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Evaluation of Renewable Energy Usage Versus Fossil Fuel Usage: A Case Study

Justin Blau[1], Calvin Chen[1], Jason Liu[1*], Eli Aba[1]

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ABSTRACT

The construction industry has historically relied on non-renewable energy sources, particularly fossil fuels, to power equipment and support project execution. However, increasing concerns regarding climate change, greenhouse gas emissions, and long-term energy sustainability have accelerated interest in renewable energy alternatives. This study evaluates renewable energy usage versus fossil fuel usage within the construction industry, with a particular focus on construction equipment and organizational decision-making. Using Company XYZ as a case study, the research examines industry readiness, employee perceptions, technological feasibility, and potential barriers to implementing renewable energy-powered equipment. Data were collected through a structured survey administered to construction professionals with varying levels of experience, education, and roles within the organization. The results indicate growing awareness and acceptance of renewable energy solutions, especially for small- to medium-sized construction equipment such as skid steers and forklifts. Solar energy emerged as the most viable renewable option due to its accessibility and adaptability on job sites. Despite these positive trends, challenges remain, including limited battery capacity, cold-weather performance, equipment downtime, and the current lack of manufacturer readiness for large-scale implementation. The findings suggest that renewable energy-powered equipment is likely to enter the construction industry incrementally, beginning with smaller projects and less energy-intensive machinery. While fossil fuels are expected to remain in use during the transition period, continued technological advancement and investment could significantly reduce their reliance over time. Ultimately, the study highlights the potential for renewable energy adoption to improve sustainability, reduce emissions, and position construction organizations as leaders in environmental responsibility.

INTRODUCTION

The construction industry is one of the largest consumers of energy globally and a major contributor to greenhouse gas (GHG) emissions. Traditional construction practices rely heavily on fossil fuels such as diesel, coal, and natural gas for material production, on-site machinery, and building operations. According to recent global assessments, the buildings and construction sector accounts for over one-third of global energy consumption and a substantial share of CO_2 emissions (Chen *et al.*, 2024).

In response to increasing environmental concerns and international climate commitments, the adoption of renewable energy sources-such as solar, wind, geothermal, and biomass-has gained momentum within the construction sector. Renewable energy integration offers potential benefits including emissions reduction, long-term cost savings, and enhanced energy security. Despite these advantages, widespread adoption remains uneven due to high initial investment costs, technological barriers, and regulatory constraints (Karakosta and Papathanasiou, 2025). Although renewable energy technologies are increasingly promoted as sustainable alternatives, the construction industry continues to rely predominantly on fossil fuels. There is limited empirical research on the assessment of industry readiness, employee perceptions, technological feasibility, and potential barriers to implementing renewable energy-powered equipment. A comprehensive evaluation is needed to inform policymakers, construction firms, and stakeholders about the feasibility and effectiveness of transitioning toward renewable energy (Bondyopadhyay, 2025).

Thus, the purpose of this study is to evaluate renewable energy usage versus fossil fuel usage within the construction industry, with a particular focus on construction equipment and organizational decision-making. Using Company XYZ as a case study, the research examines industry readiness, employee perceptions, technological feasibility, and potential barriers to implementing renewable energy-powered equipment. Data was collected through a structured survey administered to construction professionals with varying levels of experience, education, and roles within the organization.

LITERATURE REVIEW

The construction industry is one of the largest contributors to global energy consumption and greenhouse gas emissions, accounting for approximately 36–40% of total energy uses worldwide. This significant environmental footprint has accelerated interest in sustainable construction practices that integrate renewable energy systems to reduce carbon emissions, enhance energy

