

# Cultural and Socioeconomic Impacts of Solar Powered Refrigerators in the Peruvian Amazon

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## Introduction

The Peruvian Amazon specifically Calleria District, which is the focus of this study faces significant food spoilage due to the lack of reliable refrigeration. This challenge affects household food security, small businesses, and overall community well-being. This research seeks to answer the question, “How could solar-powered refrigerators affect the dynamics of culture and socioeconomic development in the Peruvian Amazon?”

What makes this study important is that it:

- Focuses on the human dimension of technology uptake, an essential component for sustainable implementation.
- Considers the unique socioeconomic conditions of Calleria, providing a grounded understanding of local realities.
- Complements the technical research being conducted by another student, whose focus is on the engineering and performance aspects of the refrigeration systems.

## Interdisciplinary Aspects & Contributions

This research is interdisciplinary, combining energy, environment, & socioeconomic aspects thereby contributing to ongoing efforts to achieve:



This research adds to the growing body of research through the following:

- analyzing affordability dynamics
- assessing social value of the project
- identifying the barriers & enablers for the adoption of the technology

## Methods

IMP framework is a global initiative that was developed to have an international approach to managing, reporting and measuring impact from environmental and social projects based on five key aspects as shown in the table below. It guided both the design of the questionnaires and analysis of the collected data. What- which focuses on the expected outcome, Who-which looks at the affected stakeholder, How Much – which focuses on the scale, significance or magnitude of the expected outcome, Contribution – projects role in the potential outcome, and Risk – which focuses on if the expected outcome does not occur.

