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COLD CHAIN AS A RESILIENCE FEATURE OF THE SUPPLY CHAIN IN CHANGING CONDITIONS OF THE ENVIRONMENT

Zbigniew **Bentyn** [1,*], Sylwia **Konecka** [2]

[1] Poznań University of Economics and Business, Institute of International Business and Economics, Al. Niepodległości 10, 61-875 Poznań, e-mail: zbigniew.bentyn@ue.poznan.pl, https://orcid.org/0000-0002-2061-2616

[2] Poznań University of Economics and Business, Institute of International Business and Economics Al. Niepodległości 10, 61-875 Poznań, e-mail: sylwia.konecka@ue.poznan.pl, https://orcid.org/0000-0001-9283-7059

* Corresponding author

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Abstract

Purpose:
This paper assesses the adequacy of existing Cold Chain technologies for use during increased temperature, increased demand, and required environmental protection. The research problem lies in determining whether adopting the process of cold chain technologies due to observed environmental changes significantly improves the supply chain's resilience. The main hypothesis is that cold chain technologies deliver increased supply chain resilience. However, they require additional energy.

Methodology:
The paper consists of a description of existing CC technologies' conditions across industrial standards that relies on two stages: a description of regulations regarding cold chain technologies and a verification of the theoretical approach towards cold chain applications in the environmentally friendly supply chain.

Findings:
Energy usage restrictions and many regulatory requirements affect existing supply chains. Due to increased ambient temperatures, maintaining optimal temperatures in storage facilities becomes more difficult. This can lead to spoilage of perishable goods and require additional energy to maintain cool storage conditions. Product shortages and price fluctuations for various goods can also occur, creating uncertainty and instability within supply chains.

Originality / value:
Cold chain technologies improve the quality and efficiency of supply chain processes, yet changing environmental conditions make such systems more energy-hungry. Therefore, the demand for reliable and environmentally friendly cold chain solutions is increasing.The paper summarises selected requirements from public contracts, relating to WIM preselection systems in Poland. The difference between WIM and HS-WIM requirements is presented, and the differing requirements based on both international documentation and the standardised requirements that new or refurbished stations must meet are described.

Key words – cold chain, green supply chain, logistics, resilience, supply chain management

JEL Classification – M21, O32, L16

INTRODUCTION

Sustaining supply chain resilience may be one of the main goals in the world economy nowadays. Many events and disruptions create logistics barriers and significantly influence logistics operations. One of the disruptors is the changing climate. Observations and scientific research bring conclusions about factors and directions of changes awaiting the world economy. Adaptation of the supply chains is twofold. There is an observed effort to secure the flow in the global supply chain by employing, among others, cold chain

technologies. On the other hand, another goal is to curb emissions in the logistics processes because of new regulations. The research problem is determining whether adopting cold chain technologies due to observed environmental changes significantly improves the supply chain's resilience. Cold chain technologies may maintain safety for some reasons in logistics operations, but at the same time, they should deliver environmentally friendly solutions. These conditions pressure logistics operators and force them to assess existing cold chain technologies [1]. Overall, using cold chain technologies increases the supply chain's resilience by mitigating risks, enhancing product quality, improving visibility and traceability, reducing waste, ensuring regulatory compliance, and enabling flexible responses to disruptions. Therefore the main hypothesis is that cold chain technologies deliver increased supply chain resilience. By investing in cold chain infrastructure and best practices, businesses can build a more resilient supply chain capable of withstanding unforeseen challenges and consistently delivering value to customers.

1. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Resilience of the supply chain is a prerequisite for sustaining international operations. Long and complex relations, natural in global logistics, increase risk and multiply the number of potential disruptions. Li et al.'s [22] conclusion definition of supply chain resilience (SCR) as responding to disruption and returning to its original state, stresses maintaining the previous level of operationality. In this context, Shishodia et al. [25] state that the supply chain resilience framework improves thanks to diversification, international partnerships, on shoring, and demand management, in addition to inventory building and preserving capacity. McKinsey report compares the level of preparedness of business players in the supply chain. Well prepared and unprepared to react to extreme weather events. The report concludes with a warning pointing out a significantly more significant loss in sales happening for those unprepared (-5% to: -35%) [32]. The proposed study supports actions towards preparedness of the supply chain; however, it limits the scope of potential threats to extreme weather conditions. Aguila and ElMaraghy [2] describe resilience in SC as balancing the desired performance and the costs of achieving resilience. One of the main disruptors is climate change, and Baskin observed that supply chain units need mitigation plans and strategies to bring back a previous normal state of operations in SC [5]. It is proven that preserving resilience stresses the identification of risks and decreases potential impact while securing the revenues of supply chain participants [3]. All that consideration is critical in the context of the real political situation in the year 2024. As shown in the graph Figure 1, the fluctuation of the GSCPI index in recent years become significantly bigger. The influence of Ukraine-Russia and Izrael-Palestine conflicts happening right after Covid pandemic crisis may have multiplied pressure on the global supply chain.

Maintaining resilience is a crucial aspect of sustaining the logistics flow and, therefore, supporting the global economy. In conclusion, resilience is a central issue, and therefore, assessing ways of helping it is worth an effort, especially in a changing and demanding environment. Due to the increasing complexity and uncertainty in the global agri-food sector, stakeholders, including farmers, agribusinesses, and governments, must adapt their risk management strategies. The World Bank's Rapid Agricultural Supply Chain Risk Assessment provides a valuable framework for identifying and addressing potential risks within the entire agri-food system. This tool can help assess the vulnerability of supply chains, evaluate the severity of potential losses, and explore various risk mitigation options [10]. The tool provided by the World Bank helps to assess the threat of what is beneficial for the business participating in the supply chain. Unfortunately, to effectively secure the logistics flow, there are additional investments needed.

That is why cold chain procedures encompass a set of practices and protocols designed to maintain optimal temperature conditions for temperature-sensitive products throughout the supply chain. Effective cold chain procedures are the backbone of maintaining product integrity in temperature-sensitive supply chains [30]. By implementing these procedures, companies can ensure the quality, safety, and regulatory compliance of their products.

2. CHANGING ENVIROMENTAL CONDITIONS

Years of progress and development have positive and negative consequences. Leaving the obvious positive one it is certain that one of the negatives is global warming. Observed changes consisting of increased temperature accompanied by increased demand create a challenging mix for the global supply chain - Figure 2. Moreover, regulations created to withhold environmental change put pressure on logistics operations and require environmental protection enforced by restrictions. Decreased use of energy, restrictions towards emissions and consequently, change of means of transportation are some of the factors modelling the modern supply chain.

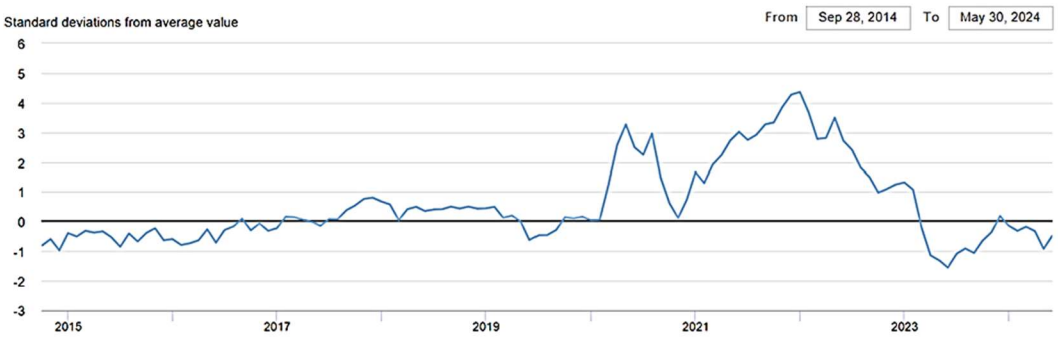

Fig. 1. Ten-year period observation in the fluctuation of GSCPI index

Source: Global Supply Chain Pressure Index (GSCPI), https://www.newyorkfed.org/research/policy/gscpi#/interactive

