REPOBLIKAN'I MADAGASIKARA
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AGRICULTURAL & FISHERIES

COLD CHAIN ANALYSIS AND PRIORITIZATION

AGCAP MADAGASCAR

SUSTAINABLE ENERGY FOR ALL

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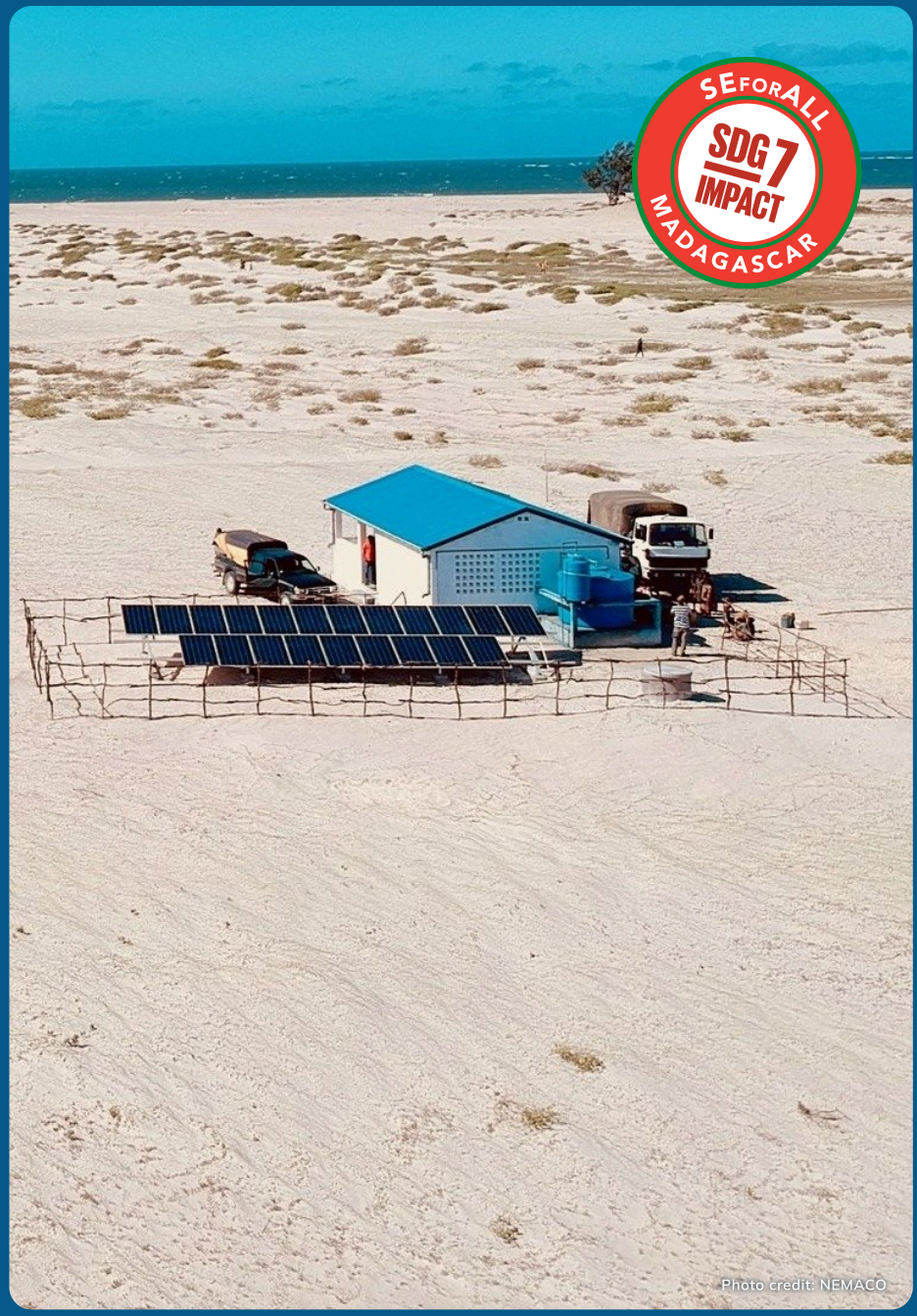

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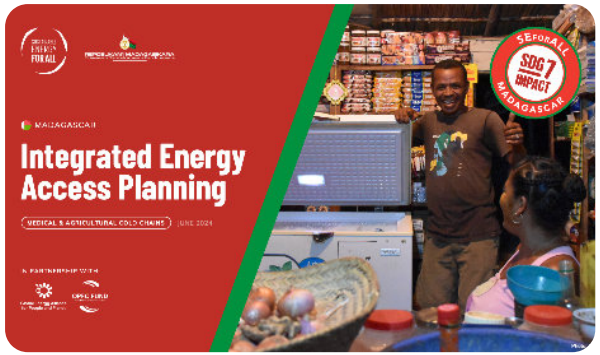

Madagascar – Cold Chain Summary Report

This summary report includes the results of the high-level cold chain capacity utilization and assessment, facility energy needs assessment, and recommendations for effective cold chain management for both the medical and agricultural sectors in Madagascar as part of the Integrated Energy Access Plan (IEP)

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Madagascar – Electrification Summary Report

This summary report covers the least-cost electrification pathways for Madagascar to reach universal electrification. It provides actionable spatial intelligence on technological options and energy end uses that can contribute to decision-making for the public sector, donors, and private and civil society organizations.

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The full-length technical reports for all components of the Madagascar IEP are available for download here

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CHAPTER ONE

AGRICULTURAL COLD CHAINS

AGRICULTURAL AND FISHERIES COLD CHAIN CHALLENGE IN MADAGASCAR

Estimates indicate that over 30 percent of harvested perishable products in Madagascar's key value chains are lost to spoilage. This represents a major missed opportunity, as access to sustainable cooling and energy could significantly improve food security, rural livelihoods and local economies.

The challenges of missing agricultural cold chains in Sub-Saharan Africa are well diagnosed, yet a persistent lack of credible, investment-guiding data continues to hold back financing. Cooling demand is difficult to estimate; suitable sites depend on many factors; and projects in the communities that would benefit most tend to be less bankable.

In Madagascar, these constraints compound the two structural challenges identified throughout the Madagascar Integrated Energy Access Plan (IEP): limited access to reliable electricity and insufficiently developed infrastructure.

From an energy access perspective, productive uses of energy (PUE) such as cooling can enhance the impact and economic viability of rural electrification, while reducing post-harvest losses and strengthening food security and climate resilience.

This report presents a national analysis of sustainable cooling potential in Madagascar's agricultural and fisheries value chains, undertaken by Sustainable Energy for All (SEforALL) in partnership with the Government of Madagascar (GoM), to guide cold chain investments.

Effective development of agricultural and fisheries cold chains faces a number of challenges:



ELECTRICITY ACCESS

Lack of access to reliable power is a major obstacle to the establishment of cold chains in Madagascar.



DATA AND EVIDENCE

A lack of granular, investment-guiding data on cooling potential and suitable sites holds back financing for cold chain deployment.



FINANCING AND INVESTMENT

Insufficient access to financing and investment opportunities limits expansion and modernization of the agricultural cold chain.



TECHNOLOGY AND EQUIPMENT

Unavailable, unaffordable or inaccessible technologies and equipment further exacerbate cold chain shortcomings.



AWARENESS AND TRAINING

Lack of awareness and technical know-how in cold chain management.



INFRASTRUCTURE

Inadequate cold storage and transport facilities and infrastructure throughout the country.

BUILDING ON THE MADAGASCAR IEP COLD CHAIN ANALYSIS

The cold chains component of the Madagascar IEP addressed sustainable cooling in agricultural and fisheries value chains through a high-level analysis of cooling potential, based on production data at the regional level. Four priority value chains were identified and validated during the IEP: potatoes, tomatoes, fish and dairy. The IEP estimated that just 20 percent penetration of modern cold chain equipment in these four value chains could prevent up to USD 230 million in annual losses.

To unlock this potential, Madagascar needs granular, actionable data and insights to guide investments. Geospatial cold chain analysis and prioritization can fill this gap by pinpointing opportunities and identifying high-potential sites for cold storage interventions. This approach aligns with Madagascar's Mission 300 compact implementation support, in which data-driven geospatial planning was identified as a priority activity.

