Transforming Warehouses Towards a Sustainable Future

By: Osama Alhasan and Kirill Lobanov
Advisors: Dr. Eva Ponce and Dr. Miguel Garcia

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Summary: The warehousing industry is a significant source of greenhouse gas (GHG) emissions contributing to the climate change that is being witnessed by the world in the past few years. In response to that, our capstone sponsor Maersk tasked us with identifying actionable steps to reduce GHG emissions at the warehouse level. We evaluated 13 technologies to reduce GHG emissions and conducted an in-depth review of seven of them. Our methodology assessed the environmental and economic impacts of implementing these technologies. The project was concluded with a framework for evaluating different sustainable solutions in an integrated way.

Before coming to MIT, Osama worked in the oil and gas industry and held various commercial and supply chain related roles. He graduated with a bachelor's degree in civil engineering and engineering management from the American University of Sharjah.

Before coming to MIT, Kirill spent over 6 years in sourcing and supplier management. He holds bachelor's degree in management and master's degree in economics from Plekhanov University. Kirill has an experience in working internationally.

KEY INSIGHTS

1. Sustainability costs less than it is perceived.
2. Individual warehouses require specific analyses to determine applicable sustainable solutions.
3. The project developed an economical and environmental assessment methodology along with a framework to evaluate solutions' feasibility.

Introduction

As the global community becomes increasingly conscious of the growing climate crisis, the attention is shifting towards the reduction of CO2 emissions, the main driver of global warming. The year 2021 was marked as the sixth warmest on record, with the global surface temperature registering 1.51 °F (0.84 °C) higher than the 20th-century average. Though this increase might seem minor, its impacts are severe and costly. From 2009 to 2015, the U.S. incurred damages of approximately 1.16 trillion USD due to weather and climate disasters. This figure is projected to escalate to a staggering 2 trillion USD per annum by 2030.
Such stark realities underscore the importance of sustainable development as a critical tool to mitigate our environmental impact. Every year, human activities produce around 50,000 megatonnes of CO2 equivalent in greenhouse gas emissions. Notably, the logistics and transport sector contribute about 5.5% of these emissions. Given this, industries with significant logistical elements, like warehousing, have a considerable role to play in shifting the sustainability paradigm.
As the largest players in various industries, including logistics, begin to realize the environmental implications of their operations, there is a growing trend towards focusing on sustainable development. Green innovation performance is being enhanced not only by pressure from regulatory bodies but also by increasingly environmentally conscious consumers.

Background

Our project sponsor, Maersk, one of the global leaders in transportation and supply chain solutions, has set a decarbonization target of net zero emissions across all businesses by 2040, aiming for 90% green contract logistics by 2030. With a presence in 130 countries and over 3 million square meters of global warehousing, Maersk is a key player in the shipping market. Maersk considers warehouses vital to supply chains and is initiating modernization efforts. While efforts are underway to make new warehouses sustainable, the challenge lies in reducing emissions from existing warehouses built before 2010, which represent 75% of North American warehouses.

Research Question and Hypothesis

This project aims to equip Maersk with a standardized approach to identify, assess, and implement sustainable initiatives in their North American warehouses. Our project goal was to help the company to prioritize crucial greenhouse gas reduction efforts. The deliverables include:

- An assessment of potential sustainable warehouse solutions;
- A ranking of these solutions based on cost-effectiveness and environmental impact;
- A guideline for implementing these solutions;
- A framework for evaluating sustainable warehouse solutions.

This approach will enable Maersk to effectively identify sustainability opportunities, guide their implementation, and support their broader sustainability goals. The final framework could also aid other industries in evaluating and implementing sustainable warehouse solutions.

