THE IMPACT OF SUSTAINABLE DEVELOPMENT ON WAREHOUSING

Lilyana Mihova[1]

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Abstract: *The sustainable development is very emerging topic in the last two decades. This global trend has implications for the development of warehouse systems and technologies and the purpose of this article is to reveal the impact of sustainable development on green logistics practices in warehouses and the formation of sustainable warehouse systems. For this purpose, a literature reviews of sustainable or "green" warehouse is made. Also, the impact of the warehouse on the environment during the stages of construction and exploitation is researched. Other important issues concern the practices and technologies used in the warehouse to reduce energy consumption and harmful emissions. Last but not least a review of the legislative measures and certification methods for the construction and design of sustainable warehouses is made. In conclusion the guidelines for the state of development of sustainable logistics practices in warehousing in Bulgaria are given.*

Keywords: *Sustainable warehouse, Green warehouse, Sustainable logistics practices.*

1. INTRODUCTION

Beyond doubt, the topic of sustainable development affects all spheres of the economy and becomes a significant international factor in the development of many industries. Setting requirements in the form of legislation and developing measures to reduce harmful effects on the environment through various mechanisms make the topic relevant and important. Global trends are aimed at reducing emissions in all areas of the economy due to their impact on climate change. This trend is global due to the fact that many countries sign international agreements such as the Paris Protocol signed in December 2015, the UN Sustainable Development Goals and others. At national level, many countries also take individual measures to limit their carbon footprint. Although not specifically targeted to warehouses or separate logistic activities, setting such targets affects all areas of the economy and has a direct impact on the supply chain. The topic is becoming more widely used in logistics and supply chain management under different concepts, such as "sustainable" or "green" supply chain management, corporate social responsibility, circular economy and more. Following this global trend, many companies are deepening their focus, not only into operational and economic goals but in addition they begin to consider the environmental and social issues of warehouses. As a result of a literature review Bartolini et al. state that "an increasing interest in sustainability topics within the warehousing literature, where energy saving has been the most frequently studied objective, followed by environmental impact of warehouse buildings, and green warehouse management in general" (Bartolini et al., 2019, p. 243).

2. CONCEPT OF SUSTAINABLE WAREHOUSING

According to Ries et al. "amongst others, logistic activities in global supply chains have become a major cause of industrial emissions and the progressing environmental pollution" (Ries et al., 2017). Although a significant amount of logistic-related carbon dioxide emissions is caused by storage and material handling processes in warehouses, prior research mostly focused on the

[1] Univesity of Narional and World Economy, Students Town 1700 Sofia, Bulgaria

transport elements. This thesis is also confirmed by other authors such as Plambeck, who noted that "carbon emissions from storage are often overlooked in many studies at the expense of transport" (Plambeck, 2012). However, there has been increasing attention to sustainable storage processes, leading to many new research findings on the management concepts, technologies and equipment for reducing carbon footprint of warehouses.

The terms "green" and "sustainable" are often used, and usually they are perceived as interchangeable. However, "green" emphasizes the environmental aspects of sustainable development, while "sustainable" covers all its aspects (environmental, economic and social). For this reason, the term "sustainable storage" and "sustainable warehousing" is used in this paper. The concept of sustainable warehousing begins to be distinguished as a separate element in the literature on sustainable supply chain management. McKinnon et al. dedicate a special chapter in their book "Green Logistics" named "Reducing the environmental impact of warehousing", (McKinnon et al., 2012, p. 173) and Grant et al. devote a chapter called "Sustainable Warehousing" (Grant et al., 2013, p. 77) in their book "Sustainable Logistics and Supply Chain Management". Although these authors are known in the field of sustainable supply chain management, they do not give a precise definition of "sustainable warehousing". Their focus is on exploring the impact factors of warehouses on the environment and reducing their harmful effects. However, in the literature, Bartolini et al. provides a definition of the term "green warehousing" as a "managerial concept integrating and implementing environmental friendly operations with the objective of minimizing energy consumption, energy cost and GHG emissions of a warehouse" (Bartolini et al., 2019). However, this definition lacks the social dimension of sustainable development, involving on the one hand employees in the warehouse and, on the other, the impact of warehouses on society. This social aspect might be important for the location of warehouses in areas with different levels of development, the opening of new jobs, safety conditions for workers and more. Similar to the explanation for "green" and "sustainable" a wider definition is given by Malinovska et al. They define "sustainable warehouses as a set of organizational and technological solutions aimed at efficient realization of the warehouse process, while maintaining the highest social standards, minimizing the environmental impact with regard to financial efficiency" (Malinovska et al., 2018). Therefore, when considering the sustainable nature of warehouses, economic, environmental and social impacts must be considered at the same time.

