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Sustainable Warehousing

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Abstract

Bringing sustainability in warehousing is very crucial for the implementation of green logistics. It is estimated that industrial buildings consume 4% more energy than transportation and with growing population and less resources, the challenge of building green warehouse is getting harder. Building a green warehouse has two possible options, one is new construction and the other is renovation of existing warehouse. Both options require huge investments.

The main purpose of this research is to find the most common features for developing the sustainability level in warehouses and the estimated implementation cost for the features. Green building, renewable energy, LED lights, district heating, electric forklifts and conveyors etc are the most common requirements for sustainable warehouse. Using renewable energy for LED lighting, district heating and electric warehouse equipment saves up to 50% of operational costs withing a 10-years' time.

Making a sustainable warehouse can reduce the amount of carbon emission by as much as 32%, and only a few changes in traditional warehouses can bring this change to the environment. Investment in sustainable warehousing initially is very expensive, and often very difficult to convince the investors about its long-term benefits.

Keywords/tags (subjects) Sustainable warehouse, Renovation, Construction, Renewable energy, Cost estimation.

Miscellaneous (Confidential information)

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1 Introduction

Sustainability has become a household word in our society and therefore we must consider the future when making our decisions about the present. One of the major challenges of 21st century is to achieve sustainability in the industrial sector which is one of the main sources of pollution. With the growing population and less natural resources, this work will not be easy but with every single effort, we are nearer to the goal.

The sustainability of a warehouse is often an estimated calculation of the occupied land, building materials, direct energy consumption, water consumption, carbon emissions and the equipment used in it. In the logistics supply chain, transportation is the most unsustainable element due to its energy consumption but EIA 2020 states that industrial buildings consume 4% more energy than transportation (Monthly Energy Review, 2020).

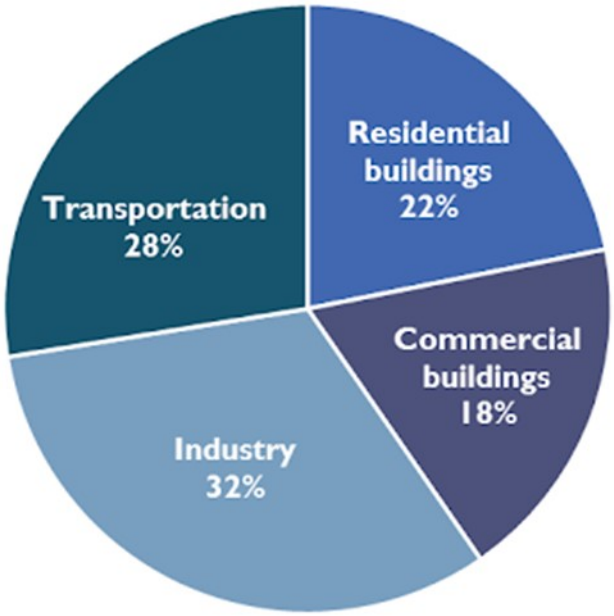

Figure 1: World Energy Consumption adapted from (Climate Change, 2014)

In Figure 1, it is clearly shown that industrial buildings consume more energy than transportation and that percentage will only grow with time if necessary measures are not taken in time.

2 Research Questions

Bringing sustainability to a logistics warehouse is a revolution for the future. The purpose of this thesis was to find the answers to these following questions.

1. What are the features required in sustainable warehousing?
2. What would be the estimated investment cost when increasing sustainability in warehousing?

3 Background

Figure 2: Background of sustainable features in warehousing

3.1 Sustainability

The word “sustainability” refers to everything that is essential for our existence and welfare. Pursuing sustainability generates and preserves circumstances in which

human and nature can create productive harmony to support the present and future generations.

We are now living in a modern and urbanized world and consuming much more natural resources than what is sustainable every day. For example, turning a rural area into an urban area is estimated to use 40 percent more resources every year. Sustainability and sustainable development help to balance our need and consumption economically and they also help the environment in which we are living. Sustainability is based on these three pillars which must be considered in present to create a better future. (Mason, 2018)

3.1.1 Economic Development

Economic development refers to people's needs without compromising their quality of life and reducing the economic pressure especially in the developing world. Sustainability means managing the natural resources in a manner that reduces the use of natural fuels to create economic development.

3.1.2 Social Development

Social development ensures that people's health and wellness are protected. It also means that the basic requirements are maintained and people are educated to participate in environmental sustainability.

3.1.3 Environmental Development

Environmental development is the third pillar which is the prime concern of the future of civilization. It defines the ways to protect ecosystems, air quality as well as the integrity and sustainability of our resources. It also defines the technology to of future.

3.2 Sustainable Development

It is not a secret that the world's population is rising and by 2050, the world's population is estimated to be 9.8 billion (United Nation: World population, 2017). This population growth is possibly one of the greatest reasons why sustainable development is so important.

Figure 3: Global goals of sustainable development Adapted from (Sustainable Development Goals, n.d.)