Methodology

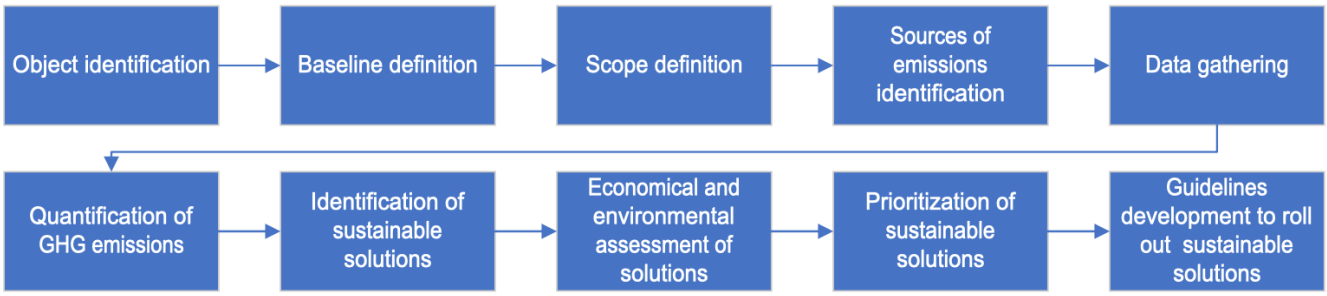

Figure 1. Methodology

The developed methodology aligns with both the GHG protocol guidelines and Maersk's expectations. The process begins with object identification, where we selected two specific facilities in the US, Facility A and Facility B, as the subjects of our study. The next step is baseline definition, which involves establishing the level of emissions as of November 2022 prior to the introduction of the sustainable solutions. This is followed by scope definition, where we agreed to cover only scope 1 and scope 2 emissions for this project.

In the sources of emissions identification step, we analyzed potential emission sources at the warehouse level. Data gathering was the next step, where we collected information from Maersk, industry reports, scientific articles, and solution providers through interviews and on-site visits.

Quantification of GHG emissions is a key step, requiring careful calculation of the contribution of each asset to total emissions. Identification of sustainable solutions involves analyzing the applicability of these solutions to each warehouse and estimating potential outcomes.

The economic and environmental impact assessment of sustainable solutions takes into account two factors: payback and environmental impact. Following this is the prioritization of sustainable solutions, where we rank the solutions based on their potential impact.

Finally, we developed guidelines for the rollout of sustainable solutions, using records of logistics industry practices and equipment manufacturers' recommendations. The results delivered through this methodology contribute to the main goal of retrofitting existing warehouses to a sustainable level.

Results and Insights

Before ranking sustainability solutions by key performance indicators, we split them into two groups: those that need building owner approval and those that don't. This is critical because Maersk doesn't own the buildings it operates in, thus some solutions may need owner permission. Also, it may not be prudent to invest heavily in improving a building the company does not own.

The first group of solutions included electric forklifts, electrified yard tractors, 5 kWh wind turbines, and micro wind turbines. These solutions fit easily into the existing operations, promising immediate operational benefits and long-term financial and environmental gains. The KPIs assessment for Facility A ranked electric forklifts and yard tractors as the most feasible solutions, with their lower operational costs, reduced emissions, and quieter operation offsetting their initial investment.

Solution	Expected payback, years	Annual CO2 reduction, tons	Rank based on payback	Rank based on environmental impact
Electric Forklift	2.47	154.18	1	1
Wind Turbine (5 – kWh)	3.82	21.38	2	3
Electric Yard Goat	6.60	26.00	3	2
Wind Turbine (micro)	8.55	9.57	4	4

We also examined solutions requiring substantial facility alterations, including high-volume, low-speed (HVLS) fans, solar panels, and 15 kWh wind turbines. HVLS fans improve air circulation, reducing air conditioning needs and improving indoor air quality. Solar panels and wind turbines, although requiring a larger initial investment and possible approval from the building owner, can offer

substantial long-term energy cost savings and carbon reductions.

According to our KPIs assessment for Facility A, solar panels installed via a Power Purchase Agreement (PPA) emerge as the top-ranked solution for both warehouses, followed by HVLS fans and 15 kWh wind turbines. However, the effectiveness of these solutions is highly dependent on location-specific environmental conditions.

Solution	Expected payback, years	Annual CO2 reduction, tons	Rank based on payback	Rank based on environmental impact
Solar: PPA	0	333.61	1	1
HVLS fans*	3.95	107.11	2	2
Wind turbines (15 - kWh)	11.15	7.64	3	3

We also considered rainwater harvesting as a potential solution. Yet, our analysis showed it to be unfeasible for the chosen locations due to high infrastructure and maintenance costs and low annual rainfall.

Importantly, we found that implementing a combination of solutions could create financial synergies. For instance, the introduction of solar and wind energy could decrease the payback period for other solutions, improving the economic viability of warehouse decarbonization. Our research highlighted the rising significance of alternative energy sources, providing benefits such as energy independence, property value enhancement, peak demand charge reduction, and brand differentiation. This necessitates a few key recommendations for Maersk and other companies:

1. Monitoring advancements in hydrogen technology as a potential source of clean energy, despite current constraints.
2. Evaluating the prospect of owning warehouses, considering factors like decision-making control, operational efficiency, real estate appreciation, availability of suitable rental properties, and potential for business expansion.
3. Prioritizing the transition to mobile assets (like forklifts, yard goats) due to current limitations in facility upgrades imposed by warehouse owners, while concurrently negotiating for the implementation of other solutions.