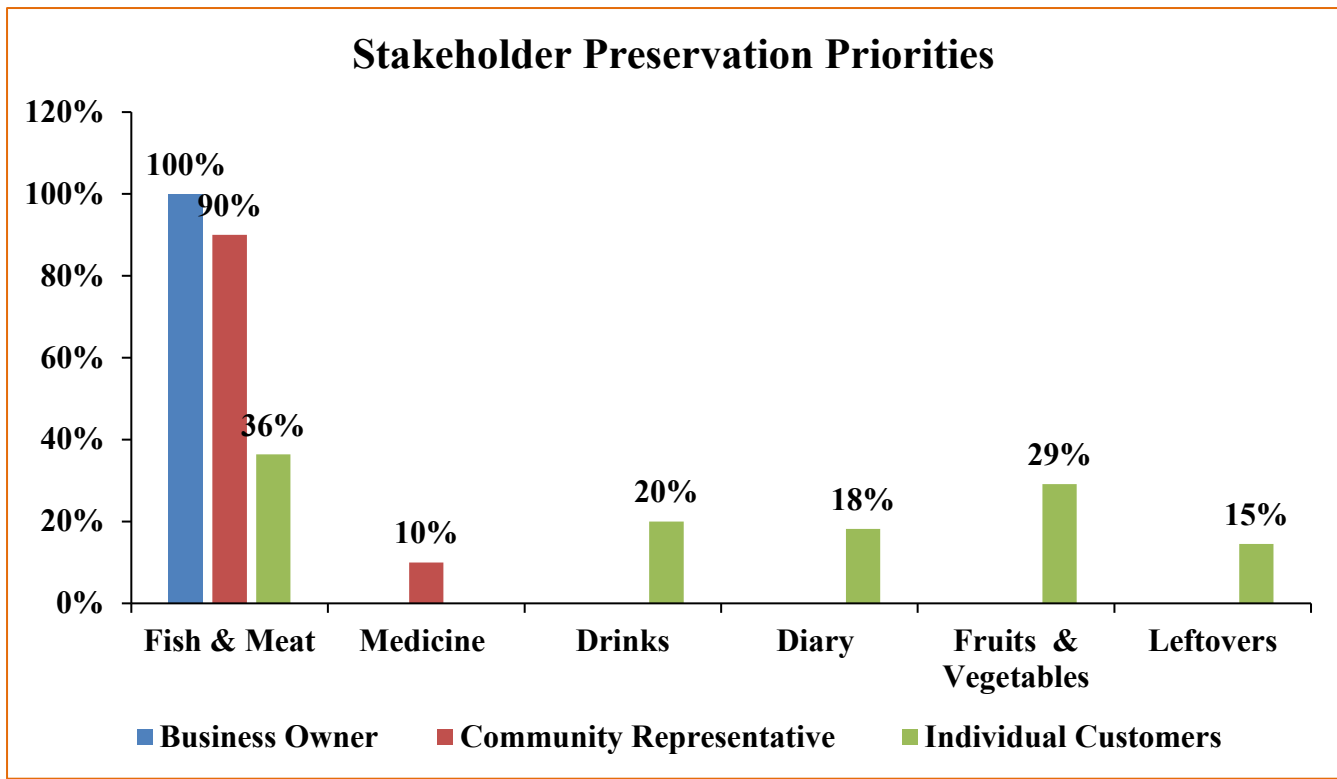
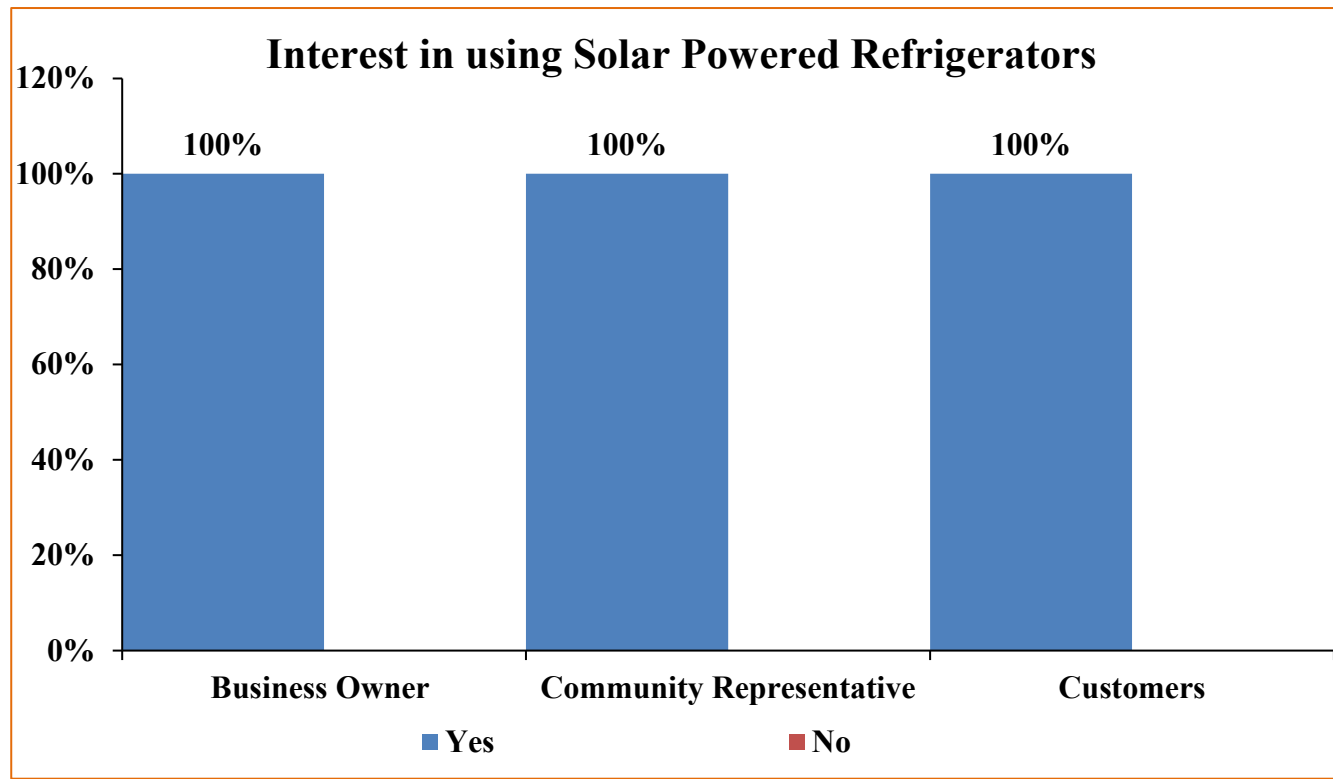
Impact Dimension	Impact Questions Each Dimension Seeks to Answer
 WHAT	<ul style="list-style-type: none"><li>What outcome occurs in period?</li><li>How important is the outcome to the people (of planet) experiencing it?</li></ul>
 WHO	<ul style="list-style-type: none"><li>Who experiences the outcome?</li><li>How underserved are the affected stakeholders in relation to the outcome?</li></ul>
 HOW MUCH	<ul style="list-style-type: none"><li>How much of the outcome occurs – across scale, depth and duration?</li></ul>
 CONTRIBUTION	<ul style="list-style-type: none"><li>What is the enterprise's contribution to the outcome, accounting for what would have happened anyway?</li></ul>
 RISK	<ul style="list-style-type: none"><li>What is the risk to people and planet that impact does not occur as expected?</li></ul>

