Comparison of Solar Panel System between Finland and Germany

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Description

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Abstract

Sustainability has become one of the most fundamental concepts in the world of business today. Most especially, sustainability of the environment has been gaining significance not only in the industrial sector buts also in the supply chain and logistics. One of the ways to implement sustainability is through the use of renewable energy in warehouses. This review sought to study solar panel in sustainable warehousing in German and Finland and to compare between the advantages of using solar power system in past, present and future. Also, to review benefits of Solar System.

The main objective of this study is to compare between Finland and Germany, which includes many findings such as total investment cost for solar panel system in a warehouse, price of the normal electricity, hours of sunshine per year, amount of electricity generated from solar panel system during the peak time and production analysis. Also, to find the reasonable country to operate solar system.

As a result, and on the basis of the geographical weather condition, Germany has more sunlight compared to Finland so, it has more electricity production, uses of more solar energy and more reasonable.

Keywords/tags (subjects)

Solar Panel system, Sustainability, investment cost, renewable energy, production

Miscellaneous (Confidential information)

Data source: Qualitative and Quantitative data

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1 Rsearch Background

For many years in the past, emissions of greenhouse gases (GHG) presumed to induce significant damages to the environment and to be a major climate change cause, has substantially augmented due to unremittingly rising production of carbon dioxide (CO_2) (Boden et al., 2013). Particularly, the industrialized nations still remain as the major cause of environmental pollution even though developing countries show a recent increase in CO_2 emissions. In this context, activities of logistics like finished goods and materials storage and transportation, which are, however, essential for maintaining economic prosperity, are regarded to significantly contribute to CO_2 emissions and are the largest single source that is polluting the environment in the worldwide supply chains (Ries, Grosse & Fichtinger, 2017). Altogether, logistic activities is estimated to cause between 5.5 and 13 percent of the international GHG emissions in supply chains. Out of this, transportation accounts for 23 percent of the GHG emissions while warehousing, especially activities of material handling, accounts for 13 percent of the overall emissions from the global supply chains (Boden et al., 2013). For instance, in the UK, it is projected that warehouses accounts for nearly 10.2 million tonnes of CO_2 emissions while the nation can easily save 1.5 million tonnes by just making simple modifications (Ries, Grosse & Fichtinger, 2017).

Since warehouses are vital global supply chain element, it is unavoidable to consider the carbon concentration of handling and storage operations for evaluating complete life cycle of services and products emissions, and to find effective measures to decarbonize the total logistic activities to attain a sustainable practice for long term in business. Coupled with the increased concern for environmental conservation and protection of natural resources depletion amidst rising climate change, sustainability has become a major concern for organizations (Ries, Grosse & Fichtinger, 2017). Boztepe and Çetin, (2020) assert that sustainability has become one of the most fundamental concepts in the world of business today. Most especially, sustainability of the environment has been gaining significance not only in the industrial sector buts also in the supply chain and logistics. Organizations are increasingly pressurized to show sustainability in their actions or operations, with the demands originating from investors, consumers, stakeholders, media band government. This has led to organizations being identified as a means for facilitating sustainable practices implementation, in addition to the need of meeting stakeholders' interest and create competitive advantage for their operations (Sánchez-Flores et al., 2020).

In this regard, Knez, Bajor, and Seme (2011) note that the logistics industry has an essential responsibility in world energy consumption. Thus, businesses are striving to implement new, eco-friendly standards and instruments, such as adopting sustainable or green supply chain management (SSCM or GSCM). On the one hand, SSCM concentrates not only on the economic goals of the SC but also the social and environmental goals by coordination of processes to attain long-term performance. On the other hand, GSCM refers to considering ecological factors in SCM Warehouses, as part of the SC, have a vital role in sustainability of the environment.

Res et al. (2017) affirm that warehousing is accountable for significant carbon dioxide emissions. However, even though it is one of the essential SC activities, the majority of warehousing firms have little effort for environmental problems. In this context, sustainable warehousing has many aspects, including warehouse facility design, management of inventory, warehouse layout, warehouse activities, staff, onsite facilities, mechanical handling equipment, and warehouse management system. The elements for sustainability for facility design are reported to entail utilizing renewable sources of energy such as solar power, biodiversity, daylight use, temperature control, artificial lighting scheme, and noise pollution control (Kachitvichyanukul et al., 2015). According to Öztürkoğlu (2018), among the new operations linked to sustainable warehousing is electricity production with solar panels fitted in the warehouses' roofs. This has brought significant benefits, including reduction of carbon emissions and increase in revenues. Despite this significance, sustainable warehousing academic research is still limited compared to other activities of the supply chain. Therefore, this study focuses on exploring sustainable warehousing and solar panels in Europe, with the main focus on Finland and Germany.

1.1 Significance of the study

The study explored solar panels in sustainable warehousing in Finland and Germany. Ries et al. (2017) extracted a sustainable warehousing study that focused on reducing energy emissions and usage in the activities of the warehouse. Similarly, Boztepe (2020) conducted a study on the selection of facility location utilizing Analytic Network Process (ANP) by employing a criterion set including infrastructure, economic, geographic, site of the solar warehouse, and social environment. Although these studies and literature are significant, many of them are not focused on Finland and Germany. Therefore, this study will focus on Europe (the case of Finland and Germany) to add knowledge on the significance of sustainable warehousing and solar panels. In a practical sense, this study seeks to equip logistic company managers in Germany and Finland to adopt sustainable warehousing and solar panels to reap the benefits of GSCM.

1.2 Research aim and review question

This aim of the thesis is to review the existing literature on solar panels in sustainable warehousing. The study will be guided be the following questions:

1. What is the total investment cost of solar panel system in a warehouse?
2. How much electricity (KW) can you get from the rooftop of 5000meter square warehouse?
3. Is it more reasonable to use Solar Panel system in Finland or Germany?
4. What are the challenges and solutions of using solar panels in Finland and Germany?
5. How many hours sun is shining and what is the cost of normal electricity in Finland and Germany?

2 Literature Review

2.1 Introduction

Since this study is a systematic review of solar energy in sustainable warehousing in Finland and Germany, this literature review focus on establishing the premises of conducting this study. This is unlike conducting literature review in empirical research where articles used in the literature review can answer the research questions posed in the empirical research. Therefore, this literature review offers background information and theoretical underpinnings regarding the main problem of solar energy and how it relates to sustainable warehousing through the derived advantages. Through literature review, the author gets a better opportunity to understand the variables and factors that influence solar energy in sustainable warehousing. This creates the base for initial conceptual framework that directs this study. This literature review entails discussion of solar energy; solar energy in a warehouse (past, present and future); disadvantages advantages of solar energy usage in warehouse; warehouse energy consumption; comparison between solar energy electricity and fossil - based electricity in warehousing; and conceptual framework for the review.

2.2 Solar energy

Solar energy is the most abundant and cleanest renewable source of energy available. This energy source has the potential of contributing a major RES proportion in the future (Pihlakivi, 2015). According to Haukkala (2015), solar energy presents one of the largest electricity source in the world by 2050. Regarding this, there are three main technologies by which solar power is commonly harnessed. These include concentrating solar power (CSP) that utilizes thermal energy (heat originating from the sun) for driving utility-scale electric turbines; photovoltaics (PV) that directly translate light to electricity; and cooling and heating systems that gather thermal energy to offer air conditioning and hot water. Also, solar power deployment can occur in the form of distributed generation (DG), in which the equipment is situated on top of the roof or ground-mounted arrays near to the place the energy is utilized. Certain solar technologies can be established at utility-scale to generate power as a principal power plant. Current technology can harness solar energy for different uses such as electricity generation, providing a comfortable environment of the interior or light, and water heating for commercial, industrial and domestic use (Solar Energy Industries Association, 2015).

