, meaning that the theoretical framework lays the foundation of the study, which is later built upon by the empirical findings. These two chapters are then combined to help the analysis, which results in the conclusion.

## 2.3 Quality of the Research

After identifying the paradigm, either positivist or interpretivist, the quality of the research also needs to be secured. Two key aspects can characterize any research findings, reliability and validity (Collis & Hussey, 2014). As the findings and conclusions will be put under heavy scrutiny, the researcher will have to question whether their research upholds these two aspects (Raimond, 1993).

*Reliability*

Reliability refers to the extent to which the research is replicable with high accuracy and precision (Collis & Hussey, 2014). The reliability of the study is essential in a positivist research perspective, as the findings and result ideally should be replicable. Still, for an interpretivist view, it is more critical to build reliability if interpreted differently. Instead of relying on replicability, interpretivist reliability lies in whether the observations and interpretations performed on different occasions and by other observers can be explained and understood. This is due to the interpretivist perspective acknowledging that the researcher's bias can affect the research, thus cannot possibly obtain reliability from a positivist perspective. The emphasis is instead on creating rigid protocols to strengthen the reliability and authenticity of the thesis (Collis & Hussey, 2014).

For this thesis, reliability builds upon the diversity in information sources. When analyzing secondary sources, certain assumptions and interpretations are necessary to make as the information or results are not collected to be used in this report. This is also the case for the primary data collected, as qualitative data demands interpretation. Thus, the reliability stems from the author's ability to present his interpretations and their logic. Here, the analysis chapter of the thesis becomes vital. The author now renders their picture of how all the different pieces of information connect through the analysis. Therefore, the reliability lies in the author's transparency.

*Validity*

Validity describes to which extent the researcher's measures and results accurately measure the phenomena the research intended to explore (Collis & Hussey, 2014). Problems that affect the validity negatively are errors committed by either the researcher, poor selection of interview persons, or inaccurate measurements. There are multiple assessment measurements of validity, whereas "face validity" is the most commonly applied for this type of thesis. Face validity entails that the research researches and measures the values and ideas that it has stated to represent. Also, as validity implies that the findings correctly describe a given phenomenon, the validity is probable to be more significant when using an interpretivist research method than a positivist (Collis & Hussey, 2014).

To ensure a high level of validity, the author interviews various interview persons from different industries to build a more cohesive portrait. The variety in interviewees is foundational in increasing the validity of the research as the collected information from various sectors appearing or operating within one common industry paints a richer picture. The aim is to fill the pitfalls of information of one sector, by the competencies from another. Also, this stands true for the theoretical framework, as much of the literature is not necessarily related to "green warehousing". Several of the sources used originate from related research areas relevant to this subject.

*Generalizability*

Generalizability is to which extent a research finding can be replicated in different contexts, either by measuring other samples or in other settings (Vogt & Burke Johnson, 2011). When researching through an interpretivist perspective, it is imperative that the study correctly reflects the interactions and characteristics of the examined phenomena, as it otherwise creates difficulties for generalization (Collis & Hussey, 2014). Given the thesis' limitation of researching the 3PL industry's warehousing paradigm in a Swedish context, the possibility of obtaining a desirable level of generalizability for warehousing in Sweden is established. To succeed in achieving the generalizability of the research, the patterns, concepts, and theories presented also apply to a Swedish environment, which also demands a great understanding of the subject's activities (Collis & Hussey, 2014). The generalizability of the thesis develops through the limitations being one set area of research within one specific environment. Due to the thesis is written in collaboration with Kuehne+Nagel, some data or information may be more inclined to follow their set standards or prerequisites. However, the intent is to establish a general idea of what green 3PL warehousing means in a Swedish context and reach a higher generalizability level.

## 2.4 Data Collection

This thesis will analyze two types of data, primary and secondary data. Collis and Hussey (2014) define primary data as original data collected from, i.e., interviews, and secondary data as research data collected from prior research, such as articles, literature, or databases. In this thesis, primary and secondary data will be divided into different chapters. Its secondary data will be the majority of data in the theoretical framework. In contrast, primary data is more prevailing within empirical findings. Due to the thesis' interpretivist perspective and the usage of primarily qualitative data, the researcher needs to contextualize the information presented through collecting relevant background information, also known as contextualization (Collis & Hussey, 2014). Contextualization is so that the reader has the necessary information regarding the setting, time, political, economic, or social contexts. The contextualization helps expose unconscious biases, as persons of different cultures are likely to interpret findings differently, thus also identifying different conclusions.

### *Theoretical Framework*

The theoretical framework intends to introduce the reader to secondary sources of data, which includes data in the forms of published books, academic journals, conference papers, professional journals, governmental publications, statures, corporate reports, and internal documents or records from an organization (Collis & Hussey, 2014). Here, literature from relevant research areas presents a context that increases the reader's understanding of the subject. Also, since the research area of the thesis is narrow, i.e., green 3PL warehousing, literature in relating areas will be included as they apply to the topic. The literature helps build insight and thus becomes the foundation that allows more substantial analysis and conclusions.

Moreover, the theoretical framework will include a myriad of other secondary data sources. For example, reports from both within and beyond the 3PL industry will be included. The intent is to develop a further understanding of the underlying factors that affect the topic. Also, other cases of similar projects are given to the reader, for example, projects achieving high-grade energy performance certificates. The data are reports extracted from Kuehne+Nagel and other companies and are thus subject to some bias. However, data collected from Kuehne+Nagel is used to measure its current efforts and estimate its energy efficiency performance to enable improvements. Therefore, their data arguably have a level of credibility, as the motive is self-beneficial due to possible advances.

### *Empirical Findings*

The empirical findings primarily consist of primary data sources that are collected through interviews. Under the interpretivist paradigm, the goal of the interview is to collect data of the interviewees' opinions, attitudes, feelings, and understanding of a common topic, an area that they have in common (Arksey & Knight, 1999). The questions will be semi-structured in the interview, which means that there is a set of questions prepared beforehand for every interview. However, these questions will not follow a script, as they are flexible and subject to adjustments depending on the interviewee's responses (Collis & Hussey, 2014). The prepared questions are mainly "open questions", meaning that short questions are asked. The interviewer allows the interviewee to interpret the question, thus demanding reflection and enabling longer and often broader answers. The idea is to attain opinions and information about common themes, experiences, and feelings (Collis & Hussey, 2014). Although, open questions might not be optimal for very talkative persons (Collis & Hussey, 2014). Also, the semi-structured approach to interviews allows the interviewer to utilize "probes", which are short follow-up questions.

For example, “how did that affect your organization” or “could you elaborate on X”. Probes are utilized by interviewers to explore the interviewee’s answers more in-depth and allow for greater understanding (Collis & Hussey, 2014). The questions have significantly varied for the interviews, so there is no specific template for any given interviewee. Instead, the questions were changed to fit the interviewee’s experience better and expertise, to better extract better information. For example, not all interviewees would be able to discuss the benefits of switching to LED lighting systems, and thus they were not asked to.

*Interview-persons*

The selection process for persons to interview originates in contacting companies and organizations working with Kuehne+Nagel, such as real estate developers within the logistics industry and people internally at Kuehne+Nagel. At first, the author primarily considered sources within the Kuehne+Nagel’s sphere due to principally understanding the company's environment before considering other organizations. Following the initial selection of organizations to contact, the author contacted companies within different industries based on a presumptive idea of having the ability to contribute with good information. Thus, the sample became explorative, where the author aimed to create a richer picture by interviewing multiple persons within multiple industries about similar topics. A compilation of the interviewees can be found below, in alphabetical order.

| Name | Position | Company (Industry) |
|---|---|---|
| **Bergqvist, Rickard** | Professor | University of Gothenburg |
| **Campbell, Simon** | Project Leader | Logicenter (Real estate) |
| **Carlsson, Christin** | Sustainability Manager | Castellum (Real estate) |
| **Delgado, Adrian** | Site manager Eskilstuna | Kuehne+Nagel |
| **Engdahl, Henrik** | Chief Engineer Charging | Volvo Trucks (Electromobility) |
| **Friedrich, Joakim** | AP & Assessor, BREEAM | SWECO (Engineering consultancy) |
| **Gillholm, Gunnar** | VP, Country Manager | Prologis (Real estate) |
| **Hegårdh, Hans-Erik** | QSHE National Manager | Kuehne+Nagel |
| **Kautonen, Arttu** | Solutions Product Manager | Mitsubishi/Logisnext (Forklifts) |
| **Knudsen, Thomas** | Product Manager & Energy Consultant | Jungheinrich (Forklifts) |
| **Laurén, Tobias** | National Director of Contract Logistics | Kuehne+Nagel |
| **Merkel, Torsten** | Corporate Program Manager<br>Real Estate and Facilities | Kuehne+Nagel |
| **Scano, Alberto** | Global Head of Facility Management | Kuehne+Nagel |
| **Sjövall, Karin** | Head of Sustainability | Logicenter (Real estate) |
| **Wulf, Torbjörn** | Sales | Ferroamp (Energy/Cleantech) |
| **Zielfelt, Henrik** | Business Development | Solkompaniet<br>(Solar energy equipment supplier) |
| **Österplan, Alexandra** | PR & Communications Manager | Nissan Sweden (Electromobility) |

*Table 1 - Interviewees*

# 3. Theoretical Framework

*The theoretical framework aims to survey the existing knowledge and prior research in related areas relevant for building a greater understanding of the topic. Here, the reader will be presented with the areas that are imperative to understand for continued reading, why these topics have been relevant in previous studies, and how these areas will be further utilized in this paper. The areas covered are Green Logistics, Warehousing, Energy Consumption, and Energy Management.*

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## 3.1 Green Logistics

Traditionally, the term 'Logistics' has been used to describe the process of a product's journey from raw material to production, transportation, storage, distribution, to its' final destination, consumption, as defined by McKinnon, Cullinane, Browne, and Whiteing (2010). Logistics always has been decisive in any companies' economic development and performance in business, though it is not until around 60 years ago that the field has been acknowledged as such. McKinnon et al. (2010) explain that logistics was first seen as a profession and an area worth academic studies when the world discovered the effects that the function had on business performance. Though, at this point, what was primarily measured and studied was how logistics could be adjusted and optimized to maximize profitability. Moreover, the factors being measured were economic costs, i.e., the direct costs that companies sustain due to their operations. Therefore, not including the indirect cost, such as environmental or social costs, also sustained from their actions (McKinnon et al., 2010).

However, around the millennia shift, these other costs started to receive attention as well. As a result of changing public opinion and governmental bodies realizing a growing threat to our planet's longevity, academia and companies began considering all the costs related to their organizations, direct and indirect (McKinnon et al., 2010). Again, before the change, only costs directly associated with the company's operations were accounted for. Then, with the change of focus, companies realized that their impact stretched wider than covering economic implications, including environmental and social aspects. Green logistics derives from sustainable development. The intent behind green logistics is, therefore, the same as the "Brundtland" report's definition of sustainable development: "development that satisfies the current needs without reducing the availability and quality of resources to allow future generations of people to meet their own needs (WCED, 1987)". Notably, when "greening" inbound, production, and outbound movement, there are significant indicators that these factors also increase competitiveness and boost the firm's economic performance (Rao & Holt, 2005). Thus, companies did arguably realize Elkington's (1994) Triple Bottom Line (TBL) paradigm of accounting for financial, environmental, and social aspects in their logistics function to increase business performance.

In this thesis, the definition of 'Green Logistics' is the same as Thiell, Zuluaga, Montañez, and van Hoof's (2011) "…all activities related to the eco-efficient management of the forward and reverse flows of products and information between the point of origin and the point of consumption whose purpose is to meet or exceed customer demand". McKinnon et al. (2010) agree with the definition, though also including their extended definition of "It assesses the nature and scale of these and examines various ways of which they can be reduced". Thus, the field has now evolved from being considered purely 'logistics' into also including the 'green' aspect of environmental consequences of operations.

## 3.2 Warehousing

Within this thesis, the definition of the term 'warehouse', and thus also warehousing, is the point where goods are stored for longer or shorter periods, and the movement of goods within, rapid fulfillment of customer orders, and also customization of services, adding value to customers value chain (Baker & Canessa, 2007). However, this thesis researches one 3PL company's warehousing operations, and their warehouses only entail storage, flow, and movement of customer goods.

Modern businesses are heavily reliant upon their supply chain's success, and a vital aspect of the process is the warehouses (Frazelle, 2002). Considering how supply chains are commonly structured, warehouses are a natural part of that chain because having direct supply from production to customers is seldom possible (Baker & Canessa, 2007). Thus, warehouses become hubs in between nodes within the supply chain. Moreover, supplier lead times rarely correspond with customers' lead times in demand, and warehouses help companies maintain stock to meet customer demand instead of a made-to-order system (Baker & Canessa, 2007).

*Green Warehousing*

When building green houses, the objective is to produce sustainable buildings for the people, the community, and the surrounding environment (Lee, Smith, & Carswell, 2012). Multiple factors need considering when evaluating the environmental impact of a warehouse. In their article, Marchant and Baker (2012) explain that it is crucial to reflect on the relative scale and the tendencies of the occupied land, direct energy usage, produced emissions, water consumption, and embedded energy emissions from the building material when developing a warehouse. Also, there are three ways of measuring these before-mentioned factors. The first one being when considering the area under occupation, the norm is to report the measures of the internal floor of the warehouse in square meters, thus excluding the surrounding area. Second, when measuring the energy usage and needles of which type of energy and method of generation used, energy should be measured in kWh, which creates the standard of calculating the energy usage as $kWh/m^2$. Furthermore, emissions omitted from the direct and embedded energy are measured in $CO_2/m^2$ (Marchant & Baker, 2012).