According to United Nations, there are 17 goals to achieve sustainable development (Figure 3). Achieving these goals requires both financial and social sustainability elements. They contain:

1. Facility to use resources for long-standing sustainability.

2. Resources must be constant and used for different purposes.

Social sustainability considers the ways in which a business influences not just the employees but retailers, clients, and the local community. If cities follow sustainable development, they can possibly make better ways for new housing and business developments. Renewable energy sources such as wind power and solar power are admirable examples of development approaches which are sustainable. Developing

countries could use the opportunity of growing and economic development by employing sustainable practices. Free energy from the sun or wind means that these countries can save the fossil fuel costs and invest it in the development of the country.

3.3 Sustainability in Logistics (Green Logistics)

”Lowering costs by increasing energy efficiency, reducing waste and pollution, creating safe working environments – supply chain sustainability is high on the agenda of many businesses” –Alan McKinnon, Professor of Logistics at KLU (2017). Sustainability in logistics is a necessary requirement as logistics operations are polluting the environment directly by producing greenhouse gases, impairing air quality and creating noise disturbance. It is estimated globally that about 8 % of Green House Gasses (GHGs) are produced by logistics operations and that by 2050, the amount will be doubled (McKinnon, 2017).

Green logistics is a term for rearranging logistics activities in a way that both our environment and economy remain sustainable. There are many possible ways to bring sustainability into logistics, and many companies have already started to apply the measures of green logistics to reduce their ecological impact (ARAUJO, 2018). These measures include:

1. Using eco-friendly packaging materials to ensure a long-term use.
2. Packing items in a way that uses the maximum efficiency of a single box.
3. Planting trees to outweigh the amount of CO2 released.
4. Using load optimization – ensuring a truck is fully loaded before leaving a warehouse.
5. Using route optimization to save travel costs, time or distance.

However, there are many things that can be done, such as using recyclable items, reusing packaging whenever possible and choosing eco-friendly companies.

3.4 Sustainable warehousing (Green Warehousing)

We often think before buying a product that how sustainable it is. For example, if we buy a bottle of soft drink, we try to think how to reuse or recycle the bottle. However, we often forget how it was made, where it was produced and how it was stored. We also need to think whether the warehouse where it was kept for most of its lifetime, is sustainable or not.

There are many good reasons for building a sustainable warehouse. For example, a sustainable warehouse not only saves the environment, but also lowers the operational costs, creates new marketing opportunities and higher employee satisfaction. (DMADDEN, 2019)

3.4.1 Reduced Operational Costs

Sustainability is a great way to reduce extra expenses and save resources for future development. For example, limiting fuel consumptions and using solar energy shows an immediate reduction in the bills. Plastic containers are reusable and a long-time investment in case of storing different goods and products. As sustainability is a trendy topic now a days, it can also be a good marketing strategy. Using words, such as green and sustainable, in campaigning creates a good impression of the company among the consumers, business leaders and investors.

3.4.2 Improved Employee Morale

Employer should always be concerned about the environment, especially in the warehousing sector where pollution is created in production. In this situation, we could give some extra responsibilities to some employees to organize the production chain with less pollution. This attempt will save the local environment and improve the moral values among the employees.

3.4.3 Increased Independence

Warehousing is a combination of different moving parts. If one of the parts does not work or causes any delay, the whole production chain is affected. There have been many cases in which the business has come to a halt. Delivery times are delayed, or we might lose the customer. However, gaining independence by investing in sustainability helps to prevent these expensive delays. Creating renewable fuel sources or reusing the same storage materials increases independence in business.

4 Sustainability in the industries of Finland

Finland has always been concerned about the environment and sustainability. Finland has excellent potential for achieving the UN sustainable development goals for 2030. In the Environmental Performance Index (see Figure 4), Finland has ranked in the 10th position among 180 countries and achieved the 1st position in environmental health (2018 EPI Results, 2019).

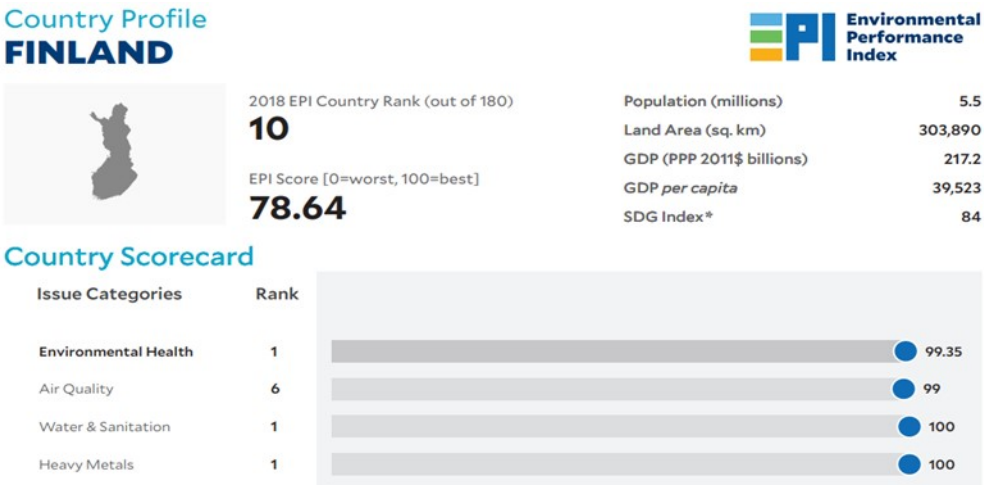

Figure 4: 2018 Environmental Performance Index report (2018 EPI Results, 2019)

The sustainability levels of Finish companies are also well known in the corporate world. According to the report of Corporate knights, six Finnish companies have earned a place in the 2020 GLOBAL 100 companies (2020 GLOBAL 100 Ranking, 2020)(see Figure 5).