- Thirty-six samples of data were collected from three categories of participants:
  - Six from business owners due to their potential to changing the socioeconomic status in their community.
  - Ten from community representatives due to their knowledge of the community and that they are well respected members in the community.
  - Twenty from individual customers to assess the level of adoptability of the refrigerators in the community.
- Data analysis was conducted using Excel, given the small sample size of the collected data. The qualitative data was manually coded to identify recurring themes and patterns related to adoption barriers, perceived benefits, and community readiness.
- The analysis of the Risk dimension of the IMP framework, was assessed using literature review of academic journals and studies on related topics, particularly food loss, refrigeration access, and economic vulnerability.
- The questionnaires were reviewed and approved by my academic supervisors, the industry partner and the University of Calgary's Conjoint Faculties Research Ethics Board (CFREB).
- All participants provided verbal consent, and their participation was voluntary and anonymous, ensuring compliance with ethical research standards - especially in vulnerable and remote communities.

## Results

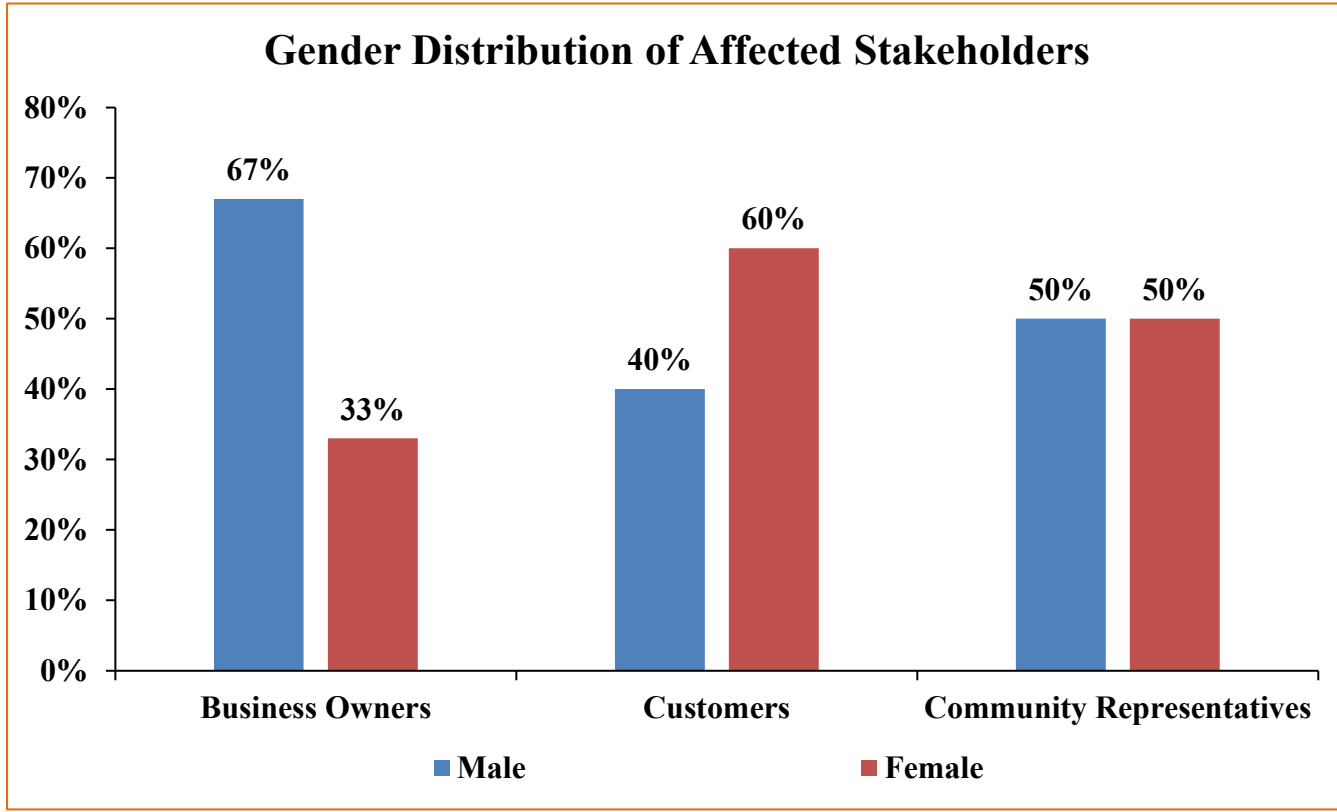
### What: Expected Outcomes

- All stakeholders revealed that food wastage is a significant challenge across all three groups due to inadequate preservation methods.
- Business owners cited frequent power outages and high electricity costs as their motivation for transitioning to solar powered options.
- Both business owners & community representatives identified improved food preservation as the primary expected outcome especially for fish and meat.
- Individual customers expressed interest in preserving fish & meat too followed by fruits & vegetables and drinks.