In 2009, the World Economic Forum (2009) issued a report on "Supply Chain Decarbonization - The role of logistics and transport in reducing supply chain carbon emissions". This report presents emissions from logistical activities, which are estimated at 2,800 mega-tonnes of carbon dioxide or about 6% of all emissions in the economy. Of these, it is estimated that about 12% are from "logistic buildings" identified by the authors as warehouses and sortation facilities. This shows that while transport is responsible for the largest share of carbon emissions in logistics, warehouses also have a significant share of pollution caused by logistics activities in the supply chain.

The following research questions are posed to clarify the causes of the harmful effects of warehouses on the environment and how to reduce them:

Question 1: What are the environmental impacts of the warehouse during the construction and operation phase?

Question 2: What methods and technologies can be used in the warehouse to reduce the energy consumption and emissions?

Question 3: What are the legislative measures for buildings used for warehouses and what standards are used in the design and construction of warehouses?

3. THE IMPACT OF THE WAREHOUSE ON THE ENVIRONEMENT DURING CONSTRUCTION AND OPERATION PHASE

Grant et al. consider that the environmental 'costs' stem from the construction phase and from the operations. In the construction phase, emissions are caused by the construction materials and the construction processes and other environmental issue are connected with the land use, water, etc. In the operational phase, the energy consumption for lighting, heating, cooling, ventilation, equipment, etc. is taken into account (Grant et al., 2013). They also claim that whereas much of the energy consumption is determined at the design stage of the warehouse, the warehouse's energy consumption and its environmental impact can also be reduced to some extent later through the installation of energy and water saving technology, for example in updating temperature control or lighting systems. Sustainable elements in warehouse design include renewable energy, use of daylight, control and planning of artificial light used, temperature control of premises, efficient use of water, noise pollution, personnel training, optimization of storage processes, distribution and shipping of stocks , use of transitional rooms to avoid temperature costs when opening and closing doors, etc. Although the two phases are closely related because of the characteristics of the building, which are determined in the design phase, the operation phase of the warehouses will be discussed in more detail, since improvements to existing warehouses may be made after their construction and therefore, that the logistics functions of the warehouse are carried out in the course of its operation. However, "it should be remembered that the overall environmental impact of a warehouse is the sum of all stages of its life cycle" (Menzies, 2011). Although very important decisions in the construction phase are the choice and quality of the input materials in the building, the location of the warehouse (proximity or distance from major transport hubs), the quality of the land used (it is recommended the use of infertile areas away from livelihoods, agricultural areas and areas with high biodiversity) and the construction process (heavy construction equipment that can disrupt surrounding areas is used).

4. PRACTICES AND TECHNOLOGIES USED IN THE WAREHOUSE TO REDUCE ENERGY CONSUMPTION AND HARMFUL EMISSIONS

The main energy consumption in the warehouse is distributed differently depending on its functions for heating, cooling, ventilation, lighting, equipment, etc. In temperature-controlled warehouse the main energy consumption would be for cooling and heating, while in other types of storage the consumption of energy for lighting and equipment may prevail. Carbon Trust is an expert partner for businesses, governments and organizations around the world who is supporting them in realizing ambitious plans for a sustainable, low carbon future and achieving greater resource efficiency. (*Carbon Trust, 2019*). This organization presents in its report 'Warehousing and Logistics - Energy Efficiency Opportunities for a Warehousing and Logistics Company' at the beginning of 2019 important data on the possibilities of reducing energy consumption, which, on the one hand, reduce the environmental impact and, on the other hand, it reduces costs in the long term. According to their research in the warehousing and logistics companies the main energy using systems are, namely: lighting, heating and ventilation, forklifts, carnage and automation, and energy management. Non-refrigerated warehouses operating with legacy lighting solutions can typically reduce electricity costs by 70% by moving to LED, with further savings through heating measures. Of great importance are the area and height of the warehouse, as well as its internal layout design. One of the trends in warehousing is that the warehouses are becoming more automated, which, in addition to the improved efficiency of the facilities, leads to higher energy consumption.