The PV devices are by far the ones that provide effective way of generating electricity from solar radiations. It is accepted that photovoltaic offers the simplest technology to install and design, but still it is the most costly renewable technologies. However, the PV advantage lie in the fact that it is non-pollutant environmentally friendly source of energy with low cost of maintenance (Pihlakivi, 2015). In the recent past, the PV's competitiveness has been increasing and for the first time in over a decade, solar energy use outperformed all other clean energy technologies with regard to new capacity of power generation installed with 29 percent increase compared to 2012 (Haukkala, 2015).

The production of energy through solar system occurs through radiations that can be converted indirectly or directly to power using different technologies discussed above like the photovoltaic (PV). The radiation which originates from the sunlight is assumed as white light because it spans a wide wavelength spectrum, from the short-wave electromagnetic to ultraviolet. This radiation is key player in electricity production, either generating high temperature heat for powering an engine mechanical energy that in turn powers an electrical generator or through directly translating it to electricity by the photovoltaic effect means (Pihlakivi, 2015). According to Haukkala (2015), the energy amount originating from solar radiation is extremely large, signifying the potential of solar energy use in the world to replace non-renewable sources of energy. The earth gets around 170 000 terawatts (TW) of incoming radiation at the upper thermosphere, but energy amount that can be utilized is very small. In this case, solar energy restrictions include costs, the number of places in which the heat producing technologies are utilized and amounts of radiation by the period of the year.

2.3 Solar energy in sustainable warehouse (past, present and future)

The concept of sustainability in a warehouse has emerged in the recent past to lessen the social and environmental warehouse impacts while they still result in economic prosperity and growth. This is due to the fact that warehousing has been recognized as a major contributor of GHG emissions worldwide, accounting for close to 3 percent of nation GHG emissions in UK (Öztürkoğlu, 2018). Boztepe and Çetin (2020) define sustainable warehousing as integrating, managing and balancing the environmental, social and economic outputs and inputs of the operations of a warehouse. It encompasses several aspects including warehouse layout, staff, operations, inventory management, warehouse facility design, onsite facilities and mechanical handling equipment. The main aim of sustainable warehousing through the use of solar panels is to reduce energy emissions and utilization in warehouse activities.

According to Taşçıoğlu and Keser (2019) energy generation from solar power is not a new concept in the modern energy industry. The history of solar power goes back to the 7th century B.C in which mankind utilized mirrors and glasses to light fires. However, in the past, the use of solar power in warehouse was not common like today. This can be majorly attributed to the relatively high cost of investment as upfront expenses for installing solar panels in warehouse were too high for many organizations to make it practical (Taşçıoğlu& Keser, 2019). Besides, many warehouses in the past were concerned with ways of cost reduction to maximize profits and hence many had little effort for issues of the environment (Knez, Bajor & Seme, 2011). However, with the recent increase in the concern of sustainability, the use of renewable sources of energy in the supply chain have been on the rise. International Renewable Energy Agency (2019) allude that decreasing energy-related emissions of CO2 is at the center of energy change. Rapidly altering the world away from fossil fuels consumption that lead to climate change and towards cleaner renewable energy forms is crucial if the world is to reach the agreed climate goals in Paris. As a result, many businesses have considered the concept of solar in their operations.

Today, energy generation from solar power is placed into everything from rooftops in households to large warehouses and other structures. The unprecedented increase in solar power use to generate energy is associated with the sophisticated solar technology of modern day which enables warehouses to become more efficient with regard to environmental protection and cost saving (You, 2016). Thus, the use of solar panels to generate electricity in warehouses through the concept of green warehousing is projected to overtake energy generation through fossil fuels as companies are striving to enhance their sustainability strategy to meet both the economic, social and environmental dimensions of sustainable development (Kachitvichyanukul et al., 2015). The concept of green warehousing entails several aspects with numerous options of renewable energy production such as wind and solar. However, Taşçıoğlu and Keser (2019) remark that even though there are several options of renewable energy generation that are available for the logistics sector and warehousing, solar panel system is by far the most practical and cost effective option. As Knez, Bajor and Seme (2011) assert, the use of solar panels on the roof of warehouse is the most easiest and common way of generating renewable energy.

In future, solar energy will be one of the most important source of electricity as it is really good for the environment and climate. Most likely it will be used in the large volume all over the world. As, the price of solar energy has been reduced over the past decades, it is obvious that in future, due to new technologies the price of the solar system will be more convenient. I think it will be more effective than the fossils fuels. As the installation process will be easy and quick, more installation process will continue in the coming future. In the future, beyond the solar panels in roofs, new technologies will invent solar system in solar firm, solar windows, solar roadways, etc. which will improve in size, efficiency and cost.

2.4 Advantages and disadvantages of using solar energy in warehouse

According to Payel (2020), the key advantage of utilizing solar energy in the warehouse is the production of its own renewable source of energy that results in saving a substantial amount of money overtime after solar panels installation. Quickline (2016) affirms that using renewable energy for business was expensive, but the present and future of solar energy is promising as Forbes report indicate that solar PV use is growing currently while the costs of installation are reducing. Moreover, Report indicates that solar energy is inexpensive compared to how it has been for the past years and by 2027, solar energy will consist of up to 20 percent of worldwide energy. Averagely, in a warehouse, energy is utilized in a number of things including lighting, warehouse equipment and heating. This implies that if energy can be replaced with renewable energy and utilize sustainable lighting, warehouse equipment and lighting, this can lessen the total consumption of energy by up to 30 percent, with a likelihood of creating a 100 percent sustainable warehouse (Payel, 2020).

Secondly, using solar panels in warehouses has a good return on investment. Knez, Bajor and Seme (2011) contend that solar installation average break-even point in the US is eight years. With strong back up systems of warranties in solar systems, which is mostly up to 25 years, this implies once a firm reaches the break-even point, all other energy that is saved beyond this time is money saved in the bank. Therefore, once the initial investment in capital is recovered, the solar system may be able to generate a good return on investment and this can occur for a long time. Additionally, sustainability through using solar energy in warehouse helps to reduce operational costs of companies. Limiting the consumption of fuel and utilizing solar energy indicates an immediate reduction of expenses (Payel, 2020). Banker (2014) asserts that warehouse firms can substantially reduce their bills of energy with a solar power system. According to the author, energy bills are normally responsible for about 15 percent of a warehouse facility operating costs because of lighting and systems of temperature control. By installing solar panels that generate their own free electricity, these energy expenses can be significantly reduced.

Moreover, since sustainability is a trendy topic nowadays, installing solar panels in the warehouse roofs generates green (renewable source of energy) for the warehouse operations which can help to save the planet by minimizing carbon emissions and consumption of fossil fuel (Knez, Bajor & Seme, 2011). Solar panels provides a means for warehousing to become more sustainable and reduce their carbon emissions which translates to saving the planet by positively responding to the concern of climate change and global warming. One of the benefits include reduced carbon emissions in which the CH2 saves more than 128.2 tons of CO_2 emissions yearly (You, 2016). Nonetheless, sustainability forms a good marketing strategy in today's world. For instance, using worlds like sustainable and green in a marketing campaign generates a good impression of an organization among the investors, consumers and business leaders (Payel, 2020).

Conversely, one disadvantage linked to solar panels use in the warehouse is the high upfront costs involved in installation and implementing solar power to generate energy in the warehouse (Knez, Bajor & Seme, 2011). Solar projects are multidimensional and need coordination between initial cost, the power use, investment resources and local policy. Overall, in the past, the installation solar energy in warehouses were associated with high upfront cost which turned many businesses off from using solar power in managing warehouse activities. However, investing in solar panels in warehouse provides a compelling benefit now and into the future that outweighs the disadvantages that are associated with it. Furthermore, the costs of industrial solar panels are declining and new technology is being produced every day and module prices are anticipated to decrease further (Payel, 2020). This offers an opportunity for businesses to solar panels to generate electricity for their warehouses.