To address this challenge, SEforALL developed and piloted the Agricultural Cold Chain Analysis and Prioritization (AgCAP) tool, a first-of-its-kind, customizable, multi-criteria cold chain analysis tool. AgCAP identifies the communities most likely to benefit from cold storage solutions, enabling detailed site identification and commercial viability assessments to inform investment opportunities at the pre-feasibility stage.

In partnership with the GoM, SEforALL deployed AgCAP as a national pilot, working closely with a working group composed of relevant ministries and public agencies at the nexus of agriculture, fisheries, industry and energy. The pilot took an iterative and participatory approach, combining stakeholder consultations, data collection and model validation to ensure robust results. This report presents the methodology, results and recommendations of that deployment.

ONGOING PARTNER INITIATIVES:

- Several international organizations, including the WFP and FAO, have established or rehabilitated walk-in cold rooms and ice makers to reduce food losses in the fisheries value chain.
- Additional partners, including the WWF, UNDP and AfDB, are working to improve the living conditions of fishing communities or have initiated energy access programmes.
- Most interventions focus on three regions of southern Madagascar at high risk of food insecurity, examined in the fisheries case study of this report.

OBJECTIVES AND METHODOLOGY OF THE AGCAP ANALYSIS

STEP 1: DATA COLLECTION

- Assembly of openly available geospatial and non-spatial datasets, complemented by country-specific data from government stakeholders.

STEP 2: SPATIAL ANALYTICAL UNITS

- Definition of settlements as the unit of analysis and extraction of the characteristics of each settlement and its surrounding influence area.

STEP 3: COOLING POTENTIAL INDICES

- Construction of normalized composite indices that proxy cooling potential for agriculture and fisheries across market segments.

CROPS COVERED

- Banana, plantain, citrus, tropical and temperate fruits, cassava, yam and other roots, potato, sweet potato, tomato, onion, and other vegetables.
- Marine and inland fisheries via proxies.

OBJECTIVES

- Determine settlement-level hotspots for cooling in agriculture and fisheries.
- Develop a shortlist of evidence-based high-potential investment opportunities.
- Enhance PUE data on government data platforms.

STEP 4: MULTI-CRITERIA PRIORITIZATION

- Filtering, weighting and ranking of settlements against use-case-specific criteria to define priority sites.

Note: dairy and meat value chains were not included due to a lack of standardized sector data.

Note: The full methodological description for AgCAP is available on the **SEforALL website.**



Photo credit: NEMACQ

OVERVIEW OF WORKSTREAMS AND OUTPUTS

Table 1: Overview of the AgCAP workstreams, scope and outputs

WORKSTREAM	SCOPE, FOCUS AND OUTPUTS
Workstream 1: Nationwide agricultural cooling hotspots	National coverage of horticultural and fisheries value chains, with an initial site-suitability focus on value chains prioritized in the IEP; analysis at settlement level, adaptable to community level. **Outputs**: (1) a geospatial dataset of agricultural and fisheries cooling potential for each settlement; (2) an overview of the most suitable sites on an interactive map; (3) a validation of identified hotspots through primary data collection, informing a pre-feasibility analysis (presented in the site validation section).
Workstream 2 Case study 1: Sustainable cooling for small fisheries	Focused on the Atsimo Andrefana, Anosy and Androy regions, where food insecurity risks are highest and most partner interventions in fisheries cold chains are concentrated; developed in partnership with the WFP and WWF. **Outputs**: (1) a geospatial dataset of cold room deployment potential for fisheries; (2) a validation of locations against planned partner cold room sites; (3) a co-construction workshop with public, private and development partner stakeholders.
Workstream 2 Case study 2: Agricultural cooling as productive use at off-grid sites	Off-grid focused analysis starting with the WFP Rapid Rural Transformation (RRT) solar hub sites in Androy and Anosy and including privately operated mini-grids and JIRAMA isolated grids for the potential of scaling nationwide. **Outputs**: (1) cooling potential indices for the assessed off-grid sites; (2) identification of the value chains that could benefit from cold storage at each site; (3) validation based on on-the-ground information collected through pre-feasibility analysis.

Note: The results of Workstream 1 and of each case study are presented in the results section of this report, and the validation of identified sites in the site validation section.

PURPOSE OF THIS REPORT:

- This report presents the AgCAP analysis in Madagascar, including an overview of the cold chain landscape, followed by the AgCAP methodology, the results of the nationwide hotspot analysis and the two case studies, the validation of identified sites through a pre-feasibility study, and key conclusions and recommendations.
- Readers interested in the underlying regional cooling potential estimates are referred to the Cold Chains component of the Madagascar IEP, which this analysis complements and refines.

STAKEHOLDER ENGAGEMENT AND VALIDATION

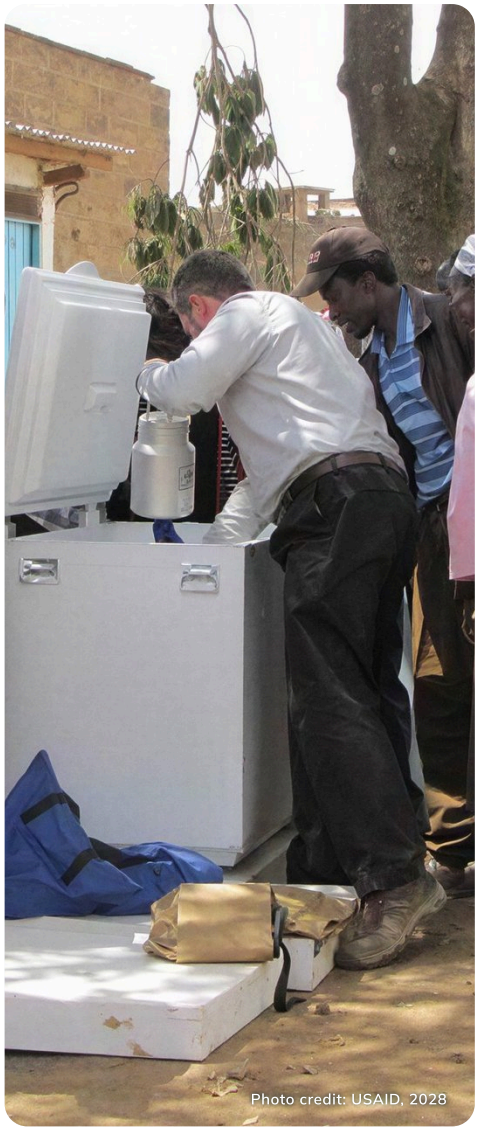
During the data and value-chain identification workshop jointly organized by the Ministry of Energy and Hydrocarbons (MEH) and SEforALL in May 2025, participants agreed to establish an agriculture-fisheries-industry-energy nexus working group, composed of focal points from the relevant ministries and public agencies and supported by key development partners and NGOs.

The working group steered the implementation of the AgCAP pilot. They shared sectoral data and initiatives, providing feedback and strategic guidance, ensuring alignment with national priorities, reviewing deliverables, and supporting the adoption and dissemination of results.

The implementation followed a phased approach, starting with data preparation, presentation of preliminary results, model adjustment, validation data collection and final results. All elements were discussed through working group engagements, workshops and private sector consultations. Building on the final outputs, a series of marketplace gatherings is envisaged to define specific project opportunities with public, development and private sector players.

Table 2: Members of the Agriculture-Fisheries-Industry-Energy Nexus Working Group

CATEGORY	ORGANIZATIONS
Public institutions	Ministry of Energy and Hydrocarbons (MEH) Ministry of Agriculture and Food Sovereignty (MiASA) Ministry of Livestock (MINEL) Ministry of Fisheries and the Blue Economy (MPEB) Ministry of Environment and Sustainable Development (MEDD) Ministry of Industrialization and Private Sector Development (MIDSP) National Statistics Institute (INSTAT)
Development partners and NGOs	WFP WWF GIZ FAO UNDP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STATUS OF AGRICULTURAL COLD CHAINS IN MADAGASCAR

No systematic data exist on the deployment of cold chain infrastructure in Madagascar. To establish a baseline for this analysis, a landscape analysis was undertaken, building on the IEP and drawing on a comprehensive data audit, document review and key informant interviews with approximately 20 stakeholders, including government ministries and agencies, development partners, NGOs, rural electrification operators, and private sector organizations.

Cold storage remains extremely limited across most agricultural and fisheries value chains, with existing infrastructure primarily developed for fisheries, dairy, and fragile fruits and vegetables. This capacity tends to be concentrated within structured, national or export-oriented value chains dominated by formal private sector organizations with the capacity to invest in and operate cold chain equipment. The cold chain therefore begins at major aggregation hubs: before aggregation, storage and transport are conducted at ambient temperatures for nearly all products.