Based on data from several sources, table 1 summarizes the possible methods and technologies in the warehouse that lead to sustainable results in economic, environmental and social aspect. They can be defined also as measures that can be taken in the warehouse during its operational phase (Grant et al., 2013; McKinnon et al., 2012). The table outlines the areas of application of energy-based practices and the possibilities of reducing such consumption.

Table 1. Fields of application of energy efficient warehouse practices.

Application fields	Opportunities for reducing energy consumption
Lighting	• Replacing inefficient light sources such as metal halide and fluorescent with low energy LED products; these bulbs give less heat and have a longer life. • Reduce the number of luminaires by placing reflectors under the light source. • Roof windows for daylight entry, which reduces the need for artificial light. This light is also better for staff health. • Cleaning of light sources from dust, in order to improve light intensity. • Turn off the lighting in unused areas and turn off the lighting in the presence of sufficient natural daylight. • Installation of sensors for light control.
Temperature control	• Precise zoning of the warehouse with appropriate barriers or insulation depending on temperature differences. • Opening of doors and barriers only when passing.
Heating systems	• Electricity, solid fuels or renewable energy is used. • The loss of heat depends on temperature differences, insulation, ventilation and passage to rooms with different temperatures. • Energy-saving heating systems and connection with ventilation and cooling systems for better temperature control in different zones.
Control of humidity	• Proper zoning is important so that only humidity control of the required area is carried out, as it also increases energy consumption.
Insulation	• The thickness of insulation reduces the temperature loss and therefore also reduces the required energy for constant temperature adjustment.
Barriers between areas with different temperature conditions	• Fast-closing / opening doors; • Sensor opening/closing of doors without human intervention.
Ventilation	• Natural and mechanical ventilation may be used. • Particularly important for the quality of the air. It is important for temperature equalization at high warehouses. • Use of heat from the cooling process for heating through ventilation system.
Energy efficient handling and storage equipment	• Improvements in battery technology, better battery energy efficiency and faster charging modes. • Optimized, reduced or shorter routes of handling equipment in the warehouse through warehouse management systems (WMS) • Extending the working hours of the warehouse to avoid peak hours and the accumulation of vehicles for loading.
Water consumption	• Used for worker's needs, cleaning the warehouse lorries and in the processing of goods, etc., • Large roof surface can be used for harvesting rainwater and use it for warehouse needs. • Cleaning and filtration systems for purification of water used.
Energy production within the warehouse	• Wind turbines, solar panels, residual energy recovery, kinetic energy.

Source: Adapted from Grant and McKinnon

On the one hand, these practices for reducing the negative effects on the environment lead to positive environmental results, and on the other hand, financial investments are needed to achieve them. In the short term, investments can be significant, especially in the overall renovation of an existing warehouse, but in the long term, these environmental practices also lead to economic benefits for businesses by reducing energy consumption costs.

Another important element in the technologies reducing energy consumption and harmful emissions used in the warehouse is the so-called "green energy". According to McKinnon, "green energy" can be defined as the generation of energy from a number of low carbon renewables near or at the site of use (McKinnon, 2012). As the main sources of such energy he identifies biomass (sawdust or other waste), wind and solar; recovered technological waste energy, such as heat from refrigeration installations or air compressors; recovered kinetic energy. The use of green energy can significantly improve the carbon footprint of the warehouse activity, and the full use of green energy sources can lead to zero carbon emissions. Such warehouses and green building already exist and attend more and more attention such as the European Logistics Campus of Nike in Netherlands, etc.

In addition to energy consumption in the warehouse, it is important to note that the warehousing activities also accumulate a significant amount of packaging and other waste that need to be treated appropriately. Although no production activities are carried out in the warehouse, activities related to fragmentation, cargo consolidation, repackaging, etc., generate waste that also has environmental and economic effects and the objective is to achieve positive environmental and economic benefits. Two important factors are, on the one hand, to reduce the amount of packaging and waste used so that they fulfill their protective function, but not to use unnecessary resources that burden transport and space and, on the other, to properly treat waste from packaging. This may include packaging reuse practices, recycling of packaging depending of their material, use of recyclable or recycled packaging materials, etc. Due to the wide variety of packaging and packaging waste, there are relevant regulations in the EU that are defined in Directive 2004/12/EU on packaging and packaging waste. This establishes an obligation for companies and in particular warehouses to treat their packaging waste.