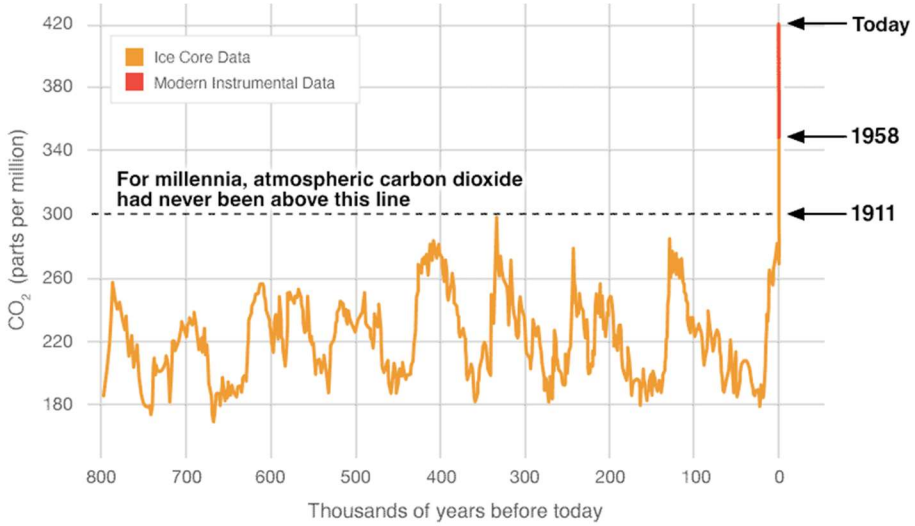

Fig. 2. Reconstruction of carbon dioxide levels from ice cores in time

https://climate.nasa.gov/vital-signs/carbon-dioxide/?intent=121

As noted by [28], change in climate adversely impacts human societies, business operations and the environment. Therefore, climate change-prone operations become an emanation of corporate strategic responses to sustainability issues [13]. Additionally, new customers require, as Christopher predicted, conscious strategies delivered by supply chains of corporations addressing climate change issues [12]. One of them is reducing emissions across the supply chain. Partnering with suppliers who prioritize sustainable practices, such as using renewable energy or adopting water-saving techniques. Utilizing more sustainable transportation options like electric vehicles, rail freight, or biofuels for long-haul journeys. Optimizing routes, utilizing larger capacity vehicles, and improving warehouse efficiency to reduce overall transportation emissions. Investing in energy-efficient equipment and appliances throughout the supply chain, particularly including cold chain technologies. Moreover, strategies of this kind also refer to resource efficiency. Embracing circular economy principles by incorporating recycled materials into packaging and products, extending product lifespans, and exploring opportunities for remanufacturing. Setting ambitious yet achievable emissions reduction targets across the supply chain and working towards transparent reporting on progress. Collaborating with suppliers to understand their environmental footprints and jointly develop strategies for emission reduction and resource efficiency. By implementing these strategies,

they can reduce their environmental impact while improving resource efficiency. Participating in ongoing industry-wide initiatives and partnerships focused on developing and implementing sustainable supply chain practices. One example of such a strategic goal is Walmart's Project Gigaton, aiming to reduce a gigaton of greenhouse gas emissions from its global supply chain by 2030. Similarly, Maersk's Carbon Neutral Goal sets a target of achieving carbon neutrality across its entire operations by 2040. Unilever's Sustainable Living Plan outlines ambitious goals for reducing the environmental footprint of its products throughout its lifecycle, including supply chain practices.

Supply chains should adapt, remembering that vulnerability to climate change is expressed as a function of exposure, sensitivity, and adaptive capacity in the context of resilience [10]. In the case of the supply chain, precisely intrinsic sensitivity to the hazard and a lack of capacity to modify, absorb, and eventually recover from losses may threaten its functioning in the long term.

Due to innovations and gathered experience, there are particular ways to secure logistics operations. Some of the resistance strategies to cushion on the food supply chain may include climate-controlled storage facilities, improved crop cleaning and drying, better storage to avoid losses to pests, additional processing to reduce spoilage, and more robust packaging to withstand difficult transport conditions [29]. Naturally, the most vulnerable kind of merchandise is food. The fragility of cargo, the complexity of the supply chain, and the degree of inter-connectedness of and dependency on other industries make a dedicated supply chain prone to disruption [7].

Globally, the ramifications of severe weather phenomena like floods, droughts, and hailstorms are presently compromising the efficiency of supply chains. This is evident through decreased agricultural output, damage to processing and transportation facilities, and the decline in export revenue. This pattern is foreseen to persist and exacerbate, propelled by climate change-induced heightened occurrences of extreme events, alterations in precipitation trends, and escalating temperatures [21].