Critically, however, the vast majority of losses are borne by producers and small collectors upstream. As noted in the IEP, producer-level losses reach up to 60 percent for fragile products such as tomatoes, compared with roughly 10 percent at the aggregator level and 2 percent at retail level. Community-level cold storage close to harvesting sites, landing sites and local markets could therefore drastically improve yields, rural livelihoods and food security. However, these are currently the least developed link in Madagascar's cold chain.

Table 3: Overview of current cold storage deployment by value chain

VALUE CHAIN	CURRENT COLD STORAGE DEPLOYMENT
Fruit and vegetables	Almost no modern cold chain infrastructure at production or aggregation level; even low-technology passive solutions are not widely used. Structured exporters use modern cold storage at aggregation and export points, but transport to these hubs is generally at ambient temperatures.
Dairy	Community-level milk chillers (500-2,000 litres) with refrigerated collection serve an estimated 6-10 percent of milk produced. Most of the remaining milk is made into yoghurt or cheese to avoid the need for cooling.
Meat	Minimal use of refrigeration as live animals are typically transported and held by butchers before slaughter, and meat is sold fresh in local markets. Cold storage is emerging only in urban supermarkets and export-grade channels.
Fish and seafood	The most developed cold chains. Industrial fleets and trading companies use ice, freezing tunnels and cold rooms, and public-private concession models are established. Small-scale fisheries, however, often have no means to cool or protect their catch, and keep fish fresh by sprinkling it with water or packing it in fresh leaves.

TECHNOLOGIES AND DELIVERY MODELS

Several development projects and private operators have tested community-based storage and service hub models, particularly in the fisheries sector, and often on a cooling-as-a-service (CaaS) basis whereby users pay a fee per kilogram or volume stored. These models have met with mixed success, and five recurring challenges were identified:

1. **Financing.** High upfront costs make access to finance a major barrier for individuals, cooperatives and businesses, while existing microfinance mechanisms are perceived as too onerous. Once infrastructure is in place, revenues may not cover the recurring costs of operations and maintenance.
2. **Local adoption and market conditions.** Capacity to pay for CaaS is generally reported as very low among rural producers, and many market actors have limited knowledge of post-harvest handling practices or the benefits of cold storage, pointing to a need to couple deployment with training.
3. **Management.** Operating cold storage requires business and technical skills that are scarce in highly fragmented value chains; community-based management has proven challenging, and poor management erodes user trust and leads to underutilized investments.
4. **Energy access.** With only around a third of the population estimated to have access to electricity, energy access remains a core constraint. Larger cooling loads can strain mini-grids and isolated grids, where reliability concerns often necessitate diesel backups. While solar cold chain equipment offers a promising alternative, its deployment remains limited.
5. **Land acquisition.** Several cold storage interventions and multi-service hubs have faced land rights and permitting problems that subsequently displaced or suspended projects.

TECHNOLOGIES IN USE OR EMERGING:

- **Ice-making machines.** A priority for fisheries, though energy-intensive and constrained by high ice prices.
- **Cooler boxes, retail refrigerators and freezers.** Often seen as productive uses on mini-grids.
- **Solar direct-drive units.** Widely used in healthcare but not yet accessible in agriculture.
- **Walk-in and solar-powered cold rooms.** At early stages as community-based solutions.

DELIVERY MODELS IN USE:

- **Fully private.** Agri-businesses own and operate cold storage in their own supply chains.
- **Public-private partnerships.** State infrastructure under long-term private concessions; common in fisheries.
- **Grant-funded, community-managed.** Donor infrastructure run by community groups; long-term management has proven challenging.
- **Grant-funded, privately managed**. Donor infrastructure operated by private or producers' organizations.

POLICY AND DATA LANDSCAPE

Table 4: Key policies and strategies relevant to cold chain deployment

POLICY OR STRATEGY	RELEVANCE FOR COLD CHAINS
General State Policy	Cold chains support its priorities of food self-sufficiency, industrialization, employment and universal energy access.
National Action Plan for Small-Scale Fisheries	Explicitly identifies the weak cold value chain as a principal sector challenge and calls for strengthened cold chain infrastructure in isolated zones.
National aquaculture and livestock strategies	Identify cold storage and ice production as essential gaps in expanding rural value chains, without dedicated cold chain targets to date.
New Energy Policy and M300 National Energy Compact	National electrification targets and an emphasis on mini-grids, solar solutions and energy efficiency provide the enabling foundation for climate-smart cold chains.
Global Cooling Pledge	Signatories commit to cut cooling-related emissions while expanding access to sustainable cooling, explicitly including cold chains to reduce food loss.
National Electrification Strategy and National Energy Plan (under development)	Productive uses of electricity, including cold chains, have been identified by energy sector stakeholders as a key priority to be addressed.

There is currently no national policy, strategy or action plan specifically dedicated to the development of agricultural or fisheries cold chains. Cooling is instead addressed indirectly across sectoral policies, with the notable exception of fisheries. At the same time, the national energy policy framework emphasizes decentralized renewable solutions, an enabling foundation for cold chains as a productive use of energy.

The absence of a coherent strategy, planning frameworks and consistent data significantly constrains the scalability of existing pilots and isolated infrastructure. Limited visibility on market potential makes it difficult for investors and donors to commit to scaling up, and stakeholders have consistently called for reliable data that could directly facilitate concrete investments.

A comprehensive data audit found that most environmental, demographic and infrastructure layers are publicly available, while critical gaps remain in spatially disaggregated production and yield data, the location of agricultural cooperatives, and private processing, storage and cold room infrastructure. Emerging national data initiatives are expected to progressively narrow these gaps, and supporting data collection and validation was accordingly made a core function of the stakeholder working group.

Taken together, this confirmed both the opportunity identified in the IEP and the barriers holding it back. The greatest losses, and therefore the greatest potential impact, sit at the community level, precisely where data, financing and planning are weakest. Geospatial cold chain planning was identified as an instrument to help close this gap.



CHAPTER TWO

THE AGCAP APPROACH

METHODOLOGY: OVERVIEW OF THE AGCAP ANALYSIS

The Agricultural Cold Chain Analysis and Prioritization (AgCAP) tool is an open-source, geospatial, multi-criteria prioritization tool developed by Sustainable Energy for All (SEforALL) to identify the communities most likely to benefit from cold storage interventions.

The tool works at the settlement level, which is the same unit of analysis typically used in least-cost electrification planning, so that its results can be integrated into national electrification and agricultural development strategies, including the Madagascar Integrated Energy Access Plan (IEP) tool. It combines openly available datasets on agricultural production, climate, market connectivity, electrification status, food security and socio-economic conditions into composite indicators that estimate the potential for cooling across export, national and fresh-market value chains, for both crops and fisheries.

It is important to note that the outputs of this methodology should be interpreted as a first-level prioritization to guide investments, not as final investment decisions. The indices are relative proxies for cooling potential rather than quantitative measures, and they do not replace the technical, market and financial assessments required to confirm site-level viability.

The **AgCAP code** and **documentation** are openly available, and the full methodology, including a description on the used datasets, formulas and known limitations, is presented in the methodology.

THE FOUR STEPS:

1. Data collection - assembly of openly available geospatial and non-spatial datasets, complemented by country-specific data.
2. Spatial analysis units - definition of settlements as the unit of analysis and extraction of their characteristics.
3. Cooling potential indices - construction of normalized composite indices for agriculture and fisheries across market segments.
4. Multi-criteria prioritization - filtering, weighting and ranking of settlements against case-specific criteria, performed through the AgCAP Insights Platform.

METHODOLOGY: DATA COLLECTION

The data inputs were selected with a focus on open-access data to ensure that the results of the analysis are accessible and replicable for all stakeholders. Key to the analysis, however, is the opportunity to integrate country-specific datasets.

Grid footprint and mini-grid location data were obtained from national stakeholders, and the electrification status and least-cost modality of each settlement were extracted from the Madagascar IEP, ensuring consistency with the national electrification plan.

A complete inventory of the individual datasets, their sources, formats and known limitations is provided on the AgCAP Madagascar code repository.

The integration of country-specific microdata, such as census, survey or production data, is possible and recommended where available. Data shared by working group members were evaluated for national-level integration, but deemed more suitable for local-level refinements.

After conversion to a geospatial format, these layers can be overlaid with the settlement data on the AgCAP Insights Platform.