In addition to packaging waste, other types of waste are generated in the warehouses, which must also be treated properly in order to determine the storage activity as sustainable. These can be municipal waste, toxic waste, rejects, waste water, etc. In order for a warehouse to be sustainable, waste management becomes an important issue because of the amount of waste generated due the large amount of goods that pass through it.

5. LEGISLATIVE MEASURES AND CERTIFICATION METHODS FOR THE DESIGN AND CONSTRUCTION OF SUSTAINABLE WAREHOUSES

Legislative measures specifically targeting storage facilities are difficult to find in most countries in the world. Existing legislation focuses on the energy efficiency of buildings and therefore warehouses can be considered as buildings. The legislation in EU gives guidelines for most countries in Europe through many regalement, directive and strategies such as Circular Economy and Energy Efficiency of Buildings. In the other parts of the world the situation is similar and often the legislative measures concerning the warehouse can be searched in energy efficiency policies for buildings or industrial facilities.

With the advent of sustainable practices and energy efficiency in building construction, independent organizations are developing standards for the certification of green buildings, and so far, several widely used environmental assessment systems for buildings are known. These systems can be used to evaluate different types of buildings, including warehouses. Each of these systems has been developed in different countries and the use of one or the other certification system is prevalent in different parts of the world. There are already several certified warehouse facilities in Bulgaria, which will be specified when considering the standards.

One of the most widely used method for measuring the environmental impact of buildings and certifying building sustainability is BREEAM (Building Research Establishment Environmental Assessment Method) (BREEAM) developed by the British organization Building Research Establishment – BRE Group in 1990. BREEAM can apply for new buildings at the construction phase, but also there is a compulsory standard for in-use and refurbishment buildings which means that an old warehouse could be reconstructed and fulfill environmental criteria. Depending on the category in which each building falls, it is assessed according to different criteria and as a result of the overall assessment formed the building is certified for a certain level - from "Pass" to "Outstanding". The first BREEAM certified warehouse in Bulgaria is the Zagorka warehouse in 2012.

The other most commonly used green building certification method is LEED (Leadership in Energy and Environment Design) (LEED green building certification | USGBC). This is the second internationally recognized certification system created by the US Green Building Council. Similar to the previous standard, this one includes a set of rating system for design, construction, operation and maintenance of green building, including warehouses with certification levels from "Certified" to "Platinum". In Bulgaria, a gold certificate is awarded to the newly constructed warehouse of "JYSK" with one of the most impressive facilities on the Balkan Peninsula.

Other popular systems are the German DGNB (DGNB – German Sustainable Building Council) , the French HQE (High Quality Environmental standard), the Japanese CASEBEE (Comprehensive Assessment System for Built Environment Efficiency) and others.

The optional nature of these forms of certification for energy efficient buildings shows that their introduction is a voluntary act of increasing the energy efficiency of the warehouses, improving their processes and reducing the environmental impact in and around the facility in long term. The fulfillment of these standards and the investment made demonstrate increased awareness and commitment of management, which in addition to the economic benefits, also bring benefits to the environment, employees and society.

6. FUTURE RESEARCH DIRECTIONS

This paper was developed as a part of university project named: Warehouse Systems and Technologies in Logistics. An empirical study will be conducted within this project and the degree of application of sustainable practices in the warehouses in Bulgaria will be researched. Other future research direction would be to make a research in different countries and compare the state of development of sustainable logistics practices. The harmful effects of warehouse activities compared to other logistics activities could be also another field for separate research, as well methodologies that could be applicable for further researches. Every of the three main questions in this paper could be researched in more detail in separate papers because of its importance and wider implementation in different countries.

7. CONCLUSION

This article presents an overview of some essential questions in sustainable warehousing. The two important phases of construction and exploitation of warehouse are considered because of their different impact on environment. This is made due to the increasing interest of sustainable buildings in particular for logistics purposes. There are several certification programs for buildings, which allows to assess the level of sustainability of a building, and the most common of them are presented. Last but not least a list of most common methods and technologies used in the warehouses to reduce the impact on the environment is made. The purpose of this list is to give a direction for assessment of level of sustainability in the warehouses and to be a ground for an empirical research. In conclusion, the sustainable development has a more and more significant impact to warehousing and storage activities in logistics and is to be considered in the construction of new warehouses as well as the renovation of existing ones.

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