Rank 2020	Rank 2019	Company	Peer Group	Country	Overall Score
3	3	Neste Oyj	Petroleum Refineries	Finland	83.64%
18	12	Outotec Oyj	Machinery Manufacturing	Finland	76.88%
24	23	UPM-Kymmene Oyj	Forestry and Paper Products	Finland	75.20%
32	43	Kone Oyj	Machinery Manufacturing	Finland	72.17%
66	49	Metso Oyj	Machinery Manufacturing	Finland	63.75%
99	88	Kesko Corporation	Food and Beverage Retail	Finland	41.30%

Figure 5: Finnish companies ranking in 2020 GLOBAL 100 companies (2020 GLOBAL 100 Ranking, 2020)

A company's sustainable success is always depending on production, warehousing and transportation, which results in a sustainable product.

According to the reports of Sweco (2019), many Finnish cities are reconstructing and renovating old building into new ones to maximize the efficiency of land use for carbon emissions. Therefore, the mayors of the six largest cities of Finland have proposed constructing new buildings by using woods because it is a renewable material and releases less carbon dioxide in production. Renovation might be slightly cheaper but constructing a new building gives more efficient use of land and less carbon emissions. Renovation might not reach the level of energy efficiency as the construction of a new building, but improving energy efficiency is crucial for reducing the carbon footmark. (Sweco, 2019)

5 Features required for Sustainable warehousing

Renovating older trends with newer technologies and innovative techniques gives a fresh approach to warehousing design. Sustainable business practices growing stronger with time and more warehouses are adopting "green" initiatives. Investing in the transformation of the warehouse gives benefits to the business, customers

and environment. It is quite difficult to mention all the sustainable changes because of the rapid development of technologies and inventions. Every single day something new is invented which is more sustainable than yesterday. However, there are more external elements to be considered that have a direct impact on the environment and society. These external elements relate to the impact of land use, atmospheric emissions, waste management, traffic and overcrowding, public transport, visual disturbance and ecology. The efficiency of a warehouse depends on energy inputs that are usually fossil based. Fossil fuels ultimately provide the power for equipment, such as forklift trucks, conveyors and other appliances as well as regulation of temperature, light for the internal and external areas of the warehouse, water for personal hygiene and processes. (Mckinnon, Browne, & Whiteing, 2012)

Figure 6 below presents some of the major possible ways to achieve sustainability and energy efficiency with green warehousing practices.

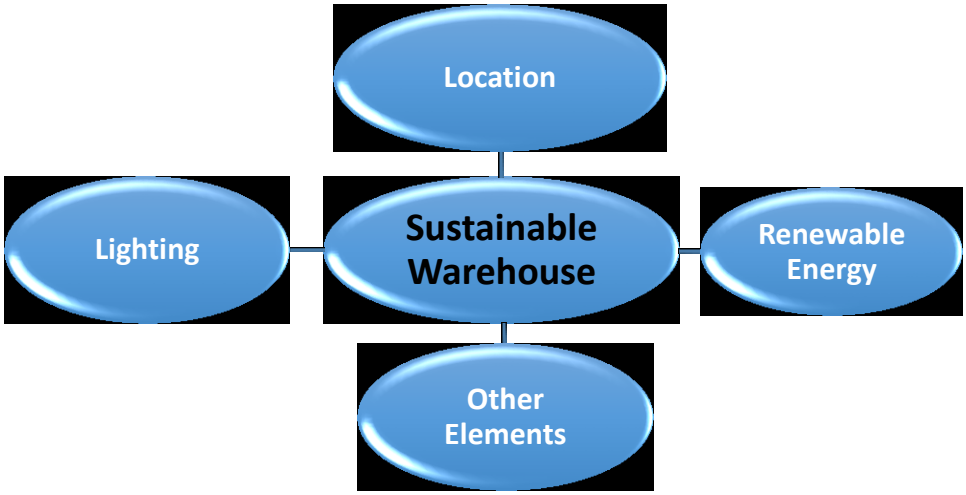

Figure 6: Sustainable warehousing features

5.1 Sustainable warehousing location and building

5.1.1 Suitable Location

Today sustainability is considered a real need. As with the increasing population, the need for buildings increases as well as energy consumption. It is already mentioned earlier that 32% of global energy is consumed by industrial buildings and 29% are used in transportation (Monthly Energy Review, 2020). So, to reduce transportation energy, choosing the right location plays an important role. It is wise to choose the distribution center located near the urban areas. It helps the consumers to minimize transportation in and out of the building. It is always preferred by the customer to have easy access to freeways, ports, highways, and airports. When distribution centers are close to city areas, trucks do not need to drive long distances between transportation centers like airports or rail yards. It is also benefited for the company as the employees can easily get to work using public transportation. Construction in a central location also decreases the necessity for supplementary infrastructure, as the roads, water pipes, and utility lines are all available there. (Kaplan, 2019) (Napolitano, 2013)

5.1.2 Sustainable building

Constriction of a Green building is now a part of a modern trend. A green building refers to a combination of suitable design, modern construction and operation, energy-efficient, and environment-friendly building. Green buildings preserve precious natural resources and improve our quality of life. Constriction of green warehousing buildings will help to reduce the amount of energy consumption and less pollution to the environment. There are some major features which can make a regular warehouse building into a green warehousing building (World Green Building Council, n.d.)