Table 5: Categories of data used in the AgCAP analysis and their function

DATA CATEGORY	EXAMPLES OF DATASETS	FUNCTION IN THE ANALYSIS
Administrative and settlements	Administrative boundaries, settlement extents, population counts and projections	Define the spatial analytical units, assign settlements to administrative divisions and estimate the population served
Agricultural and fisheries production	Cropland extent, gridded crop production for perishable crops, proximity to coastlines and inland water bodies	Estimate the relative magnitude and intensity of farming and fishing activity around each settlement
Market connectivity and infrastructure	Locations of airports, ports, railway stations, major cities and the capital, and travel times to each	Assess the ease of delivery and distribution of perishable goods for export, national and fresh markets
Energy	Electrification status and least-cost modality (Madagascar IEP), medium voltage lines, mini-grid locations, night-time lights, solar PV output	Distinguish on-grid, off-grid and mini-grid contexts and assess the feasibility of solar-powered cold chain facilities
Climate and environment	Temperature, hot days, diurnal range, humidity, precipitation, aridity, elevation, cyclone hazard	Assess the need for cooling, spoilage risk, suitability for passive cooling and climate-related risks to infrastructure
Socio-economic and risk	Relative wealth index, food insecurity classification, livelihood zones, recorded conflict events	Target interventions towards commercially viable or the most vulnerable communities, and screen for site security

METHODOLOGY: SPATIAL ANALYTICAL UNITS

Population clusters, or settlements, serve as the default spatial unit of analysis. This choice ensures compatibility with the level of detail typically used in least-cost electrification studies and supports insights at a policy-relevant level of granularity. For Madagascar, an open-access settlement extents dataset covering Sub-Saharan Africa was used, and the unit of analysis is adaptable to the fokontany or community level where deemed more suitable by the stakeholder working group.

Settlements with fewer than 100 buildings were excluded, based on the assumption that communities of this size are generally too small to support cold storage projects (Figure 1). This threshold is adjustable within the analysis code, and also serves to limit the analysis to the polygons with the highest potential.

For each settlement, a set of characteristics was extracted covering all the data categories presented in Table 5, including population within the settlement and within a 20 km radius, administrative division, climatic conditions, electrification status, market connectivity based on travel times, and socio-economic and risk indicators.

Agricultural statistics are calculated within each settlement's influence area, defined through a spatial tessellation that divides the territory into continuous, non-overlapping zones based on proximity to the nearest settlement (Figure 2). Cropland extent and the production of the perishable crops covered by the analysis are attributed to each settlement within its influence area.

It should be noted that gridded crop production data is produced by downscaling national and sub-national statistics, and inherent uncertainties therefore remain. The data were therefore used as a complementary layer to the physical cropland extent.

Figure 1: Population clusters before and after filtering out settlements with fewer than 100 buildings

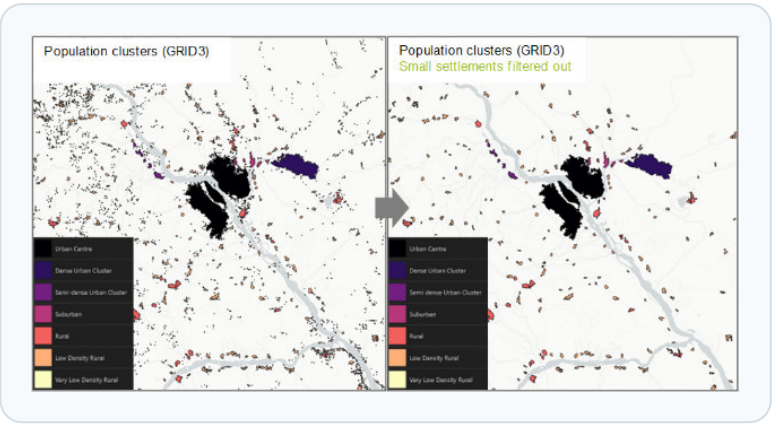
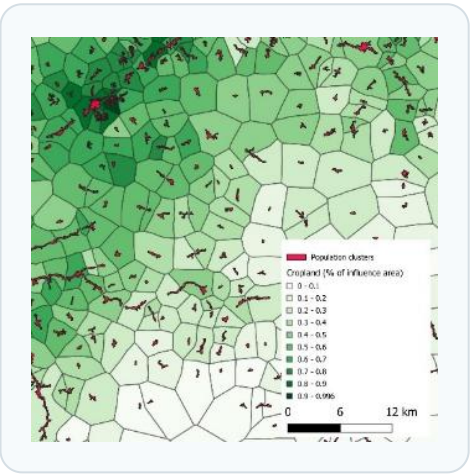


Figure 2: Settlement influence areas used to attribute agricultural production data to each settlement



METHODOLOGY: COOLING POTENTIAL INDICES AND PRIORITIZATION

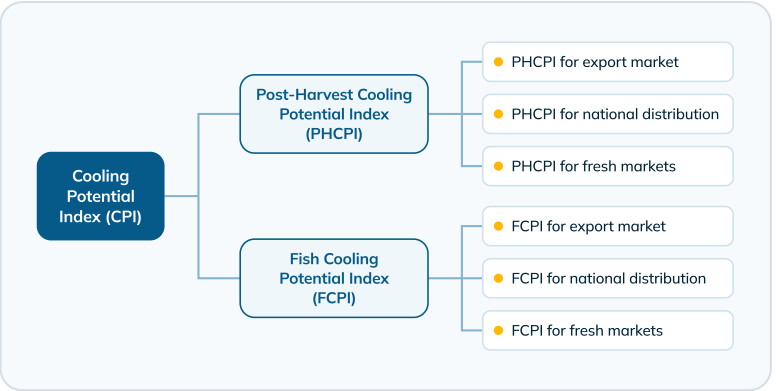
To synthesize the settlement data into comparable scores, the analysis constructs composite indicators: normalized indices ranging from 0 (low potential) to 1 (high potential), calculated as weighted averages of selected input variables. Market connectivity indices reflect access to export, national and fresh markets; cooling potential indices combine production activity with market connectivity to proxy the potential for cooling in each market segment.

Cooling potential is assessed separately for agriculture and fisheries. The Post-harvest Cooling Potential Index reflects the potential for cooling of perishable crops, while the Fish Cooling Potential Index reflects the potential for cooling and ice making for seafood, based on proximity to the coastline or to permanent inland water bodies. Each index is calculated for the export, national and fresh market segments.

It should be noted that these indices are relative indicators of geographic potential. Their values are comparable across settlements but do not represent a quantifiable demand for cooling services, and their construction and assigned weights introduce a degree of subjectivity. The aggregated indices were therefore used as a screening heuristic rather than a planning input.

The final step, multi-criteria prioritization, combines these indices with the more objective primary settlement attributes. Users apply filters and assign custom weights, producing a final score and ranking for each site. The criteria were selected and validated through the stakeholder working group; the three configurations applied are summarized opposite and presented in full alongside the results.

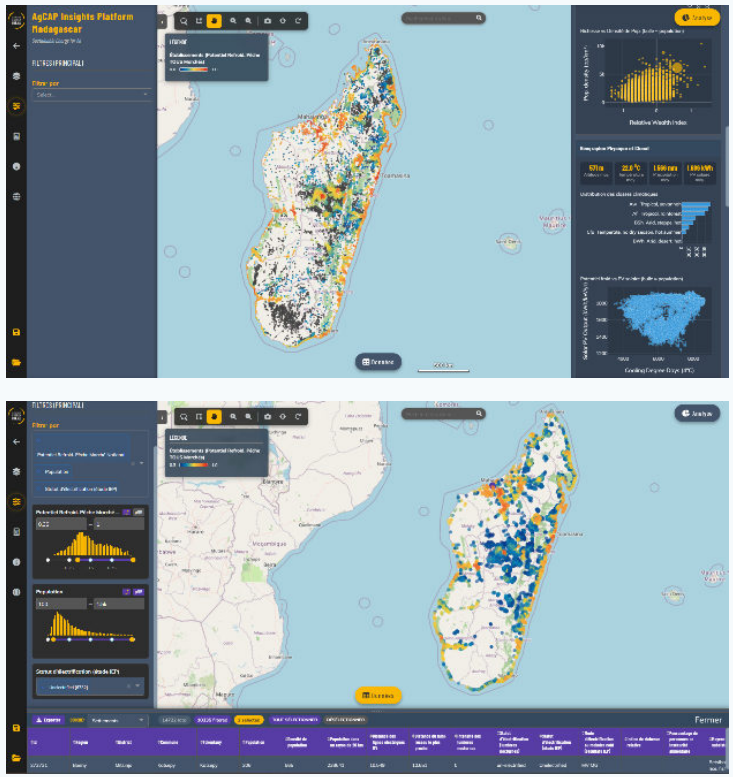
Figure 3: Structure of the cooling potential indices by application and market segment



- **Nationwide hotspots:** community-based cold storage for perishable horticulture crops and fish, for both marine and inland fisheries.
- **Case study 1:** community-based, solar-powered ice makers and cold storage for small-scale fisheries in southern Madagascar.
- **Case study 2:** post-harvest cold storage as an anchor load at existing and planned off-grid electrification sites.