A global supply chain is intrinsically connected with strategies and business models of Multinational Enterprises (MNEs) The influence MNE's of on global greenhouse gas (GHG) emissions necessitates their inclusion in comprehensive climate change mitigation strategies. Proactive MNEs present a unique opportunity for substantial emissions reductions through the implementation of stringent sustainability standards and facilitation of green technology transfers throughout their extensive supply chains, potentially impacting millions of producers.

Understanding and employing various sustainability strategies in global supply chains is dependent on business decisions. Unfortunately, further analysis indicates a concerning trend, with the combined direct and indirect emissions from only 157 large MNEs potentially reaching 60% of global industrial emissions. Moreover, the data suggests insufficient commitment to decarbonization efforts within the majority of these MNEs. Only 25% have pledged to achieve net-zero GHG emissions by 2050, with even fewer outlining a concrete decarbonization strategy (long-term: 20%, medium-term: 13%, short-term: 5%) [27]. Due to the policy shift towards environmental protection, it is expected that also supply chain operations will face more regulations in the form of monitoring emissions, direct laws and regulations, new taxes, incentives or fiscal support and pressure towards corporate commitments and obligatory information.

3. Description of regulations regarding Cold Chain technologies

Due to the international reach and complexity of tasks undertaken in the global supply chain, there isn't a single, universal set of regulations regarding cold chain technologies. However, regulations from various bodies apply depending on the specific application and region. One differentiator is industry. Two main categories here are pharmaceuticals and food.

In the pharmaceutical group, the Food and Drug Administration (FDA) in the US has regulations (CFR 21 Part 211) for drug storage and handling, which include temperature control requirements. Similar regulations exist in other countries from their health agencies. Similarly, food category. In most of the countries, regulations for food storage and transportation often come from national or regional food safety agencies. They typically focus on maintaining safe temperatures for specific food types to prevent spoilage or growth of pathogens [29].

Another differentiator is the subject. Regulations describe limits in the areas of temperature, data monitoring, equipment, and packaging. In the case of temperature control, regulations may specify the required temperature ranges for different products during storage and transportation. Data monitoring in some country's regulations may require recording and maintaining temperature data throughout the cold chain to ensure compliance. Equipment and packaging: Regulations might exist for the qualification and validation of cold chain equipment (refrigerated trucks, freezers) and packaging materials (insulated containers) to ensure they meet performance standards. Despite some differences due to the location of specific logistics

operations, the following bodies deliver rules for the industry. Among them are governmental health agencies like the FDA in the US, Industry associations related to pharmaceuticals, food, or cold chain logistics and international organizations like ISO (International Organization for Standardization) publish standards for good practices in cold chain management (e.g., ISO 22000 for food safety).

However, the ISO 22000 standard itself doesn't provide a specific set of rules for cold chain management. It focuses on establishing a Food Safety Management System (FSMS) that incorporates all aspects of food safety, including temperature control. Therefore ISO 22000 can be used to develop a cold chain management plan that aligns specific needs and complies with other relevant regulations.

Incorporating the following elements into FSMS, ISO 22000 helps ensure your cold chain processes are effectively managed to minimize the risk of food spoilage or contamination due to temperature fluctuations.

Hazard Analysis and Critical Control Points (HACCP) involve identifying potential hazards throughout the food chain, including temperature control failures. For cold chain processes, this might involve identifying critical control points (CCPs) like receiving temperatures, storage temperatures, and transportation conditions.

Operational prerequisite programs (PRPs) are programs that establish the basic conditions for food safety and can be tailored to address cold chain management. Examples of PRPs related to a cold chain could include [17]:

1. Calibration and maintenance procedures for temperature monitoring equipment.
2. Training for personnel involved in cold chain activities on proper temperature control procedures.
3. Documentation for temperature control protocols and monitoring records.
4. Validation of cleaning and sanitation procedures for cold chain equipment.