Therefore, developing sustainability in warehousing is possible, not only in new developments but also in redesigning or restructuring existing ones. Marchant & Baker (2012) draw a framework for assessing the development of sustainability in warehouses in their article. They render a general layout of macro- and micro perspective factors that need consideration. Though not all of these factors are necessarily relevant to a 3PL as they often rent the warehouse they operate in from a landlord, as a prospective tenant, one could make demands before the development of what a green warehouse requires. There are also Marchant and Baker's (2012) three "stages towards sustainability" in the before-mentioned framework. The first stage is reaching a "Baseline energy-efficient warehouse". This stage includes adjusting lighting and heating levels to appropriate levels, investing in luminaries, controlling air changes, battery maintenance, meeting minimum standards, active maintenance and control, measuring building energy, and overall cost. The second stage is "Low-emission and green energy warehouse", which focuses on switching energy used into renewable energy, such as solar energy, and generating renewable energy in-house through Combined Heat and Power systems (CHP) and wind. For this stage, the company should focus on cost, direct emissions, improve operations and equipment specifications. The primary aim of this stage is to adopt green energy and switch from carbon-intensive energy sourced from oil or coal. The last stage is "Sustainable warehouses", which is the most extensive one, including solar-, thermal-, and water recovery and management, local sourcing of building low energy materials, and overall supply chain sustainability. At this stage, it is no longer about meeting given minimum standards or environmental certification standards that we will go into later, but rather exceed these standards and go beyond those standards. The focus now shifts towards the total lifetime emissions and costs instead of today's direct emissions and costs (Marchant & Baker, 2012).

*Lighting Systems*

Nevertheless, some measures are arguably easier to make to decrease energy usage, for example, upgrading the lighting system. Traditionally, fluorescent lighting has been the standard in commercial buildings. More specifically, fluorescent tubes are by far the most common form of lighting systems found in commercial buildings (DoE, n.d.). Compared to incandescent lamps, fluorescent is much more energy-efficient, and their illumination is ideal for any large indoor area. However, LED lighting is becoming increasingly more prominent globally as they are more energy-efficient than all current alternatives. More specifically, LEDs require twenty percent less energy to omit the same lamination as a fluorescent solution (Relumination, 2016).

Prologis has an innovative program where they streamline innovation to increase efficiency in their facilities. The program bases on Prologis making large-scale procurement deals with suppliers, which they then offer their customers to implement into their systems. One example is their LED solution developed in 2019, where LED lights combined with motion sensors and monitoring systems control that dim and adjusts lighting levels by analyzing daylight and motion in the facilities and increasing energy efficiency (Prologis, 2019). The combination of LEDs and smart motion systems forms a lighting system that expects to decrease energy usage further.

*Heating Systems*

Warm air, or heat, has a lesser density than cold air, resulting in it rising above the cold air. This phenomenon causes a heating issue for warehouses as they tend to be rather tall buildings consisting of large and tall operation halls. In Wang & Li's (2017) article, they explain that this common phenomenon, of the warm air rising and cool air descending, is called thermal stratification. They elaborate by saying that the phenomenon is one of the largest sources of energy waste during winter as companies have to heat their warehouses resulting from the high heat fluxes through walls and roofs. One way of counteracting the phenomenon is through thermal destratification, meaning air circulates and mixes within the building (Wang & Li, 2017). It is often necessary to utilize heat in buildings in Swedish conditions due to the cold climate. When heating facilities, it is more efficient to actively deliver conditioned warm air and mix in with the air further down in the building, allowing smaller local air mixing devices such as small fans to mix the air (Wang & Li, 2017). Also, allowing the warm air to push downwards, warehouses can utilize large ceiling-mounted fans to enable further circulation in the building. However, there is a maximum amount of fans to be utilized within buildings to optimize the airflow and a specific air exchange rate within the facility  (Wang & Li, 2017), depending on size and other such variables. However, this requires a unique investigation for any given facility subject to these actions.

*Carbon Neutral Warehouses*

Internationally, there are examples of warehousing projects with a stated commitment to being carbon neutral or positive while in a similar environmental context as Sweden. The following sub-chapter will summarize two of these projects, showing which actions these projects lift as a part of their work towards carbon neutrality.

*Borås – Logicenter*

In Borås, Sweden, Logicenter built what was at the time the Nordics' most extensive roof-based solar panel system on their 83 000 $m^2$ logistics facility. The system covers a total area of 60 000 $m^2$. According to the tenant currently occupying the facility, it estimates annual production of 4 GWh of renewable energy annually, approximately equal to around 400 regular villas, according to the tenant currently occupying the facility (Speed Group, 2020). However, Speed's production volume is significantly larger than the energy demand from the building and its operations. The estimated production exceeds the expected energy demand by thirty-three percent, and the surplus goes to the grid to other customers interested in purchasing renewable energy (Speed Group, 2020). The logic that Speed themselves presents for this action is that the abundance of produced renewable energy then adds up to the warehouse becoming $CO_2$-positive (Speed Group, 2020), as they are solely using renewable energy in the warehouse.

*Muggenstrum – Prologis*

In Muggenstrum, Germany, Prologis and their tenant L'Oréal have together developed modern logistics facilities to build a climate-neutral site. The facilities cover a total of 101 000 $m^2$, with solar panels that can produce up to 1.8 MW, but in this case, all the energy goes to an energy companies grid and then sold back to L'Oréal per required demand (Prologis, 2018). Also, when needed, L'Oréal purchases additional renewable energy generated by wind turbines (Prologis, 2018), although they are not involved in producing wind energy.

Other functions used in the warehouse are rainwater being used for irrigation of green spaces, cleaning in the halls, and water for flushing toilets. The central buildings management system allows for energy savings; for example, lighting is controlled centrally. The central system can also track energy usage to match and identify potential savings easily directly. (Prologis, 2018)

## 3.3 Energy Consumption

*Green Energy*

Green energy can be defined as "… (green energy) is generally used to refer to renewable resources and power derived from human effort (Harper, 2011, Defining Green Energy section, para. 1)". The term "human effort" does not entail solely human effort in this case; rather, it implies energy that derives from natural energy flows, such as water or wind, where no harmful emissions omit in production. What sets aside green energy from fossil fuels and eventually makes it sustainable is that green energy harnesses "ambient" energy and, therefore, cannot be emptied (Harper, 2011). However, when arguing for or against green energy technologies, it is imperative to acknowledge that no power sources have zero environmental impact, though some sustain less than others (Harper, 2011).

Researching green energy is pivotal in sustainability, as the traditional energy source of fossil fuels omits large volumes of greenhouse gas. Simply put, burning fossil fuels for energy purposes puts a heavy strain on our environment. Switching to green energy sources is good for the environment because fewer fossil fuels burned also means less air pollution (Lee et al., 2012). Furthermore, the change from fossil fuels is vital as they are non-renewable, i.e., a finite volume, implying that the planet eventually will be emptied of the energy source and that dependency needs to reduce. Possible long-term renewable sources are solar, for example, solar heating, solar thermal, photovoltaic (PV) solar cells, as well as solar-generated hydrogen (Lee et al., 2012). Companies should engage in multiple possibilities in both local and sustainable energy sources to move past settling for energy efficiency (Marchant & Baker, 2012).

*Renewable Energy Sources*

Renewable energy is energy sourced from sources that replenish during the human timescale (Iris & Lam, 2019), meaning that it does not have a finite volume available. The most common types of renewable energy sources from solar, wind, water, and geo-thermal heat (Iris & Lam, 2019). FMEAE's (2017) report covering the German maritime sector stresses the importance of renewable energy in ports, specifically wind, solar, and geo-thermal energy. This lead the Port of Hamburg to install multiple wind turbines and covered warehouse rooftops with solar panels with an expected renewable energy output of 500 MWh annually, which is around one-third of their current annual consumption (Iris & Lam, 2019). Ports and warehouses generally have flat surface rooftops, which is optimal for installing solar panels (Acciaro, Ghiara, & Cusano, 2014). Most projects considering renewable energy sourcing focuses on implementing solar panels. Though, it is also possible to choose wind power. However, the process of evaluating wind technology requires at least one year of monitoring to analyze the possible value of the surrounding wind conditions (Acciaro et al., 2014). A problem with organizations installing solar panels is that many stop their efforts there, likely due to unawareness or lack of education in energy efficiency performance (Acciaro et al., 2014).

Needlessly, the utilization of renewable energy in operations has become a large part of warehouses' carbon footprint, as described by the interviewees later under the empirical findings. There are several ways to acquire renewable energy. A company can self-produce solar- or wind energy or simply purchase renewable energy from an energy production company. Either way, many companies have chosen to purchase purely renewable energy to minimize their environmental footprint, but some companies choose to produce themselves. When self-producing energy, most companies choose to build solar PV systems (hereafter shortened to “solar panels” for the sake of simplification). When developing solar panels, most companies design the system to the estimated demand. As stated by all real-estate interviewees, it is too expensive to sell energy to the grid due to energy taxation. One of Sweden’s largest solar cell plant developers, Solkompaniet, explains that energy taxation strikes hard against companies choosing to develop production systems (Solkompaniet, 2020). Companies that produce energy for private usage or to sell will be taxed for said energy as soon as the solar cell plant exceeds a power limit of 255 kWh systems (Solkompaniet, 2020). However, the Swedish parliament now has decided to increase this limit to 500 kWh, starting July 1st, 2021 (The Swedish Government, 2021). The increased limit shows intent, by the Swedish Government, to allow more extensive local renewable energy production in the future, although their goals are still not clear. However, Solkompaniet further compares this with the potential power output from below warehouse in Borås, which’s output is ten times as large as 500 kWh (Solkompaniet, 2020). Nevertheless, there are still companies that decide to produce more than needed in order to reach climate neutrality or positivity, despite the taxation.

*Energy Performance Certificates*

In 2004, buildings represented forty percent of all energy-related CO2 emissions, and they expect to increase their share (de Ia Rue du Can & Price, 2008). In contrast, thirty percent derives from the heating, cooling, and ventilation of buildings (Olesen, 2005). However, buildings offer considerable energy-saving capabilities as roughly twenty-nine percent of emissions could be eliminated (ürge-Vorsatz, Koeppel, & Mirasgedis, 2007). Resulting in either an economic or a net environmental level benefit to society (ürge-Vorsatz et al., 2007). The EU created a directive in 2002 which required all member states to form Energy Performance Certificates (EPC) for all buildings, intending to reduce the energy usage by twenty percent by 2020, which in Sweden was extended with the goal of fifty percent by 2050 (Mangold, Österbring, & Wallbaum, 2015). EPCs are standardized rating systems formed by governmental bodies, with the intent to diminish GHG emissions and make energy usage of buildings visible for the market (Fuerst & McAllister, 2011; Turley & Sayce, 2015). For example, by switching to LED lamps instead of high-pressure sodium lights, the ECT Delta terminal in the Netherlands saves 300,000 Euros annually (Iris & Lam, 2019). The factors that are determinants in the assessment process are (Turley & Sayce, 2015):

- elements of structure - i.e., walls, floors, roofing, and draught-proofing
- heating – i.e., the energy efficiency systems and green installations
- lighting – i.e., energy-efficient lighting, smart switches, LEDs
- glazing – i.e., installation of thermally efficient units, unit replacements, and secondary glazing

As a result of EPCs and state of residence, both owners and occupiers could benefit from either subsidies or taxation benefits (Fuerst & McAllister, 2011). Other benefits include reduced operating costs through energy and utility savings, improved productivity, and competitive advantages in marketing and image (Fuerst & McAllister, 2011). As 3PLs likely are tenants, all these above factors could incentivize choosing greener buildings as they affect them positively in terms of operational- and energy efficiency.

In Sweden, the EPC was implemented to help inform property owners of possible improvements for increased energy efficiency, even more so as the Swedish system also includes measured energy usage (Mangold et al., 2015). The scale for the grading is from G, being the worst grade, to A, which is the highest grade (The Swedish National Board of Housing Building and Planning, 2020). The EPC aims to promote green energy and overall energy reductions, as the annual energy cost is visible when a property is to be sold (Mangold et al., 2015).

*Environmental Certificates*

Along with the introduction of EPCs, other environmental certifications have been introduced but originating from the private sector instead of governmental bodies. Since the year 2000, there has been an introduction of various environmental certifications for the commercial real estate sector. Environmental Building (Miljöbyggnad) aimed to form a certification that followed Swedish conditions and easily related to the Swedish National Board of Housing, Building and Planning's green buildings guidelines, which would help fulfill the nation's sustainability goals (Malmberg, 2015). GreenBuilding is another certificate that originates from an EU initiative, though only considering the energy usage of a building, and is thus primarily used to help companies increase energy efficiency (Malmberg, 2015).

While national or international regulatory entities are changing the fulfillment of their environmental goals from compulsory to voluntary, these private labels such as BREEAM and LEED grow "quasi-compulsory" as the line between compulsory and voluntary is blurred (Fuerst & McAllister, 2011). The before-mentioned energy labels, the Building Research Establishment Environmental Assessment Method (BREEAM), and Leadership in Energy and Environmental Design are the most common performance rating systems globally (Schwartz & Raslan, 2013). BREEAM is a method, from the UK, for assessing sustainable developments in properties, meaning energy and water usage, materials used, social conditions, and the property's environmental impact (Jelley, 2019). LEED is the US version, with a similar mission to engage environmentally responsible design and construction of profitable buildings (Clevenger, 2008). These assessment methods have proven results of lowering energy usage. For example, a study shows that the LEED-certified buildings have around thirty percent lower energy usage than the U.S.'s average (Turner & Frankel, 2008). As the given energy reduction goals vary between different continents and countries, the original designs of these assessment methods are not directly applicable to the Swedish market and thus vary in relevance for Swedish companies. In Malmberg's (2015) report, she concludes that the most common certifications in Sweden are Miljöbyggnad, GreenBuilding, BREEAM, and LEED. However, BREEAM is the most comprehensive method in the group, while LEED and Miljöbyggnad fails to cover as many assessment areas (Malmberg, 2015).