2.5 Warehouse energy consumption

Warehouses functioning is clearly linked to the consumption of energy in its different forms. Among the different varieties and forms of warehouses, the heated and cold warehouses are characterized by comparatively high demands of energy (Zajac & Kwasniowski, 2017). Zajac (2015) adds that most warehouses are driven by electric energy, and its utilization is regulated by control systems and design-related factors. In this case, the consumption of energy in warehouses is majorly linked to the handling systems operations. Furthermore, Zajac and Kwasniowski (2017) assert that warehouse energy consumption is influenced by a number of factors including storage technology, goods turnover, warehouse equipment, assortment quantities, warehouse work organization, authorization and mechanization degree, microclimatic requirements, automatic identification technics advancement, and external factors such as humidity and temperature, warehouse size and requirements inside warehouse. Zajac (2015) affirms that activities done in a warehouse that involve energy consumption include transportation, storage, cross-docking and packaging. Thus, warehouses uses a range of energy types to perform these activities. In a typical (ambient) warehouse, the energy used in is majorly from non-renewable energy sources from fossil fuels such as natural gas and electricity (Marchant & Baker, 2010).

Other energy sources in logistic warehouse system management (LSM) include fossil fuel energy such as diesel, leaded petrol, gas, LPG, fuel cells, and CNG. Diesel, gas and leaded petrol are commonly utilize to power material handling machines and equipment, while solar and geothermal energy is sporadically utilized as source of power because of high costs of installation and little interests in the new technologies from venture capitalist. Additionally, the process is hindered by lack of incentives or legislation to its application, but in countries like Germany the use of these sources of power are becoming more widespread. Other than fossil fuels, other sources of power used in LSM is electricity, which is majorly used to power auxiliary equipment and transport (Zajac, 2015). According to Burnett (2014), the primary source of energy for heating space is natural gas, while electricity is used for outdoor and indoor lighting, charging batteries for forklift trucks, space cooling and heating in office areas, handling equipment like motors and welding machines, towveyor, conveyor and automatic retrieval and stacking systems, and trucks block heating. On the other hand, natural gas and electricity is used in fueling cafeteria equipment where present in a warehouse.

The amount of energy that warehouses require for operation, irrespective of the type of warehouse, is enormous. However, the use of energy varies considerably depending on whether a warehouse is ambient or refrigerated. For instance, in the US, non-refrigerated warehouses consume an average of 6.1 kilowatt-hours (kWh) of electricity while for natural gas, they consume 13,400 Btu per square foot yearly. From this figure, space and lighting account for averagely 76 percent of total energy consumption is ambient warehouses, making them excellent energy savings systems target in most warehouses. In this case, energy normally accounts for 15 percent of the operating budget of ambient warehouses but in warehouses that are refrigerated, 60 percent of electricity utilized accounts for refrigeration (Dhooma & Baker, 2012). In another example, the United Kingdom Warehousing Association (UKWA) estimated that in 2018, there were more than 1,500 individual units of warehouses in the United Kingdom (UK) with a total 420 million feet square of property floor area. This is equates to 41 square kilometers, which is large enough to the whole Oxford district and city. On this basis, electrical energy consumption 33 kWh/m2 and 47kWh/m2 for gas consumption. This is equivalent to 3.2 TWh (3.2 billion kWh) of total energy utilized for warehousing, with associated carbon emissions of 698,000 tons of C02 yearly. The author further notes that lighting accounts for largest share of energy consumption, equating to between 65 and 95 percent of energy utilization in ambient warehouses (Marchant & Baker, 2010).

Burnett (2014) provides an example of energy use in a typical warehouse through a research conducted in Canada. Regarding energy consumption, natural gas for space heating averagely accounts for close to 82 percent of the total energy used. This represents a split of 82/18 percent between electricity and natural gas, which is space heating versus other requirements of energy. However, this proportion may be anticipated to decrease with very large warehouses. However, the amount of fuel used for space heating in warehouses is a function of different variable such as internal levels of temperature, operating schedules and setback procedures all affect space heating energy utilization and potentially account for values of energy variations. On the other hand, the electrical usage particularly for more lighting are compared to volume-dependent. Overall, this research reveals a high consumption level of electricity, indicating that warehouse building are prime targets for conservation of electrical energy.

Also, depends on the size of the solar panel we want to install. For example, 320Watt solar panel with the dimension 5.5 ft in Length and 3.2 ft in width which is 17.6 square ft. Basically, one solar panel takes 17.6 square ft. Therefore, we need 284 solar panels for 5000 m2 rooftop.

Regarding cost, Burnett (2014) demonstrate the high energy consumption in a warehouse translates to higher costs. For instance, total investment cost of solar Panel system in 5000 square meter roof in both Finland and Germany is around 1 million Euro. This is substantially high money amount that firms spend to operate warehouses. On the other hand, Lewczuk, Kłodawski and Gepner (2021) through a case study revealed energy consumption and costs in a warehouse and its relation to land consumption and automation level.

It can produce around 700 KW electricity per day in Finland as the sun is shining for minimum 10 hours a day during summer- time from March to August. Similarly, in Germany, 5000 square meter roof of solar panel system can produce around 1000 KW per day as the sun is shining comparatively more than in Finland and also the production cost of electricity from solar panel in Finland and Germany is approximately 189,000€ and 589,000€ per year. So, basically Germany has the most production cost.

2.6 Solar energy electricity and fossil based electricity in a warehouse

Compared to electricity and other non-renewable source of energy used in warehouse, solar power presents a cheaper option. The project of solar warehouse entails various time perspectives: one for the provision of energy to the material handling equipment like forklifts in side he warehouses, and the other one for provision of energy for road transportation vehicles like lorries and trucks while they wait for unloading and loading near the warehouse (Knez, Bajor & Seme, 2011). Taşçıoğlu and Keser (2019) remark that even though there are several options of renewable energy generation that are available for the logistics sector and warehousing, solar Power is by far the most practical and cost effective option. Nonetheless, Knez, Bajor and Seme (2011) add that the use of solar panels on the warehouse roofing is the most easiest and common way of generating renewable energy.

Solar Panel system change sunlight directly into electricity. With decreasing prices in the recent years, the return on investment for solar plant can be attractive. In this case, solar panels are normally solid-state semiconductors that produce electrical current when they are exposed to sunlight. These panels are available in different materials of plastic and glass based systems, which includes plain cladding, aluminum-framed panels, custom built glazing and solar roof tiles with integral PV cells (International Renewable Energy Agency, 2019). According to Marchant and Baker (2010), with large roof area expanses available, the logistics and warehousing sector proves to be a good match for PV solutions. Additionally, the synergy between the need for electric vehicle and forklift charging and battery storage of excess PV power can be put to good use in systems that are well matched. To be effective, new-build sites are particularly ideal for solar panel installations since architects can design the structures of the roof to become fully integrated and compatible. For instance, utilizing PV solar roof tiles and ensuring accessibility for maintaining them.

The installation cost for solar panels may seem a bit high (this was the major obstacle for considering solar energy in warehouses), but technological innovations and inventions have made the cost and pricing cheaper. Cost of maintenance of the cells is low and only entail panels cleaning and electrical checks (Marchant & Baker, 2010). Besides, the approximated payback period for investing in solar energy ranges substantially and depends on each site circumstance, though some payback time can be lengthy (ranging from 7 to 10 years), and the estimated solar panel life is close to 25 years (International Renewable Energy Agency, 2019).