Finally, while ISO 22000 doesn't dictate specific temperatures, it requires you to determine the appropriate temperature based on the food product and relevant regulations. Additionally, the FSMS should include procedures for monitoring temperatures at CCPs throughout the cold chain and maintaining records to demonstrate compliance. The system should define procedures for taking corrective actions if temperature deviations occur to reduce food safety risks. Overall, ISO 22000 provides a framework for managing food safety, including cold chain processes. By implementing an FSMS that incorporates these principles, you can ensure your cold chain operations are aligned with best practices and contribute to overall food safety. A practical example of the application of regulations is a set of the IATA Temperature Control Regulations (TCR), addressing temperature management issues identified by the industry [18]. Thanks to collaborations with leading authorities and governments IATA has improved preparedness for COVID-19 vaccine transportation, which, in the past, posed a high risk to the pharmaceutical supply chain.

4. COLD CHAIN APPLICATIONS IN THE ENVIRONMENTALLY FRIENDLY SUPPLY CHAIN

Climate changes and customer pressure influence supply chain strategies. A proper cold supply chain that takes sustainable suppliers into account is considered necessary in the demanding modern market. Cold product manufacturers and suppliers adopt sustainable procedures and try to comply with sustainable standards. It takes time and investment in the infrastructure, but in the long term, it may secure market attention to a product and service. The suppliers of frozen foods, often dispersed in remote locations, need to incorporate sustainable practices to ensure that their products are accepted globally [20]. Characteristics of cold chain technologies help to do just that. One of the main goals in application of cold chain is preserving product integrity. Cold chain technologies maintain optimal temperature conditions to safeguard the quality and efficacy of temperature-sensitive products. The outcome characterizes CCT as environmentally friendly, considering its role in maintaining optimal temperature conditions for temperature-sensitive products. Cold chain technologies significantly reduce food spoilage by maintaining proper temperatures during storage, transportation, and distribution [16]. Less food waste translates to less environmental impact associated with food production, such as water usage, land use, and greenhouse gas emissions. In the process, proper cold chain technologies deliver improved efficiency. Efficient cold chain systems optimize energy consumption by maintaining precise temperatures without excessive cooling [26] This can be achieved through advancements like insulated packaging, intelligent sensors, and route optimization software, leading to a lower carbon footprint.

Adjusting the temperature of transportation and storage allows CCT to minimize the use of preservatives. Cold chain technologies often significantly reduce the need for chemical preservatives in food products [6]. This is because optimal temperatures inhibit microbial growth, allowing for a more natural and potentially healthier product while minimizing the environmental impact of chemical production and disposal. Similarly, to the food industry, temperature-sensitive pharmaceuticals and vaccines are very vulnerable. Cold chain technologies ensure their efficacy by preventing degradation. This

reduces the need for overproduction and disposal of expired medication, minimizing resource use and potential environmental contamination from pharmaceuticals.

The development of cold chain technologies includes environmentally friendly practices. These consist of utilizing recyclable or biodegradable packaging materials, using natural refrigerants with lower environmental impact, and adopting renewable energy sources for powering cold storage facilities [15]. Thanks to CCT, logistic operators may mitigate economic risks and reduce the risk of spoilage, degradation, and supply chain disruptions.

Another critical goal of cold chain management is ensuring regulatory compliance. Cold chain practices preserve compliance with stringent regulatory requirements governing the storage and transportation of temperature-sensitive goods. There are three aspects of reaching this goal: temperature monitoring, documentation and traceability and standard operating procedures. Thanks to temperature monitoring, using validated temperature sensors delivers data accuracy and compliance with regulatory requirements. Continuous temperature monitoring throughout the cold chain is crucial for compliance. This involves deploying data loggers, thermometers, and other monitoring systems to track and record temperatures during storage, transportation, and handling [19]. In the area of documentation and traceability, electronic data management systems applied often in supply chain management facilitate efficient recordkeeping and traceability, enhancing compliance efforts. Maintaining detailed records of temperature data, including timestamps and product identification, is essential for demonstrating compliance during audits [9]. This allows for tracing product movements and identifying potential temperature deviations, effectively securing the risk of distributing spoiled goods. Another effort in creating standard operating procedures helps deliver regulatory compliance. Developing and implementing standardized procedures for all cold chain activities is critical. These procedures should outline protocols for temperature monitoring, handling practices, corrective actions in case of deviations, and equipment maintenance. Reliability in delivering operations is supported by the documentation created and secured throughout the whole supply chain [23]. This upholds consistency and compliance with regulatory requirements across the cold chain. By implementing robust cold chain practices and a focus on regulatory compliance, companies can ensure the integrity and safety of temperature-sensitive products throughout the supply chain. This not only safeguards public health but also fosters market trust and facilitates global trade supporting supply chain operations.