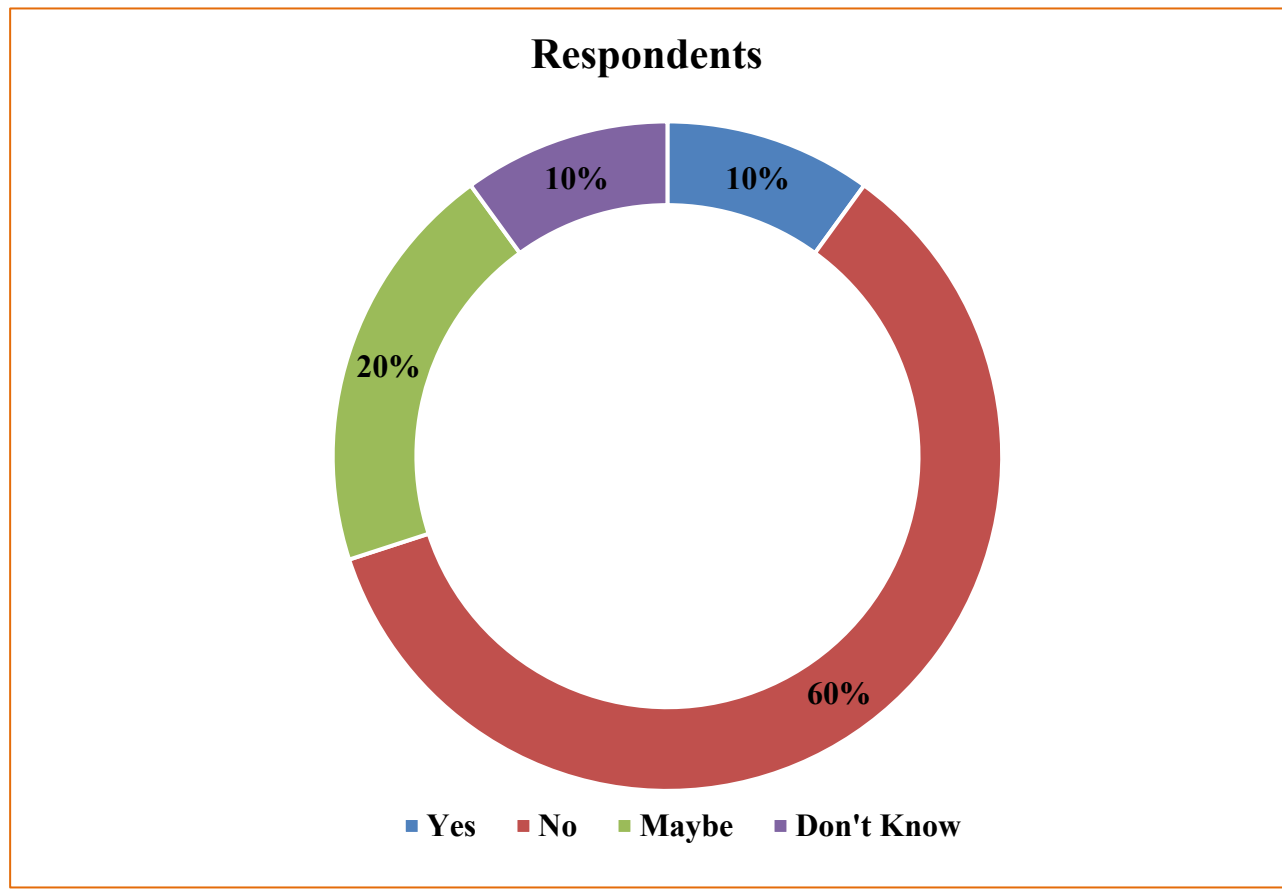