[1] Department of operations and management, university of wisconsin-stout, menomonie, United States
[*] Corresponding author's email: liuj@uwstout.edu

efficiency, and support global net zero targets (Chen *et al.*, 2024). Recent literature emphasizes that sustainable construction is no longer limited to material efficiency but increasingly incorporates renewable energy technologies throughout a building's life cycle (Mahmoud *et al.*, 2023). Sustainable construction refers to the planning, design, construction, operation, and end of life management of buildings in ways that minimize environmental impacts while maximizing economic and social benefits(Portillo *et al.*, 2024). Recent studies highlight key drivers such as climate policies, green building certifications, and urbanization pressures as catalysts for adoption. The rise in international commitments to carbon neutrality by 2050 has intensified research on low carbon materials, energy efficient envelopes, and renewable integration strategies (Lu *et al.*, 2025). The integration of renewable energy systems-particularly solar photovoltaics (PV), wind, geothermal, and biomass-has become central to sustainable construction. Chen *et al.* (2024) report that solar energy alone can contribute up to 83% of building energy demand when effectively integrated with efficient design strategies (Chen *et al.*, 2024). Hybrid systems combining multiple renewable sources and energy storage technologies further improve reliability and energy independence (Mahenthiran and Sathiyamoorthy, 2025). Building integrated photovoltaics (BIPV) and rooftop solar systems are widely discussed in recent literature as effective solutions for urban environments with limited land availability. These technologies not only reduce operational emissions but also align with aesthetic and functional architectural requirements (Reddy *et al.*, 2024). Net zero energy buildings represent an advanced model of sustainable construction, balancing annual energy consumption with on site or nearby renewable energy generation. Recent reviews indicate that NZEBs rely on a combination of passive design strategies, high performance building envelopes, renewable systems, and smart energy management technologies (Zahedi *et al.*, 2024). Studies published after 2023 show that photovoltaic systems can supply up to 70% of residential energy needs in favorable climates, significantly reducing lifecycle carbon emissions (Li *et al.*, 2025). Despite their potential, barriers such as high initial costs, climate dependent performance, and regulatory fragmentation remain challenges to large scale adoption. Scholars emphasize the need for standardized codes and financial incentives to accelerate implementation (Li *et al.*, 2025).

Life Cycle Assessment (LCA) has emerged as a critical tool for evaluating the environmental impacts of sustainable construction and renewable energy systems (Carvalho *et al.*, 2025). Recent research stresses that operational energy reductions alone are insufficient; embodied carbon from material production and construction processes must also be addressed. Comparative LCAs demonstrate that renewable energy systems, particularly solar PV, generate substantially lower lifecycle emissions compared to fossil fuel based energy systems(Iluyomade and Okwandu, 2024). The integration of LCA during the design phase enables more informed decision making and supports holistic sustainability outcomes. Harmonization of LCA methodologies has been recommended to improve comparability and policy relevance (Horzela Miś and Semrau, 2025). Material innovation plays a complementary role in renewable based sustainable construction. Recent studies highlight engineered wood, recycled aggregates, and bio based materials such as hempcrete as key contributors to reducing embodied energy (Kyei *et al.*, 2025; Ridoy *et al.*, 2026). When combined with renewable energy systems, these materials enhance overall building sustainability and resilience (Caballero Güereca *et al.*, 2024). Digital technologies such as Building Information Modeling (BIM), Internet of Things (IoT), and AI driven energy management systems are increasingly integrated with renewable installations to optimize energy performance and lifecycle efficiency. These smart solutions are identified as critical enablers of future sustainable construction practices (Umar *et al.*, 2024).

Although significant progress has been made, recent literature identifies several research gaps, including the scalability of renewable systems in dense urban settings, the economic feasibility of advanced technologies in developing regions, and the need for interdisciplinary collaboration. Future work is expected to focus on circular economy principles, climate adaptive design, and policy harmonization to support widespread renewable integration in construction.

In summary, recent literature confirms that the integration of renewable energy is fundamental to achieving sustainable construction objectives. Advances in renewable technologies, net zero energy buildings, life cycle assessment, and innovative materials collectively support the transition toward a low carbon built environment. Continued research, supportive policies, and technological innovation will be essential to overcoming existing barriers and realizing the full potential of sustainable, renewable powered construction.

