Project Title

Development and Commercialization of Solar-Powered Cold Storage Systems Using Locally-Sourced Phase Change Materials for Rural Agriculture in Nigeria

Submitted by the Research Team

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Executive Summary

This project seeks to develop, pilot, and commercialize a solar-powered cold storage system integrated with phase change materials (PCMs) derived from locally available paraffin-sand composites. The innovation is aimed at mitigating post-harvest losses in rural Nigerian communities lacking access to reliable electricity. By leveraging renewable energy technologies, local materials, and NASENI fabrication centers, the system will ensure sustainable food preservation, create local jobs, and support Nigeria's Renewed Hope Agenda on food security, renewable energy, and industrialization. The project will progress through design, prototype development, pilot deployment, and commercialization. Technical

calculations for cooling load, PCM sizing, and solar PV design confirm feasibility, while the business model ensures affordability for farmer cooperatives and agro-SMEs through lease-to-own financing structures.

Problem Statement & Rationale

Nigeria loses an estimated 40–50% of perishable agricultural produce annually due to inadequate cold storage. Rural farmers are disproportionately affected because they lack grid-connected refrigeration infrastructure. Imported cold chain systems are costly and unsuited to rural environments. This project directly addresses these gaps by developing a low-cost, modular, solar-powered cold storage solution that leverages local content in PCM production and fabrication, aligning with NASENI's mandate for indigenous technology development.

Objectives

General Objective: To design, develop, and commercialize solar-powered cold storage systems using locally-sourced PCMs for rural agriculture in Nigeria.

Specific Objectives:

1. Develop a PCM-based energy storage system from paraffin-sand composites.

2. Design and fabricate a solar-powered cold storage prototype.

3. Conduct pilot testing in rural communities of Anambra and Nasarawa States.

4. Carry out a market feasibility and commercialization study.

5. Train local engineers and technicians for system fabrication, installation, and maintenance.

Innovation & Novelty

1. First indigenous PCM-based cold storage system in Nigeria.

2. Hybrid solar + PCM technology for night-time operation.

3. IoT integration for real-time temperature monitoring via mobile apps.

4. Import substitution through local PCM and fabrication centers.

Design Concept, Calculations & Sizing

1. Cold Storage Design Parameters

Storage Capacity: 5 m^3 chamber (for vegetables, fruits, fish).

Desired Temperature: 5°C.

Ambient Temperature: 30°C.

Operating Hours: 24 hrs.

2. Cooling Load Estimation

Cooling load (Q) is given by:

$Wall\ Area\ (A)$: $\sim 25\ m^2$.

Overall Heat Transfer Coefficient (U): 0.35 W/m²K (insulated panels).

ΔT: $(30 - 5) = 25°C$.

$Transmission\ Load = 0.35 \times 25 \times 25 \approx 220\ W$.

Product Load ≈ 2.0 kW (assumed 200 kg produce/day, cooled from 30°C to 5°C).

Miscellaneous Loads (infiltration, lighting, equipment) ≈ 0.8 kW.

$Total\ Cooling\ Load \approx 3.0\ kW$.

3. PCM Energy Storage Requirement

$Latent\ Heat\ of\ paraffin - sand\ PCM \approx 180\ kJ/kg$.

Cooling Energy Needed (12 hrs storage): $3.0\ kW \times 12\ hrs = 36\ kWh = 129{,}600\ kJ$.

Required $PCM\ Mass = 129{,}600 / 180 \approx 720\ kg\ PCM$.

4. Solar PV System Sizing

$Daily\ Cooling\ Energy$: $3.0\ kW \times 10\ hrs = 30\ kWh/day$.

$PV\ Panel\ Rating$: $300\ W\ per\ panel$ ($1.5\ kWh/day\ at\ 5\ peak\ sun\ hours$).

$Required\ Panels = 30 \div 1.5 \approx 20\ panels$ ($300\ W\ each$).

