Conversion of Softlogic Furniture Factory to a Net-Zero Energy Facility

***Abstract*— The manufacturing sector is a major contributor to global energy consumption and greenhouse gas emissions. In Sri Lanka, the heavy reliance on imported fossil fuels has led to increasing economic vulnerability and environmental stress. This study explores the feasibility of converting the Softlogic Furniture Factory into a net-zero energy facility through renewable energy integration, energy efficiency measures, and circular economy principles. The methodology combined energy audits, life-cycle cost analysis, return on investment (ROI) calculations, and employee surveys. Findings show that solar photovoltaic (PV) systems provide the highest ROI (292%) with a payback period of less than five years, while biomass boilers and LED conversions also yield strong economic and environmental benefits. Staff surveys revealed high awareness and readiness for sustainability transitions, though production staff expressed some skepticism compared to management. The study concludes that a phased transition towards net-zero is feasible, replicable, and vital for Sri Lanka's industrial sector..**

I. Introduction

The transition to net-zero energy facilities has become a global priority in the context of climate change, energy security, and sustainable development. The manufacturing industry accounts for a large share of global energy use, and developing countries face unique challenges due to their dependence on fossil fuel imports. In Sri Lanka, approximately 50% of total energy demand is met through petroleum imports, leading to significant exposure to international price fluctuations. With rapid industrialization and urbanization, energy demand is expected to rise further, increasing the urgency for sustainable alternatives.

The furniture manufacturing sector is energy- and resource-intensive, making it an ideal case for exploring net-zero transitions. The Softlogic Furniture Factory, as one of the country's leading manufacturers, provides a useful case study to examine the potential of integrating renewable energy systems, energy-efficient technologies, and circular economy practices. This paper aims to analyze the technical, economic, and organizational feasibility of converting the factory into a net-zero energy facility, while also providing insights applicable to the broader Sri Lankan manufacturing industry.

II. Literature Review

The concept of net-zero energy facilities has emerged as a critical pathway in addressing climate change and reducing industrial energy dependence. Globally, the manufacturing sector consumes nearly one-third of total primary energy and contributes significantly to greenhouse gas (GHG) emissions (Acerbi & Taisch, 2020). This has spurred increasing research into sustainable manufacturing frameworks that integrate renewable energy, energy efficiency, and circular economy practices (Zhang & Haapala, 2019).

A. Global Perspectives on Net-Zero Manufacturing

Studies in Europe, North America, and East Asia highlight solar photovoltaic (PV) systems and biomass as the most viable renewable technologies for industrial applications (Meng et al., 2018). The deployment of energy-efficient technologies such as LED lighting and optimized HVAC systems has also shown strong results in reducing industrial energy intensity (Bag & Pretorius, 2020). However, the transition is often hindered by high capital costs, limited technical expertise, and institutional barriers (UNIDO, 2020).

B. Net-Zero Transitions in Developing Economies

In developing countries, the push for net-zero energy facilities intersects with the broader goals of economic growth and energy security. For example, India and Bangladesh have explored industrial applications of solar PV and biomass, reporting both cost savings and enhanced energy independence (Sivakumar & Jayawardena, 2022). However, many facilities face barriers related to financing and lack of skilled labor. This makes the role of government incentives and international financing mechanisms crucial (World Bank, 2021)

C. Sri Lankan Context

Sri Lanka's industrial sector is highly dependent on imported fossil fuels, with energy expenditures significantly affecting competitiveness. Previous research highlights that renewable energy adoption in the country is technically feasible but underutilized due to fragmented policy frameworks and low institutional readiness (Wijesinghe & Perera, 2019). A study by Koswatte, Perera, and Abeysekera (2024) emphasizes the potential of solar PV as a cost-effective pathway toward a net-zero future, while Nanayakkara et al. (2021) demonstrated the positive life-cycle economics of biomass adoption in industrial facilities.

D. Organizational and Behavioral Factors

Beyond technology, employee and stakeholder perceptions play an essential role in facilitating sustainable transitions. Studies reveal that organizational culture, leadership commitment, and employee engagement strongly influence the success of net-zero initiatives (Acerbi & Taisch, 2020). In the Sri Lankan context, research on sustainability adoption has highlighted gaps in staff training, communication, and participatory decision-making as critical barriers (Sivakumar & Jayawardena, 2022).