One recurring environmental assessment method and certificate seemed more common throughout the interviews than others, and that was BREEAM-SE. Today, BREEAM has grown to become the world-leading sustainability assessment within infrastructure and buildings (BREEAM, 2021). The organization's assessment and guidelines help companies globally build better from an environmental, social, and economic perspective (BREEAM, 2021). Licensed assessors conduct the assessment, which evaluates the properties within the scale; *unclassified, pass, good, very good, excellent,* and *outstanding*. The grading depends on how a property scores within the different assessment areas and results in an overall percentage score (BREEAM, 2016). Less than one percent of the assessed buildings reach the "outstanding" score, implying extremely high demands. The goal of BREEAM is to provide market recognition of buildings with a low environmental impact and ensure that best practices are part of every step in the development and the operations within buildings. BREEAM also aims to keep constant pressure and provide incentives for continued innovation, creating cost-effective solutions while minimizing the environmental impact (BREEAM, 2016).

## 3.4 Energy Management

Any building that aims to reach a higher level of energy certifications needs to practice good energy management. An Energy Management System (EMS) is a systematic approach of considering both the energy demand and supply to enable planning and usage of smart energy management by connecting the supply and demand in one system (Iris & Lam, 2019). Also, this demands the organization to measure their operations to better estimate which areas require more attention to increase energy efficiency. Furthermore, it is complicated to estimate environmental or economic effects without reliable information, as considering daily consumption as an estimate will result in inadequate information for informed decision-making. Equivocal information will lead to false estimates of the operations' carbon footprint but also increased energy prices. To accurately measure energy consumption, real-time monitoring through smart meters and smart energy management systems could prove crucial (Iris & Lam, 2019).

However, there are ways to decreasing the environmental footprint of warehouses without drastic changes to the operations. Below is data from a prior sustainability project from Kuehne+Nagel Sweden, tracking the $CO_2$ emissions for two of their warehousing facilities. The project started in 2016, with the goal for each site to decrease their $CO_2$ emissions by 15%

before 2019. Therefore, actions made primarily intended to minimize the waste in their operations, resulting in reductions of fifty-one and seventy-eight percent for the respective site.

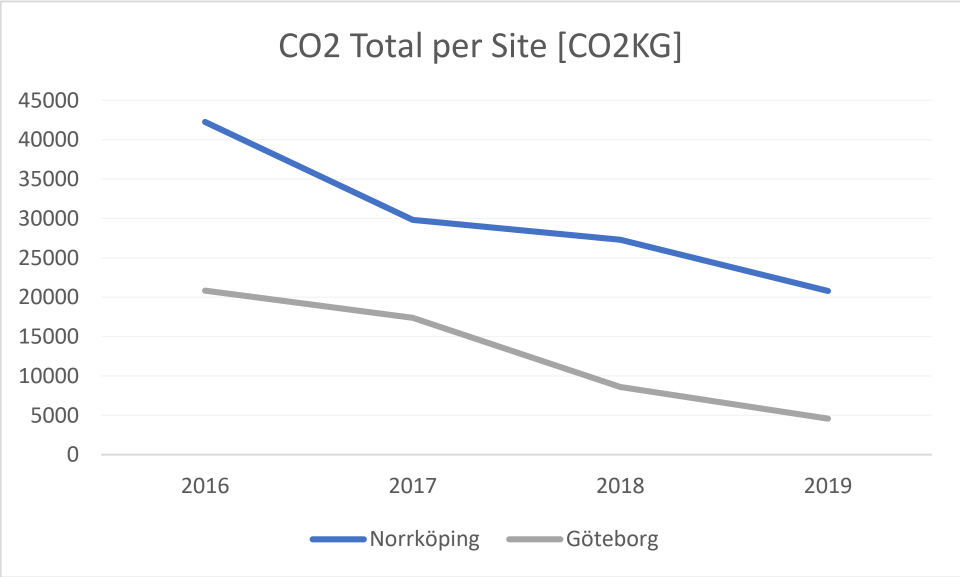


*Figure 1 - Emissions Data*

| Norrköping | 2016 | 2017 | 2018 | 2019 | Σ Reduction |
|---|---|---|---|---|---|
| $CO_2$ Total | 42 275 | 29 847 | 27 316 | 20 825 | 21 450 |
| Δ% last year | 9% | 29% | 8% | 24% | 51% |
| $CO_2/m^2$ | 2,11 | 1,49 | 1,37 | 1,04 | 51% |

| Göteborg | 2016 | 2017 | 2018 | 2019 | Σ Reduction |
|---|---|---|---|---|---|
| $CO_2$ Total | 20 680 | 17 404 | 8 622 | 4 597 | 16 083 |
| Δ% last year | -17% | 16% | 50% | 47% | 78% |
| $CO_2/m^2$ | 2,15 | 1,81 | 0,90 | 0,48 | 78% |

*Table 2 – Emissions data*

Another way to increase energy efficiency in operations is to implement a BMS, which continuously tracks energy data and steers the energy. For example, Swedish cleantech company Ferroamp has developed a platform that combines renewable energy production, power equalization, EV charging, and optimization of renewable energy production (Ferroamp, n.d.). Ferroamp's platform builds on their "EnergyHub" as the central hub that collects data from the other and steers the components of the system, such as the solar panels, energy storage units, and the building's grid, to further optimize the energy usage within the system (Ferroamp, n.d.). In a system such as Ferroamp's, a 3PL could track their energy data to understand their usage better and identify areas of improvement. Also, including energy storage into the system further enables peak-shaving abilities, as the stored energy decreases the demand of energy from the grid, thus reducing the peaks of the operations.

*Peak Shaving*

Generally, an electricity bill depends on two factors: a fixed cost for using the electricity and a variable cost dependent on the periods' consumption level (Iris & Lam, 2019). Thus, to decrease the overall consumption level, an organization could practice "peak shaving", which is defined by Iris and Lam (2019) as "… addresses the electricity consumption which fluctuates during the day depending on the workload". Therefore, peak shaving entails creating a more relaxed consumption usage by decreasing peak electricity demand on the grid, balancing peak demand hours to off-peak demand (Yesilyurt, Bauer, Emde, & Sauer, 2021). An organization has limited influence on the fixed cost of energy. However, through peak shaving, a company can reduce the variable cost as it depends mainly on peak electricity and total consumption (Chua, Lim, & Morris, 2016; Iris & Lam, 2019). Therefore, energy management strategy and peak shaving require the organization to identify the optimal unit commitment strategy, as it will balance the daily energy demand and generation (Chua et al., 2016). An example of peak shaving is to store energy in battery units that can be charged overnight, when energy costs are low, and used as extra power during the peaks (Roberts, 2006).

*Energy Storage*

Energy storage is also valuable in diminishing waste in renewable energy production. One challenging aspect of sourcing renewable energy is the fluctuant nature of power production (Yesilyurt et al., 2021). Also, even though there are enormous productions of devices to increase renewable power production capacity to compete with fossil fuels sufficiently, there are still problems in that the production profile does not match its requirements (Taylor, 2018). The volatile supply needs to be adjusted, creating a need for energy storage to balance the power demand on the energy grid during peak hours (Taylor, 2018; Yesilyurt et al., 2021). Energy storage thus generates increased security of energy supply, even during hours where renewable energy would not sufficiently cover demand (Yesilyurt et al., 2021).

Furthermore, energy storage can be considered resource neutral as it allocates energy to all power sources proficiently (Taylor, 2018). For example, renewable energy production has developed rapidly in China. However, the unpredictable power output has created a need for energy storage technology to reduce the peaks and induce the dips (Yu, Duan, Du, Xue, & Sun, 2017). Thus, energy storage is needed to stimulate renewable energy production output and the economic performance of the investment. Therefore, Yu et al. (2017) argue that energy storage becomes a “pre-condition” for large-scale renewable energy production integration. Nevertheless, the current standard of electric systems requires significant digitization to attain completely automated peak shaving (Yesilyurt et al., 2021).

*Energy Storage in Automated Guided Vehicles*

In Yesilyurt et al.'s (2021) article, the authors conclude that Automated Guided Vehicles (AGV) batteries could be valuable for organizations to be utilized for energy storage in their facilities to reduce peaks. AGVs are “inhouse, floor-supported materials handling systems comprising automatically controlled vehicles whose primary task is materials transport rather than transport of passengers” (Yesilyurt et al., 2021). Advantages of utilizing AGVs for energy storage are the flexibility in their usage and that they require low levels of infrastructure. Furthermore, they can also be replaced by the more conventional forklift truck (Yesilyurt et al., 2021), given that they are also battery-driven. This study explores forklift prospects instead of AGVs because Kuehne+Nagel Sweden does not have any AGVs in its operations. However, as Yesilyurt et al. (2021) suggest, forklifts are a possible alternative for a similar appliance in energy storage.

*Electrical Vehicles and Fast Charging*

Another alternative for energy storage is to charge Electric Vehicles (EV) (Forrest, Tarroja, Zhang, Shaffer, & Samuelsen, 2016). The automotive industry is becoming increasingly electrified (Bryden, Hilton, Cruden, & Holton, 2018). As the International Energy Agency is making their prediction for the increase of total EVs on the road in the future, their estimation is somewhere between 40 to 70 million EVs on the road by 2025, compared to 2 million in 2016 (Bryden et al., 2018). Also, most fast-chargers installed globally only charge up to 50kW, although multiple newer fast-chargers have capabilities up to 350 kW. However, certain aspects limit the development of fast-chargers, and one is the charging standards, where the two most common ones are the Combined Charging System (CCS) and CHAdeMO (Bryden et al., 2018), where only a few EVs are utilizing these charging standards. Moreover, in Bryden et al.'s (2018) estimations for developing fast-charging stations, a charging power of 400 kW should be sufficient to “future-proof” fast-chargers for the foreseeable future, implying that the chargers should not have to update at the same pace as batteries in EVs are evolving.

*Vehicle-2-Grid*

The Vehicle-2-Grid (V2G) technology regards the link between EVs' connection to the grid and how that link utilizes more than just one-way charging. In Forrest et al.'s (2016) article, they explain three different charging categories. The first category is “immediate charging”, which is when the system charges the battery immediately from the connection until reaching full charge or the driver decides to disconnect. The second charging category is “smart charging”, where the charging is optimized to charge when the energy cost is estimated to be lowest. This mode allows the vehicle to charge during hours when the net load of the energy grid is low, to either high availability of renewable generation or general load decline of the net. For these first two categories, there is no option for supplying energy back to the grid. However, the third category, V2G charging, is similar to smart charging but with the additional function of supplying energy back to the grid. V2G allows the EVs to be utilized as additional energy capacity to the grid during times of high energy load and to charge during low demand. Thus, the V2G solution allows for peak shaving, as companies can shave peaks through additional power during peaks and fill valleys during times of otherwise low consumption (Forrest et al., 2016).

Forrest et al. (2016) does present some interesting ideas that sprung from their research. The first being that in the short run, simply switching from immediate to intelligent, i.e., smart, charging will reduce the need for energy storage, which can help bolster the renewable penetration rates. According to Forrest et al.'s (2016) calculations, the switch from immediate to smart could decrease seventy-five percent in the total required power capacity of stationary energy storage (SES). However, these calculations bases on the entire state of California and not a separate warehouse.

The next takeaway presented by Forrest et al. (2016) is that V2G could potentially eliminate the need for SES in environments with high-level EV presence. V2G allows greater utilization of renewable energy that otherwise would waste due to its ability to supply extra renewable energy when the demand exceeds possible production. As Forrest et al. (2016) state it “This service is key in removing the need for stationary energy storage”. During their calculations, the V2G system primarily charged the EVs during the daytime and then unloaded them to meet energy demand during the evenings. However, this solution also meant that the EVs were more likely to need new fill-ups the following day. Nevertheless, in the real world, this leads to some practical obstacles resulting from the individual drivers' willingness to possibly not have a fully loaded battery for traveling home (Forrest et al., 2016).

Nevertheless, both smart charging and V2G are constrained by the pre-planned travel trips by the users, meaning that if a driver needs to travel a long way for their next trip, this also affects the system's ability to charge and discharge energy from the battery (Forrest et al., 2016). The authors elaborate by stating that one possible and significant disadvantage of the system is its impact on individual drivers. Both smart charging and V2G demand that drivers are willing to delay charging for the most optimal time and, as mentioned, to pre-plan trips. Also, V2G capability can result in an increased number of energy cycles for the battery, as the discharging of the battery will eventually lead to a decrease in the batteries' total lifetime. The drivers could also possibly experience discomfort because their batteries may not be sufficiently filled once they need it, for example, if the battery discharges during low renewable energy generation (Forrest et al., 2016).

*Electric Trucks and Fast Charging*

Electric trucks (eTrucks) are also becoming increasingly more available globally. In a McKinsey article, the authors estimate that eTruck adoption will exceed thirty percent by 2030, across all the different eTruck categories; Light Commercial Vehicle (LCV), Medium-Duty Truck (MDT), and Heavy-Duty Truck (HDT) (Furnari, Johnnes, Pfeiffer, & Sahdev, 2020). The authors state that the potential uprise in eTrucks is likely due to multiple factors: regulation, supply of trucks, battery electricity technology improvements, and general economics. As eTrucks enter the transport industry, the companies have to decide their potential use of the vehicles and the best charging strategy. The three most relevant commercial uses that could benefit from eTrucks are last-mile deliveries, dry-goods transports, and point-to-point long-haul transports. These are the commercial cases with somewhat predictable routes, relatively short ranges, and do not require "cold chains" (Furnari et al., 2020).

In Furnari et al.'s (2020) article, the authors identify the two currently most viable charging strategies to be either "overnight-only" or "overnight and mid-route"-charging, stating that other solutions will "remain niche applications or are commercially impractical". Overnight-charging entails that the eTruck is charged during the nights while stationary and intended to last throughout all of the next day's transporting endeavors. Mid-route charging means that the eTruck will charges at some point along the way, such as a public charging point, truck stop, public retail locations, or a destination warehouse. The factor that can affect the efficiency between these two strategies is the battery's size. A smaller battery could perform longer transports if it can have good mid-route charging (Furnari et al., 2020).