THE AGCAP INSIGHTS PLATFORM

Figure 4: The AgCAP Insights Platform for Madagascar



EXPLORE THE RESULTS FOR YOURSELF:

www.agcap-insights.org/mdg/en

The results of the analysis are available on the AgCAP Insights Platform, a browser-based interactive map that requires no coding or GIS experience. It allows stakeholders to explore the settlement-level dataset, perform their own multi-criteria site selection analyses and export the results, turning the analysis presented in this report into a reusable planning resource. Advanced users can run customized analyses through the underlying open-source notebooks and code repository, facilitating the integration of proprietary or government data in a private session.

On the platform, users can visualize the settlement data using self-defined symbology on any of the data attributes. It is also possible to filter the map by production activity, specific crop production, demographics, geography, market connectivity, socio-economic conditions, electrification status, risks, climate and solar resources. Furthermore, users can create custom aggregated indicators by assigning weights to attributes. It is also possible to import and overlay contextual geospatial datasets. Finally, the user can rank and shortlist settlements, export the results and share the analysis sessions as templates.

The platform supports a whole range of users, including government planners, development partners and NGOs, as well as mini-grid developers, solar contractors and cold storage providers with identifying high-potential sites and pre-screening candidate communities.



CHAPTER THREE

NATIONAL & LOCAL INSIGHTS

AGRICULTURAL AND FISHING ACTIVITY ACROSS MADAGASCAR

Figure 5: Farming Activity Index by settlement

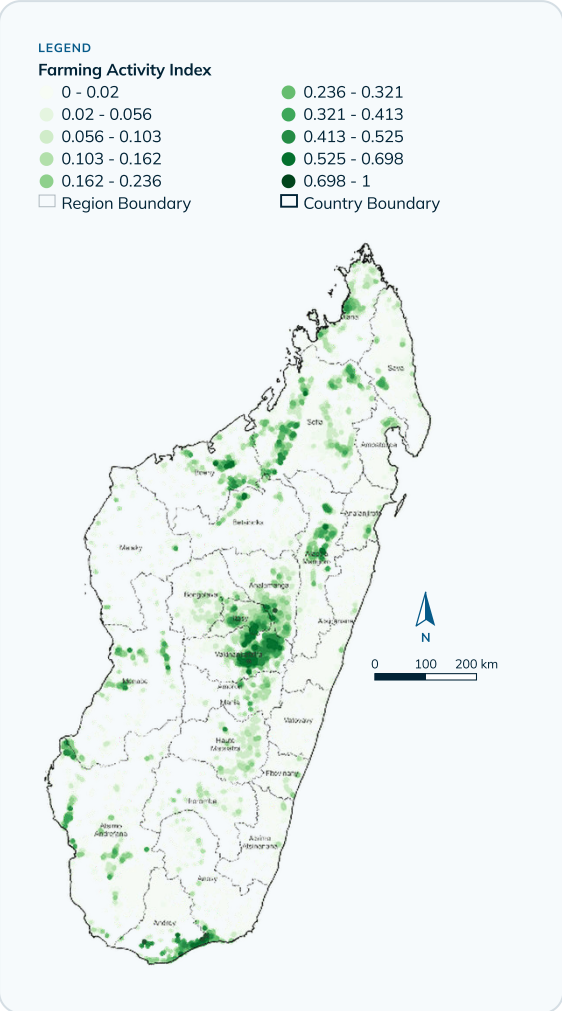
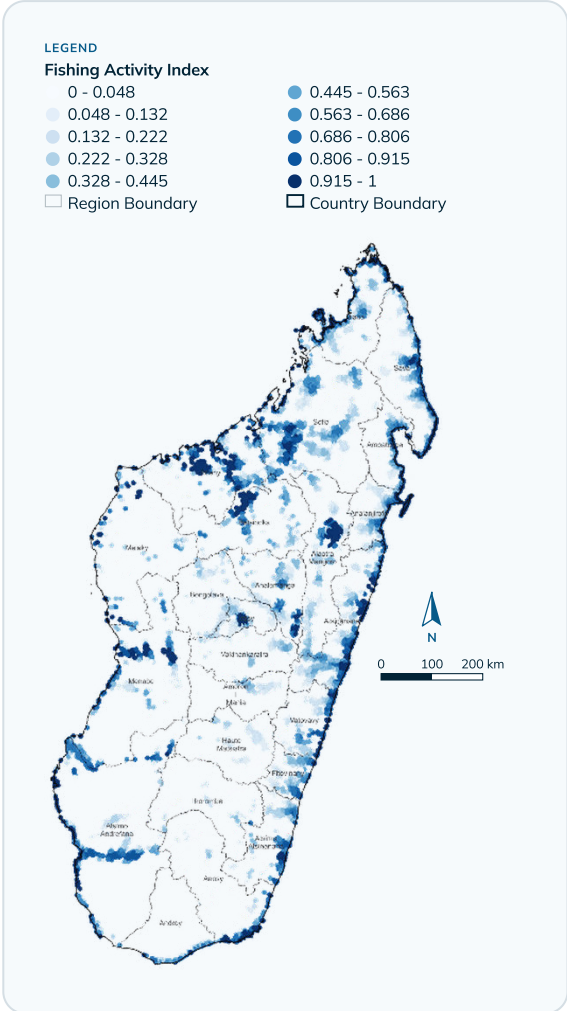


Figure 6: Fishing Activity Index by settlement (marine and inland)



The nationwide hotspot analysis mapped and characterized approximately 14,500 settlements across Madagascar. As a first step, the farming and fishing activity indices were calculated for every settlement, proxying the intensity of perishable crop production and of marine and inland fishing activity around each site.

- Settlements with strong farming activity in perishable products are common throughout the country, with the highest concentrations in the Central Highlands and along the northern and eastern corridors.
- Only around 15 percent of sites with high farming activity are electrified or likely electrified, indicating substantial potential for off-grid agricultural cooling.
- Approximately 10 percent of the settlements analysed show a relatively high fishing activity index, whether marine (along the coastline) or inland (around permanent water bodies).
- Just under 10 percent of these high-fishing-activity sites are electrified, enabling active cooling solutions such as ice making at those locations.

COOLING POTENTIAL AT THE NATIONAL LEVEL

Productivity indices alone do not accurately estimate cooling potential across agricultural and fisheries value chains. To address this, market connectivity indices were calculated based on travel times to airports, ports, cities, the capital and railway stations. By combining these connectivity metrics with productivity activity indices, the analysis generated post-harvest and fisheries cooling potential indices for each settlement across export, national and fresh market segments.

Of the more than 14,500 identified settlements, approximately 2,900 show strong post-harvest cooling potential, and 4,000 fish cooling potential. The most favourable sites are surrounded by extensive cultivated land and are well connected to regional hubs.