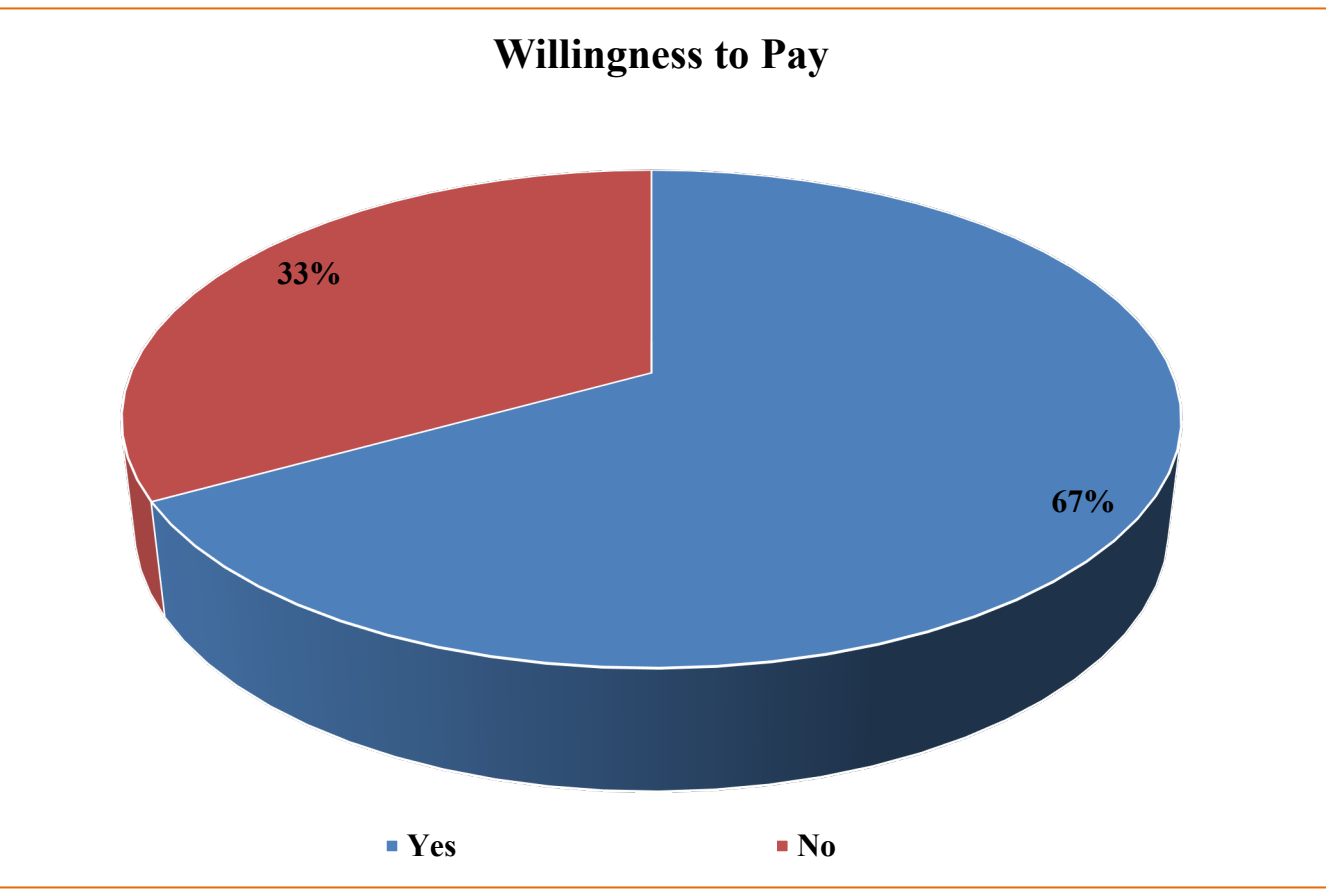
### Who: Stakeholders Affected