- Efficient use of energy, water and other resources

- Use of renewable energy
- Pollution and waste reduction measures
- Re-use and recycling
- Good indoor environmental air quality
- Use of materials that are non-toxic, ethical and sustainable
- Consideration of the environment in design, construction and operation
- Consideration of the quality of life of occupants in design, construction and operation
- A design that enables adaptation to a changing environment

A sustainable building optimizes, restores, and renews consumed resources. Constructing Green buildings often seems to be a very heavy investment, but it has proved to be cost-efficient in the long run. Green buildings are designed to be healthier and have a more enjoyable working environment. For example, it reduces energy and water consumption ensuring the comfort level, provide better lighting quality, and includes natural lighting, improves thermal comfort, and provides better ventilation, increases the productivity of workers and machines. (Gupta, 2010)

Leadership in Energy and Environmental design, shortly known as LEED is known for the international green buildings rating system. LEED is for all types of building including new construction or renovation of an old building. The LEED rating system is a combination of these seven areas shown in the Figure 7:

Figure 7: LEED credit categories (LEED, 2009)

Green Building Council (GBC) Finland provides significant benefits for the owners, investors, users, builders, and developers of the Finnish built environment. GBC Finland also adapts international environmental certifications LEED in construction. The boards of GBC Finland are attentive around six ideas:

- Energy,
- Sustainable Urban Planning,
- Real Estate Management,
- Education,
- Environmental Certifications and Assessment Methods,
- Sustainable Infrastructure

GBC Finland committees work with both public and private areas and there are over 185 specialists from 80 administrations working in the committees. (GBC Finland, 2020) (Ganapathy, 2017)

5.2 Lighting

Choosing the right lighting for the warehouse is one of the major sustainable goals. Warehouses contain large, windowless halls with high shelving structures and comparatively slender aisles. Providing additional lighting known as luminaires is affected by warehouse natural structure. Providing too much lighting is also consider as a disadvantage which can cause glare and operator discomfort. Lighting contains the major part of energy consumption and choosing the right lights can help the cost reduction on a large scale.

There are a couple of things that should be considered before choosing a light for the warehouse, such as frequency of switching, lamp's runtime, restrike rate, and average lifetime of the light. Replacing old mercury discharge lamps with high-pressure sodium lamps should produce a 15% saving in energy costs and it is also possible to expect 20% energy saving by using high-frequency control gear. (Mckinnon, Browne, & Whiteing, 2012)

There are three choices to choose the best one for the warehouse: high-intensity discharge (HID), fluorescent, and LED (Davis, 2019).

HID lamps ware the old version for lighting warehouses and still some companies often use them. These lights are very cost-efficient but have a fifteen-minute time to lit up or shut down. Which not very convenient for sustainability.

Fluorescent lighting is a good alternative to HID lighting, but they are more energy-efficient and consume less energy than HIDs. But they have a negative impact on extreme change in temperature. Their lifetime gets affected by high or low temperatures.

The use of Light-emitting diodes (LEDs) has improved intensely in recent years. LED lights are the most adaptable and energy-efficient choice for lighting the warehouse.

They might not be cost-efficient initially but has a lifetime of 100,000 hours which helps in the long run for the business.

Lighting large spaces like warehouses, sensors can be the best option. Using sensor lights can save the cost of around 30% of total energy expenses.

5.3 Renewable Energy

Renewable energy is referred to as Green energy for its low carbon generation to the environment. Renewable energy is generated from natural sources or processes which can be replaced easily. Renewable energy is often the base of newer technology and these powers have been used for heating, transportation, lighting, and more. For example, wind power is used for sailing boats the seas and windmills are used to grind grain. In warehouses, renewable energy is mainly used for electricity or heating. Generating renewable energy in a huge amount is quite a big challenge as it is depended on the nature, but local generation of green energy provides a partial solution to this problem. (Mckinnon, Browne, & Whiteing, 2012)

In this present world, it is possible to create even 100% renewable energy sources. Several countries have been trying to produce 100% renewable energy and very close to the target. For example, Ice land 85%, Norway 98%, Portugal 66%, Paraguay 90%, Germany 98%, and Scotland have generated 100% renewable energy for use (Alternative Energy, 2020). Nike's European Logistics Campus acclaims that they use 100% renewable energy sources to maximize the level of sustainability.