$Inverter\ Rating$: $5\ kVA$.

$Battery\ Storage$: $20\ kWh\ (for\ 1 - day\ autonomy) . \rightarrow$
$\sim 16\ batteries\ @\ 12\ V, 200\ Ah$.

5. System Block Diagram

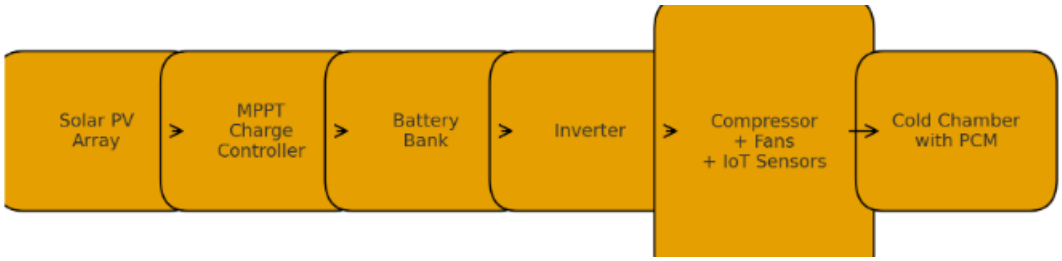

Figure 1; Block Diagram of the Process

Methodology & Work Plan (12 Months)

Work Plan (12 Months)

S/N	Phase Activities	Duration	Deliverables
1	Design & Material Development (PCM + Solar integration)	Months 1–3	Detailed design, lab-tested PCM
2	Prototype Fabrication & Testing	Months 4–6	Functional prototype
3	Pilot Deployment in Rural Communities	Months 7–9	Field performance data
4	Commercial Viability & Market Research	Months 8–10	Business & financing model
5	Scalability & Policy Engagement	Months 10–12	Commercialization roadmap, investor partnerships

Commercial Viability & Business Model

Target Users: Farmer cooperatives, agro-SMEs, local markets, health centers.

Business Model: Lease-to-own via microfinance and cooperatives.

Partnerships: Agricultural boards, private produce buyers.

Value Proposition: 30% reduction in spoilage, affordable financing, local jobs.

Alignment with NASENI Thematics

1. Renewable Energy: Solar PV and PCM energy storage.

2. Agriculture & Food Security: Reduction of post-harvest losses.

3. Local Content & Industrialization: PCM from Nigerian resources, fabrication at NASENI centers.

4. Job Creation: Engineers, technicians, rural operators.

5. Sustainability: Low-carbon, modular, scalable.

Technology Readiness Level (TRL)

Current TRL: 5 (validated in lab environment).

Target TRL: 7–8 (prototype in operational environment, near commercialization).

Expected Outcomes & Impact

- Working prototype of solar-PCM cold storage.
- 30% reduction in food spoilage in pilot communities.
- Commercialization roadmap with investor interest.
- Local workforce trained for long-term sustainability.
- Contribution to Nigeria's energy transition plan.

Budget Estimate (₦)

S/N	Category	Cost Estimate (#)
1	Design & Materials (PCM, solar PV, IoT (Sensors))	45,000,000
2	Prototype Development (fabrication of refrigeration unit, inverter, controllers)	35,000,000
3	Pilot Testing (2 rural communities)	25,000,000
4	Market & Feasibility Studies	15,000,000
5	Capacity Building & Training	10,000,000
6	Contingency & Overheads (logistics, inflation buffer etc)	20,000,000
	TOTAL	**150,000,000**

Conclusion

This project offers a transformative cold storage solution tailored to Nigeria's rural agricultural needs. By integrating solar PV with PCM storage, it ensures reliable, cost-effective, and sustainable refrigeration. The innovation directly supports NASENI's mandate on renewable energy, agriculture, and industrialization, while reducing post-harvest losses, boosting food security, and creating rural jobs. With proper funding and support, the project is positioned to scale nationwide and beyond.