Cold chain infrastructure also plays a critical role in enhancing supply chain flexibility, particularly for products sensitive to temperature fluctuations. This allows businesses to adapt and thrive in dynamic environments with changing environmental conditions. Cold chain infrastructure enables agile responses to changing environmental conditions, allowing businesses to adapt and thrive in dynamic environments. Climate change is increasing the frequency and intensity of extreme weather events like droughts, floods, and heatwaves. These events can disrupt transportation routes, damage infrastructure, and disrupt power supplies, impacting cold chain operations. Cold chain infrastructure consisting of refrigerated storage facilities, insulated packaging, and controlled atmosphere transport allows for maintaining optimal temperatures regardless of external conditions [11]. This ensures product quality and safety even during environmental disruptions. Robust cold chain infrastructure supports the use of alternative transportation options like refrigerated trucks or air cargo even when traditional routes are disrupted due to weather events or infrastructure damage. The real-time monitoring and control deliver data, allowing adaptation of the supply chain operations. Advancements in sensor technology and data management systems facilitate real-time monitoring of temperature conditions throughout the cold chain [24]. This allows companies to proactively respond to any deviations caused by environmental changes and take corrective actions. Investing in resilient and flexible cold chain infrastructure is not just about maintaining product quality but also about building agility in the face of environmental uncertainty. This allows businesses to adapt their supply chains effectively, minimize disruptions, and thrive in a dynamic global marketplace.

An environmentally friendly supply chain goal is to minimize unnecessary waste. Cold chain technologies play a crucial role in minimizing waste within the supply chain by extending the shelf life of perishable products. This allows for efficient resource utilization throughout the food production cycle, from farm to fork. Here's a breakdown with scientific evidence: By extending the shelf life of perishable products, cold chain technologies contribute to reducing supply chain waste and optimizing resource utilization. The Food and Agriculture Organization (FAO) estimates that one-third of global food production is lost or wasted [16]. This translates to significant environmental impact, including wasted water resources, land use, and greenhouse gas emissions. Perishable products like fruits, vegetables, and meat are highly susceptible to spoilage due to microbial growth and biochemical degradation.

Their shelf life, the period they remain safe and maintain quality, is limited by these factors. By extending shelf life and minimizing waste, cold chain technologies optimize resource utilization throughout the food supply chain.

Additionally, reduced water usage is another environmental goal of a green supply chain. Less food spoilage means less water is wasted during production, transportation, and storage.

Similarly, lower land use decreases environmental impact and may benefit producers, distributors, and consumers. Food production requires substantial land resources. With less food waste, the demand for agricultural land decreases. Reducing greenhouse gas emissions is a very important area of focus in the supply chain due to many transportation operations. However, wasting food contributes to greenhouse gas emissions, including methane from decomposition [4]. Minimizing waste, therefore, reduces this environmental burden often caused by worldwide distribution operations.

The environmental impact of cold chain technologies is a complex issue with both positive and negative aspects. Cold chain technologies significantly reduce spoilage of perishable goods, leading to less food waste. This translates to reduced environmental impact associated with food production, such as water usage, land use, and greenhouse gas emissions. Cold chain technologies often reduce the need for chemical preservatives in food products. This is because optimal temperature control inhibits microbial growth, allowing for a potentially healthier product and minimizing environmental impact from chemical production and disposal. Advancements in cold chain technologies include better insulation materials, energy-efficient refrigeration systems, and route optimization software. These advancements can lead to reduced energy consumption compared to older technologies. Howevers, refrigeration units used in storage facilities and transportation require significant energy consumption. This can contribute to greenhouse gas emissions depending on the source of electricity used. Traditional refrigerants used in some cold chain systems can be potent greenhouse gases. Strict regulations are phasing out some harmful refrigerants but leaks and improper disposal of older refrigerants can still contribute to climate change [14]. Disposable packaging materials used in cold chain logistics can generate waste. However, developments in reusable and recyclable packaging are offering more sustainable options. There is a possibility to point outs environmentally friendly CC technologies. Replacing traditional refrigerants with ammonia, carbon dioxide, or hydrocarbons offers a lower environmental impact. These natural refrigerants have lower global warming potential. Powering cold storage facilities with solar, wind, or hydroelectric energy significantly reduces reliance on fossil fuels and associated emissions. Utilizing thermal energy storage systems can optimize energy consumption by storing excess cooling capacity during off-peak hours for use during peak demand [11]. While existing cold chain technologies have drawbacks, advancements are constantly evolving towards a more sustainable future [8]. Focusing on energy efficiency, natural refrigerants, renewable energy sources, and waste reduction strategies will be crucial for minimizing the environmental impact of cold chain operations.