MATERIALS AND METHODS

The Company XYZ has started as an industrial and fabrication company in 1949, which provided the company with excellent services for fossil fuels to larger organizations. Since the recent transition into renewable energy, Company XYZ has started to make the transition into making an impact on renewable energy for the years to come. It would benefit the company to start investing in LEED to achieve a greener organization and clients keep choosing the organization for how the projects are being completed. Company XYZ must start investing in newer technology that will create less of a carbon footprint during the projects that will be soon. This will have an impact with Company XYZ toward creating their choices for leading the construction industry in renewable energy while making a greater impact on saving the environment and reducing climate change.

Subject Selection and Description

The subject selection will be human subjects with surveys that will create more options to invest in and improve the company by updating their standards to achieve and leading the industry in the construction industry. The human subjects will be people within Company XYZ that could be union workers and people in the office that run the company behind the scenes. The subjects will be interviewed within the organization and the partnering company that will impact their choices for a greener organization for future projects. A sample of 80 was randomly selected from a population of 100 at a 0.05 significance level.

Instrumentation.

The survey questions will be specific towards making an impact on renewable energy and using the information to have the company expanding to lead the industry. Questions have been created to have a greater impact on how the company and partnering company make choices on renewable energy usage. This elevation could impact the usage of renewable energy in construction equipment. It could also make an impact in regards towards when they would enter the construction industry. Plus, how it would make the manufacturer's impact on making the change from non-renewable energy to renewable energy.

Data Collection Procedures

The data that has been required to create an option for the organizations to make their choices for a greener impact on the projects and clients that they will work with to complete the job. This has been allowed with permission from the human resources division to allow the participants to use Qualtrics to answer the survey questions. They have been informed that their answers have been anonymous and kept in a confidential manner to select people who have access only to the answers that they have been provided. The population will be Company XYZ and their partnering company that will allow 50 to 75 employees to create enough data to make the organizations rely on the data. The sample has been selected with current employees that are working on renewable energy projects and how their organizations will make an impact on creating a greener world. The location of the data will be collected mostly from Wisconsin; however, the organizations have employees that are around the United States that could impact the employees home states in creating renewable energy. The period that the data has been collected has been over six months to allow the organizations to allow them to work around their work schedule hours to keep the projects completed on time. To ensure the information privacy the employees remained anonymous and consented to continuing the survey without being recognized throughout the organizations.

Data Analysis

The data that has been analyzed has shown patterns that organizations want to keep creating an impact on the world with renewable energy. The companies have seen an increase in renewable energy projects and want to continue creating an impact on future projects for reducing the impact of climate change.

In summary, Company XYZ has been trying to incorporate renewable energy into their organization to create a new wave of income compared to continuing the usage of fossil fuels, along with their partnering company. The subjects will be coming from the two companies that want to start making an impact toward a greener society and reducing climate change. There are some limitations to how the organizations human subjects will give accurate data and honest answers within the survey they have been given. It will also create some clearer information about how the organizations will continue with creating renewable energy with equipment being used and projects that will be completed in the future.

RESULTS AND DISCUSSION

With the help of Company XYZ, we have started to see a major impact on renewable energy in the industry along with the future of equipment being impacted using renewable energy. With the results showing that most of the employees are expecting to have renewable energy equipment within the next few years. However, they show that it could have a major impact on the sustainability of the equipment due to colder temperatures and longevity of the renewable solutions that are currently available. Most of the employees have a higher role in the company, as well as overall experience and knowledge in the construction industry. The age group for this has been between 22-55 and has been in the construction industry from fresh out of college to over 20 years. Where most of the participants have the highest degree of high school to a bachelor's degree. Trying to have the upper management get more involved with the testing as they have more experience and knowledge with the equipment. As well as people that are working in the field to help get a better understanding of what the future has to offer for renewable energy on equipment.