The solar power is cheaper after installation, even though the installation cost may be higher, but the solar panels can generate amount of energy enough to drive all the operations of a warehouse. But almost 60 percent of the total energy consumption required to operate a warehouse. This implies that solar power is cheaper as firms will not have to pay the yearly expenses for electricity or other non-renewable sources to power equipment and handle other operations in the warehouse for the subsequent years (up to over 25-30 years lifetime of solar panels). This represents a significant save for warehouse and hence advocating for solar energy use in warehouses.

Moreover, energy cost of a firm using solar panel is now fixed for the next 25 years, not like diesel power that keeps on rising and hence making energy consumption in the warehouse more expensive. Nevertheless, International Renewable Energy Agency (2019) accentuate that irrespective of the future solar cells price, the other solar power plant installation costs (called BoS costs) are very stable. The costs entail engineering costs, racks, voltage inverters, installation, site prep, foundations, control and permitting among others in more mature solar markets such as Germany have witnessed these costs gradually decreasing.

Additionally, investing in solar panels is cheaper compared to normal electricity that originates from non-renewable sources because it encompasses low costs of maintenance. Generally, solar power systems do not need a lot of maintenance since the only thing required is to keep them relatively clean over time. Many reliable manufacturers of solar panel offer 20-25 years warranties. With little tear and wear because there are no moving parts, maintenance costs remains low. The inverter is normally the only part that requires alterations after 5-10 tears since it is constantly operating to change solar power into heat and electricity (solar PV vs. solar thermal). Other than the inverter, the cables also require some maintenance for ensuring that the system of solar power runs at optimum efficiency. Thus, after the initial cost of buying solar panels and installing them is covered, a firm can expect very minimal spending on repair and maintenance work. This means the company can save a significant amount of money for the subsequent years up to the 25 years guaranteed when using solar power (Banker, 2014).

Finally, solar energy leads to reduced carbon emission. Reducing consumption of fossil fuels and carbon footprints and saving the planet is more relevant today, and solar power generate electricity with no carbon pollution or other GHGs. As more and more final consumers pay are concerned about suppliers' social responsibilities, solar power becomes the future of many warehouses, which is expected to increase with the projected decreasing costs of purchasing and installing (International Renewable Energy Agency, 2019). Consequently, solar power provides the cheaper option or a warehouse than the non-renewable sources of energy and normal electricity.

2.7 Conceptual framework for the review

This study will be guided by the following conceptual framework. This conceptual framework is developed to show how using solar energy significantly contributes to saving the operation costs and energy consumption of a warehouse, which further results in environmental conservation through reduced GHGs emissions. In this framework, the independent variables are represented by solar energy use such PV, CSP and solar thermal while dependent variable is the advantage derived from using solar energy.

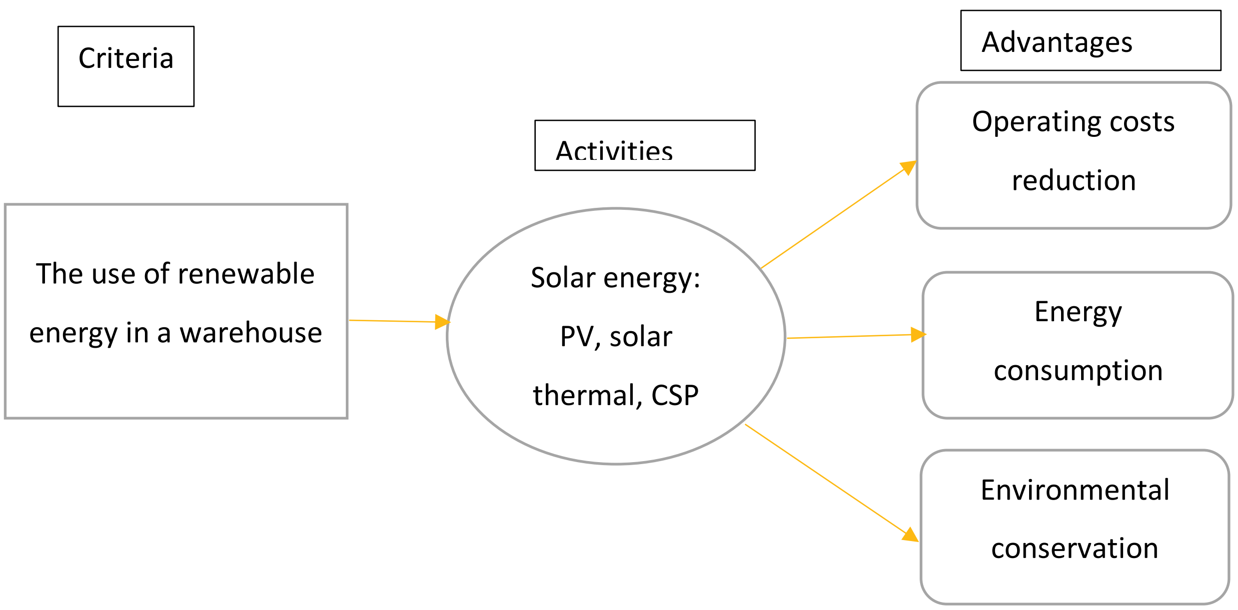

Figure 1: Conceptual framework for the review (developed by the Author)

3 Methodology

The main aim of this investigate is to find out the use of solar panels in sustainable warehouse drawing from a systematic review of the existing literature. The study will strictly adopt the protocols of systematic literature review as explained by Xiao and Watson (2019). Nightingale (2009) defines systematic literature review as a rigorous technique in assessing, selecting and analyzing the existing literature in an attempt to answer research questions. By review of the relevant literature, one gets to internalize the depth and breadth of the extant literature and ascertain gaps to examine. By performing synthesis, summary and analysis of a sample of literature related to the research topic, a researcher can be able to test a specific hypothesis and create emerging theories. Additionally, one can also examine the quality and validity of the existing research work against a criterion to disclose contradictions, weaknesses and inconsistencies (Xiao & Watson, 2019).

This study prefers systematic review because this topic has drawn sufficient interest and attention in the area of sustainability and hence it warrants a comprehensive review to determine what is known from the unknown to disregard resource wastage in future studies. Moreover, no systematic review has been conducted on this topic (solar panels in sustainable warehousing in Finland and Germany). This systematic literature review adopted in this study will strictly follow the six steps: study identification, study strategy, research selection (exclusion and inclusion criteria), data synthesis, data extraction, quality assessment and data analysis as indicated in figure below (Xiao & Watson, 2019).

Figure 2: Methodology of systematic review (Xiao and Watson, 2019)

3.1 Research identification

The main aim of the study is to assess solar panels in sustainable warehouse by investigating the review question.

3.2 Research strategy

The search of literature included in this study was done on electronic databases including google scholar, ProQuest, EBSCOHOST, Medline, and Embase. The search strategy entails derivation of major terms linked to the review questions followed by the identification of alternative spellings and synonyms of these terms to perform a pilot test. The search process used terms such as OR & AND to connect the selected terms on the topic. These key terms deployed in the research process include “solar energy and sustainable warehouse’, “solar panel and sustainable warehousing in Germany”, “solar panel or solar energy and sustainable warehousing in Finland”, “challenges of solar energy in sustainable warehousing”, “advantages or disadvantages of solar energy in warehousing in Finland/Germany,” ”total investment cost for installing solar panel system in Germany and Finland”.