Table 6: Settlements analysed by region

REGION	SETTLEMENTS	REGION	SETTLEMENTS
Sofia	1,358	**Anosy**	437
Atsimo Andrefana	1,309	**Bongolava**	422
Vakinankaratra	1,187	**Ambatosoa**	418
Analamanga	1,116	**Menabe**	413
Sava	1,065	**Boeny**	412
Alaotra Mangoro	899	**Atsimo Atsinanana**	389
Atsinanana	771	**Vatovavy**	353
Itasy	711	**Fitovinany**	311
Analanjirofo	708	**Amoron'i Mania**	303
Haute Matsiatra	565	**Betsiboka**	247
Diana	525	**Ihorombe**	175
Androy	490	**Melaky**	133

Figure 7: Cooling Potential Index (all markets) by settlement

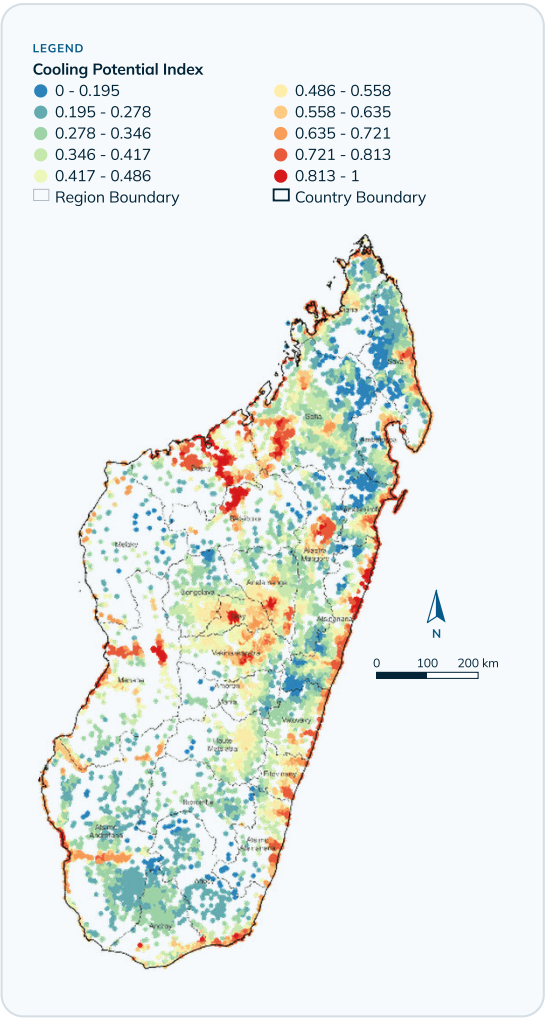


Figure 8: Fish cooling potential per settlement

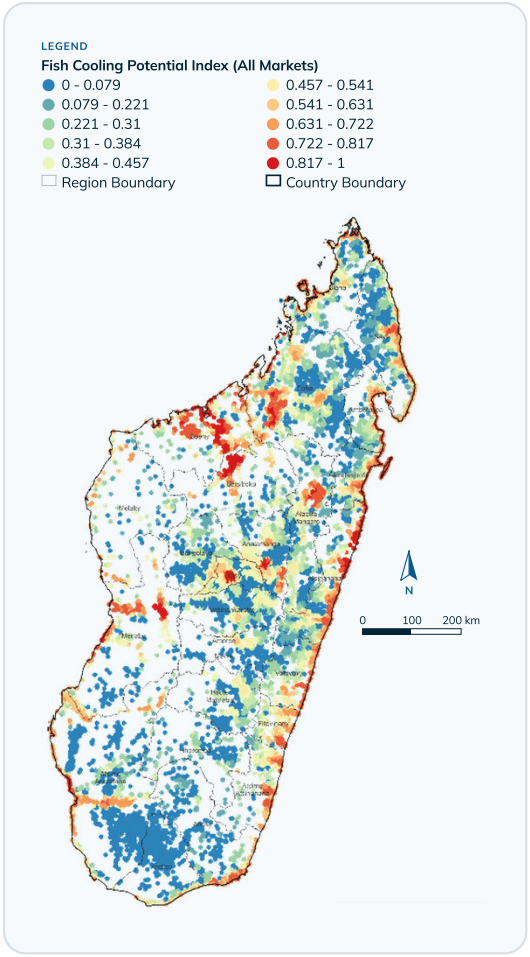


Figure 9: Post-harvest cooling potential per settlement

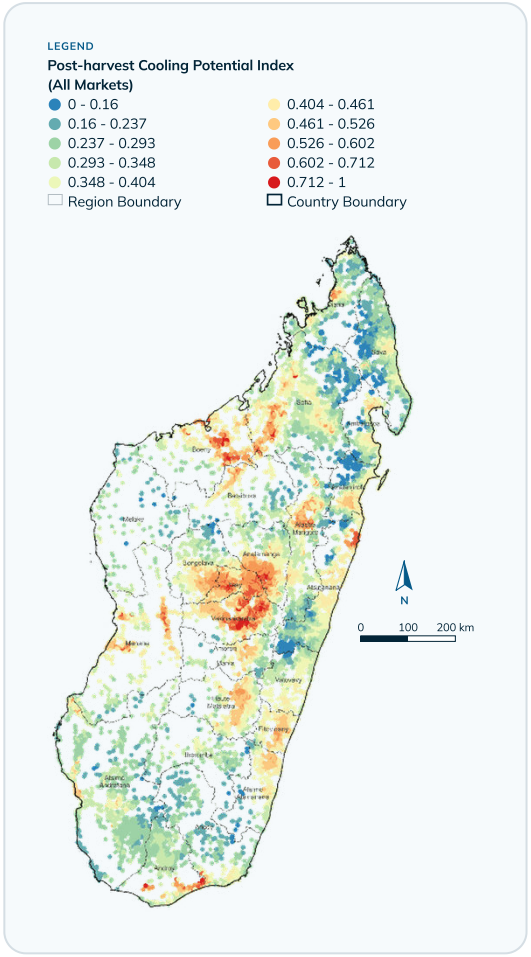
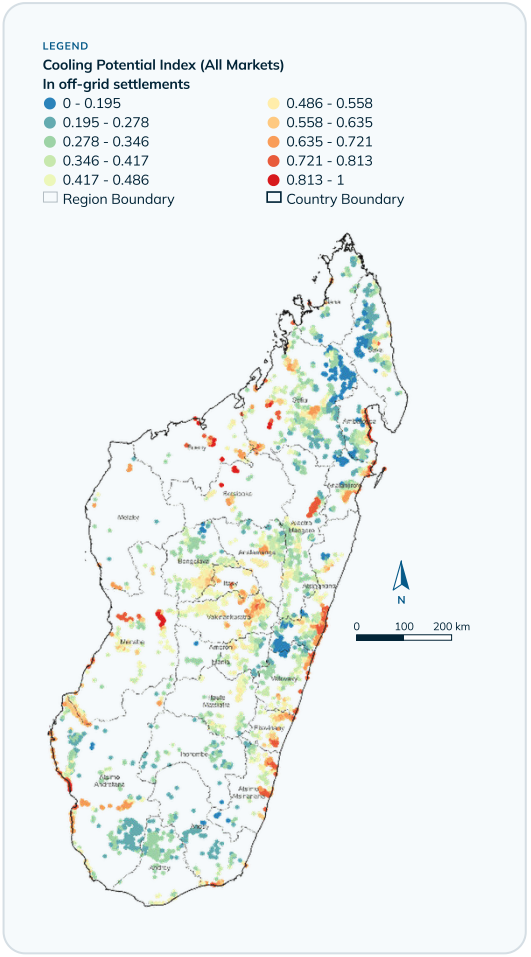


Figure 10: Cooling potential at off-grid settlements



CASE STUDY 1: SUSTAINABLE COOLING FOR SMALL FISHERIES

Applying the multi-criteria configuration for community-based, solar-powered ice makers and cold storage for fish, the analysis screened the settlements of the Atsimo Andrefana, Androy and Anosy regions – the three regions where food insecurity risks are highest and where most partner interventions in fisheries cold chains are concentrated.

The screening identified 270 candidate settlements with high fishing activity. The majority lie along the coastline between Toliara and Fort-Dauphin (Tolagnaro), with electrification status differentiating sites suitable for grid or mini-grid solutions from those requiring standalone solar equipment.