Renewable energy types that best facilitate the application of renewable energy equipment on projects

The type of renewable energy that would help facilitate the application of renewable energy on equipment on construction projects would be the manufacturing companies of the equipment start developing a way to have renewable energy on the equipment. According to the responses for Q5 "In your opinion, what type of renewable energy would help facilitate the application of renewable energy equipment on projects?", most responses (69.56%) hold that solar energy has become the most popular renewable energy option for construction equipment. Figure 1 shows the results regarding type of renewable energy to apply to construction equipment, which is supported by previous studies (Chen *et al.*, 2024). Construction projects often operate in temporary, mobile, or remote locations where grid access is limited or unreliable. Solar energy systems, particularly

photovoltaic (PV) panels combined with battery storage, can be deployed quickly on-site to power equipment, lighting towers, monitoring systems, and temporary offices. Solar PV is the most practical and widely adopted renewable energy type for construction projects due to its modularity, scalability, and ease of integration. PV panels can be installed on rooftops, temporary site structures, or as building-integrated photovoltaics (BIPV), allowing renewable energy equipment to be incorporated during both construction and operational phases. Solar systems can power on-site equipment, site offices, lighting, and, in permanent buildings, contribute directly to operational energy demand. Studies show that solar energy dominates renewable integration in buildings because it adapts well to diverse project scales and site constraints while offering predictable performance and falling costs (Chen *et al.*, 2024).

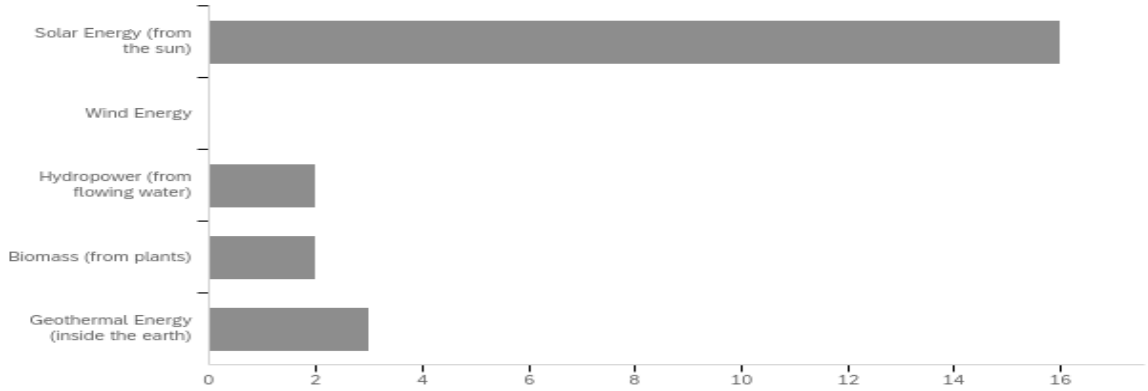

Figure 1: Type of renewable energy to apply to construction equipment

Perception of using renewable energy equipment to construction equipment

Figure 2 and 3 show the results of participants' responses and perception on use of renewable energy on construction equipment and to be sustainable and sustainability of construction equipment with renewable energy. According to participants' responses for Q6 "To what extent do you see equipment having renewable energy for future construction projects?" and Q9 "To what extent do you agree with the statement that the use of renewable energy in construction equipment during the construction execution to be sustainable?", 13 of 23 participants hold that to large extent that they see equipment having renewable energy for future construction projects as shown in Figure 2 and 9 of 23 participants agree with that the use of renewable energy in construction equipment during the construction execution will make construction sustainable as shown in Figure 3.