3.3 Research selection: exclusion and inclusion criteria

For determination of literature for inclusion in the review, there is need to generate a clear criteria which stipulates the studies for inclusion in the literature review. In this study, the existing literature to be included have to directly link to one of the review questions mentioned above. As such, search terms such as solar panel, solar energy, sustainable warehousing, challenges of solar energy and solar energy investment in warehouse in Finland and Germany. These articles must be written in English and must be published in scientific journals.

According to Templier and Paré (2015), journal papers are preferred because practitioners and academicians like using them to obtain new information and disseminate new research findings since they signify the highest level of research. Moreover, the literature included were chosen in recency order in which the literatures published between 2011 to date were included. However, some older studies with key theoretical background for the study were also considered. The research base involved empirical study mainly from qualitative and quantitative research. Besides, the criteria for inclusion must entail explicit transparency in the research literatures methodology like data collection instruments, analysis and sample size.

Moreover, articles that were found to be duplicated were remove from the list of papers to be included for analysis and synthesis. Furthermore, the literature findings have to be valid and reliable taking into account the research type of the papers to be included. Articles such as reviews, commentaries, editorials, partisan institution reports or notes related to warehousing were excluded. Overall, all the grey literature were exempted from this study but were maintained for reproducibility, record keeping and cross checking.

3.4 **Quality Assessment**

Quality assessment involves a process of scrutinizing research evidence systematically to assess its relevance and validity before including it in the list of articles to be used in a study (Jones & Evans, 2020). To determine the quality of every article included in this study, first, only journal articles and books from respectable publishers were deemed as high-quality research and thus, were extracted for inclusion in the review. Many of the online presentations and technical reports were excepted from the review since there is a lack of the process of peer-review. Secondly, two researchers were incorporated to perform a parallel and independent quality appraisal to identify any disagreements. This disagreements were then resolved through consultations between the independent researchers and author. Incorporation of these researchers is vital as they offer an opportunity to eventually check on the criterial for inclusion and exclusion while also carefully reviewing every study against the quality criterion. Articles that fail to satisfy criteria for inclusion in the steps mentioned above are excluded from the final list of papers that will be used in analysis of this study.

3.5 **Data Extraction**

Data was extracted from the qualified papers after the final articles selection. The study questions was the approach used to guide data extraction of each of the articles used. The data extraction emphasis was based on two issues; the methodology that each article used to derive the results and the findings of the study.

3.6 **Data analysis and synthesis**

Eventually, the extracted data assisted in derivation of some results for the study. The data synthesis process follows an integrative method that provides summary which is appropriate for compilation as well as aggregation. Since the concepts that were extracted from literature review are all defined well and their contents are considered consistent with other papers, this review therefore focused on these existing literature to extract, summarize and describe the information from the various articles.

Figure 2 below represent a flow chart demonstrating the methodology used in the search of literature, assessment and selection process to arrive at the final articles used in the review for analysis.

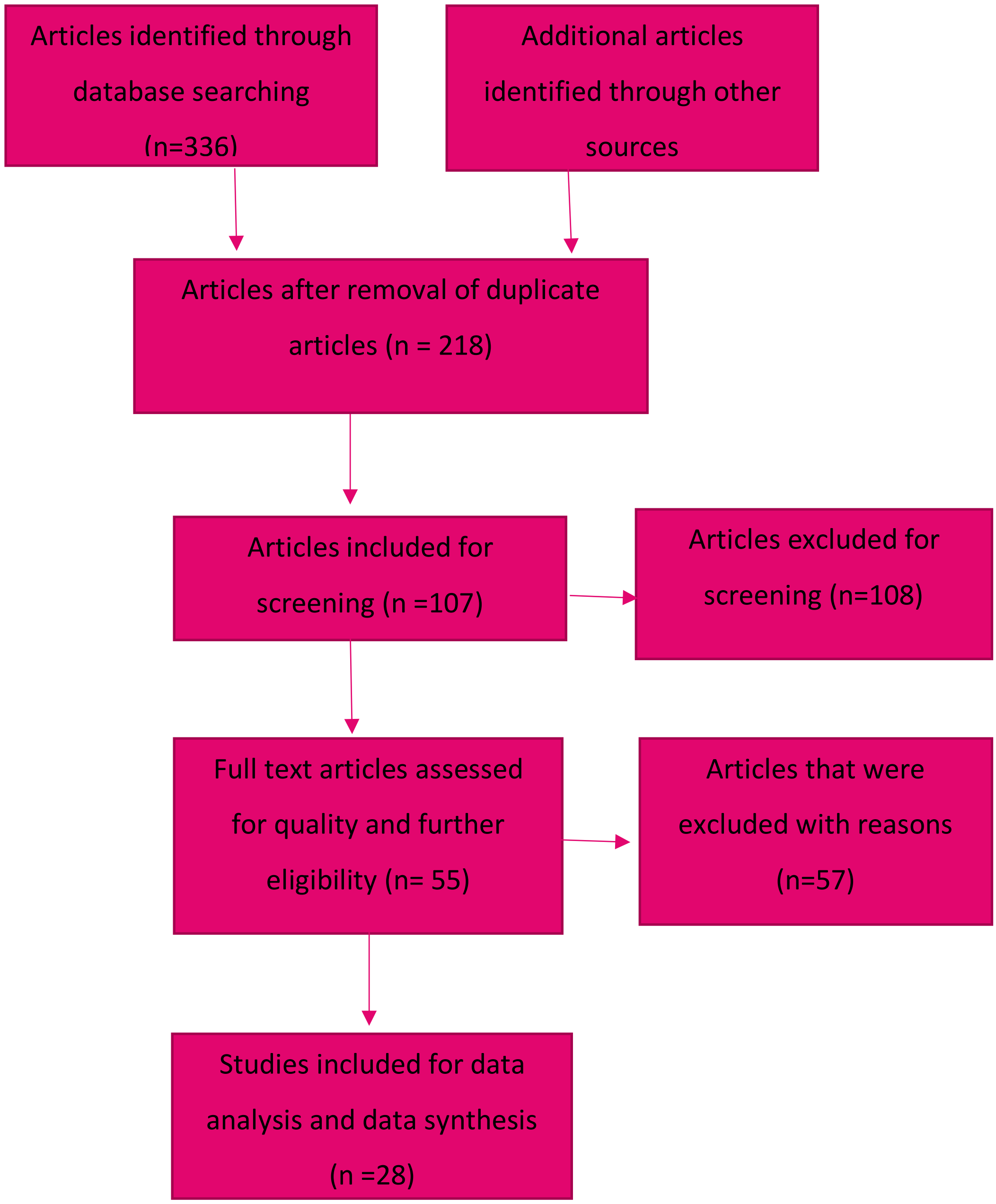

Figure 3: Prisma flow chart of the systematic literature review six steps(source: Author)

4 Findings and Analysis

The concept of sustainability is gaining importance in the business world today. One of the areas focused on sustainability of a warehouse with solar power plant system. This is because logistics and warehousing is one of the areas that significantly contributes to GHGs emissions (Payel, 2020). The concept of installing solar panel system in both Finland and Germany is increasingly becoming a widespread practice. For instance, Germany and Finland and the other European countries at large have been focused on renewable sources of energy towards attaining its goal to reduce carbon footprint. In this case, sustainability has been increased mainly towards sustainable buildings (warehouse) and investment in energy efficient equipment in the warehouse operations. However, investing in solar energy as a warehousing sustainable element is still at its infancy and it is not very widespread in the two countries compared to other renewable energy such as wind power. Simultaneously, solar energy in warehousing varies considerably within the two nations. Additionally, extensive search and analysis reveal that the use of solar energy in warehouse is different in both Finland and Germany because of some challenges that the countries have encountered with regard to the cost and geographical change. However, solutions for these challenges have been proposed and thus an expectation of solar energy increase (Hedberg, 2017; Lindahl et al., 2020). Therefore, this section discusses the findings and analysis on the current state of solar panel in sustainable warehousing in Finland and Germany divided under solar energy in warehousing in Finland and solar energy in warehousing in Germany. Where necessary, the author will relate the subtopics findings to validate the weaknesses and strengths in both areas to improve the authorizing quality of this article.