E. Synthesis and Research Gap

The literature demonstrates strong global and regional evidence supporting renewable energy and efficiency measures in industrial contexts. However, few studies have comprehensively analyzed the technical, economic, and organizational aspects of transitioning a Sri Lankan manufacturing facility to net-zero. This research addresses that gap by evaluating the Softlogic Furniture Factory as a case study, combining energy audits, cost-benefit analysis, and employee perception surveys to provide a holistic assessment.

III. METHODOLOGY

This research adopted a mixed-methods case study design to evaluate the technical, economic, and organizational feasibility of converting the Softlogic Furniture Factory into a net-zero energy facility, combining energy audits, renewable energy assessments, cost-benefit analysis, and stakeholder engagement. The quantitative component began with a detailed energy audit that measured electricity consumption of lighting, HVAC systems, and production machinery using digital meters and one year of utility records, and benchmarked the results against both national and international standards for energy intensity in furniture manufacturing. Feasibility of renewable energy technologies was then assessed, with solar photovoltaic (PV) potential simulated using solar irradiation data from the Sri Lanka Sustainable Energy Authority, while biomass boilers were evaluated based on local feedstock availability, combustion efficiency, and operational requirements. Energy efficiency interventions such as LED lighting retrofits, optimized HVAC, and process improvements were modeled using vendor specifications and energy savings factors to estimate reductions in energy use. Economic viability was examined using life-cycle cost analysis (LCCA), net present value (NPV), return on investment (ROI), and payback period calculations to compare interventions and prioritize investments. Complementing this, the qualitative component explored organizational readiness, where a structured survey was administered to 75 employees from management, administration, and production divisions to assess awareness of sustainability, willingness to adopt renewable energy, and perceptions of potential risks. In addition, 10 semi-structured interviews were conducted with key stakeholders, including managers, engineers, and external energy consultants, to capture deeper insights into institutional enablers, barriers, and leadership commitment. Quantitative data were analyzed through descriptive statistics, ROI comparisons, and correlation tests (Pearson's r), while qualitative responses were thematically coded to identify recurring patterns related to awareness, resistance, and enablers. While the approach provides a holistic understanding of the technical and organizational dimensions of a net-zero transition, the methodology is limited by its focus on a single case facility, reliance on financial assumptions such as fuel prices and discount rates that may vary over time, and constraints in fully generalizing findings across Sri Lanka's diverse manufacturing sector.

IV. RESULTS

This section presents the key findings from the comprehensive analysis conducted to assess the feasibility of converting the Softlogic Furniture Factory into a net-zero energy facility. The results are derived from quantitative data (energy audits, cost-benefit analysis, and employee surveys) and qualitative insights from stakeholder interviews.

A. Current Energy Performance and Inefficiencies

Energy audits conducted over a 12-month period revealed significant inefficiencies in the factory's operations. The analysis of major equipment showed a substantial disparity between actual energy consumption and industry benchmark targets. The mean monthly energy intensity was found to be 53.89 kWh per unit, consistently exceeding the target intensity of 45.81 kWh per unit (representing a 15% reduction goal) across all monitored periods (Table 1). The highest energy intensity was recorded in July, exceeding 60 kWh per unit (Figure 1).

Comparative descriptive analysis of monthly energy consumption at the Softlogic Furniture Factory indicates huge consumption differences among the various machines. The average monthly energy consumption values show that the Wood Cutting Machine consumes the highest energy, with an average of 1,170 kWh, then the Curing Oven (780 kWh) and the Dust Collector (624 kWh). Conversely, machines like the Air Conditioner and the Edge Banding Machine indicate consumptions of 312 kWh and 390 kWh, respectively, which are relatively lower by a wide margin. The equipment identified in Table 1 is around 4,368 kWh of a total of 9,167 kWh consumption in a month (110,000 monthly consumption in a year). The remaining amount of energy usage at about 4,799 kWh per month is owing to;

- Facility lighting systems throughout the production and office areas
- Additional HVAC and ventilation systems
- Smaller production equipment and tools
- Office equipment and administrative systems
- Auxiliary systems including compressed air and material handling equipment

These numbers show the highest consumers of the energy load, and denote where efficiency improvement and cost-saving measures should be applied, particularly on high load equipment like drying and processing equipment. The overall energy character exhibits a substantial margin of both optimizing major equipment and large-scale facility-wide efficiency.

Equipment-specific analysis identified the Wood Cutting Machines and Drying Kilns as the most energy-intensive processes (Figure 2). Regarding the demographics of the workforce as shown in Figure 3, 42 surveyed respondents provided the biggest occupational group as being Production Workers (35.7), Technical Staff (14.3) and Maintenance Technicians (9.5). Less represented are the roles of

Factory Manager, Customer Representative, and Policy Advisor, with proportions of 4.8, 4.8 and 4.8 per cent of responses respectively. Such a distribution implies an extreme operational level bias of the workforce, and provides valuable information on practical, ground-level awareness, attitudes towards energy practices.