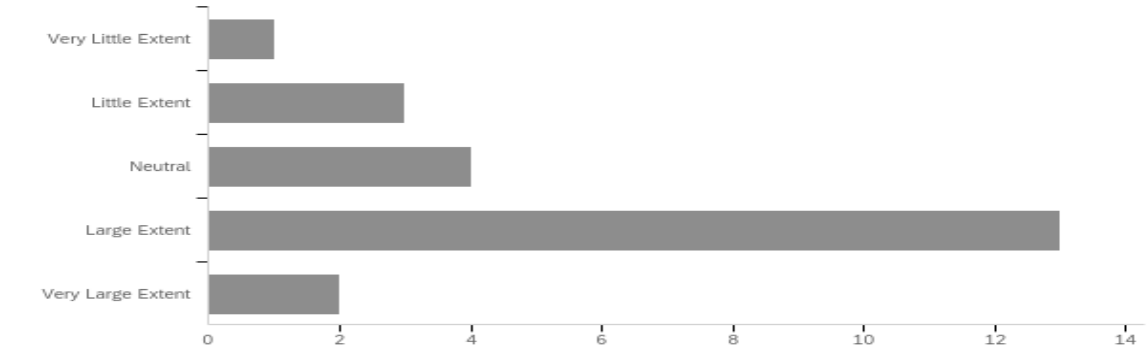

Figure 2: Use of renewable energy on construction equipment and to be sustainable

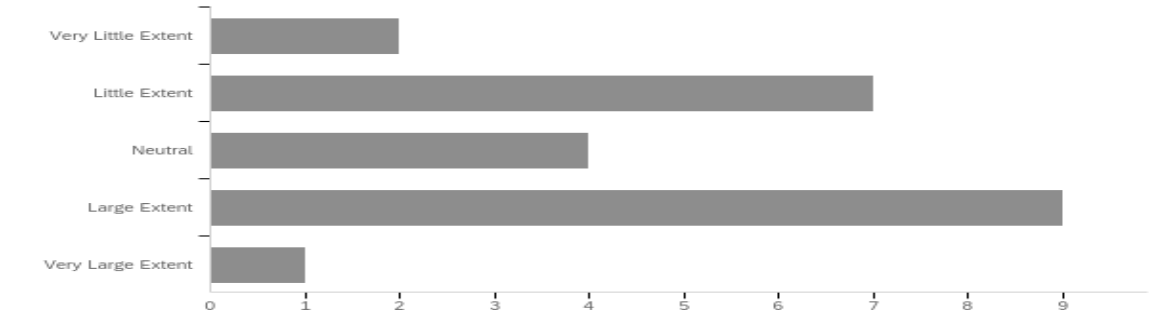

Figure 3: Sustainability of construction equipment with renewable energy

The findings revealed that having renewable energy on equipment in future construction projects show that it will play a large role in the future of the construction industry. It may seem that we have the technology and resources to make the construction equipment using renewable energy, which leads back to manufacturing companies need to start investing in renewable energy for construction equipment. The information from (Monasterolo & Raberto, 2019), (Khare *et al.*, 2016), and (Oró, *et al.*, 2015), have shown that we have seen the economic impact it has created over the past 10 years and have the investment from developers to start making the change toward renewable energy in construction equipment. This would lead to less pollution of carbon dioxide and reduce the greenhouse gas emissions that have been created for centuries, which may lead the future generations to continue making an impact towards new and improved technologies.

Throughout this study, the answer seems to have been that there is an agreement that will play a huge role that renewable energy in construction equipment during the construction execution phase will be sustainable seems to be that it would succeed and play a large extent in the construction industry. The employees at Company XYZ seem to think that will play a huge role during the construction execution, due to the fact that it may have an impact on the schedule and the amount of time will be wasted waiting for an equipment repair or charging of the batteries. The unknown or lack of data out there with renewable energy in construction equipment is due to the demands and needs of the current construction industry that we need to use the non-renewable energy in construction equipment, as manufacturers need to keep making replacement parts for current construction equipment. Which leads to show that a lot of data and other researchers do not have a definitive answer to give to construction companies across the world to promote renewable energy equipment or having the time to develop new equipment with the current renewable energy resources that have been currently developed.