CONCLUSIONS

CCT will have to be sustained to continue operating despite demanding conditions. Environmental changes constantly pressure the global supply chain. Increased temperature due to emissions is one cause of extreme heat events like droughts and heat waves, which damage crops, reduce agricultural yields, and limit the availability of raw materials for various industries. Rising temperatures can lead to more frequent and intense storms, floods, and wildfires. This can damage transportation infrastructure like roads, bridges, railways, and ports, causing delays and disruptions to supply chains. Maintaining optimal temperatures in storage facilities also becomes more difficult due to increased ambient temperatures. This can lead to spoilage of perishable goods and require additional energy to sustain cool storage conditions.

Increased demand in some market segments may lead to another negative impact. Disruptions in production and transportation due to extreme weather events can lead to product shortages and price fluctuations for various goods, creating uncertainty and instability within supply chains. Moreover, unpredictable weather patterns make it difficult for businesses to forecast demand and maintain optimal inventory levels accurately.

Required environmental protection may lead to stricter regulations on energy consumption in various sectors, including cold chain operations. This may drive the development and adoption of energy-efficient refrigeration systems, better insulation materials, and optimization software for storage and transportation. Regulations and economic incentives may encourage the integration of renewable energy sources like solar, wind, and hydropower to power cold storage facilities. Additionally, cold chain practices improve by increasingly embracing principles of a circular economy, reducing waste and increasing resource reuse and recycling.

ŁAŃCUCH CHŁODNICZY JAKO CECHA ODPORNOŚCI ŁAŃCUCHA DOSTAW W ZMIENIAJĄCYCH SIĘ WARUNKACH OTOCZENIA

Cel:

Niniejszy artykuł ocenia adekwatność istniejących technologii łańcucha chłodniczego do stosowania w warunkach podwyższonej temperatury, zwiększonego popytu i wymaganej ochrony środowiska. Wdrożenie technologii łańcucha chłodniczego ze względu na obserwowane zmiany środowiskowe znacznie poprawia odporność łańcucha dostaw.

Metodologia:

Artykuł składa się z opisu uwarunkowań wdrażania technologii łańcucha chłodniczego w różnych normach przemysłowych, w dwóch częściach. Pierwsza polega na opisie przepisów dotyczących technologii łańcucha chłodniczego a druga na weryfikacji teoretycznego podejścia do zastosowań łańcucha chłodniczego w przyjaznym dla środowiska łańcuchu dostaw.

Wyniki:

Ograniczenia w zużyciu energii i wiele wymagań prawnych wpływa na istniejące łańcuchy dostaw. Ze względu na podwyższone temperatury otoczenia utrzymywanie optymalnych temperatur w magazynach staje się trudniejsze. Może to prowadzić do szkód powstałych w grupie towarów nietrwałych lub wymagać dodatkowej energii do utrzymania odpowiednich warunków przechowywania. Efektem tego mogą być także niedobory produktów i wahania cen różnych towarów, co powoduje niepewność i niestabilność w łańcuchach dostaw.

Oryginalność / wartość:

Technologie łańcucha chłodniczego poprawiają jakość i wydajność procesów łańcucha dostaw, jednak zmieniające się warunki środowiskowe sprawiają, że takie systemy są bardziej energochłonne. W związku z tym rośnie zapotrzebowanie na niezawodne i przyjazne dla środowiska rozwiązania w zakresie łańcucha chłodniczego.

Słowa kluczowe: logistyka, łańcuch chłodniczy, odporność, zarządzanie łańcuchem dostaw, zielony łańcuch dostaw.

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