4.1 Solar panel system in warehouse in Finland

Finland is one of the leading users of renewable energy sources (RES) worldwide. RES offer one fourth of Finland's energy consumption in total, and the most significant RES include solar energy, bioenergy, ground heat, wood-based fuels, wind power and hydropower. This increase in the use of RES in Finland is associated with the national climate an energy strategy objective to increase RES use. Besides energy conservation, the utilization of RES is one of the most vital approach by which the climate targets of Finland can be attained. This is because RES do not increase emissions of carbon dioxide, while promoting regional policy goals and employment and enhance energy supply security (Pihlakivi, 2015). This and other enabling factors such a policies that encourage solar power investment, is a reflection that Finland's solar energy is ripe for firms to invest in solar energy for their warehouses. However, Finland's in solar energy investment is still at its infancy as only a few warehouses have adopted solar energy in their operations (Paiho et al., 2018). Moreover, there are also challenges associate with solar power investment, which are discussed in the following sections.

4.2 Technological issues

First, there is the challenge of high solar PV penetration levels in an energy system. While Finland has very high solar irradiation amounts during summer solstice months, this is contrary during the months surrounding winter solstice as there is low solar energy productio due to low solar irradation amounts. This simply means that Finland has a long, dark and cold winters that makes energy generation through solar system seems unfeasible (Child, Haukkala & Breyer, 2017). According to Pihlakivi, Finland has a more diffuse radiation than direct radiation. Diffuse radiation implies the scattering of sunlight particles and molecules at the atmosphere, but still make it down to the earth's surface. In northern Europe, solar radiation is lower compared to southern or central Europe. Thus, in Finland, according to the study, ideally, in no shading rooftop fitted with solar panel can approximately produce 700KW electricity per day. This electricity production is affected by the geographical location, alignment and the actual solar radiation amount every year. Notably, there is no sunlight during winter- time but From March to September Finland has maximum amount of sunlight. So, during summer, coupled with modern and efficient solar panels, solar panel can produce a lot of electricity than required and the excess electricity can be sold to Electricity Company. The price of normal electricity in Finland is 17 c which is comparatively lower than the price of electricity in Germany. Similarly, on average, the annual hours of total sunlight in Finland is 1860 hours.

Hence because most of the radiation comes from diffuse radiation, meaning finding and locating the right position for PV's affects the amount of energy the system can collect (Pihlakivi, 2015). Thus, this challenge presents a problem of unreliable energy for operating warehouses through solar power and hence the need for technologies that can maximize power generation both during summer and winter. However, Child, Haukkala and Breyer (2017) content that there are storage technologies currently present in the market that can help mitigate this issue of intermittency of solar PV high shares. These storage technologies include thermal and electric storage systems in addition to strong role of technology of Power-to-Gas. For instance, like in Germany where new PV systems are being purchased already with battery solutions of storage, the same is also introduced in Finland. Moreover, in the Finnish system of energy from Energy PLAN simulation for 2050, about 45 percent of electricity generated from solar PV was utilized directly all through the year, showing how relevant these storage technologies have become.

Other technological problems of solar power in Finland include grids and grid monopoly. Some concerns exist regarding probable effects of the powerdistributed through the electrical grid, metering issues and lack of a standardized grid connection procedures. Grids also require to have an easier access for producers of small-scale for connection and producers should also get better compensation, for example, a net metering based on hours. Currently, utilities are still managing connection costs of solar in households to the grid and ensure the grid is working efficiently and is reliable (Pihlakivi, 2015).

4.3 Economic issues

Investors compare cost and the competitiveness of traditional energy system to solar and these are one the leading barriers of solar energy in Finland, both for consumers and for utilities. From utilities standpoint, the incumbent firms producing non-renewable energy feel that a system of energy consisting of higher renewable energy shares is very expensive; with no energy storage system that is functioning well, intermittent renewables are anticipated to require back-up system and old firms still expect that they have the responsibility of maintaining that infrastructure and managing the costs. Ultimately, the old firms may also get compensation to maintain the old base load capacity where necessary (Child, Haukkala & Breyer, 2017). Pihlakivi (2015) adds that the biggest issue from suppliers' point of view are the expertise knowledge for PV technology and trained stuck human resources. Majority of solar panel suppliers in Finland import their panels and grid connections from Germany and Eastern Asia mostly China. The author adds that in Finland, the expertise is more in designing, delivery, marketing and installation of PV systems and grids. The system deliveries are about 10 firms, which majority bring solar grids from abroad. However, the solution is, rather than holding on to the way things used to operate in the past, the old utilities could start treating solar energy as a gateway into a novel market: utilities could do the selling of solar modules, offer grid connections and financing, and create a service relationship. Since solar is projected to become the largest energy source globally by 2050, this mplies there is also a wide market abroad. Thus, home market in Finland that is well-functioning would promote the possibilities for companies to enter attractive markets. Hence, overall, there is need for need for new rules and kinds of market of electricity as well as new business models (Child, Haukkala & Breyer, 2017; Holopainen, 2016).

From prosumers and consumers' perspective, prices of solar modules have been higher in Finland compared to other nations because of the inefficiencies of sales channel and lower volumes of market in Finland. However, prces of module are persistently decreasing and will be competitive on in the future in broader range of market divisions. Additionally, the installation costs in Finlands been somehow high because of expensive labor and inexperienced installers in the country. But once the domestic market develops, the costs of installation will be cheaper. This can be expedited by certification and training of solar PV installers at a nationwide level (Holopainen, 2016). Also, historically, the traditional system of energy has gotten subsidies in various forms which enabled it to stabilize and grow its market position. However, solar PV in Finland has not gotten essentially any subsidies and this has also supported the use of conventional system of energy in the country. As such, there is no level playing field for conventional and renewable energy technologies because of these unfair inefficiencies in the market, which further distort the market for solar energy (Child, Haukkala & Breyer, 2017).

On the other hand, Finsolar (2015) adds that costs of solar panels and installation has been a challenge in Finland especially for large scale consumers of solar energy. However, the author assert that as a technology that is rapidly developing, assumptions concerning solar PV technology entails substantial reductions in the costs of investment as solar energy is becoming more and more profitable RES in Finland. In the last years, solar energy market share has increase more and it is projected that for commercial property installation makes it to 6 euro cents per kilowatts for the next 25 years.

4.4 Behavioral issues

Another bigger challenges and obstacles appear to be the general attitudes towards Finland solar energy. Haukkala (2015) study revealed that there is an attitude issue, a change resistance, toward new approaches of operations and this concurs with Sovacool's (2018) behavioral barriers including misunderstanding, apathy of the public and psychological resistance. The people of Finland holds a strong belief that there is no sunshine in Finland and Finland's political will has not been available to address this myth among people. Additionally, there is a common misunderstanding that rarity of metals on earth will limit the modules production ability in the future, and that modules will eventually consume higher energy than what they generate. Even though research dispels these myths, they still persists in Finland. However, to overcome this challenge, Finland has started to restructure the energy sector especially through its EnergyPLAN simulation for 2050. Additionally, there is an attempt toward providing more information and correcting misunderstandings linked to solar energy (Child, Haukkala & Breyer, 2017).