Framework:

Our research has led us to develop a comprehensive framework that categorizes sustainable solutions into moving, semi-fixed, and fixed assets based on the extent of facility modifications required for their implementation. This framework is pivotal for systematically evaluating the sustainability potential, feasibility, and profitability of each solution, considering various factors like usage rates, cost disparities, owner restrictions, and natural conditions.

Moving assets, such as forklifts and yard goats, are highly portable and require minimal facility modifications. Their economic attractiveness hinges heavily on their utilization and the cost differential between electricity and fuel. The larger this disparity, the quicker the payback, despite significant upfront costs.

Semi-fixed assets, like HVLS fans and mobile wind turbines, depend more on electricity costs. These solutions can help reduce specific electricity consumption or eliminate certain points of grid dependency. They offer moderate upfront costs and installation ease, but their viability could be affected by natural factors like temperature and wind speed.

Fixed assets, including solar panels, rainwater harvesting systems, and stationary wind turbines, necessitate substantial building modifications and owner approval. They typically involve longer payback periods and high upfront costs. However, solar's commercial model (PPA) alleviates the company's direct expenditure. The feasibility of on-site solar and wind energy generation heavily relies on natural factors and utility costs.

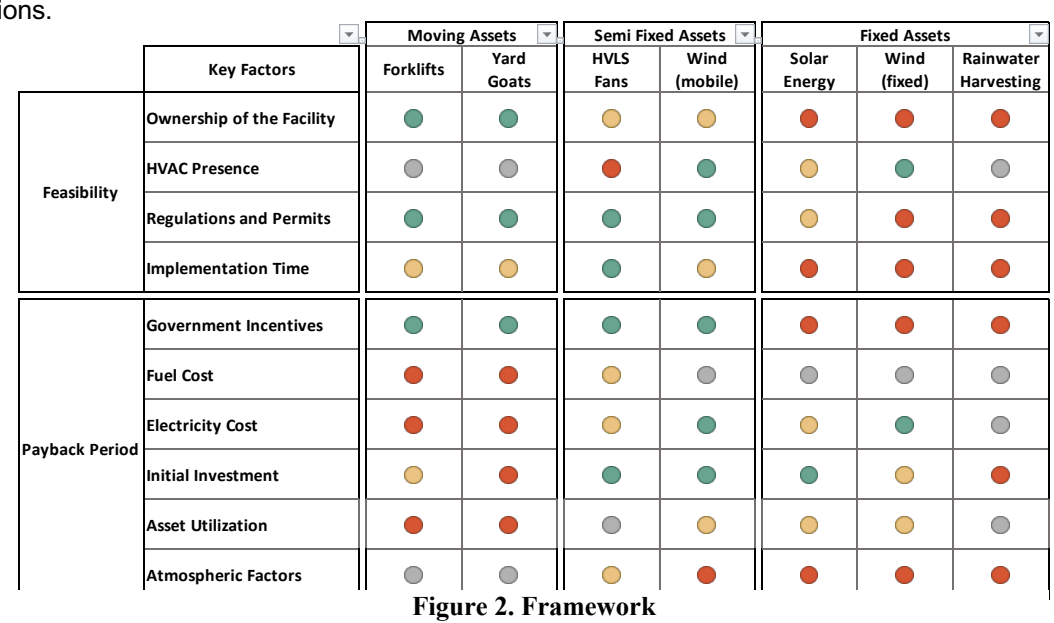

Figure 2. Framework

Conclusion

In the quest to assist Maersk in reaching its sustainability goals, this project explored two specific warehouses, developing a comprehensive understanding of what constitutes a sustainable warehouse, both scientifically and within industry norms. A detailed methodology was designed for each potential solution, scrutinizing their technical feasibility, economic viability, and alignment with industry practices. This resulted in a set of recommendations for Maersk, including a prioritization of solutions based on their environmental impact and payback period. The crowning achievement of this project is the creation of a comprehensive framework that provides a structured approach for assessing sustainable solutions. It offers a systematic and holistic process, aiding in the identification of key factors and relationships that can influence outcomes. This tool not only facilitates communication and collaboration among stakeholders but also provides a valuable contribution to global efforts for a more sustainable future.

For future research, the project encourages exploration into emerging technologies like hydrogen fuel cells and fast-charging systems. The current framework can be revisited and expanded to include these solutions, continuing the quest for more sustainable and efficient warehouse operations.