Figure 8: Nike's European Logistics Center (Zhang, 2016)

Renewable energy sources are beneficial than fossil fuels because of their very limited negative environmental impact. In the past, they were too expensive to be used widely but with time they are becoming cost-efficient and beneficial for the long run decision for homeowners, businesses, and governments. Here are the most popular five key sources that are considered as renewable energy foundations. (Marsh, 2019)

5.3.1 Solar Power

Solar energy is a great option for property owners who want to reduce their environmental footprint while saving money. Solar power is one of the most common renewable energy and beneficial for the environment as well as a bank account. The cost of solar is continuously reducing and installing solar energy almost always saves money over a lifetime. This form of energy relies on nuclear fusion power from the core of the Sun. Solar panels harvest energy directly from sunlight and can be collected and converted in a few different ways. For example, solar energy can be converted into electricity which can be used for water heating or cooling with solar attic fans for domestic. Solar energy can also be used to produce hot water or charge battery systems. Constructing solar energy does not poison or release fossil fuels.

5.3.2 Wind power

Another type of renewable energy coming from nature is the wind. Due to the uneven heating of Earth's surface caused by sunlight, a massive amount of speed is created by wind. This huge amount of speed is used to run massive turbines, which generate electricity when they spin. Wind energy can be used to pump but requires wide-ranging areal coverage to produce significant amounts of energy. Enormous wind farms spanning many square miles can be seen around the world. Like solar energy, wind power is also fundamentally pollution-free and environment friendly. Wind power is a growing and important renewable energy source providing electricity to networks around the world.

5.3.3 Hydropower

Hydropower is also known as hydroelectricity. Just like air, renewable energy can be produced by the movement of water. Moving water runs through a turbine to generate energy and spinning it to produce electricity. This often happens at large dams or waterfalls, where water drops significantly in elevation.

Hydropower is also a non-polluting energy source, as there are no emissions generated from hydroelectric facilities. But unfortunately, hydropower has a larger environmental influence than other renewable sources of energy, because they can change water levels, currents, and migration paths for fish and other freshwater life.

5.3.4 Geothermal energy

Earth contains a massive amount of energy within it. The heat was trapped while our planet formed, the outcome in an enormous volume of geothermal heat energy. Volcanic eruptions on the surface is also a form of escaped geothermal energy. This energy is capture and used the steam of heated water by spinning a turbine. In a geothermal spring system, water is pumped below ground and after it is heated, it rises back to the surface in the form of steam and spins a turbine to generate electricity.

In addition, geothermal heat is also used to provide heating or cooling to buildings. This technology is called a ground-source heat pump where a fluid is pumped below the ground surface to be heated or cooled and the temperature remains constant up to 50 degrees. For example, In Iceland, geothermal energy provides 90 percent of home heating needs and 25 percent of electricity needs (Alternative Energy, 2020). However, constructing a power plant of geothermal energy might cause surface instability and earthquakes.

5.3.5 Biomass

One last example of renewable energy is biomass. Biomass energy is produced from organic life-like plants or animals. Biomass is renewable resource process because plants are regrown relatively quickly with the help of a renewable energy from the sun. Fuels like ethanol and biodiesel are also updated forms of biomass. Biomass energies are considered as “carbon-neutral,” meaning they do not provide any additional carbon dioxide into the air.

The use of renewable energy is rapidly increasing and the maximum amount of this is using for district heating. In the last five years, the productions of district heating using renewable energy has doubled to 36 % and according to estimation this will reach up to 55% very soon (Statistics Finland, 2019).

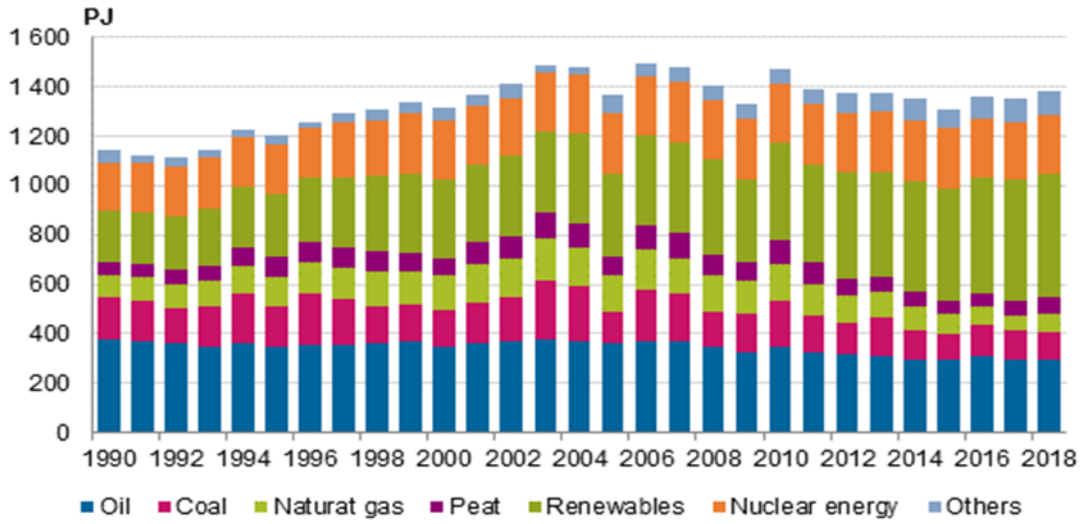

Figure 9: Total energy consumption in 1990 to 2018 (Statistics Finland, 2019)

In Figure 9, we can see how the use of renewable energy in Finland is growing with time. In 2015, the share of renewables in electricity generation was 45% where the largest share was hydropower followed by wood and wind power. At present, almost 80 percent of electricity generation is emission-free, which will rise to 90 percent by 2030.