Therefore, the strategy comes down to the vehicle- and battery size (Furnari et al., 2020). For example, LCVs or MDTs used for one route per day with a transport route less than 200 km, said vehicles can sufficiently be charged solely on overnight charging, and that also by a slower charger. Furnari et al.'s (2020) present two different charging solutions: an AC charger of 22 kW and a faster DC charger supplying 50 kW. Although, if the transport route is longer than 200 km per day, the vehicle will require more than just 220 kWh and fast chargers while at the point of charging. Additionally, HDTs running long-haul operations of more than 400 km will require fast charging mid-route as their batteries will have an even greater battery capacity. Suppose these eTrucks are to be efficient in operations. In that case, infrastructure, including fast charging, will be needed, and possibly also mid-route charging, depending on the vehicle's size and operational use (Furnari et al., 2020). However, due to the high volumes required for fast charging, the grid is another challenging factor, as the grid’s connection power often is not enough to deliver the required power. However, one solution to this is to use stationary batteries to store energy, which can be exploited as a buffer between the grid and the fast charger. (Bryden et al., 2018).

# 4. Empirical Findings

*The empirical findings will present the primary data gathered through interviews and reports specifically conducted and produced for this research.*

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## 4.1 Warehousing

A large part of a 3PLs environmental impact relies on the relationship with the real estate developer and landlord. As 3PLs most likely rent the property from a real estate owner/developer, the buildings are not developed or designed by themselves. Kuehne+Nagel Sweden does not own any warehousing facilities (T. Laurén, Personal Communication, April 13, 2021). Therefore, the 3PL must communicate the expected sustainability level of the building to the developer when designing the building to give the best pre-conditions possible for operating a warehouse sustainably. The interviewed actors within the Swedish real estate developers within the logistics industry utilize different building standards. Both Logicenter and Prologis are using the BREEAM-SE certification as their standard for developing new properties. BREEAM-SE is the Swedish standard within BREEAM and is adjusted to reflect better the Swedish environment (J. Friedrich, personal communication, March 9, 2021). Friedrich also explained that BREEAM-SE adjusts according to the Swedish National Board of Housing, Building, and Planning's standards called "Boverket's Building Regulations" (BBR), with a general aim of being around twenty percent lower than the BBR's demands. However, Friedrich also mentioned that BREEAM-SE covers more areas than the BBR, such as climate adaptation and how well the building expects to follow the changes in the surrounding environment. BREEAM's more comprehensive manual is why many companies decide to seek BREEAM certification instead of just following the BBR recommendations, according to Friedrich.

Prologis has had the "very good" level as their standard since 2016 (G. Gillholm, personal communication, March 8, 2021), and Logicenter have also recently adopted the same level for all their new developments (K. Sjövall, personal communication, March 5, 2021), meaning that their buildings reach a BREEAM-score exceeding fifty-five percent (BREEAM, 2016). Logicenter has also certified a few facilities post-development with BREEAM In-Use, which certifies already standing buildings. Both companies agreed that environmental certification is essential in business today, as it shows intent and accountability of sustainability in their actions. Concerning choosing a certification level for a project, Friedrich added that the desired certification level varies depending on where a company intends to build. He exemplified by saying that if a company builds an office within “Slussarna” in Stockholm or “Vallgravarna” in Gothenburg (the city centers in both cities), then companies cannot build the project with a lower standard than “excellent”, as this is where the market is today. The same goes for warehousing, that depending on where a company builds the warehouse, the selected certification level would have to adjust. However, Friedrich summarized it by saying that he believes that “very good” probably is the standard today for companies looking for certification, as he considers “good” to almost being Swedish building standards. However, BREEAM is not a given standard in the industry. Another common standard in Sweden is Miljöbyggnad, used by real estate developer Castellum when environmentally certificating their facilities (C. Carlsson, personal communication, March 23, 2021). When asked, Carlsson did not have any concrete reasoning as to why they are using this certification. However, Carlsson speculates that it might have to do with their logistics facilities primarily being geographically localized in Sweden. A Swedish standard might be the more recognized choice for real estate developers operating primarily in Sweden.

Furthermore, Gillholm presents that there are generally two motives for building green buildings. The first one is that companies today want to reduce their environmental footprint. The second is that sustainability can now be financially encouraged, as building green can make companies eligible for green bonds when searching for funding. Green bonds are something that both Gillholm and Friedrich lifted as an incredibly positive aspect, where the banks have gone together and created these green bonds. GRESB (2015) defines green bonds as “debt obligations tied to investment activities targeting new and existing projects with environmental benefits”. Friedrich added that the banks' demands of sustainability are generally remarkably high. However, seeing as it helps real estate developers a lot in funding, the green bonds become a win for all the involved parties: the banks, the developers, and the environment.

Building sustainably requires the developer to consider sustainability in all aspects of development. As explained by Sjövall, sustainability is not limited to any phase of the facility’s lifespan. The building's pre-development is as crucial as post-life and maintenance when designing the building. Sjövall says that when planning the building material, the whole life cycle needs consideration. For example, using a foundation built with concrete may not be the most sustainable solution short term. However, due to the longevity and logistics of the material facilities' high demands on buoyancy, it becomes the only feasible long-term solution as substitutes may have to be replaced or refurbished if considering a longer horizon. Also, some materials such as wood, an otherwise popular building material in Sweden, may not be appropriate when considering materials for walls due to fire hazards.

The afterlife of a building also grows essential for building sustainably. Sjövall states that they "think of the development of the building as you would a LEGO-house", where the used materials can always be either re-used or recycled. The materials, therefore, need to be as "pure" as possible, where they avoid mixed materials as they often are less suited for recycling. Sjövall continued by explaining that all their used materials are recyclable and that the steel and concrete they are using are all possible to either meltdown or break to reuse.

*Lighting Systems*

Fluorescent lighting systems are the old standard that is now becoming increasingly outdated in the modern warehouse, as both Prologis and Logicenter are switching all their lighting systems to be replaced by LED solutions. Gillholm and Sjövall both state that their new standard is LED as they are superior in energy efficiency, which also is beneficial from a financial perspective. Carlsson also states that they encourage their customers to choose LED lighting, although they do not demand it as it depends on what kind of contract the companies settle. The LED lighting systems integrate with sensors that adjust the lighting to turn off or reduce when not needed. Both the operational warehousing areas and office spaces have LED as a standard per the companies. However, it is ultimately up to the tenant to choose what type of lighting they want, but most choose LED for the financial benefit. Scano repeated throughout their interview how important LED-lighting systems are for decreasing the energy consumption in their facilities (A. Scano, personal communication, March 30, 2021). Scano also states that the switch to the modern LED system is estimated to improve the energy efficiency by sixty to eighty percent, depending on the prior lighting system.

Furthermore, Gillholm lifts the "Prologis Essentials" initiative to offer streamlined products for increased efficiency in their customers' operations. The example Gillholm used was the developments in LED lighting systems where customers can invest in LED without an up-front payment for the cost. Instead, Prologis offers the LED system as a complete service where customers instead pay an increased cost over five years for the system. Also, if a tenant only has two years left on the lease, then the plan can be planned instead to pay the total cost within the remaining lease. The idea is to encourage a tenant to switch to a more sustainable solution while removing the required financial investment that might hinder the change.

*Heating System*

Carlsson, Gillholm, and Sjövall state that their buildings are heated through district heating, stating that less than five percent of their buildings are heated by geothermal heating. The reasoning is primarily the pricing difference. Gillholm extended their reasoning by saying that district heating will continue as the standard practice for the foreseeable future. However, companies would choose to purchase district heating labeled with the Swedish eco-label, “Good Environmental Choice”, according to Gillholm.

A sound heating system can heavily affect the environmental impact a warehouse inflicts. Gillholm states that an increase of one or two degrees Celsius can heavily affect the energy bill each month and the carbon footprint. He exemplified this by saying that giving the employees fleece-shirts and long trousers, instead of t-shirts and shorts, can be great from an energy perspective, given our geographical location. Sjövall also highlights the importance of the heating system as it is one common energy thief in warehouses. Warehouses often consist of very tall halls, where heating intends to heat the personnel operating at ground level. However, due to heat rising and the cold coming down, a sound heating system in warehouses also includes fans that make sure that the air and heat circulate in the facility. If the heat is constantly rising, the heating system will have to work overtime to keep the hall warm, resulting in abundant energy consumption.

Again, the airflow in the building is an essential aspect for keeping the energy costs down. Therefore, a common “energy-thief” is the ports to the warehouses (S. Campbell, personal communication, March 2, 2021). Considering that most warehouses have more than one port for truck deliveries, and some warehouses could have over twenty, the ports enable air to travel through the facility in a way that disturbs the heating system. Campbell continues to explain that this requires warehouses to have automated doors that only open once needed and good quality doors that are sufficiently shut, making no room for unnecessary air leakages. Friedrich also added that ports could utilize air curtains to make sure that as much climatically adjusted air as possible stays inside the facility. Air curtains also apply to keeping air outside, as on warm summer days when hot air otherwise would enter a currently airconditioned facility.

## 4.2 Energy Management

Energy management and utilizing renewable energy sources have played a pivotal role in the sustainable warehousing projects that have been presented thus far and when discussed during the interviews. As stated by a Kuehne+Nagel site manager, the first thing that came to his mind when discussing sustainable warehouses was to use renewable energy sources and making sure that everything produced is of sustainable standards, as well as minimizing all types of waste (A. Delgado, personal communication, March 24, 2021). Scano also backed up the importance of sustainable resources. He stated that switching to renewable sources while optimizing energy efficiency was of the highest importance for sustainable warehouses. For example, Delgado stated that this could be done by optimizing the lighting systems through LED-lighting and motion sensors and active heating systems adapting to air conditioning demands. Also, Laurén explained, Kuehne+Nagel in Sweden are today still mainly using manual labor in their operations, meaning that there is no automation in standard operations. Though Delgado witnessed, they are currently considering different automation solutions such as implementing AGVs, but no such solutions are currently a part of their operations.

Talking to Scano, he proclaimed that Building Management Systems (BMS) has been of great assistance in increasing the energy efficiency in their warehouses. BMS allows the user to track and streamline the energy usage in the building in real-time, enabling and disabling energy to connected units instantly. The data generated through the BMS can help warehouses to more easily identify where and when a given energy flow is drawing more energy than needed, i.e., wasting energy. Merkel agrees that these control systems are essential to further advance in the sustainability aspect (T. Merkel, personal communication, March 30, 2021). They elaborate by explaining that data, or "big data", is vital in increasing efficiency in the warehouses. It will help expose factors that are working inefficiently, thus eliminating waste, according to Merkel. Sjövall stated that as a result of their energy audits, they found the most significant impact stemmed from adapting the lighting system (through optimization of operating times and demand-based control), heating control (identifying optimal temperatures, and automized doors), and the ventilation (referring to night operations).

Utilizing an EMS or a BMS helps in visualizing the warehouse's energy consumption. Wulf explains in his interview that Ferroamp has a product that involves many different products that together form a platform that allows companies to understand better and steer their energy usage (T. Wulf, personal communication, April 28, 2021). The conductor of the system is the "EnergyHub", which measures the consumption and production of the system, and then collects the data on a portal where users can quickly analyze their energy usage. According to Wulf, their product uses the data to optimize energy usage and optimizes energy sources. For example, suppose there is no solar energy available from the solar panels. In that case, the system purchases energy from the grid, though switching back to self-produced energy once it is available. Also, when self-producing solar energy, the system can include a DC nano-grid with a capacity of 760w, which the user can connect stationary batteries to and thus enabling energy storage within the system, according to Wulf. Here, Wulf explains that the user can, in principle, connect anything to the nano-grid to utilize solar energy directly. For example, a user could connect ventilation or lighting systems directly to the grid nano-grid to always have self-produced energy as the primary energy supply. However, Wulf again underlines that the EnergyHub controls everything, as it is the conductor that steers the energy of everything connected to it.

*Renewable Energy*

Nevertheless, if the energy inserted into the system sources from a finite source, i.e., fossil fuels, the energy system cannot be considered carbon neutral. Again, as stated by Scano, switching to renewable sources is pivotal in creating a sustainable solution in warehousing. Scano and Merkel explain that a company has different preconditions to obtaining renewable energy depending on multiple factors. For example, important factors are a warehouse's location geographically and environmentally, current regulation, and supply available from energy companies. If the available supply is not sufficient to cover the warehouse's needs, other solutions will be necessary.

*Solar Energy*

Today, Kuehne+Nagel Sweden does not have any installed solar panels connected to their warehousing operations. However, a noticeable movement from the interviewed real estate developers' side in the development of solar panels is that it is becoming increasingly more encouraged by them. As witnessed by all the interviewees from real estate, logistics facilities in Sweden are often ideal for implementing solar panels because the facilities almost always have flat roofs. The flat roofs allow large-scale systems that can efficiently be utilized for solar energy optimization. Also, Zielfelt stated that it is far less complicated to be allowed to build a solar panel system on top of the roof of a logistics facility, about building a system straight on land (H. Zielfelt, personal communication, April 7, 2021). Carlsson added that it is quickly becoming more popular for real-estate developers because solar panels have not until recently become affordable to the degree that is competitive with purchasing energy from an energy producer from a financial perspective. According to Bergqvist, the current estimated price of solar panels is 6,500 SEK per kW, where one kW is estimated to produce 1,000 kWh annually

(R. Bergqvist, personal communication, April 6, 2021). All interviewed real-estate companies are positive about their tenants switching to renewable energy and offering a solution to build solar panels for the 3PL. Generally, all interviewees propose that solar panels are a win-win for both parties. They are switching to a more sustainable energy source for most or all of their energy consumption, which is good from a corporate social responsibility perspective. The switch is also a win from the financial perspective, as it is the real-estate developer that financially invests in developing the system. At the same time, the 3PL now has a dedicated supply of renewable energy at an attractive price point. For example, one company had a custom solution where they invested in solar panels. The company then sold to the customer through an increased rent fee, including “free” solar energy. This solution allows the 3PL to financially reimburse the landlord’s investment through the increased rent while obtaining cheap renewable energy. Therefore, all the interviewed real-estate companies suggest that there is a win-win solution for customers in their logistics facilities, as solar panels offer a combination of good corporate social responsibility at a lesser price than previously available.