Impacts of construction equipment on renewable energy usage

The data as shown in figure 4 seems to show that cranes heavier construction equipment would have the lowest impact, while the greatest impact for renewable energy usage would be she smaller to medium sized construction equipment. To be more specific, the smaller construction equipment like, a forklift, a skid steer, and a dump truck, which would definitely become before any of the heavier equipment, like a crane, an excavator, and any other heavy construction equipment. It does not seem

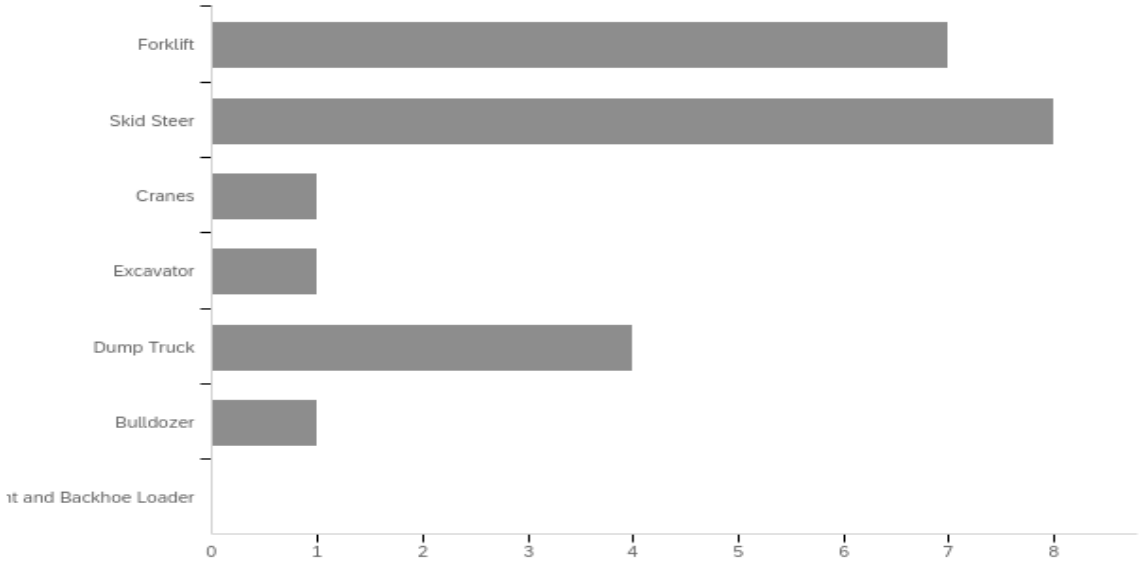

Figure 4: Greatest impact with equipment with renewable energy usage

that it would help with a lot of equipment that would be moving earth or materials around to create a project foundation to build any structure or building that will be helping to create more jobs and opportunities to build renewable energy in or on construction equipment. It also supports the previous data and researchers mentions of showing the economic growth and sustainability of the current renewable energy resources that are being used, produced, in the construction phase, and in the full operational phase of the usage of renewable energy and disadvantages some other renewable energy resources.

Barriers to implement battery-operated equipment on construction projects

As shown in Table 1, the answers from the people seem to have been a consistent answer and theme seem to revolve around the weather during the winter months and how long the batteries will last on the construction equipment, which will it make throughout the day to minimize delays in the projects. Granite, everybody continues to see new and improved ways to create renewable energy resources and continues to have material to make the resources available to improve the process that needs to be up to

Table 1: Implementing of battery-operated equipment on construction projects.