5.4 Other Elements in sustainable warehouses

The productivity and consistency of warehousing elements have a marvelous impact on warehouse processes. Selecting the right power-driven products can improve the uptime due to their lesser maintenance requirements. They might also reduce fuel consumption and fuel costs. (Sistevaris, 2018)

5.4.1 Sensors

Using sensors in different sections also helps to reduce energy waste. Apart from lighting, other types of resource management, like water can also use sensors. (Kaplan, 2019)

5.4.2 Cooling or Heating

Fuel oil or gas is the primary source of energy for heating a warehouse, and electricity is used for cooling. Constriction material has a direct influence on the need for heating or cooling the warehouse. Apart from construction materials, warehouse volume, ventilation, external temperature and warehouse equipment influence the warehouse internal temperature. (Mckinnon, Browne, & Whiteing, 2012)

Warehouses are usually quite big in size and even with a proper ventilation system, the inside temperature remains very high. Especially eastern countries face extreme heat in the summertime and western countries face extreme cold weather in winter. To adjust the inside temperature, it is always challenging to have the right kind of temperature settings. For example, in the USA, warehouses use HLVS fans. These fans are very powerful and during the winter, HVLS fans can run in reverse to de-stratify and re-distribute the air. These fans can lower the temperature up to 5 degree Celsius in summer and raise the temperature up to 12 degree Celsius in winter. HLVS fans have a saving range of 12 to 50 percent in cooling and heating cost. (Kaplan, 2019) (Napolitano, 2013)

Heating used in the warehouse depends on warehouse location and size. District heating is the most popular form of warehouse heating in the northern counties. These systems are usually powered by fuel oil or gas but the most sustainable way of achieving energy is to use renewable energy.

In Finland, the use of district heating is improving by 2% every year. New warehouses are built with highly energy-efficient and the renovation of prevailing buildings cut down the heating demand. Finland has a long-term goal of building CO2 neutral society and the energy sources have reached a share of 46%. To promote renewable energy, coal-fired electricity will be banned from May 2029. (District Energy in Finland, 2019)

5.4.3 Forklifts and Conveyors

Forklifts are usually divided into two sections, indoor use and outdoor use. Diesel fuel or liquefied petroleum gas (LPG) is mostly used in forklifts. Electric forklift trucks are the best choice for green warehousing to reduce a warehouse's carbon footprint, but not all-electric forklifts are equally green. Despite having limited energy requirements and the accompanying electricity costs, electric forklifts are keeping the warehouse running all year round.

Apart from forklifts, some warehouses also have eco-friendly conveyor systems that lessen energy use and maintain a productive workflow.

6 Estimated investment cost in sustainable warehousing

6.1 Investment in sustainable warehousing

Every time the question comes of making a regular warehouse into a sustainable warehouse, the question the cost follows. Investment in sustainability is too high for any regular company and they required a very good list of the benefits of investing in the sustainability of their warehouse. The chapters below discuss the three best benefits of investment in sustainable warehousing which can inspire company owners to invest. (Merle, 2014)

6.1.1 Savings on energy cost

Investment in sustainability often results in lower utility costs. Initial investment in sustainable equipment might cost more than the regular equipment but in the long run, sustainable equipment provides more profit at less cost and better image to the company than the regular one. For example, the initial price for motor driven roller conveyor is approximately 12.5% more than that of the traditional conveyors. However, in a time period of 10 years, it saves 50% more energy than the traditional conveyors. A motor-driven roller conveyor not only reduces energy consumption, which

in turn reduces a warehouse's carbon footprint, it delivers other benefits to the business as well.

6.1.2 Making the Work Environment Safer

Being aware of the environment, companies are investing in their employees' welfare and in protecting warehouses from accidents. Companies' goodwill ensures employee safety much more than they used to do a few years ago. For example, motor driven conveyors produce much lesser noise than the traditional conveyors, which provides the employees with a more safer working environment.

6.1.3 Improving Existing Warehouses

Investment in a warehouse is always done by thinking of cost reductions and the profit increment. For example, installing new equipment in a warehouse minimizes the down time and increases production. It also requires less maintenance and saves more energy than the traditional one. Ultimately it accomplishes the same tasks as always while spending less energy and cash. Using sustainable technologies in the right places helps make that happen by creating a greener, safer and more efficient environment in a warehouse or Distribution Centre.

6.2 Estimated investment cost

There are always many different solutions for every problem. Investment on sustainable warehousing starts with a sustainable location. If a company has enough money to invest, they can also build a completely new warehouse in a sustainable location.

If we consider an average warehouse with an area of 1200 m2 and 7m in height with a storage capacity of 2500kg /m2, the construction cost for a new warehouse is 1500 €/m2 with leased land (and 1900 €/m2 with purchased land).