TABLE I. MONTHLY ENERGY CONSUMPTION (KWH)

Valid	Monthly Energy Consumption (kWh)			
	Frequency	*Percent*	*Valid Percent*	*Cumulative Percent*
312	*1*	*14.3*	*14.3*	*14.3*
390	*1*	*14.3*	*14.3*	*28.6*
520	*1*	*14.3*	*14.3*	*42.9*
572	*1*	*14.3*	*14.3*	*57.1*
624	*1*	*14.3*	*14.3*	*71.4*
780	*1*	*14.3*	*14.3*	*85.7*
1170	*1*	*14.3*	*14.3*	*100.0*
Total	*7*	*100.0*	*100.0*	

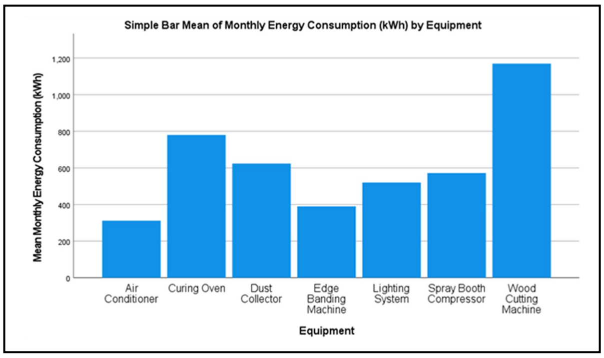

Figure 1. Monthly Comparison of Actual vs. Target Energy Intensity (kWh/unit).

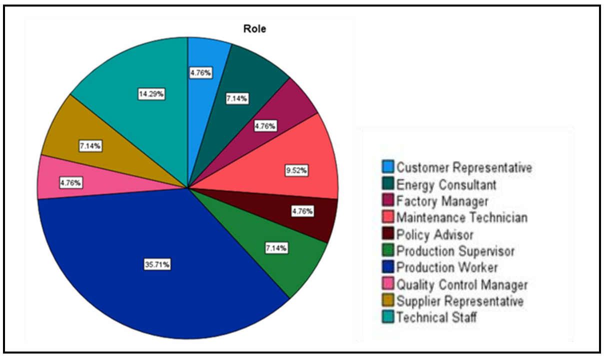

Figure 2. Energy Utilization.

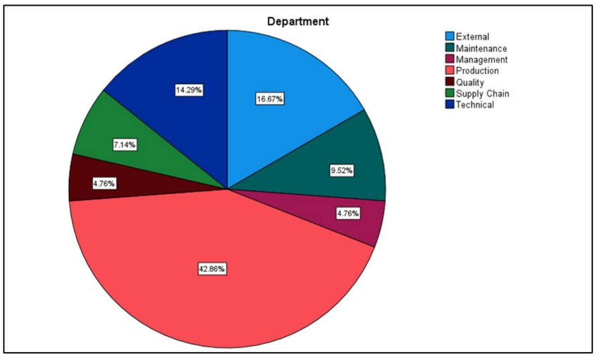

Figure 3. Employee response

According to the departmental segmentation of the survey respondents, 42.9 per cent of respondents are of the Production department, External stakeholders 16.7 percent, and Technical staff 14.3 percent. Small representations are observable through Maintenance (9.5%), Supply Chain (7.1 %), as well as both the Management and Quality teams (4.8 % each). This spread signifies that the majority of insights are gathered through actual participants of operational and production processes, providing a hands-on view regarding energy consumption and include a consideration of input from outside consultants and assistance centres.

A negative correlation between Rated Power (kW) and Current Efficiency (%) is evident in Figure 4 (Scatter Plot), indicating that those pieces of equipment that possess a greater power rating are likely to have less efficient performance. As an example, equipment with power ratings above 20 kW has efficiency levels below optimal values (>85%), indicating that the power intake is too high, and the operational efficiency should be improved.

This analysis provides a well-understood foundation for prioritising any retrofit effort or unit replacement, particularly for high-power, low-efficiency units. It provides the technical basis for energy-saving actions within the net-zero roadmap.