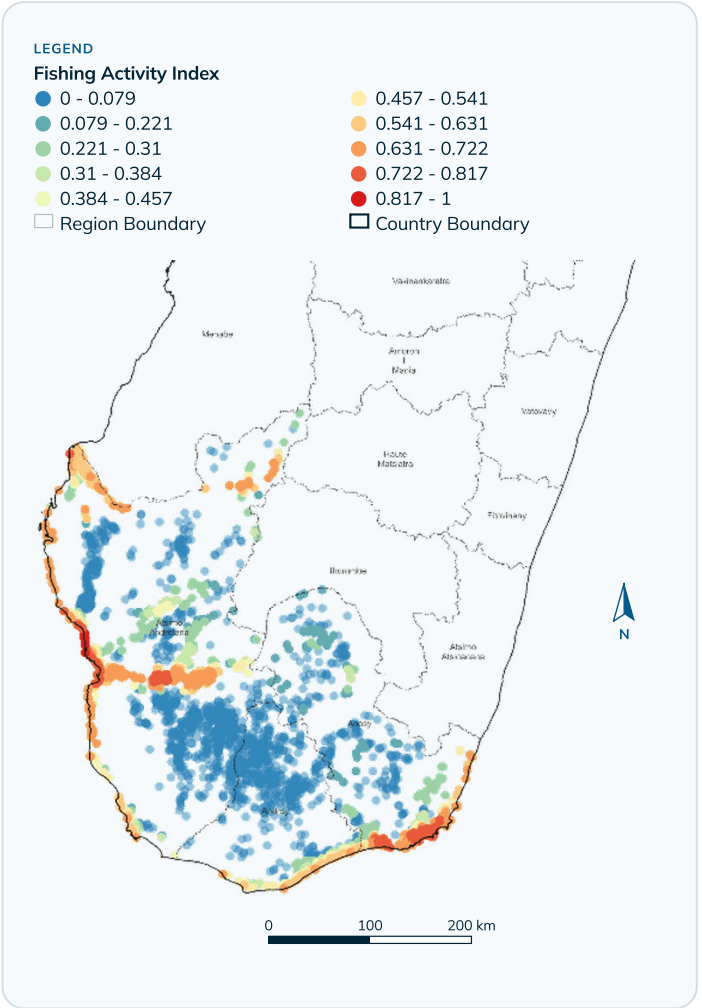
Table 7: Case study 1 – screening criteria and filters applied

CRITERION	ATTRIBUTE FILTER APPLIED
Region	"Androy", "Anosy", "Atsimo Andrefana"
Fishing activity	Marine / Inland Fishing Activity Index > 0.6
Market potential	Fish Cooling Potential Export Market > 0.5 OR Fish Cooling Potential National Market > 0.5 OR Fish Cooling Potential Fresh Market > 0.5
Local market size	Population within 20 km > 5.000
Socio-economic	Relative Wealth Index < 0
Food insecurity	Fraction of food-insecure people > 10%
Environmental	Annual air temperature >= 23,5
Settlement size	Population > 150

Table 8: Case study 1 - candidate settlements by region

REGION	CANDIDATE SETTLEMENTS
Atsimo Andrefana	240
Androy	8
Anosy	22
Total	270

Figure 11: Settlements for fisheries cooling along the southern coastline, by Fishing Activity Index



CASE STUDY 2: AGRICULTURAL COOLING AT OFF-GRID SITES

The second case study applied the multi-criteria configuration for cold storage as an anchor load at off-grid electrification sites, screening settlements by their electrification context and post-harvest cooling potential rather than by a specific value chain.

The screening retained 890 settlements nationwide, with the largest concentrations located in Vakinankaratra, Fitovinany, Alaotra Mangoro, and Boeny. At these sites cold storage has the potential to serve as a revenue-stabilizing anchor load for mini-grid and solar hub operators while reducing post-harvest losses in surrounding communities.

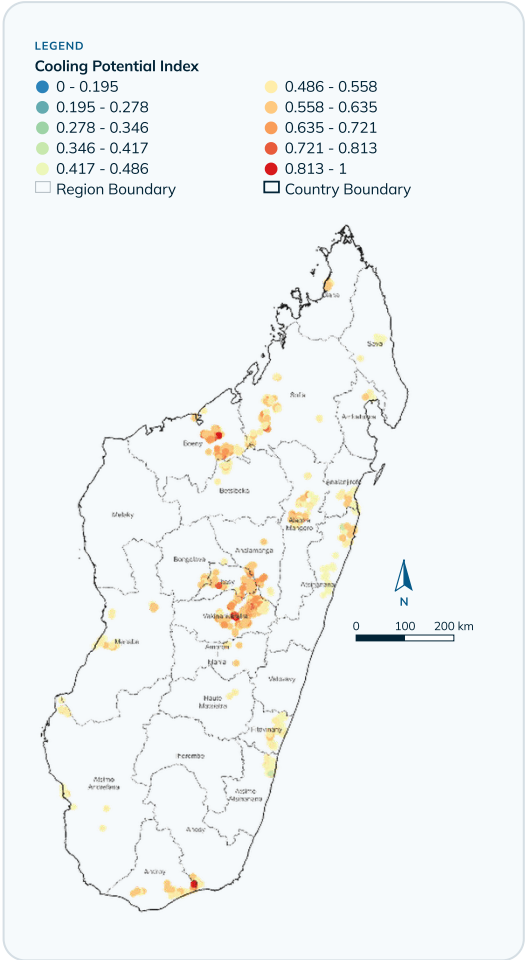
Table 9: Case study 2 – screening criteria and filters applied

CRITERION	ATTRIBUTE FILTER APPLIED
Off-grid energy context	Least-cost electrification technology = 'LV MG' OR 'MV MG' OR 'SHS'
Market potential	Post-Harvest Cooling Potential Export Market > 0.6 OR Post-Harvest Cooling Potential National Market > 0.6 OR Post-Harvest Cooling Potential Fresh Market > 0.6
Local Market Size	Population within 20 km > 50.000
Settlement size	Population > 200

Table 10: Case study 2 – retained settlements by region

REGION	SITES	REGION	SITES
Vakinankaratra	246	**Atsimo Andrefana**	27
Fitovinany	76	**Analamanga**	24
Alaotra Mangoro	75	**Analanjirofo**	23
Boeny	64	**Sava**	22
Sofia	59	**Bongolava**	15
Itasy	54	**Betsiboka**	12
Atsimo Atsinanana	42	**Diana**	11
Atsinanana	41	**Anosy**	11
Androy	39	**Ambatosoa**	5
Menabe	37	**Amoron'i Mania**	4

Figure 12: Retained off-grid settlements by Post-harvest Cooling Potential Index (all markets)



SITE VALIDATION: PRE-FEASIBILITY AT 10 AGCAP-IDENTIFIED SITES

To validate the AgCAP screening results and translate them into concrete investment intelligence, a pre-feasibility study was conducted at 10 sites pre-selected through the AgCAP analysis in the three case study regions of southern Madagascar: Atsimo Andrefana, Androy and Anosy. Six of the 10 sites are fishing communities identified through the fisheries case study and four are agricultural communities in line with the off-grid productive use case study; two agricultural site host a WFP Rapid Rural Transformation (RRT) solar station, and 2 others are (partially) powered by mini-grids.

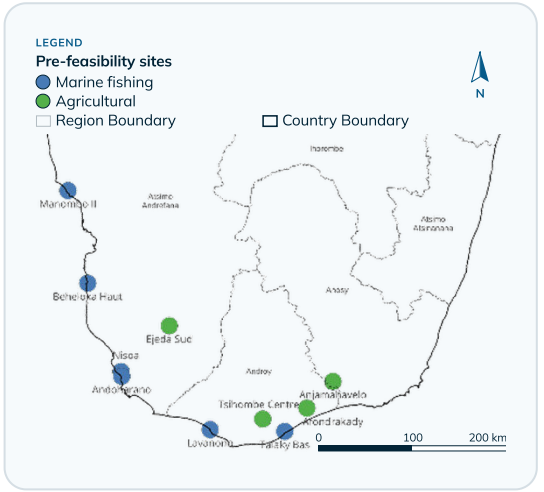
Primary data were collected through a mixed-methods approach: a quantitative household survey of 246 households (126 fishing and 120 farming) across up to three fokontany per site; four key informant interviews with community and fokontany authorities; three interviews with market aggregators; and one focus group discussion per site. Candidate cooling solutions, including community refrigeration hubs, individual cold rooms, ice production units and solar milk cooling tanks, were dimensioned based on the available energy resources and compared through technical and financial analysis, including net present value, internal rate of return (IRR) and return on investment (ROI).

The assessment did not seek solely the solutions with the best financial indicators, but systems that are technically appropriate, economically sustainable and compatible with local conditions.