Category	Barrier	Description
Cost & Technology	Battery longevity	Current battery life needs improvement for reliability and cost-effectiveness.
	Short battery life	Limited operational time impacts productivity.
	Cost of equipment	High upfront cost compared to traditional equipment.
	Charging infrastructure cost	Expensive to install and maintain charging systems.
	Equipment conversion cost	Converting gas-powered equipment to battery-driven systems is costly.
Infrastructure & Charging	Limited charging stations	Insufficient charging availability on job sites.
	Charging time	Slow charging affects workflow and scheduling.
	Power availability	Need for reliable energy sources; renewable energy may not meet demand consistently.
Environmental Conditions	Cold weather performance	Batteries perform poorly in low temperatures.
	Battery degradation	Harsh site conditions can reduce battery lifespan.
Operational Challenges	Downtime risk	Equipment may stop unexpectedly due to battery depletion.
	Logistics & planning	Requires careful planning for charging cycles and equipment use.
Supply Chain & Materials	Raw material limitations	Mining and supply of battery materials may slow production and adoption.
Adoption & Industry Readiness	Industry transition time	Shifting to battery-powered equipment will take significant time.
	Limited experience	Lack of familiarity with battery-powered systems among workforce.

the standards that everybody expects things to last. That especially means the ability to create new equipment from the manufacturing companies to implement a new process, design, and product that will change how we look and know how long batteries should last and minimize the delays in construction projects. Everybody is starting to notice the increase of battery-operated vehicles and battery-operated power tools are becoming the normal but also need to understand the importance of extra storage or space to have the renewable energy equipment stored in warm environment during the colder months.

The adoption of battery-operated equipment on construction projects is hindered by a combination of economic, technical, and operational barriers. The initial purchase price is a major obstacle, as electric models can cost double their diesel counterparts, and uncertainty over battery life and future resale values further discourages investment. Inadequate charging infrastructure on job sites compounds the issue; local grid connections often lack sufficient capacity for rapid charging, and a lack of standardized chargers leads to slow, overnight charging that disrupts work schedules. Furthermore, technical limitations persist. Battery energy density restricts the continuous working time of heavy machinery like excavators to roughly four to six hours, and the added weight of battery packs can create new durability and operational challenges. These performance constraints often make it difficult for electric equipment to meet the demands of large-scale or continuous-operation projects. Beyond hardware issues, operational barriers include the need for specialized staff training, obtaining additional driver certifications, and redesigning site logistics to accommodate charging schedules (Droogleever, 2025). Overcoming these barriers will require not only technological advancements in battery technology but also substantial investment in charging infrastructure and supportive regulatory frameworks.

CONCLUSION

Non-renewable energy will be the thing of the past within the next 10 years, due to the major impact of transitioning into renewable energy. The changes to renewable energy in construction equipment could be implemented in the duration of my construction career. It would also be beneficial to start making the manufacturers understand that they need to start investing in making changes to renewable energy that would make an impact in the construction industry. It may take fifteen to twenty years before we see all non-renewable energy in construction equipment to phase out, due to the lack of information and technological advancements of any construction equipment. However, it would be easier to make a change and start testing the equipment with renewable energy; along with making it happen in the short run instead of the long run. This would cause the construction industry to change and adapt to the new way of what construction

equipment could be; even though the change may be more difficult for people to accept the change. The type of renewable energy that would help facilitate would be conducted by solar power to charge up the batteries to run the machine, along with the type of projects that it could be used on would be solar fields and the start of the building. The usage of renewable energy in construction equipment during the execution phase may be a little difficult to maintain, as the equipment might not have enough battery storage or die while holding a load. Which some of the main hurdles would start off with not having enough battery storage and knowing how long the equipment will run before it stops working, along with working with the colder climates may change the lifespan on the equipment. The perspective between small-scaled and large-scaled projects would have to be beneficial to have renewable energy equipment be used on a small-scaled project to help eliminate any impact on the cost and duration of the project, which the greatest impact it would have for equipment usage would be a skid steer. The skid steer would have the capabilities to have more space on the equipment as they could put multiple solar panels onto the roof and sides of the skid steers.

The limitations of the study have shown that there is still a lack of information with the usage of renewable energy in the United States and other countries trying to make the change to renewable energy. Along with having reliable resources that will take the time to fill out the survey information with the limited time of completing with limited information. Also, the lack of honest and accurate data that human subjects can provide with the little information that is out there. Another limitation to the study is that it is only limited to Company XYZ and the participants that were given access to the survey.

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