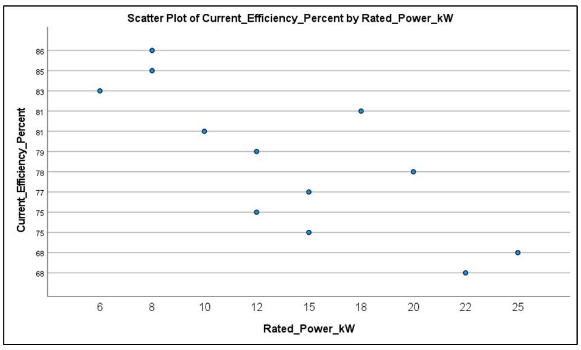

Figure 4 - Rated Power kW vs Current Efficiency

B. Financial Viability of Proposed Interventions

A detailed cost-benefit analysis was performed for three key intervention strategies: solar photovoltaic (PV) systems, biomass boilers, and a full LED lighting conversion.

The analysis demonstrated strong financial viability for all three technologies. The average Return on Investment (ROI) across the interventions was 214.26%, with payback periods ranging from 4 to 6 years. The solar PV system emerged as the most financially attractive option, with the highest ROI of 292%, despite a higher initial capital cost. The LED conversion offered the shortest payback period of 4 years, making it an ideal initial investment (Figure 5).

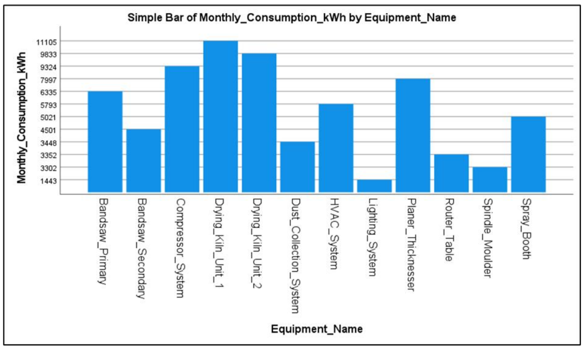

Figure 5. kWh usage of the different equipment.

C. Employee Perceptions and Organizational Readiness

A survey of 42 employees and stakeholders measured perceptions across seven sustainability constructs on a 5-point Likert scale. Overall, readiness for sustainability initiatives was moderate to high. The highest mean scores were recorded for Stakeholder Engagement and Market Considerations (SEMC_MEAN = 3.88) and Implementation Readiness and Organizational Capacity (IROC_MEAN = 3.80). The lowest, though still positive, score was for Current Energy Systems and Efficiency Opportunities (CES_MEAN = 3.29), indicating recognition of existing inefficiencies.

A strong, statistically significant positive correlation was found between stakeholder engagement and sustainable behavioral adoption ($r = 0.863$, $p < 0.001$). Similarly, support for circular economy principles was highly correlated with perceived value in energy innovations ($r = 0.805$, $p < 0.001$).

Cross-tabulation analysis revealed notable variations in perception based on job role. Factory managers and policy advisors showed strong agreement with circular economy measures, while a significant portion of production workers were neutral or in disagreement, highlighting a critical gap in engagement at the operational level.

D. Qualitative Themes from Stakeholder Interviews

Thematic analysis of in-depth interviews identified consistent themes that influence the net-zero transition:

Barriers: Key challenges included budgetary constraints, technical skill gaps, and organizational resistance to change. Management expressed concerns over investment risks despite strong ROI projections.

Enablers: Critical facilitators were strong leadership commitment, awareness of government incentives, and growing market demand for sustainable products. The availability of rooftop space for solar panels and on-site wood waste for biomass energy were cited as significant advantages.

Implementation Strategy: Stakeholders emphasized the need for a phased approach, starting with low-cost, high-impact measures like LED retrofits before moving to capital-intensive renewable energy projects.

D. Synthesis of Integrated Findings

The scope of this analysis includes comparing the present monthly energy intensity of Softlogic Furniture Factory with a 15% reduction target, which is recommended by Meng et al. (2018), to identify how this energy saving can be realised. The actual mean energy intensity is 53.89 kWh per unit, ranging from 46-62 kWh per unit, with significant variability and optimisation potential. The Target_Energy15 benchmark (15% reduction) lowers the monthly intensity to an average of 45.81 kWh per unit, while the Target_Energy30 (30% reduction) yields a more ambitious mean of 37.72 kWh per unit. The Potential_Saving_15, calculated as the difference between actual and target values, averages 8.08 kWh per unit, reinforcing the tangible benefits of even moderate improvements.