4.5 Political and institutional issues

Another evident challenge that sluggish Finland's solar energy growth is the conflicting expectations and wishes that institute vested interests. In this case, the old energy firms have a high possibility of maintaining the status quo because of the vase investment in their old system, creating a lock-in and path dependence. Simultaneously, there are new energy production forms that attempt to break these lock-ins and, in turn, this brings conflct with the present energy system that is consiting of fossil fuels and nuclear power which take advantage of the economies of scale to become profitable. This resistance coming from industry or utilities can be felt in lock-in and path dependency contexts, and in undermining RES including solar energy (Haukkala, 2015). However, irrespective of the fact that Finland hardly have many solar PV support policy, there is a growing interest among Finnish people in relation to investing in solar energy as many people (88 percent) feel there is need to increase solar energy according to a Finnish Energy Industries survey (Paiho et al., 2018).

Child, Haukkala and Breyer (2017) state that a range of support instruments exists in other nations like feed-in-tariffs, tax and investment incentives, green certificates that have quota system, and quota system bids, all that have proven to generate a increasing home markets these nations.

Even nations that are rich in coal such as Poland recently demonstrated more progress compared to Finland after the country introduced a solar PV feed-in tariffs in 2015. In this case, even though Finland has a feed-in tariff system designed to increase the utilization of renewable resources to produce electricity, currently FIT is not available for solar energy. These FIT in Finland are in form of subsidies granted by the Energy Authority to give investors a realistic return on investment. Thus, due to lack of solar PV FIT, the Finland solar energy market is not livelier compared to countries like Germany that have solar PV FIT (Pihlakivi, 2015).

Paiho et al. (2018) raises an important concern that dynamic structures of support for various novel energy technologies can assist to surge their penetrationin the market. A high subsidy period may be especially significant to create early market share growth, but subsidies adjustments should follow to inhibit markets from very fast growth. Simultaneously, Child, Haukkala and Breyer (2017) remind that support has to go past financial measures to make them sustainable. Moreover, some support forms are viewed as preferable for various distributed generation technologies. For instance, Haukkala (2015) found that tax rebates or one-off support of investment were preferable to FIT because they were perceived as more cost efficient and were more likely to instill higher confidence in in Finalnd investors. However, in the past few years, there has been new established associations and coalitions of advocacy to promote Finland's solar energy. This may alter the present perspective as overall energy dialogue becomes more representative of a larger opinion range. Moreover, Finland has also implemented various policy measures for promoting energy efficiency and renewable energy like investment grants, the obligation scheme for renewable energy 2010 and technology programmers associated with renewable energy by the Finnish Funding Agency for Innovation and Technology (Tekes, 2015).

4.6 **Solar panel System in warehouse in Germany**

Like Finland, Germany has also taken inordinate pride in the spearhead of shifting to a greener economy. Thus, the country is one of the countries globally with the largest market share of renewable energy including solar power. Thanks to its Energiewende (energy transition) that has received global attention for the ambitious effort to promote renewables share in the energy mix (Hedberg, 2017). Renewable energy is attracting market share in the electricity market of Germany. In 2017, renewable energy provided 16.4 percent of the electricity consumption in overall, while in 2014 it was only 11.7 percent (Schleicher-Tappesser, 2018). According to Weiss

(2014), by the end of 2013, Germany had installed over 35.7 GW of solar PV capacity, which is virtually one third of the world installed capacity. This makes Germany the nation with the largest installed solar PV capacity. As a result, the electricity output from solar PV plants currently covers in excess of 50 percent of demand in Germany. However, the Germany's energy transition comes with its challenges that has prevented it from fully achieving its green economy target in terms of renewable energy.

Overall, the renewable and green future of Germany is still far from becoming a reality. While renewables share in the production of electricity has greatly increased, the general picture is less positive. Focus has been majorly on the electricity sector while little has been done concerning energy transition in the transport and heating sector. Thus, fossil fuels persist to dominate as the main energy source in Germany (Hedberg, 2017). Moreover investing in solar panel in a warehousing is still in its infancy in Germany because sustainable warehousing in Germany has majorly focused on elements such as green highways (as large tracks for goods transportation in the warehouse use eco-friendly fuels and technologies for faster battery charging); and electrified last-mile trucks to reduce carbon emissions (Wirth & Schneid, 2017). This further affects solar energy as part of RES. Besides, transition to renewable energy, especially solar and wind is also faced with some challenges that inhibits full attain transition as presented in the following section.

4.7 Interminnent nature of solar power generation and technological challenge

First, the generation of solar power in Germany is whether dependent. Just like Finland, Germany is another country with the least sunny days and solar power generation is dependent on the sun. This brings the issue of power intermittency that may not the energy demand in the country (Beveridge & Kern, 2013). Baake (2013) argues power generation from renewables like solar will exceed demand at different times during a given week, especially during peak demand periods in the middle of the day due to PVs. Yet, there will be other periods, particularly during winter, when solar PVs will produce small electricity quantities. Hedberg (2017) further adds that while solar panels can generate above 50 percent of the country's demand for electricity, over a year, solar only accounts for about 5 percent of electricity generation. This is because of solar power intermittency as it is dependent on weather. The author also contends that another challenge is that solar power generation peak time is when the consumption of electricity is at the lowest: during sunny summer day's midday. During winter when the consumption of electricity is highest, solar power production only meets 1 percent of the overall electricity demand in the country. Thus, no matter how climate-friendly solar power may seem to be, the weather condition and geographic location of Germany do not allow solar to become more than a marginal electricity source in the nation. Beveridge & Kern (2013) further add that the increasing renewable energy share in Germany has been coupled with a rise in the fossil fuel use to guarantee stable supply of electricity. Practically, this has meant maintaining and keeping conventional power plants which use gas or coal to offer the needed back-up for renewables. Additionally, while frequently forgotten, gas and coal are the major energy source for the heating sector and transport sector is slowly attracting attention.

However, technology has greatly developed and solutions for storage of the produced electricity has improved (Baake, 2013). Some of these technologies include pump storage stations, compressed air storage plants, electrochemical storage application and power to gas (Deutsche Energie-Agentur GmbH, 2015). Pump storage stations are presently the only economical storage option of energy for daily or hourly compensation that is available on an industrial scale and is more likely to remain in good condition for foreseeable future. Compressed air storage plants utilize excess energy generated from volatile RES like solar power and stored in underground, which is then produced in gas turbine through compressed air when electricity is needed. Electrochemical storage entail large batteries storage that store self-generated solar energy and supply it when required. On the other hand, power to gas comprise the conversion of renewable electricity into methane or hydrogen and then the gas can be taken and stored in the gas infrastructure to be used in different application such as heating mobility or electricity generation (Sinsel, Riemke & Hoffmann, 2020). The use of the energy storage technologies help to balance residual demand fluctuations, to make available the balancing control energy, to avoid blackouts and maintain an energy supply that is safeguarded as well as absorb the occasional important excesses from renewable energies and stabilize longer floppy periods in the long term (Hayat et al., 2019).

4.8 Economic/costs challenges

Secondly, the solar energy installation are capital extensive, yet it has an extremely low costs of operation after it has been installed. But the investment cost of Solar panel system in Germany is more than 1 million Euro which is expensive. As a result, after the initial investment in a solar plant, electrical power is almost free over the next two and half decades (Schleicher-Tappesser, 2018). The high initial cost of investment hampers solar energy penetration in the energy system and this proved to be a challenge for solar energy in many countries including Germany. Moreover, just like in Finland, cost comparisons with the traditional energy system such as coal and competitiveness are among the barriers of solar energy in Germany, both for consumers and for utilities.