- Business owners expressed interest in expanding their business to sell perishable food items, most especially fish, meat & chicken.
- 33% of the business owners were female an 67% were male. This indicates that both men and women in kiosk businesses recognize the value of this technology, although men may currently dominate ownership of retail outlets in the surveyed area.
- Both community representatives and individual customers acknowledged the challenge of food spoilage due to inadequate preservation.
- All stakeholder categories indicated that solar refrigeration would help them reduce food waste and improve food safety.
- Women typically hold primary responsibility for meal preparation in households. As such, they are more directly affected by the lack of effective food storage solutions. The introduction of solar-powered refrigerators is therefore expected to reduce the burden on women, enhance household food management, and contribute to gender-sensitive impacts at the community level.

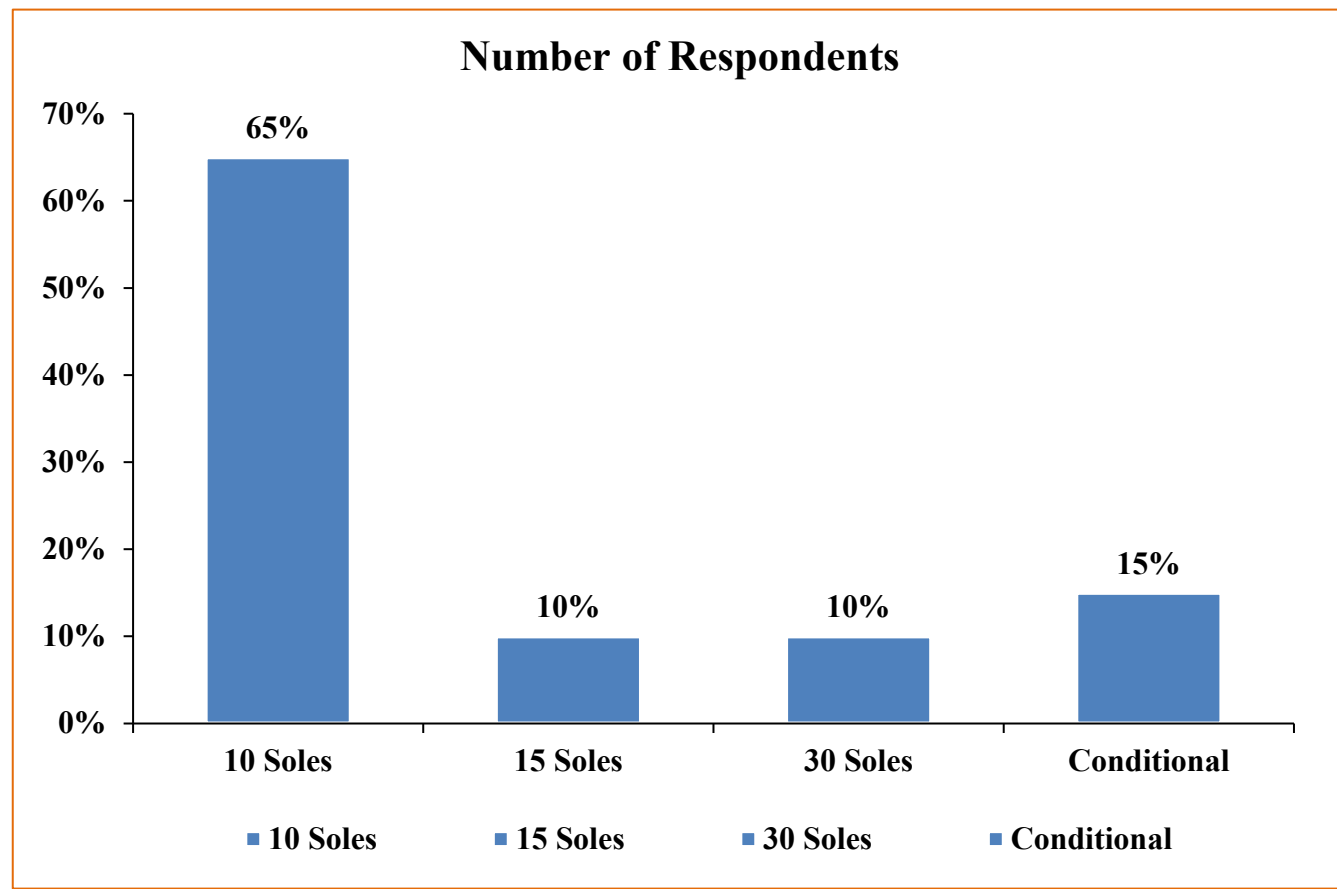


### How Much: Magnitude & Significance of Outcomes

#### a) Willingness to Pay by Business Owners



#### b) Affordability to Pay by Customers



#### c) Social Return on Investment (SROI)

No.	Parameter	Value used	Source
1	Increase in monthly sales for small businesses	2.5x	(Amped Innovation, n.d.)
2	Current monthly income for small businesses	USD 532/300	(Global Living Wage Coalition, 2023)
3	Daily food losses per household	2kg	Response from the community representatives
4	Average value of perishable food per kg	USD 8	(Numbeo, 2024)
5	Time spent cooking in rural areas	4 hrs	(FAO, 2000)
6	Value of local informal labour per hour	USD 2.5	(Global Living Wage Coalition, 2023)
7	Typical useful life of solar-powered refrigerators without needing repairs	5 years	Assumed
8	Deadweight	20%	SROI Network, SVUK
9	Attribution	15%	Social Value UK, HACT

$$\text{SROI ratio} = \frac{\text{Total social benefits} \times \text{Deadweight} \times \text{Attribution} \times \text{Displacement} \times \text{Drop off}}{\text{Total value inputs}}$$

Where:

- Total social benefits are the estimated value of all the positive outcomes that result from the project measured in monetary terms.
- Deadweight is the portion of the outcome that would have happened anyway, even without the project.
- Attribution is the portion of the outcome that can be attributed to other factors outside the project.
- Displacement is the benefit that was achieved at the expense of someone else.
- Drop off is the decrease in impact over time as the effect of the project diminishes or wears off.
- Total value inputs are the total cost or resources required to deliver the intervention, also termed as the total investment.