In an interview with Zielfelt, a business developer within a solar energy equipment development company, he presents that a company ideally would aim for eighty percent self-use of produced energy to optimize the energy production for its use. Furthermore, he explains why companies are currently reluctant to expand their solar energy plants. The first one is that the general price of electricity in Sweden today is still too cheap to justify the expansion, which also is mentioned by Sjövall. Also, Zielfelt mentions that the taxation levels, as previously mentioned in the thesis, are too restrictive where producers have to pay taxes on their self-produced energy. He insinuates that the current taxation level is too high as it hinders incentives for more extensive large-scale plants. Zielfelt suggests that a total energy taxation relief would encourage many companies to expand their plants, although this scenario is improbable to ever happen from a governmental perspective.

However, Zielfelt states that when developing solar energy plants, there are generally two driving forces from the customers’ perspective to either optimize production for self-use or produce at least the same amount of energy that the customer annually consumes. The latter example does entail that the producer most likely will have to sell the abundant energy during peak hours, as the sun does not have the same peaks as operations. Selling energy entails that the company gets taxed for selling. However, the facility would be net-zero carbon in their energy usage, as they produce at least equal to what they consume on an annual basis, according to Zielfelt.

*Optimized Energy Production and Carbon Neutrality*

According to both Gillholm and Sjövall, it is in most cases entirely possible to supply a logistics facility with self-produced renewable solar energy. Exceptions would primarily be older logistics facilities with weaker buoyancy and sub-optimal roofs. However, they elaborate by explaining that produced energy needs to be consumed coinciding with its production. When the energy has nowhere else to go, they sell the produced energy into the energy grid. Selling energy is not wrong from a sustainable perspective, but from an economic perspective, it becomes expensive as a result of current Swedish taxation legislation. Neither company had concrete numbers to share, but all stated that it is not currently economically viable to overproduce energy in Sweden due to these taxation levels.

Therefore, before developing solar panels, developers draw data of the facility’s estimated energy consumption moving forward and plan to develop solar panels that cover that given demand. Sjövall explained that they would estimate a customer’s energy demand and then add another ten percent capacity on top of that to cover any sudden changes in future demand. When asked how large a portion of the roof above example would cover, Sjövall said it varies depending on the facility's surrounding environment. However, it could cover as little as a sixth of the total available roof if the conditions are good, allowing further development and installation of solar panels when the energy demand eventually increases. To summarize what both Gillholm and Sjövall stated as the reasoning behind optimizing solar panels, it is both a sustainable solution where companies acquire significant volume renewable energy while also creating a financially positive solution.

However, companies could choose to build large-scale solar panels even though it may not make sense from a financial perspective. Gillholm draws the example of the logistics facility Prologis have in Muggenstrum, Germany, for their customer L’Oréal, where the site is designed to be carbon neutral. In this case, Gillholm states that L’Oréal and Prologis made a joint effort to structure a carbon-neutral site. Therefore, L’Oréal also disregards the possible financial downside of reaching carbon neutrality. Logicenter’s project in Borås has a similar solution. Logicenter produces enough solar energy to offer the client a carbon-neutral solution and overproduce energy, meaning that they produce more than they consume during a year and sell all abundant energy supply to the grid, according to Sjövall. According to Zielfelt, this is often the logic behind companies claiming carbon neutrality due to their renewable energy production. The logic being that as long as the company produces more renewable energy than they consume, then their operations are carbon-neutral, at least in terms of energy.

## 4.3 Energy Storage

As asserted by Sjövall, Gillholm, and Carlsson, it is currently not economically viable to produce more energy than needed due to heavy taxation. Therefore, one possible solution could be to temporarily store energy in units located in or around the facility. However, today's market for energy storage is yet somewhat limited. Also, as stated by Sjövall and Carlsson, the problem with energy storage from their perspective is that it is far too expensive at the moment. Both Sjövall and Zielfelt adds that the price for simply purchasing energy is today too low for energy storage to become an excellent option for companies producing their renewable energy.

Today, the primary incentive for energy storage is to utilize peak shaving in operations, according to Zielfelt. Companies can utilize their self-produced renewable energy by temporarily storing it to stabilize the energy demand's peaks and valleys during the day. This solution allows the company to utilize the produced energy to a greater extent. Instead, the momentarily abundant energy would be stored during hours of low demand and high supply to utilize once needed. Zielfelt also mentions that another reason for energy storage is that it could serve as additional power for peak electricity load and expand the local net's power through the additional storage units. If power outages would occur more often, or if energy becomes increasingly more expensive, the ROI of energy storage would become more compelling, according to Zielfelt. Were power shortages to become a more prevalent problem in Sweden, then the incentive for energy storage also would be more evident.

However, Wulf explains that the need for energy storage will come sooner than one might expect. As the number of EVs increases, so does the need for fast charging capabilities, which are heavily reliant on energy storage solutions. Wulf states that fast charging EVs require high energy levels, and if that energy draws from the grid, then the building's energy demand would spike. As the grid's capacity in Sweden is already tight, charging EVs from the grid, therefore, becomes sub-optimal as the tight capacity creates a bottleneck for charging, according to Wulf. Therefore, investing in stationary batteries for energy storage becomes a "necessary evil", as suggested by Wulf, as it otherwise would create energy demand influxes. Hence, Wulf suggests that a company that self-produces solar energy and wants to offer to charge EVs also should invest in energy storage as it would increase self-consumption of the produced energy. Also, Wulf insinuated that a company interested in offering to charge eTrucks definitively would require energy storage as trucks would require charging of high levels of power, and at a larger volume than EVs.

In an interview with Volvo Trucks, Engdahl (H. Engdahl, personal communication, May 4, 2021) explained that their eTruck HDTs today have a battery capacity of 540 kWh, with the ability to charge with a power limit of 250 kW, and utilizing the European standard for charging CCS. The most common HDT-models within Volvo are the FH- and FM models, which Engdahl estimates can transport a full truckload 250-300 km at an average. Today, Engdahl believes that the majority of their customers charge their trucks at the base. Charging at the base is likely due to the lack of available fast-charging stations on the road, as Engdahl suggests that customers probably would charge mid-route if the availability of fast-charging stations were to increase. Engdahl continues by stating that the reasonable way of charging eTrucks is to charge while the truck needlessly would be stationary, such as during the night, at truck stops, while switching drivers, picking up the trailer, or during loading and unloading of goods. Here, Engdahl underlines the importance of good mid-route charging, implying that the truck could charge with power around 150-250 kW. Engdahl elaborated by exemplifying that if an eTruck were to only attain a charge of five percent during a thirty-minute stop, then it is barely worth plugging in. However, if the truck could attain a charge equal to twenty to forty percent mid-route, that would be great for the continued transportation route. Also, Engdahl added that if there is good mid-route charging available, that would also allow for smaller batteries in the trucks, making additional room for cargo, which means that the overall truckload increases.

Furthermore, Engdahl proposes that it could also be interesting for a hauler to charge their eTrucks overnight at a destination warehouse. Charging at a warehouse would result in the possibility for the truck to travel even greater distances to perform transports, where they would be able to almost drain the battery entirely upon arrival to the destination. However, few 3PL companies today favor overnight stays of trucks, as it becomes an additional safety risk, according to Engdahl. Both in terms of the truck being robbed on the warehouse site and attracting more attention from possible criminals.

Following are two potential alternative solutions for efficient energy storage to resupply the building's energy supply: Vehicle-2-Grid (V2G) and battery-driven forklifts. The first one, V2G, is currently close to the market. Both Sjövall and Carlsson say that the energy storage solutions they have yet to consider are V2G-solutions and that these solutions are tested in small-scale pilots. So far, both interviewees still consider the solution too expensive, so they are not moving forward with it. The other potential solution is battery-driven forklifts, which is an explorative alternative. The author interviewed persons in that industry to explore the potential and if the forklift companies deem it a part of the future. Again, the study explores forklifts because Kuehne+Nagel Sweden does not have any AGVs in its operations. As Yesilyurt et al. (2021) suggest, forklifts are a possible alternative to a similar appliance as AGVs in energy storage.

*Vehicle-2-Grid*

The V2G-solution is currently at a pilot stage in Sweden, with relatively few actors involved. Nissan is one of the companies that are testing the technology, and their only current project in Sweden is together with Kungsbacka Municipality. The project started in 2019, though currently paused due to the technology is being replaced and upgraded with Nissan's latest V2G-tech (A. Österplan, personal communication, April 15, 2021). There are projects around the world where the technology is actively used, for example, in Amsterdam Arena, where the arena is more or less self-sufficient due to its combination of solar panels and Nissans V2G-solution, according to Österplan. Notably, Österplan adds a difference in demand for V2G, as dependent on legislation in terms of energy production, Vehicle-2-Building (V2B) is also a viable alternative. The difference between the two alternatives is that V2B resupplies the connected building and not onto the grid.

Regarding V2G and V2B potential, Österplan identifies one of the current obstacles: modern vehicles do not reach the required standards of being a part of the technology's system, which means that not enough cars can both receive and resupply the energy. Also, in terms of different standards, Nissan utilizes a Japanese fast-charging standard called CHAdeMO, a standard only used in the Nissan Leaf and Mitsubishi Outlander, meaning that very few vehicles qualify for Nissan's solution. Another available standard is CCS, used in some European brands' cars, such as BMW and Volkswagen, and Nissan will release a model with the CCS standard according to Österplan. Needlessly, Österplan clearly states that there needs to be an increase in the volume of EVs with the same charging standard to make V2G more relevant for commercial companies.

When asked about the potential for V2G as a solution for warehousing companies, Österplan again said that the charging standard and total volume of the surrounding vehicle fleet needs to be changed, as more storage power is needed for it to be efficient. Although Österplan does believe that this will happen in the future, there is still considerable uncertainty in how long that timeline is. Also, Österplan identifies a problem in those users who connect their EVs to the grid may feel discomfort in not knowing if their cars are fully charged or not for when they need them. Therefore, she believes that the company might have to offer the drivers free energy charge, as they, in return, will be able to discharge the battery if needed. Also, the total volume in capacity needs to increase for EVs, as the current volume that cars potentially would be able to resupply is not large enough, according to Österplan. For example, a Nissan Leaf currently has a power of 40 kWh, which would require a large number of EVs to substantially reduce peak load energy of large buildings, as stated by Österplan.

*Battery-Driven Forklifts*

On the Swedish market, there are primarily two types of battery-driven forklift solutions, which are Lead-acid and Lithium-Ion (Li-Ion) based batteries (A. Kautonen, personal communication, March 11, 2021). Lead is still the most common choice by customers, and Kautonen believes that this is due to its relatively low investment cost. It is not very demanding from the operational perspective in terms of time and process. He adds that it could also be much due to lead being the standard within battery-driven forklifts for a long time and that the infrastructure required for lead is often already in place.

Li-Ion is increasing in popularity, according to Kautonen, which he believes is due to Li-Ion's benefits becoming more apparent and more measurable to customers. It is more expensive to invest in Li-Ion-based forklifts, though the Total Cost of Ownership (TCO) is lower than lead, according to Kautonen. He explains that this is for multiple factors. The foremost reason is that Li-Ion is more energy-efficient, meaning that they consume less energy for the same amount of work. Also, Li-Ion is maintenance-free and has a longer expected lifetime, as Kautonen exemplified by stating that lead lasts approximately five years in an ideal world, but Li-Ion lasts eight to twelve years in the same environment. When using lead batteries, the operator has to switch the battery during the day as the battery will drain completely, but this is not the case for Li-Ion as they can be fast-charged during breaks to endure the day's workload. Kautonen says that many customers can charge their forklifts during breaks and then manage a whole workday. In their warehouse in Eskilstuna, Kuehne+Nagel has chosen only to use Li-Ion. According to Delgado, the rationale behind the decision is that the energy consumption is drastically reduced and the diminished need for maintenance.

When asked about the potential of energy storage in Li-Ion forklifts, Kautonen says that he believes that there is potential for customers producing their energy themselves, but there are a few problems. As Kautonen sees it, the first problem is that the forklifts are ideally moving most of the time. For example, customers would have to keep the forklifts connected during the hours of most solar power, though these are also hours where the forklifts are needed in standard operations. Another issue is how the additional energy cycles would affect the battery's lifespan. Kautonen elaborates by stating that when the batteries charge and discharge, this will affect the battery's lifetime. As the lifetime is part of the product and solution, this would negatively affect the solution. However, Kautonen underlines that energy storage is not part of their current offering and is not anything he has yet to have been approached about by any customer.

Another potential solution that involves forklifts is external “power banks”, as offered to Jungheinrich’s customers. In an interview with Knudsen, he explains that the power bank solution consists of stationary batteries charged by the building’s energy supply and then stored in the batteries until unloading into forklifts (T. Knudsen, personal communication, April 16, 2021). Knudsen explains that this solution is most attractive for customers with self-production of energy, high energy peaks, or poor peak energy load capabilities. Reducing the peaks of operations is the foremost reason for these power banks as they can be filled during low energy usage and then used to charge Li-Ion driven forklifts during the peaks quickly. Knudsen explains that one of the perks with Li-Ion batteries is how swiftly they charge, but fast charging requires high energy levels. As Li-Ion trucks often are charged during breaks, and for example, all workers are on break simultaneously, the point where the trucks charge will equal a remarkably high energy demand peak. Here, the power bank solution is a great way to reduce said peak, according to Knudsen. Also, Knudsen adds that the solution also makes further sense for a company with self-production of renewable energy as the power banks allow the company to store their energy when they cannot consume the energy straight into operations. This solution, therefore, allows further utilization of the energy that they have produced. When asked about the ability to resupply the energy back to the building from the power banks, Knudsen said that although none of their current customers have asked for it, that solution would be entirely possible.