In this case, the incumbent energy firms that heavily invested in coal mining to produce energy feel that a system of energy based on higher renewable energy shares is very expensive. This is because without an energy storage system that is functioning well, intermittent renewables are anticipated to require back-up system and incumbent energy firms still expect that they have the responsibility of maintaining that infrastructure and managing the costs (Hedberg, 2017). Moreover, with support from the government, the incumbent companies still continue to operate their coal energy production firms, making phase out of coal firms a challenging task to achieve the Energiewende main objective (Baake, 2013). Thus, the country continues to heavily rely on coal especially for heating which takes the larger percentage of energy consumption in Germany (Hedberg, 2017).

However, Germany has witnessed a recent increase in solar power penetration majorly tied to large industry benefit exemptions and FITs. In Germany, large industry players, especially of wind and solar energy, benefit from exemptions to conserve their single market competitiveness (Hedberg, 2017). This sets the pace for firms considering to invest in solar energy for their warehouses. Moreover, the core of solar PV program in Germany entails a set of FITs for solar PV installations of different sizes ranging from installations at the residential rooftop to utility-scale projects. For example, 5000meter square rooftop can prodce around 1000KW electricity per day with the modern and efficient solar panel technologies. Basically, compared to Finland, Germany has the most solar power production. These FITs guarantee a permanent compensation for electricity that solar PV facilities generates for a 20 year period. This program require TSOs to buy all the power generated from these PV systems and, in turn, TOSs sell the power on wholesale markets and are then made entirely through renewable levy that is collected from many customers. However, heavy users of electricity in trade-sensitive sectors are exempted partially from this renewable levy. Besides, according to German Meteorological service 2022, total hours of sunlight in Germany is around 1896 hours which is comparatively higher than in Finland. Also, the price of normal electricity in Germany is 31 c which is expensive than in Finalnd.

Under this FIT program, installations of solar PV have increased dramatically in Germany, reaching a total installed capacity in excess of 35 GW by the end of 2013. This represent almost a third of the worldwide installed capacity, making Germany by far the nation with the largest installed solar PV capacity (Weiss, 2014). Thus, this signify Germany's viability for solar energy in warehousing as solar power installation has been successfully achieved in the country. Furthermore, German firms are the leaders in development and research of novel PV technologies. As such, a requirement for positive development of the market in the future is a further costs reduction, for instance, by enhancing the efficiency degree and the amount of materials utilized, as well as increased utilization in other application areas (Weiss, 2014). This implies that the market for solar PV in Germany is blooming and warehouses can take advantage to invest in solar energy to power their operations in a bid to attain their sustainability goals.

4.9 The advantages derived from investing on solar energy in warehouses

A sustainable building restores, renews and optimizes resources that are consumed in a warehouse. Constructing green buildings, for instance, one fitted with a renewable energy system seems to be expensive with a very heavy investment, but in the long run it has proved to be cost-efficient (Terashima, Sato & Ikaga, 2020). The operation costs after investing in solar panels in warehouses reduce because of the constant energy generation from solar for several years that is used in operating equipment as well as lighting, heating and cooling of the warehouse. This is unlike energy from non-renewable sources that will result in high expenditure on daily energy consumption (Roth et al., 2015).

This finding is in agreement with Payel (2020) who accentuates that the key benefit of utilizing solar panels in the warehouse is the production of its own renewable source of energy that results in saving a substantial amount of money overtime after solar panels installation. Furthermore, this finding concurs with Quickline (2016) assertions which affirms that using renewable energy for business was expensive, but the present and future of solar energy is promising as Forbes report indicate that solar photovoltaic (PV) use is growing currently while the costs of installation are reducing. Moreover, Report indicates that solar energy is inexpensive compared to how it used to be and by 2027, solar energy will fill up to 20 percent of global energy.

Averagely, in a warehouse, energy is used in lighting, warehouse equipment and heating. This implies that if energy can be replaced with renewable energy and utilize sustainable lighting, warehouse equipment and lighting, this can minimize the total consumption of energy by up to 30 percent, with a possibility of creating a 100 percent sustainable warehouse (Payel, 2020). Additionally, the findings are in agreement with Banker (2014) who asserts that warehouse firms can substantially reduce their bills of energy with a system of solar PV. According to the author, energy bills are normally responsible for about 15 percent of a warehouse facility operating costs because of lighting and systems of temperature control. By installing solar panels that generate their own free electricity, these energy expenses can be significantly reduced.

Nonetheless, these green buildings are designed to be a healthy and more enjoyable environment for working. For instance, they minimizes water and energy consumption to ensure the level of comfort; offer better quality of lighting, and improves thermal comfort, includes natural lighting and offers better ventilation while increasing employees and machines productivity (Gupta, 2010). This finding concurs with You (2016) who assert that solar panels provides a means for warehousing to become more sustainable and reduce their carbon emissions which translates to saving the planet by positively responding to the concern of climate change and global warming. An example is Solgen Energy which installed and designed a solar system at the Healthcare (CH2) warehousing facilities in Frankfurt in 2013. One of the benefits include reduced carbon emissions in which the CH2 saves more than 128.2 tons of CO2 emissions yearly.

5 Conclusion

The objective behind this thesis work was to compare the current situation of solar power systems in a warehouse between two countries, Finland and Germany. Moreover, the literature regarding solar energy in sustainable warehousing are limited. This review contributes to research body on sustainable warehousing regarding the use of solar energy. The main study questions were:

1. What is the total investment cost of solar panel system in a warehouse?
2. How much electricity (KW) can you get from the rooftop of 5000meter square warehouse?
3. Is it more reasonable to use Solar Panel system in Finland or Germany?
4. What are the challenges and solutions of using solar panels n Finland and Germany?
5. How many hours sun is shining and what is the cost of normal electricity in Finland and Germany?

To conclude and answer the research questions firstly, the installation cost of solar power system in a warehouse in both countries is comparatively similar as the size of the warehouse is same and the price of solar panel is also the same. As a result, the investment cost is high in both Finland and Germany. Using solar energy is cheaper to drive warehouse operations as indicated in the findings on advantages of solar energy in a warehouse. This is because the operation costs after investing in solar panels in warehouses reduces because of the constant energy generation from solar for several years that is used in operating equipment as well as lighting, heating and cooling of the warehouse. Secondly, comparing between the electricity production in Finland and Germany, I calculated and found that Germany has more electricity production. However, it is possible because of the different geographical condition and more sunlight in a year. Also, Germany is one of the largest solar energy Producer in the world and they use more solar energy compared to Finland. Thus, due to lack of solar PV FIT, the Finland solar energy market is not livelier compared to Germany that have solar PV FIT. Also, the warehouse in Finland uses less solar panels comapred to Germany. On the other hand, the normal price of electricity is lower in Finland than in Germany which can turn out in a positive result when Finland starts using more solar panels. At the same time, Germany has high electricity cost but due to their high production and enormous uses of solar panel system compared to Finland it is the more reasonable country to operate solar panel system.

In my opinion, the objective of the thesis was accomplished although thesis findings were theoretical and practical both. Finally, this research recommends future studies and to focus on investigating the other renewable energy sources such as wind in combination with solar energy in sustainable warehousing to attain a more thorough understanding of how renewable energy can completely replace non-renewable sources of energy to drive warehouse operations and cut off carbon footprints as with the aim of businesses in the modern world.

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Appendices

Appendix 1. Abbreviations

FIT	Fee-in tariffs
ANP	Analytic Network Process
GSCM	Green supply chain management
SSCM	Sustainable supply chain management
RES	Renewable energy sources
CSP	Concentrating solar power
LSM	Logistic warehouse management system
CO2	Carbon dioxide
GHGs	Greenhouse gases
DG	Distributed generation
PV	Photovoltaic
TSOs	Transmission system operators
UK	United Kingdom
US	United States of America