Therefore, for a period of 5 years for a monthly income of:

- USD 300, SROI = 57.8:1
- USD 532, SROI = 75.6:1

### Contribution: Projects Role in the Potential Outcome

- Improved food security - All engaged stakeholders acknowledged the prevalence of food wastage in their communities, primarily due to the lack of reliable food preservation methods.
- Expansion of small business – 67% of business owners expressed that solar refrigeration would enable them to expand their product offerings to include perishable items and attract new customers looking for fresh or cold goods.
- Alleviation of energy dependence and costs - Currently, most businesses rely on the national grid (Mantaro Network), which respondents described as unreliable and expensive. Business owners consistently cited high energy costs as a primary motivation for seeking alternative refrigeration.
- Social and gender sensitive contribution - Solar refrigeration also provides social value, particularly for women, who are primarily responsible for food preparation at the household level. Refrigeration will enable women to plan meals more effectively and reduce stress associated with food spoilage.

### Risk: If Outcomes Do Not Occur

- Social risk; continued food wastage - If the solar-powered refrigerators are not adopted or do not function effectively, households will continue to experience significant levels of food spoilage, especially for perishable items such as meat and fish, which form important sources of protein and micronutrients.
- Environmental risk: effects of open dumpsites as a disposal method for food waste - In Peru, 57.7% of municipal waste is organic and while the country has a municipal solid waste collection coverage of 93.7%, in 80% of the municipalities, this waste ends up at dumpsites (Circular Hotspot, 2021). The decomposition of organic food waste, particularly in communities lacking proper waste management systems, results in the emission of methane (CH4) and other greenhouse gases. Methane is a potent greenhouse gas with over 25 times the global warming potential of carbon dioxide over a 100-year period (EPA, 2025). Globally, food waste accounts for 8-10% of total greenhouse gas emissions (UNEP, 2021).
- Economic risk: Missed opportunities for economic empowerment - One of the intended outcomes of introducing solar-powered refrigerators is to support microenterprise development, particularly for kiosk owners seeking to expand into selling perishable goods. If the intervention fails — due to cost, maintenance challenges, or lack of trust — business owners may miss out on income growth opportunities and remain limited to selling non-perishable, low-margin goods with lower nutrition content.