# 5. Analysis

*The analysis draws together the content of the chapters 'Theoretical Framework' and 'Empirical Findings'. This chapter analyses these areas to paint a comprehensive picture of necessary measures for designing a green 3PL warehouse. Here, the analysis will follow the structure of the research questions for a more cohesive structure for answering each question.*

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*How can a 3PL adapt its warehousing operations to maximize energy efficiency?*

As discussed by both the literature and the interviewees, it is essential to consider the building when pursuing sustainability. When developing green buildings, Lee et al. (2012) stated that the objective is to produce sustainable buildings for the people, the community, and the environment. Marchant and Baker (2012) elaborate by underlining the importance of reflecting on relative scale and tendencies of environment planned for occupation. Factors such as water consumption, energy usage resulting from the construction, the materials chosen for the building, produced emissions, and direct energy usage is crucial to account for when developing green buildings. Moreover, as emphasized by Sjövall, it is also essential to account for the building's afterlife when developing, as materials need to be recyclable to some extent, either for direct recycling or re-use. Here, Sjövall's example of the LEGO-house is vital to consider. All the pieces used for a building should also be possible to re-use post deconstruction of the building and thus re-use the material elsewhere.

However, how "green" a building becomes is ultimately up to the real-estate developer as they are designing, developing, and will most likely continue owning the building post-production. Laurén states that Kuehne+Nagel Sweden does not own any of the warehousing facilities they are operating in, meaning that they are tenants at every site. Renting the facilities is the standard practice for 3PLs in the warehousing industry, as explained by Marchant and Baker (2012). Therefore, the factors mentioned in the above paragraph eventually fall into the hands of the landlord, as they have control. Nevertheless, suppose a 3PL aspires to become green or net-zero carbon in its operations. In that case, it is also essential to set specific qualifications and standards for selecting the next facility to rent. As different aspects such as roofs, floors, and isolation of a building affect the energy efficiency, it is crucial to have set building standards that satisfy the 3PLs expectations. Here, the 3PL could decide on a given level of one of the environmental certifications for green buildings available, such as Miljöbyggnad, BREEAM, or LEED. As LEED is an American standard, without any adaptation to Swedish standards, the more appropriate choices would be either Miljöbyggnad or BREEAM-SE as they are adapted to Sweden. Depending on the 3PLs geographical presence, the ideal choice of which certification depends on the company's context. For example, both the companies Gillholm and Sjövall represent also operate outside of the Swedish borders. They have both adopted the BREEAM-SE certificate for their new developments since a few years back. While the company Carlsson represents only has this type of facilities within Sweden and are using Miljöbyggnad for their buildings. As speculated by Carlsson, the difference could be the geographical presence of the companies, but we cannot confirm this. Here, the choice should instead fall on which certificate is more comprehensive from a sustainability perspective. According to Malmberg (2015), it would be the BREEAM-certificate as it covers the most assessment areas of the two. Furthermore, choosing BREEAM-SE also makes sense for Kuehne+Nagel Sweden as it originates from an international certification standard. Choosing a solely Swedish standard, such as Miljöbyggnad, is arguably a worse choice because it does not necessarily translate the same way as BREEAM-SE or LEED would to the global Kuehne+Nagel organization.

Moving on, as presented in Marchant and Baker's (2012) three-step framework for developing sustainable warehouses, the first step is to become more energy-efficient and to reach a "baseline energy-efficient warehouse". The baseline suggests that the warehouse should always seek to eliminate waste of energy in operations, thus continuously increasing energy efficiency. Considering the emissions data presented by Kuehne+Nagel Sweden under figure 1, they have drastically reduced their waste in operations through energy efficiency, though without implementing any large-scale changes to operations. All interviewees from Kuehne+Nagel and the real-estate developers agree that increased energy efficiency is one of the first steps in sustainable warehousing. Marchant and Baker (2012) suggest that possible actions are adjusting lighting and heating to fitting levels, investing in luminaires, controlling air changes, measuring building energy usage, and overall focus on cost. These suggestions are similar to the "low hanging fruit" list presented by Sjövall, which promoted adaptation of lighting systems through optimization of operating times and demand-based control, heating control by identifying optimal temperatures, and automizing ventilation to night operations. In short, ensuring that all energy-consuming aspects of a company's operations need to be evaluated from an energy efficiency perspective, which can be done either through energy management systems or energy audits. Sjövall explained that they want to encourage their customers to become more sustainable and perform energy audits of the tenant's energy efficiency. Here, the 3PL can benefit significantly through healthy relationships with the landlord. The energy audits can aid in discovering pitfalls in energy consumption and suggest changes to increase energy efficiency. Factors that can affect energy consumption are not limited to what has been mentioned in this thesis, as a waste of energy can result from anything connected to an outlet. Therefore, conducting recurring energy audits is essential to ensure high levels of energy efficiency.

As proposed above and by multiple interviewees, the lighting system is a crucial part of becoming more energy efficient. Gillholm and Sjövall both state that their companies are currently working towards changing all lighting to LED in their facilities, as LED is far superior to their alternatives in terms of energy consumption. On average, Kuehne+Nagel expects a decrease in energy consumption of sixty to eighty percent, depending on the prior lighting system, when switching to a smart LED system, according to Scano. A lighting system consisting of LED luminaires and smart sensors should be standard practice in a sustainable warehouse. It minimizes energy usage when used, dims, and turns the lights off when unnecessary. The system is sustainably superior to any current alternative in energy efficiency and waste minimization while also being the most financially logical solution long term.

Heat control is also an essential factor for the sustainability of a warehouse. One example of heat measure is the optimization of the heating during the day and night shifts. For example, they use different temperatures during day and night, where the temperature is lowered during the night to balance air-conditioning for day operations. As mentioned by Gillholm, every degree Celsius matters regarding energy efficiency and reflects both financially and sustainably. For example, suppose a warehouse lowers the temperature by two degrees, and less energy is consumed. In that case, there is an increase in energy efficiency and less cost resulting from the facilities' heating. Therefore, a sound heating system is also crucial in sustainable warehousing. Sound heating includes air circulation systems, making sure that the warm and cool air is constantly circulating in the facility, as the warm otherwise would rise to the top of the hall, resulting in more energy needed to heat at ground level. Also, here the suggestions from Campbell and Friedrich, of automated doors and air curtains, are complements to the heating systems as it keeps air-conditioned air inside the facility and minimizes leaks and the entry of air that would disrupt the balance within the facility. Gillholm adds that he believes that district heat will continue being the standard for the foreseeable future, which is reasonable as all three interviewed real-estate companies have less than five percent of alternative heating sources in their portfolios. Therefore, a 3PL needs to ensure that as much district heating as possible is purchased with the “good environmental choice”-label, as suggested by Gillholm.

*How can sustainable energy management systems work in warehousing?*

As presented previously, energy efficiency is critical in a sustainable warehouse. Therefore, it is essential for the warehouse to continuously monitor their energy usage, which can be done through energy audits. However, the 3PL can also choose to implement an EMS that continuously tracks energy usage. Iris and Lam (2019) explained that an EMS is a systematic approach for measuring energy demand and supply to enable better planning of energy usage. This solution allows companies to measure all parts of their operations to better estimate which areas require adjustments to increase energy efficiency. EMS aids in accurately measuring the energy in real-time through smart meters and thus enabling smart energy management. Another energy management solution is to utilize BMS, as suggested by Scano, as BMS can go further than an EMS in terms of energy management. The BMS solution can instantly control which areas within the system are allowed energy or not, i.e., the BMS has more direct control of the energy flow within the building, thus enabling further possibilities of dynamic energy optimization. Also, as mentioned by Merkel, their BMS system collects big data, which further supports extensive energy efficiency efforts. To enable sustainable energy management, having either an EMS or BMS could be incredibly beneficial as it facilitates warehouses to understand their energy situation better. Depending on the warehouse’s size, the best solution may differ. For example, a small warehouse may not require a whole BMS to enable and disable energy flows in real-time, although they could greatly benefit from an EMS. An EMS would suffice as it would enable them to track their energy data throughout the day, month, or year to discover trends or other interesting changes in their energy behavior.

Tracking energy usage in warehousing operations is also essential to enable peak shaving, which again is defined by Iris and Lam (2019) as “… addresses the electricity consumption which fluctuates during the day depending on the workload”. Therefore, peak shaving is the practice of companies decreasing the energy fluctuation, meaning that the energy peaks are “shaved” and the dips, or valleys, are “filled”, thereby relaxing the energy consumption and reducing peak electricity load. The idea of implementing peak shaving as a part of a sustainable energy management system is interesting when considering Roberts' (2006) suggestion of integrating energy storage. Roberts’ (2006) approach is to fill stationary battery units during the night when energy prices are low and use them during peak hours to reduce the need to purchase energy at a higher cost. Although Roberts’ (2006) idea primarily originates from a cost-minimizing perspective, the idea is still interesting from sustainability in the future. For example, if a company produces renewable energy themselves, then they might not always be able to consume all energy at any given time. Then the company could utilize an energy storage solution to store their abundant energy instead of selling it to the grid. This solution could help decrease energy fluctuation throughout the day, thus enabling peak shaving by filling energy storage units with renewable energy during valleys and then shaving peak electricity load by re-introducing the energy into the company’s energy system at the peaks. Needlessly, energy storage will be further discussed later in the analysis.

As mentioned by several sources throughout this report, renewable energy is a pivotal part of designing sustainable warehouses. The importance of the switch to renewable energy is raised in the second step of Marchant and Baker's (2012) framework, “Low emissions and green energy warehouse”, where the focus is to stop relying on finite energy sources. Instead, a warehouse shall utilize renewable energy sources, such as solar, wind, or hydroelectric energy. Purchasing renewable energy is an excellent first step towards making the warehouse greener. As agreed by most interviewees, switching to renewable energy is vital in having sustainable operations. Though there is a scarcity in purchasing renewable energy, relying on the ability always to purchase renewable energy is not a long-term solution. Therefore, even though purchasing green energy is a step on the way to building a sustainable energy management system, the system will still be reliant on energy companies’ ability to supply green energy at all times. The reliance upon external parties’ ability to supply green energy suggests that a sustainable energy system also should include the ability to produce renewable energy locally. Local production of renewable energy agrees with Marchant and Baker (2012). They explain that companies should engage in multiple possibilities for both local and sustainable energy sources, enabling them to further expand past settling for high levels of energy efficiency.

*To what extent can a warehouse become self-sufficient in sustainable energy?*

Transforming a warehouse into becoming self-sufficient is the vastest step in Marchant and Baker's (2012) framework, including solar-, thermal- and water recovery and management, including sourcing local building materials with a low environmental impact. The focus of the third step is to consider the lifetime emissions and cost rather than today’s emissions and cost. As thermal heating and building materials have already been discussed earlier in this chapter, they will not be further discussed. Acciaro et al. (2014) stated that warehouses are generally ideal for installing solar panels due to the flat rooftops, which the interviewed real-estate developers also support. Another possible solution that could grow more common in the future is building wind plants to self-produce renewable energy, as Acciaro et al. (2014) proposed. However, the authors also mention that a year-long evaluation of the environment must precede the implementation to analyze the value in surrounding wind conditions. Also, as added by Friedrich, he suggested that a warehousing company or real-estate developer, in this case, maybe should choose the less complicated option of solar panels. None of the interviewees had any current alternative solutions to solar panels in use for their facilities. Again, solar panels are considered ideal in this situation by the real-estate developers/landlords. Therefore, as of solar panels' current position in self-production of renewable energy, that would probably be the logical choice for a 3PL.

Continuing, when asked, both Gillholm and Sjövall confirmed that in most cases, it is possible to cover a warehouse's annual demand solely on solar energy while acknowledging the exception to older existing warehouses. However, the energy needs to be consumed in connection to being produced, as it otherwise will be sold onto the grid, which creates a dilemma for the renewable energy producer. Selling the produced energy is sub-optimal for the producer as they are taxed for producing more than 500 kWh annually. The producer's price for selling the energy is lower than when purchasing, and the producer is also taxed for selling and purchasing energy. The cost of overproducing energy creates a dilemma of how much energy the producer would ideally like to produce. Optimizing the energy production for the company's demand is financially a good investment as solar panels today due to the horizon as the return on investment is relatively short. According to Bergqvist, the current price of solar panels in Sweden is estimated at around 6,500 SEK per kW, and each kW is estimated to produce 1,000 kWh annually. Then potentially, if the producer would save 1 SEK per produced kWh, then the investment of 1 kW would make a return already after 6.5 years.

$$\frac{6500\ SEK}{1\ SEK * 1000\ kWh} = 6.5\ years$$

Now, keep in mind that this example is calculated using a flat rate, estimated by academia, which does not necessarily reflect what any company offers. Also, many other factors need to be considered, such as the surrounding environment and the buoyancy of the building. However, the example draws a picture which shows that current solar panels are not as expensive as it once was, making for a better investment, as solar panels have an expected lifetime of 25 years, according to Bergqvist. Investing in solar panels and optimizing them for energy demand is also great for securing renewable energy supply, which is crucial for sustainable warehousing.

However, optimizing according to energy demand is not the only solution available. Companies can choose to overproduce energy to the extent where the produced energy is at least equal to the company's annual energy usage. Here, the company will constantly produce more energy than they are currently requiring. According to Zielfelt, the logic here is that as long as a company produces at least as much renewable energy as they consume, their energy consumption is carbon neutral. For example, in the case of "Solskenet" in Borås, where the landlord NREP/Logicenter state that the site will be carbon neutral, and the customer Speed Group (2020) even claim their operations to be carbon positive. Here, the carbon-positive logic seems to be according to Zielfelt's explanation, as the estimated production of renewable energy exceeds Speed's demand by thirty-three percent, thereby arguably making their operations "carbon-positive". Simply producing more renewable energy than the annual energy consumption does not mean that the whole product, or service, necessarily becomes carbon-neutral or "positive". Nevertheless, it does turn the warehousing product carbon-neutral from an energy perspective.