Renewable energy, Finland has the second position after Sweden in Europe. The use of renewable energy is rapidly increasing and the greatest amount of this is used for district heating. In the last five years, the productions of district heating by using renewable energy has double to 36 % and according to estimation this will reach up to 55% very soon. In 2015, about 45% of total electricity was generated from renewable energy and it was estimated that it was 80% emission free. It is predicted that 90% of energy production will be emission free by 2030 by producing more renewable energy. (Finnish Energy, n.d.)

Using this renewable energy for electricity provides sustainability in a warehouse. An average non-refrigerated warehouse consumes 6.1 kWh of energy, but this value varies between warehouse types and volume. Table 1 below gives an estimated cost of providing electricity for warehouses.

Table 1: Renewable energy estimated cost

Renewable Energy	Basic Price (euro/Month)	Unit Price (c/kWh)	Average warehouse (kWh)	Total Cost (euro/Month)
Basic	3.84	6.99	6.1	4.26639
Solar Power	3.84	7.87	6.1	4.32007
Hydro Power	3.84	4.98	6.1	4.114378
Wind Power	3.84	7.46	6.1	4.29506

Source: https://www.helen.fi

Using solar panels on the warehouse roof is the most common and easiest way to generate renewable energy. In the past, it was very expensive to use renewable energy for business, but in the present report of Forbes, the use of solar photovoltaic (PV) is growing while the installation costs are dropping (Quickline, 2016). Table 2 below presents some estimated options to choose from.

Table 2: Solar Panels estimated cost

Unit (piece)	Cells	Capacity (watt)	Warranty (years)	Price (Euro)
1	144	410	25	87
1	72	100	10	82
1	72	300	25	64
1	60	270	20	55
1	72	375	25	92

Source: https://www.made-in-china.com

The key benefit of using solar panels is the warehouse to produce its energy and saving a considerable amount of money overtime. According to the reports of climatechangenews.com, solar energy is cheaper than it used to be and by 2027 it will fill up to 20% of global energy. However Solar energy is dependent on the weather which is a big factor in northern Europe. Despite this, installing solar panels in warehouses is still a commercially profitable option and a good way utilize empty roofs. (King, 2016)

In an average warehouse, energy is used in three ways: heating, lighting, and warehouse equipment. If we can replace energy into renewable energy and use sustainable heating, lighting, and equipment in the warehouse, we can minimize the total energy consumption by up to 30% and there is a possibility to create a 100% sustainable warehouse.

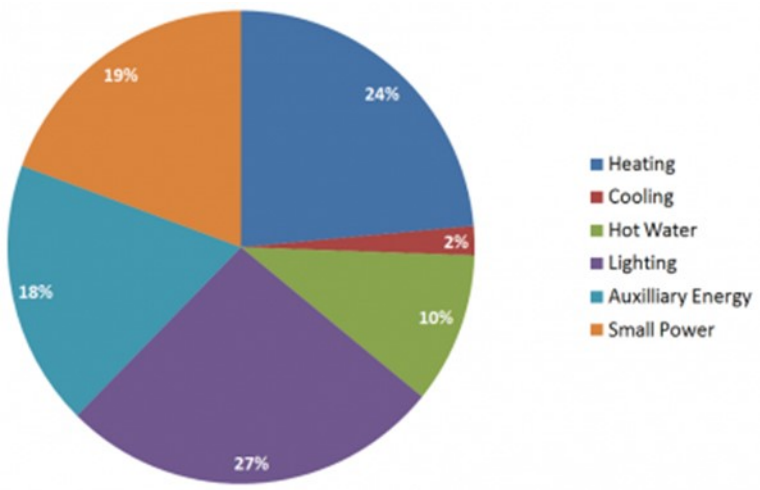

Figure 10: Energy Consumption in Warehouse (Thermal mass, n.d.)

District heating is the most popular form of heating warehouses in Finland as well as Europe. Approximately 70% of Finland's municipalities produce district heating with renewable energy sources and more than 66% of new buildings constructed with district heating systems. One third of the total production of district heating are used in industries. The use of renewable energy sources is rapidly growing, and district heating companies make substantial investments to increase carbon-neutral heat production. Finnish companies ensure to provide 24hour district heating services and the security level is up to 99,98% (FINDHC). There are always different rates in different companies for providing district heating. The standard rate with renewable energy would be 6.22 c/kWh and 6.5 euro/ month (Helen LTD, 2020). Although prices can be varied from place to place and company to company.