## Conclusion

- All the engaged stakeholders expressed interest in using the refrigerators.
- There were no identified any cultural barriers to the adoption of these refrigerators.
- The cost to own these refrigerators at monthly fee of USD 25, emerged as a significant perceived barrier to adoption. However, the high SROI of 57.8:1 to 75.6:1 suggests that long-term affordability concerns may stem more from skepticism regarding the realization of increased earnings from refrigeration than from an absolute inability to pay over a period of time.
- Individual customers reported being willing to pay an average of USD 2.80 to store their perishables. There is need to explore whether such fees would make service provision sustainable for kiosk owners.

## Recommendations

- Implement a demonstration pilot project to build trust and validate benefits - Given the initial skepticism around the perceived affordability despite a high projected SROI.
- Build local repair and maintenance infrastructure – To address the technical concerns raised.
- Launch targeted awareness and trust-building campaigns.

## Limitations

- Scope of risk assessment – The "Risk" dimension was based on targeted literature review.
- Small sample size for individual customers – A larger sample size of the individual customers could have provided a more robust understanding of their willingness to pay.
- Reliance on stated willingness to pay – Relies on stated willingness to pay rather than actual observed payment behavior.
- Assumptions used in the SROI calculation – Several assumptions were taken into consideration, including the exclusion of “displacement” and “drop-off” factors.

## Future Research

- Collecting actual data for the SROI – SROI calculation was based on assumptions and secondary sources. Future research should gather actual data and more precise figures.
- Eliciting community defined risk perceptions - Understanding how communities define and prioritize risks would provide a more culturally grounded understanding.
- Using Nvivo for qualitative data verification - This study relied on manual thematic analysis using Excel. Future research could utilize qualitative analysis such as NVivo, to verify the results obtained. This would enhance the trustworthiness and reproducibility of the qualitative insights, potentially revealing deeper thematic patterns.
- Aligning the individual willingness to pay with business sustainability models - A critical step would be to explore the financial viability of community-based refrigeration services by reconciling the amounts individuals are willing to pay with the operational needs of kiosk business owners. While this study identified individual expectations of USD 2.80 per use, further work is needed to model whether this price point is financially sustainable when factoring in equipment maintenance, depreciation, and opportunity costs for the business owners.

## References

- Amped Innovation. (n.d.). Solar Freezers. Amped Innovation
- Global Living Wage Coalition. (2023). Living wage for rural areas of San Martin, Peru. Global Living Wage Coalition.
- Numbeo. (2024). Food prices in Peru. Numbeo.
- Food and Agriculture Organization of the United Nations. (2000). Annex 16: Rural income, expenditure and poverty. In the State of Food Insecurity in the World.
- Blakeney, M. (2019). Food loss and food waste: Causes and solutions. In Food Loss and Food Waste: Causes and Solutions. Cacciottolo, C., Guardia, X., & Villicaña, E. (2024). Implementation of Renewable Energy from Solar Photovoltaic (PV) Facilities in Peru: A Promising Sustainable Future. Sustainability (Switzerland) , 16(11).
- Datt, A., Santagata, E., Bruce, A., Raturi, A., & Macgill, I. (2024). Socio-Economic Impacts of Solar Powered Freezers in Rural Fishing Communities - Fiji Case Study.
- UNDESA (2025, February 22). United Nations Department of Economic and Social Affairs. UNDESA.
- Management, B. F. (2024). Integrated Impact Management. Bridges Fund Management.
- Circular Hotspot. (2021). Waste Management Country Report: Peru. February.
- McCarney, S., Robertson, J., Arnaud, J., Lorensen, K., & Lloyd, J. (2013). Using solar-powered refrigeration for vaccine storage where other sources of reliable electricity are inadequate or costly. Vaccine, 31(51), 6050–6057.
- Palmer, Q. (2024). Choosing the Right Off-Grid Refrigerator for You — The Cabin Depot. The Cabin Depot.
- Partners in Health. (2023, October 19). How Solar Panels Are Supporting Care In Indigenous Communities In Peru | Partners In Health.
- Patil, S. (2023). Solar Refrigerator. International Research Journal of Engineering and Technology, 54–57.
- United Nations Environment Programme (2021). Food Waste Index Report 2021. Food Waste Index Report 2021.pdf