*Can energy storage become a viable part of a warehouse's energy system?*

As solar panels grow in popularity, the need for energy storage also increases in importance. Again, logistics facilities should not have any problem building solar panel systems that can supply well above their facilities' demand. The production capacity opens the doors to energy storage to become part of the warehousing facility's energy system. Energy is never a certainty and energy storage, therefore, creates an increase of security in terms of energy supply, as reported by Yesilyurt et al. (2021). Knudsen also underlines the idea of increased security of renewable energy supply. He states that energy storage could work as an extra backup in case of energy shortages.

Furthermore, in Yu et al.'s (2017) article, they state that renewable energy production is growing in China. However, the unpredictable output has resulted in the development of energy storage solutions to help reduce the peaks in energy demand and induce the dips. Yu et al. (2017) also claim that this argument makes energy storage a "pre-condition" for large-scale renewable energy production, which is an interesting point. When asked about energy storage's potential, interviewees Kautonen, Knudsen, Scano, Zielfelt, and Österplan all claim that the foremost reasoning for energy storage is peak shaving and better utilization of energy storage self-produced renewable energy. Also, Knudsen and Zielfelt both added that it could be interesting to consider it an emergency energy capacity to tackle future energy shortages. Altogether, the perks of energy storage grow evident. However, even though Yu et al. (2017) argue the point of energy storage as a “pre-condition” for a larger scale than a few warehouses, the logistics real-estate developers interviewed are considering it, although thus far deeming it “too expensive”. Energy storage is still a new product and therefore not yet widely available for commercial consumption, though V2G/V2B and stationary batteries show potential for the future. Also, Österplan identifies that the high cost of energy storage is a significant obstacle. The cost of investing in energy storage is also identified as an obstacle by Sjövall and Zielfelt. They add that the general energy prices in Sweden are too low to justify energy storage at the time of the interviews. Therefore, energy storage may not be a business opportunity from the aspect of selling energy back to the grid. Instead, it could be an operational opportunity for more extensive utilization of self-produced energy, creating a more circular warehouse.

However, a business case is to be made in terms of investing in fast-charging stations to charge EVs and eTrucks. Furnari et al. (2020) proposed that enabling eTruck operators to fast charge their vehicles mid-route allows the vehicles to travel a greater distance than they otherwise would be able to. Also, mid-route charging allowing the companies to purchase vehicles with smaller batteries to perform transports of equal distance. Furnari et al. (2020) add that the possibility of having smaller batteries in their trucks for the same workload results in a lower investment cost of eTrucks, which also could lead to more companies being willing to invest. Next, as suggested by Engdahl, to accommodate the power needed to charge an HDT, a warehouse would need to be able to supply at least 150 kW fast charging. This would mean that an HDT eTruck could charge a good percentage of the truck's capacity while the truck is, for example, unloading at the docking bay. Therefore, investing in fast-charging infrastructure could prove great long-term as the warehouse could, to a greater extent, utilize their self-produced renewable energy while also commercializing fast charging towards the warehouse’s suppliers. As proposed by Engdahl, the most reasonable time to charge trucks are while they are stationary regardless, such as when unloading. Here, producers could either sell the energy directly to the hauler after every charge or as a part of an established supplier contract between the parties.

Also, Engdahl suggested that overnight charging at the destination could be a viable solution to lengthen the potential long-haul distance of eTrucks further. However, 3PLs were reluctant to the idea due to increased safety risk. Here, a 3PL could potentially increase the security measurements of their site, thus making it possible for suppliers to stay overnight and charge. In turn, the hauler can reimburse the 3PL through “parking and security fees” and the energy that was charged overnight. This creates an even greater possibility of extending the option to sell energy to suppliers when they needlessly would standstill. Although it would require investments into more comprehensive security measurements, the potential long-term upside of revenue through parking and charging should at least make it a solution worth exploring.

Nevertheless, investing in fast-charging infrastructure creates another dilemma, as fast charging requires high levels of energy output. As suggested by Wulf, energy storage could be considered a “necessary evil” as the energy peaks resulting from fast charging would likely increase the average energy demand and increase pressure on the building's main fuse. Wulf says that the fast charging would rely on the grid’s capability to provide the necessary power without energy storage, which creates a bottleneck as the Swedish grid is already tight in terms of capacity. Therefore, Wulf suggests that energy storage will be a necessary evil, as the buffer it would provide would reduce the stress fast charging would apply on the main fuse and grid. Also, this enables the ability to further utilize self-produced renewable energy by charging the energy storage units during optimal hours and thus securing energy supply. Wulf’s suggestion of utilizing energy storage as a buffer is also supported by Bryden et al. (2018). They state stationary batteries are a great way to buffer the energy required to charge EVs, resulting in peak shaving and less stress on the grid. Hence, a company producing renewable energy and wants to ensure that their produced energy is not sold to the grid could invest in an energy storage solution to enable better and safer fast-charging infrastructure. Better meaning that it will always have the capacity to charge and safer as less stress will be on the main fuse and grid. The energy storage solution of choice can vary. However, the standard for fast charging infrastructure is seemingly stationary batteries, which also likely means that they will be able to resupply the building if it becomes necessary. When investing in any energy storage solution, a company should ensure the ability to resupply the building with the stored energy. Again, it could serve as an emergency energy supply at least.

The V2G-solution is an exciting prospect for energy storage, as it transforms stationary EVs surrounding the building into additional energy capacity. As stated by Forrest et al. (2016) and Österplan, the V2G-solution allows energy storage that allows for peak shaving. As the total EV fleet grows, so does the potential storage capacity for commercial buildings to adapt V2G-solutions. However, some obstacles hinder a V2G-revolution and the first obstacle being that current EVs are not all able to be utilized in a V2G system. Österplan lifts the use of different standards for fast charging used in different vehicles, which she believes will be less of a problem in the future, though also underlining the importance of standardization of chargers as it will swiftly enable broader use of V2G-technology. As for the example of Kungsbacka municipality, it is the municipality’s cars (Nissan Leaf) that are used for the V2G-project and thus enabling the solution, but for a commercial building, all employees or visitors cannot be expected to drive Nissan Leaf.

Furthermore, as stated by Österplan, the EVs' battery capacity also needs to increase as well as the number of EVs in the fleet. Most EVs available do not have a significant volume of energy output to resupply the grid or building, requiring many EVs to have a substantial effect on a commercial building utilizing high amounts of energy. Forrest et al.'s (2016) also lift the problem in how individual users can be reluctant to use the V2G-technology as they have to pre-plan their trips. Here, V2G would require further understanding from the individual users, as they are vital for enabling energy storage. As Forrest et al. (2016) also propose, daily discharging of the batteries’ power will eventually lead to a decrease of the batteries’ expected lifetime, which will likely affect the willingness of individual users negatively. Therefore, the technology may not be a viable option for today’s market for EVs because of the charging standards, battery capacity, and individual users’ willingness to participate. Offering individual users energy for free to compensate for possible discharges also shows a flawed business case, as the company might give away more energy than ideal. Needlessly, the solution could be a feasible option for warehouses with a fleet of either EVs or eTrucks used for transports. However, this is not researched in this thesis as transportation to and from warehouses has been excluded, as well as Kuehne+Nagel Sweden having no owned truck fleet.

In terms of forklifts, Li-Ion is slowly increasing its market share and becoming the standard of the modern warehouse as the perks of choosing Li-Ion become more evident to customers. Fast charging during breaks, diminished maintenance, and less energy consumed for the same workload result in Li-Ion being the far better choice even though the investment cost is higher, as explained by Delgado. Also, as described by Kautonen, even though the initial investment is more expensive than lead, the long-expected lifetime of the forklifts results in Li-Ion forklifts having a lower TCO. However, there currently seems to be little evidence of great potential in utilizing forklifts for energy storage. Although the growing interest in purchasing Li-Ion battery-driven trucks instead of Lead-Acid, which is the switch that would facilitate the use of forklifts as energy storage, the solution is seemingly far away from the market. Neither interviewed forklift companies offered the solution nor disclosed any hints of energy storage in forklifts being a future service that they were considering at the time of the interviews. Kautonen instead lifted some obstacles in utilizing forklifts for energy storage. First, forklifts are ideally used in operations during the same hours as those of most solar energy produced, which creates an operational hindrance for the solution. Secondly, as Forrest et al. (2016) proposed for EVs, the additional discharges of the stored energy probably decrease the expected lifetime of the batteries as the discharge creates additional energy consumption cycles for the batteries. These two obstacles are the result of how warehouses today generally operate and the financial sustainability of currently available batteries. None of the interviewees stated that they would have an abundance of forklifts available for resupplying the building's energy system during their operational energy peaks. There is no operational logic behind having an abundance of forklifts to facilitate extra energy capacity for the building's energy demand.

However, assume that the fast charging of a warehouse's forklifts constitutes a large part of their energy peak load, then the power bank solution could heavily reduce that peak, acting as a buffer between the grid and the trucks. Again, any energy storage solution could increase the utilization of self-produced renewable energy and enable peak shaving. Therefore, investing in stationary power banks would be positive in terms of being more environmentally friendly. Furthermore, even though Knudsen stated that none of their customers had thus far requested the ability to resupply the building with energy from the power banks, it is interesting to utilize the solution similar to how a V2B-solution would. Also, although the available energy from the power banks does not cover the whole energy demand, it could potentially serve as an emergency energy supply for more crucial functions of a company's operations to minimize possible damages during an energy shortage, as mentioned by Knudsen.

# 6. Conclusion

*To conclude the research, this chapter will present the contributions of the research and the answer to the research question. Also, suggestions for future and further research are included.*

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The purpose of the study was to analyze how the 3PL industry can become more sustainable in its warehousing operations. The thesis presents several different factors that affect a 3PL warehouse's environmental impact. Thus, the analysis and the following answers to the research questions structure a framework for Swedish 3PL-actors to consider when shaping their sustainable warehouse. Furthermore, the thesis explores the possibilities of self-producing solar energy, revealing the current pros and cons of producing renewable energy, and presenting two different approaches for developing solar energy production plants. Lastly, the future of energy storage is explored to draw a picture of where the market is today and the prospects of said technology.

## 6.1 Answers to the Research Questions

*How can a 3PL adapt its warehousing operations to maximize energy efficiency?*

Even though a 3PL does not ultimately control the building in terms of how they are developed, which materials are used, how solar-, thermal-, and water recovery management are designed, the 3PL can still establish minimum building standards. One convenient way of settling these standards is selecting an environmental certificate that includes both buildings- and energy efficiency standards, which BREEAM does.

Furthermore, maximizing energy efficiency of a warehouse is a continuous process, which demands constant tracking and analysis of energy usage. Here, energy audits can help structure a picture of the energy usage, but further tracking is most likely needed to optimize energy usage better. However, as energy efficiency is a continuous process, the warehouse should always track energy usage as anything could affect the energy usage.

*How can sustainable energy management systems work in warehousing?*

A sustainable energy management system can be divided into two parts. The first part is to have an EMS or BMS to help the warehouse improve its operations in terms of energy efficiency. Also, both systems can both assist in identifying warehousing operations energy peaks, which is crucial to enable further peak shaving efforts. Peak shaving is essential both in reducing costs and reducing the peak energy load of the energy system.

The second part of a sustainable energy management system is renewable energy, and when structuring the system, the supply of renewable energy needs to be secured. A green warehouse cannot rely solely on purchasing renewable energy from energy companies. Therefore, developing a system for the self-production of renewable energy, such as solar panels, becomes pivotal in creating a sustainable energy management system.

*To what extent can a warehouse become self-sufficient in sustainable energy?*

According to experts from the Swedish logistics real-estate industry, most warehouses should be able to be completely self-sufficient in renewable energy. However, as solar energy is not always available over a year, the 3PL needs to decide to which extent they want to produce their energy. The 3PL can develop solar panels to optimize production according to their demand, where most of their produced energy is consumed by their operations. This solution is likely most financially beneficial while also being a sustainably good solution as renewable energy is secured for the building. The alternative is to become carbon neutral and to produce more renewable energy than the warehouse will consume. Reaching carbon neutrality in warehousing is to become carbon neutral in energy usage, which means that the solar panels need to have an annual energy output that exceeds the warehouse's total energy consumed. This solution is more expensive due to high investments in equipment, plus the taxation of producing, selling, and purchasing energy. Nevertheless, the energy used in the warehouse can be accounted for as carbon neutral.

*Can energy storage become a viable part of a warehouse's energy system?*

Energy storage is arguably a pre-condition for future large-scale renewable energy production. It could also be an essential part of future renewable energy production systems as produced energy needs somewhere to go, if not onto the grid. Storage is positive in maximizing the producers' utilization of renewable energy and better enabling peak shaving in operations. Energy storage could minimize waste in production of renewable energy, as the energy produced would be stored locally for later use. However, the technology is seemingly not yet ready for broad commercial use as it is an expensive investment.

The V2G/V2B-solutions show promise, although likely not yet an option for commercial use, due to significant investments needed for the V2G infrastructure. Furthermore, the EV industry needs to standardize charging standards, increase EV battery capacity, and a more extensive EV fleet, in general, is a pre-condition for V2G and V2B in a commercial context. Next, performing energy storage in forklifts also seems to be far from commercial use. Even though energy storage is technically possible with Li-Ion trucks, it has operational obstacles. It is also financially complex as the additional battery cycles resulting from discharging the batteries would decrease the expected lifetime of the batteries.

As discussed in the analysis, there is an exciting business opportunity in terms of offering mid-route fast charging. A 3PL could invest in fast-charging infrastructure and sell energy to a hauler with eTrucks that needlessly would be parked at the docks. This would likely require investments in not only chargers but energy storage as well to create a buffer to minimize pressure on the main fuse when charging. Investing in energy storage for this purpose also does help in peak shaving for the whole system, increases utilization of self-produced energy while enabling additional revenue streams. Considering the projections of eTrucks continued growth, investing in fast-charging infrastructure is vital for legitimate green efforts in modern warehouse operations. Although it does not directly affect the local operations of the warehouse, not having mid-route fast charging would definitively hinder the continued electrification of the transport sector.