It is always very important to use proper lighting in the warehouse to ensure an efficient and safe warehouse. Correct lightings improve visibility in the warehouse and reduce workplace accidents. It is also important to understand that almost 27% of total energy is used for the entire warehouse and not using the right lighting might cost very expensive electricity bills. LED warehouse lighting systems are designed to maximize light output while minimizing energy consumption. LED lights might cost more than fluorescents, but they are long lasting for a better value and save energy. There are about 24000 varieties of LED lights in any lighting company. Here are some most common prices shown in the Table 3 according to the power of LED lights to estimate the value. (Prolighting, 2020)

Table 3: Estimated costs for LED warehouse lighting

Power (Watt)	Lifespan (Hours)	Min. Temperature (Celsius)	Max. Temperature (Celsius)	Price (Euro)
50	30000	-20	+55	55
20	50000	-25	+55	155
60	40000	-20	+55	48
100	43800	-20	+55	25
250	65000	-40	+70	78.9

Source: https://www.prolighting.com/applications/warehouse-lighting.html

Every warehouse has different kinds of equipment depending on its services. Warehouse equipment are mostly run with natural oils and gases. But in sustainability, it is more sustainable and cost-efficient to use electricity instead of natural resources. This will be beneficial in two ways; our natural resources will be saved for the future and we can use renewable energy for carbon emission. Table 4 below presents estimated cost for some of the most common equipment which can be found in every average warehouse.

Table 4: Estimated costs for warehouse equipment

Category	Product	Energy	Unit (Piece)	Price (euro) Lower limit	Price (Euro) Upper limit
Industrial Trucks	Stacker	Electricity	1	3000	5000
	Reach Truck	Electricity	1	3000	10000
	Counterbalance	Electricity	1	9000	15000
	Order Picker	Electricity	1	8000	12000
Conveyor	Belt Conveyor	Electricity	1	400	1000
	Roller Conveyor	Electricity	1	50	100
	Slat Conveyor	Electricity	1	60	120
	Chain Conveyor	Electricity	1	50	500
	Turn Table	Electricity	1	200	450
Sensors	Temperature	Electricity	1	10	15
	Humidity	Electricity	1	12	15
	Door	Electricity	1	14	20
	Water saver	Electricity	1	18	20

Source: https://www.made-in-china.com

7 Limitation and Risks

Sustainable development in logistics is often surrounded with some risks and challenges. Investment in a sustainable warehouse is one of them. This challenge has extended into managing energy and resources such as fuel, electricity, water, and land. However, controlling and reviewing lighting and heating, managing ventilation rates and heat loss, or using electric battery charger forklift trucks helps to save up to 50% of the overall expenses of the warehouse. Rapid economic development brings solution but leads to a shortage of resources and environment pollution. (Mckinnon, Browne, & Whiteing, 2012)

One of the big challenges of investing in a sustainable warehouse is the choice between renovation or new construction. This decision often depends on different

variables. In both cases, there are advantages as well as limitations. This decision contains the purpose of the building, budget, required time period, and investors.

Renovation of an old industrial building can often be more cost-efficient compared to building a new one. Renovation depends on how old or outdated the existing building is and sometimes it might cost close to contracting a new building. However new buildings are more efficient to serve the long-term goals. Renovation of a warehouse in a remote area is a good example of non-sustainable location. Not all renovations are a matter of taking something old and giving it a simple facelift. Some renovations require structural reinforcement, upgrades to sewage systems, or other drastic changes. New construction might be the more costly option, but it comes with several benefits and can be less restrictive than renovating.

New buildings are constructed to control energy consumption. The building design, materials, floor plans, and electrical and plumbing systems planner with a more energy-efficient way to reduce energy costs in the long-term business. It is much easier to plan and design a building with a precise requirement than converting an old building. (JBA Consulting Engineers, 2016)

Sustainability always stands for saving our resources. Practicing sustainability in warehousing reduces the risks of accidents as well as saves the resources. For example, if fire protection measures are taken correctly, it minimizes the risks of having fire accidents and this saves the waste of water.

The most crucial fact is to consider is the investors. Renovation or new construction both costs a giant amount of investment. Thinking about the sustainable investment, it does not bring initial profit to business and sometimes the calculations might seem to be way too much for investment. In these cases, it becomes very hard to convince the investors to invest this huge amount of money just for sustainable development. (Ganapathy, 2017)

8 Conclusion

For the survival of our world, sustainability is a must needed element. Green warehousing is a step towards green logistics and greener world. Making a sustainable warehouse can reduce the amount of carbon emission up to 32 % and only a few changes in traditional warehouses can bring this change to the environment.

Investment in sustainable warehousing is also beneficial for the company in the long run. It is estimated to reduce operation cost, energy cost, and cycle time up to 50 % by 10 years. Thinking about the future some companies have already started using, renewable energy, LED lights, and eco-friendly forklifts and conveyors. All the new warehouses are made with sustainable features.

In this succeeding stage to sustainability, warehouses are actively handling all forms of energy usage as well as procure and generate practicable green energy to achieve low-emission status. However, the long cycle time of sustainable warehouse leads to long term process of achieving goals.

9 Discussion

The purpose of this thesis is to improve the sustainability level of warehouses on a small scale. In this research, my goal was to find the sustainable features required for warehouses and the estimated implementation cost of the features. Both goals are achieved in the thesis. This thesis is done by virtual research and all the information is collected from e-books, journal articles, and company websites.

In my opinion, the research for this thesis is very limited. Building a sustainable warehouse consists of many other elements for example, waste management, packaging, storing, and space optimization, which was not possible to bring in this small scale of research. Also, all the prices are of the features are estimated and with time the rates are fluctuating. So, making any decision with this research is very hard. Maybe

in the future we can have a more detailed report of research so a company can be benefited and invest in sustainable warehouses.

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