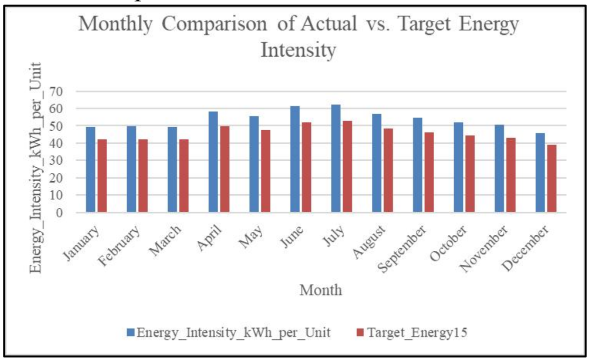

Figure 6 - Monthly Comparison of Actual vs. Target Energy Intensity

The clustered bar chart, as illustrated in Figure 6 below, presents the comparison of the actual energy intensities with the 15 per cent target every month. Throughout the months, the actual usage is continuously above what is considered to be the benchmark, indicating inefficiencies and energy optimisation practices.
These enhancements might be realised using improved operational practices, refitting inefficient equipment or

implementation of energy management systems. These findings provide an explicit justification for the application of measures that lead to lowering energy use, providing utility savings, and facilitating the goals that the factory is targeting, concerning a net-zero energy change

The cost-benefit ROI analysis aimed to assess the economic feasibility of installing three types of sustainable energy technology systems, namely Solar PV systems, Biomass boilers and LED conversions. According to the descriptive statistics obtained using SPSS, the average capital investment is USD 28,333.33 among the technologies, and this value has a significant deviation (SD = 17,559.42), which creates differences in the cost structure among the options. It is interesting to note that the solar PV system experienced the highest capital outlay, and the LED conversion exhibits the lowest.

The average projected net annual savings is USD 4,700.00 with a standard deviation of USD 2,300. These savings emphasis the possibility of reducing the cost of its operation, especially the energy-intensive processes. The overall average payback period across the technologies is 5.66 years, and indicates most of the investments make their payback within a medium-term timeframe, in line with industry averages of energy retrofits.

An essential economic viability indicator is the Return on Investment (ROI). The analysis indicates a mean ROI of 214.26%, with Solar PV having the highest ROI (292) and LED conversion has the lowest (140). The clustered bar graph reveals clearly that solar PV, although represented at a higher initial cost, the returns are the most attractive in the long run, whereas the Biomass boilers also depict a very healthy ROI, 211 though on a longer payback time of 6 years.

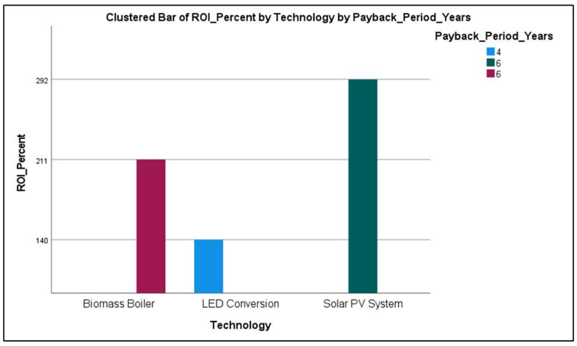

Figure 7 - ROI % Vs Technology Vs Payback Period Years

This discussion validates the acceptance of Solar PV and Biomass systems to finance the move to a zero-emission business. Of significant importance, the payback and result of the ROI indicate financial prudence, and this is a reason to invest in green infrastructure at the Softlogic Furniture Factory strategically.

Triangulation of quantitative and qualitative data painted a coherent picture. The technical and economic feasibility demonstrated by the audit and ROI analysis is supported by a generally receptive organizational culture. However, the disconnect between the strong financial metrics and management's perceived financial risk, coupled with the engagement gap among production staff, identifies the primary hurdles not as technological or economic, but as relating to communication, risk perception, and inclusive change management.

The analysis revealed several interrelated insights. Potentials of renewable energy availability were not limited by motivation, but by technical and financial presence. On the same note, circular economy initiatives are also informal and lack formal policy or procedures. The constructs of organisational capacity and stakeholder alignment were also seen to play significant enabling or growth-inhibiting roles across all themes. NVivo helped to triangulate these qualitative data with survey and energy audit results and gave a comprehensive overview of the net-zero transformation environment.

V. Discussion & Conclusion

The case study demonstrates that transitioning the Softlogic Furniture Factory to net-zero energy is both technically feasible and economically viable. Solar PV and biomass energy systems, coupled with efficiency measures such as LED lighting, present cost-effective pathways. Employee engagement and leadership support are critical to success. Policy incentives can accelerate adoption across Sri Lanka’s manufacturing sector. Future research should explore scalability of these models in other industrial sectors in South Asia.

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