## 6.2 Suggestions for Future Research

This thesis touches upon the possibilities of energy storage in forklift trucks. Here, the possibilities are not presented as currently feasible within the context of this thesis. However, future research covering this possibility more thoroughly could yield interesting results. Currently, little research exists, although the idea clearly shows potential in energy storage and V2G/V2B. Therefore, future research exploring the potential and its obstacles could help to evolve the forklift industry.

As presented earlier in the thesis, the current standard for measuring emissions in buildings is to measure $CO_2/m^2$. However, seeing to the generally tall nature of logistics facilities, it would be interesting to investigate how measuring emissions in logistics facilities in $CO_2/m^3$ affect the results. This measurement could better indicate facilities' emissions while considering the size to a greater extent. This is not discussed in this thesis for lack of time and available data.

# References

Acciaro, M., Ghiara, H., & Cusano, M. I. (2014). Energy management in seaports: A new role for port authorities. *Energy Policy*, *71*, 4–12. https://doi.org/10.1016/j.enpol.2014.04.013

Aguezzoul, A. (2014). Third-party logistics selection problem: A literature review on criteria and methods. *Omega (United Kingdom)*, *49*, 69–78. https://doi.org/10.1016/j.omega.2014.05.009

Anttonen, M., Halme, M., Houtbeckers, E., & Nurkka, J. (2013). The other side of sustainable innovation: Is there a demand for innovative services? *Journal of Cleaner Production*, *45*, 89–103. https://doi.org/10.1016/j.jclepro.2011.12.019

Arksey, H., & Knight, P. (1999). *Interviewing for Social Scientists*. London: SAGE Publications, Inc.

Baker, P., & Canessa, M. (2007). Production, Manufacturing and Logistics Warehouse design: A structured approach. *European Journal of Operational Research*, *193*, 425–436. https://doi.org/10.1016/j.ejor.2007.11.045

BREEAM. (2016). BREEAM International New Construction. Retrieved 5 March 2021, from https://www.breeam.com/BREEAMInt2016SchemeDocument/#resources/output/10_pdf/a4_pdf/nc_pdf_printing/sd233_nc_int_2016_print.pdf

BREEAM. (2021). What is BREEAM? Retrieved 5 March 2021, from https://www.breeam.com/

Bryden, T. S., Hilton, G., Cruden, A., & Holton, T. (2018). Electric vehicle fast charging station usage and power requirements. *Energy*, *152*, 322–332. https://doi.org/10.1016/j.energy.2018.03.149

Chua, K. H., Lim, Y. S., & Morris, S. (2016). Energy storage system for peak shaving. *International Journal of Energy Sector Management*, *10*(1), 3–18. https://doi.org/10.1108/IJESM-01-2015-0003

Clevenger, C. (2008). *Leadership in Energy and Environmental design (LEED)*. Retrieved from www.usgbc.org

Collis, J., & Hussey, R. (2014). *Business Research: A Practical Guide for Undergraduate and Postgraduate Students* (4th ed.). London: Plagrave.

de Ia Rue du Can, S., & Price, L. (2008). Sectoral trends in global energy use and greenhouse gas emissions. *Energy Policy*, *36*(4), 1386–1403. https://doi.org/10.1016/j.enpol.2007.12.017

DoE. (n.d.). Fluorescent Lighting. Retrieved 8 March 2021, from The U.S. Department of Energy website: https://www.energy.gov/energysaver/save-electricity-and-fuel/lighting-choices-save-you-money/fluorescent-lighting

Elkington, J. (1994). Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development. *California Management Review*, *36*(2), 90–100. https://doi.org/10.2307/41165746

Evangelista, P. (2014). Environmental sustainability practices in the transport and logistics service industry: AN exploratory case study investigation. *Research in Transportation Business and Management*, *12*, 63–72. https://doi.org/10.1016/j.rtbm.2014.10.002

Ferroamp. (n.d.). About us. Retrieved 28 April 2021, from https://ferroamp.com/en/about-us/

Forrest, K. E., Tarroja, B., Zhang, L., Shaffer, B., & Samuelsen, S. (2016). Charging a renewable future: The impact of electric vehicle charging intelligence on energy storage requirements to meet renewable portfolio standards. *Journal of Power Sources*, *336*, 63–74. https://doi.org/10.1016/j.jpowsour.2016.10.048

Frazelle, E. (2002). *Supply Chain Strategy: The Logistics of Supply Chain Management*. New York: McGraw-Hill Education.

Fuerst, F., & McAllister, P. (2011). The impact of Energy Performance Certificates on the rental and capital values of commercial property assets. *Energy Policy*, *39*(10), 6608–6614. Retrieved from https://doi.org/10.1016/j.enpol.2011.08.005

Furnari, E., Johnnes, L., Pfeiffer, A., & Sahdev, S. (2020). *Why most eTrucks will choose overnight charging*.

Göl, H., & Çatay, B. (2007). Insight from industry Third-party logistics provider selection: insights from a Turkish automotive company. *Supply Chain Management: An International Journal*, *12*(6), 379–384. https://doi.org/10.1108/13598540710826290

GRESB. (2015). *Green Bond Guidelines for the Real Estate Sector*.

Harper, G. D. J. (2011). Green Energy. https://doi.org/10.4135/9781412973816.n66

Iris, Ç., & Lam, J. S. L. (2019, September 1). A review of energy efficiency in ports: Operational strategies, technologies and energy management systems. *Renewable and Sustainable Energy Reviews*, Vol. 112, pp. 170–182. https://doi.org/10.1016/j.rser.2019.04.069

Jelley, N. (2019). Building Research Establishment environmental assessment methodology (BREEAM). In *A Dictionary of Energy Science* (Vol. 1). https://doi.org/10.1093/acref/9780191826276.001.0001

Kuehne+Nagel. (2020a). Driving our Net Zero Carbon Programme | Kuehne+Nagel Annual Report 2020. Retrieved 24 May 2021, from https://2020-annual-report.kuehne-nagel.com/sustainability/fostering-sustainability-in-the-industry/driving-our-net-zero-carbon-programme/driving-our-net-zero-carbon-programme

Kuehne+Nagel. (2020b). First in logistics: Kuehne+Nagel`s Net Zero Carbon programme | Kuehne+Nagel. Retrieved 27 May 2021, from https://home.kuehne-nagel.com/-/company/corporate-social-responsibility/carbon-offset

Lee, M., Smith, S., & Carswell, A. T. (2012). Green Housing. In *Green Cities: An A-to-Z Guide*. https://doi.org/10.4135/9781412973816.n69

Malmberg, C. (2015). *Miljöcertifiering av byggnader med Miljöbyggnad, GreenBuilding, BREEAM och LEED Genomgång av metoderna med övergripande jämförelse*. Lund.

Mangold, M., Österbring, M., & Wallbaum, H. (2015). Handling data uncertainties when using Swedish energy performance certificate data to describe energy usage in the building stock. *Energy and Buildings*, *102*, 328–336. https://doi.org/10.1016/j.enbuild.2015.05.045

Marchant, C., & Baker, P. (2012). Reducing the Environmental Impact of Warehousing. In *Green Logistics : Improving the Environmental Sustainability of Logistics* (2nd ed., pp. 173–202).

McKinnon, A., Cullinane, S., Browne, M., & Whiteing, A. (2010). *Green Logistics: Improving the Environmental Sustainability of Logistics*.

Min, H., & Kim, I. (2012). Green supply chain research: Past, present, and future. *Logistics Research*, *4*(1–2), 39–47. https://doi.org/10.1007/s12159-012-0071-3

Olesen, B. W. (2005). Editorial: The european energy performance of buildings directive (EPBD). *HVAC and R Research*, Vol. 11, pp. 505–509.

https://doi.org/10.1080/10789669.2005.10391151

Otley, D. T., & Berry, A. J. (1994). Case study research in management accounting and control. *Management Accounting Research*. https://doi.org/10.1006/mare.1994.1004

Piecyk, M. I., & Björklund, M. (2015). Logistics service providers and corporate social responsibility: sustainability reporting in the logistics industry. *International Journal of Physical Distribution & Logistics Management*, *45*(5), 459–485. https://doi.org/10.1108/IJPDLM-08-2013-0228

Prologis. (2018, February 6). Prologis Develops CO2-Neutral Logistics Facility for L'Oréal. Retrieved 29 March 2021, from https://www.prologisgermany.de/en/node/966

Prologis. (2019). *Creating Value Beyond Real Estate | 2019 Prologis ESG Impact Report*. Retrieved from https://www.thinkadvisor.com/2018/10/25/institutional-investors-warm-to-esg-investing-rbc-study/.

Raimond, P. (1993). *Management Projects: Design, Research and Presentation*. London: Chapman & Hall.

Rao, P., & Holt, D. (2005). Do green supply chains lead to competitiveness and economic performance? *International Journal of Operations & Production Management*, *25*(9), 898–916. https://doi.org/10.1108/01443570510613956

Raut, R., Kharat, M., Kamble, S., & Kumar, C. S. (2018). Sustainable evaluation and selection of potential third-party logistics (3PL) providers - An integrated MCDM approach. *Benchmarking: An International Journal*, *25*(1), 76–97. https://doi.org/10.1108/BIJ-05-2016-0065

Relumination. (2016). Six Advantages of LED Lighting over Fluorescent Bulbs. Retrieved 8 March 2021, from https://www.relumination.com/six-advantages-of-led-lighting-over-fluorescent-bulbs/

Roberts, B. (2006, October). Energy Storage. *POWER*. Retrieved from http://web.a.ebscohost.com.ezproxy.ub.gu.se/ehost/detail/detail?vid=0&sid=d17d204d-36d3-4144-8281-36ab6a687da0%40sdc-v-sessmgr03&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3D%3D#db=buh&AN=24997632

Ryan, B., Scapens, R. W., & Theobold, M. (2002). Research Method and Methodology in Finance and Accounting. *Research Methods in Finance and Accounting*.

Schwartz, Y., & Raslan, R. (2013). Variations in results of building energy simulation tools, and their impact on BREEAM and LEED ratings: A case study. *Energy and Buildings*, *62*, 350–359. https://doi.org/10.1016/j.enbuild.2013.03.022

Solkompaniet. (2020, October 9). Nu startar bygget av Nordens största soleltak. Retrieved 29 March 2021, from https://solkompaniet.se/2020/10/09/pm-nu-startar-bygget-av-nordens-storsta-soleltak/

Speed Group. (2020). *Hållbarhetsrapport 2019 - Speed Group*. Retrieved from https://www.speedgroup.se/fileadmin/user_upload/Om_oss/Hållbarhetsrapport_2019_webb.pdf

Taylor, T. M. (2018). Energy storage. *EPJ Web of Conferences*, *189*, 9. https://doi.org/10.1051/epjconf/201818900009

The Swedish Government. *Utökad befrielse från energiskatt för egenproducerad el.* , Pub. L. No. 2020/21:113 (2021).

The Swedish National Board of Housing Building and Planning. (2020, February 12). Energy performance certificate. Retrieved 10 February 2021, from https://www.boverket.se/en/start/building-in-sweden/developer/inspection-and-delivery/energy-performance-certificate/

Thiell, M., Zuluaga, J. P. S., Montañez, J. P. M., & van Hoof, B. (2011). *Green Logistics: Global Practices and their Implementation in Emerging Markets*. https://doi.org/10.4018/978-1-60960-531-5.ch018

Turley, M., & Sayce, S. (2015). Energy performance certificates in the context of sustainability and the impact on valuations. *Journal of Property Investment and Finance*, *33*(5), 446–455. https://doi.org/10.1108/JPIF-05-2015-0035

Turner, C., & Frankel, M. (2008). *Energy Performance of LEED ® for New Construction Buildings*.

ürge-Vorsatz, D., Koeppel, S., & Mirasgedis, S. (2007). Appraisal of policy instruments for reducing buildings' CO2 emissions. *Building Research & Information*, *35*(4), 458–477. https://doi.org/10.1080/09613210701327384

Vogt, W. P., & Burke Johnson, R. (2011). *Dictionary of Statistics & Methodology – A Nontechnical Guide for the Social Sciences* (4th ed.). Newbury Park, CA: SAGE

Publications, Inc.

Wang, G., Dou, W., Zhu, W., & Zhou, N. (2015). *The effects of firm capabilities on external collaboration and performance: The moderating role of market turbulence*. https://doi.org/10.1016/j.jbusres.2015.01.002

Wang, J.-J., Wang, M.-M., Liu, F., & Chen, H. (2015). Multistakeholder Strategic Third-Party Logistics Provider Selection: A Real Case in China. *Transportation Journal*, *54*(3), 312–338. Retrieved from https://muse.jhu.edu/article/588095

Wang, L. L., & Li, W. (2017). A study of thermal destratification for large warehouse energy savings. *Energy and Buildings*, *153*, 126–135. https://doi.org/10.1016/j.enbuild.2017.07.070

WCED. (1987). Our Common Future (The Brundtland Report). In *Medicine and War*.

World Economic Forum. (2009). *Supply Chain Decarbonization - The Role of Logistics and Transport in Reducing Supply Chain Carbon Emissions*.

Yesilyurt, O., Bauer, D., Emde, A., & Sauer, A. (2021). *Why should the automated guided vehicles' batteries be used in the manufacturing plants as an energy storage?* https://doi.org/10.1051/e3sconf/202123101004

Yu, H., Duan, J., Du, W., Xue, S., & Sun, J. (2017, May 1). China's energy storage industry: Develop status, existing problems and countermeasures. *Renewable and Sustainable Energy Reviews*, Vol. 71, pp. 767–784. https://doi.org/10.1016/j.rser.2016.12.103

Zailani, S., Amran, A., & Jumadi, H. (2011). Green Innovation Adoption among Logistics Service Providers in Malaysia: An Exploratory Study on the Managers' Perceptions. *International Business Management*, *5*(3), 104–113. https://doi.org/10.3923/ibm.2011.104.113

Zhu, Q., Sarkis, J., & Lai, K. hung. (2008). Confirmation of a measurement model for green supply chain management practices implementation. *International Journal of Production Economics*, *111*(2), 261–273. https://doi.org/10.1016/j.ijpe.2006.11.029