Table 11: Overview of the 10 pre-feasibility sites and recommended cooling solutions

#	SITE	REGION	TYPE	RECOMMENDED SOLUTION AND VIABILITY
1	Lavanono	Androy	Fishing	Community ice production unit (grant-based; IRR -1%)
2	Manombo II	Atsimo Andrefana	Fishing	Community ice production unit (grant-based; IRR -3%)
3	Beheloka Haut	Atsimo Andrefana	Fishing	Ice production unit - viable (IRR 3%; 4-year ROI)
4	Andoharano	Atsimo Andrefana	Fishing	Ice production unit - viable (IRR ~10%; 2-year ROI); recommended priority site
5	Sakariaka	Atsimo Andrefana	Fishing	Ice production unit with passive coolers - viable (positive IRR; ~3-year ROI)
6	Talaky Bas	Androy	Fishing	Community refrigeration hub with ice production (grant-based; not yet viable)
7	Anjamahavelo	Anosy	Agriculture	No financially viable solution; refrigerated hub conceivable as grant-funded development infrastructure
8	Afondrakady	Androy	Agriculture	Collective solar milk cooling tank (grant-based pilot)
9	Tsihombe Centre	Androy	Agriculture	Modular positive cold rooms (grant-based; not yet financially viable)
10	Ejeda Sud	Atsimo Andrefana	Agriculture	Collective hub not yet viable site-wide; two fokontany identified as possible pilots (positive IRR)

Figure 13: Location of the ten pre-feasibility sites in Atsimo Andrefana, Androy and Anosy regions



PRE-FEASIBILITY RESULTS: FISHERIES SITES

Site 1 - Lavanono (Beloha district, Androy)

Lavanono is a fishing community of about 1,600 households, 841 (53 percent) of which rely on fishing, with catches dominated by fish and high-value spiny lobster. With no reliable electricity access and the nearest market some 35 km away, an estimated 170.3 tons of the annual catch requires cold storage. The community ice production unit is the solution most consistent with local conservation practices; despite still-negative financial indicators it is recommended under a blended CAPEX grant and OPEX recovery model, operated by a fishermen's cooperative with an asset replacement fund.

INDICATOR	VALUE
Households (fishing)	~1,600 (841; 53%)
Annual production	511.4 t (481 / 30.3 by season)
Requiring cold storage	170.3 t/year
Main species	Fish (85%); spiny lobster (10%)
Electricity access	No reliable grid access
Nearest market	~35 km
Solutions dimensioned	437 m³ hub (92 kWh/day); 520 L cold rooms; 5.6 t/day ice unit
Recommended solution	Community ice production unit – CAPEX grant + OPEX recovery

Figure 14: Lavanono site



Site 2 - Manombo II (Toliara II district, Atsimo Andrefana)

Manombo II comprises 3,244 households, 88 percent of which are fishing households, with highly seasonal catches of octopus, fish, squid and shrimp. The site lacks electricity access and cold chain infrastructure; its furthest market lies about 50 km away, although it is accessible by road year-round. The solar ice production unit is the configuration closest to economic equilibrium among the scenarios studied, recommended under a CAPEX grant and OPEX recovery model operated by a community structure, with an asset replacement fund to withstand the corrosive marine environment.

INDICATOR	VALUE
Households (fishing)	3,244 (88% fishing)
Annual production	297 t (226 / 71; seasonality 3.22)
Requiring ice preservation	98.8 t/year
Main species	Octopus (38%); fish (29%); squid (19%)
Electricity access	None
Furthest market	~50 km (road accessible year-round)
Solutions dimensioned	228 m³ hub (50 kWh/day); 72 L cold rooms; 3.6 t/day ice unit
Recommended solution	Community ice production unit - CAPEX grant + OPEX recovery (IRR -3%)

Figure 15: Manombo II site



PRE-FEASIBILITY RESULTS: FISHERIES SITES

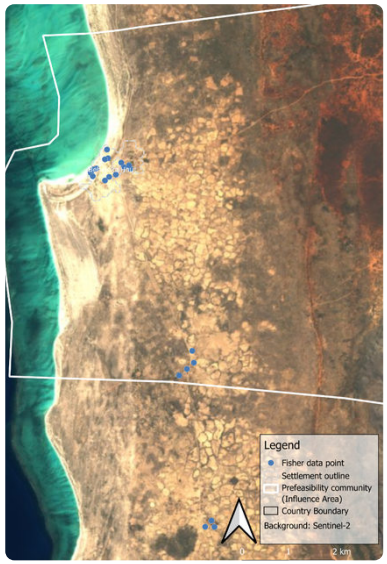
(2 | 3)

Site 3 - Beheloka Haut (Betioky district, Atsimo Andrefana)

Beheloka Haut is among the most fishing-dependent sites studied, with 1,020 of its 1,120 households (91 percent) engaged in fishing, targeting reef octopus, fish and squid. The site has no grid access and its furthest market is located about 290 km away, making conservation essential to preserve product quality during transport. The ice production unit presents the best financial indicator of the site and is recommended under a CAPEX grant and OPEX recovery model operated by a cooperative or fishermen's association.

INDICATOR	VALUE
Households (fishing)	1,120 (1,020; 91%)
Annual production	294.6 t (221.3 / 73.3; seasonality 3.01)
Requiring ice preservation	98.1 t/year
Main species	Reef octopus (~30%); fish (10%); squid (5%)
Electricity access	None
Furthest market	~290 km
Solutions dimensioned	120 m³ hub (27 kWh/day); 200 L cold rooms; 840 kg/day ice unit
Recommended solution	Ice production unit - viable (IRR 3%; 4-year ROI)

Figure 16: Beheloka Haut site

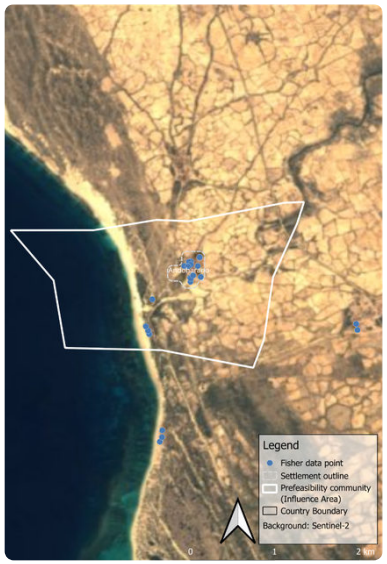


Site 4 - Andoharano (Ampanihy district, Atsimo Andrefana)

Andoharano is a smaller site of 386 households (56 percent fishing), where catches – dominated by fish and reef octopus – remain comparatively stable across the year. With no grid access and its main destination market in Ejeda about 140 km away, an estimated 73.6 tons per year of catches require preservation under ice. Local production of food-grade ice presents the best financial indicator of all 10 sites, and Andoharano is accordingly recommended as the priority site for a first deployment.

INDICATOR	VALUE
Households (fishing)	386 (56% fishing)
Annual production	221 t (169.9 / 51.3; seasonality 3.31)
Requiring ice preservation	73.6 t/year
Main species	Fish (85%); reef octopus (15%)
Electricity access	None
Main market	~140 km (Ejeda); road accessible year-round
Solutions dimensioned	170 m³ hub (38 kWh/day); 156 L cold rooms; 2.2 t/day ice unit
Recommended solution	Ice production unit - viable; priority site (IRR ~10%; 2-year ROI)

Figure 17: Andoharano site



PRE-FEASIBILITY RESULTS: FISHERIES SITES

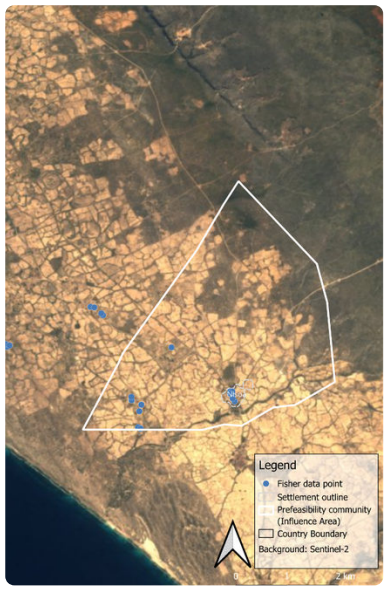
(3 | 3)

Site 5 - Sakariaka (Ampanihy district, Atsimo Andrefana)

Sakariaka comprises 1,356 households, of which 723 are fishing households. Its catches are dominated by octopus and squid and it experiences the most pronounced seasonality of the fisheries sites. With no grid access and markets at an average distance of 111.5 km, around 50.2 tons of seafood per year – 40.5 percent of production – requires cold storage, concentrated in the peak months. The recommended solution combines a solar food-grade ice production unit with passive coolers, under a CAPEX grant and OPEX recovery model in which ice sales, cooler rentals and conservation services progressively cover operating costs.

INDICATOR	VALUE
Households (fishing)	1,356 (723; ~53%)
Annual production	124 t (112 / 12; seasonality 9.3)
Requiring cold storage	50.2 t/year (40.5% of production)
Main species	Octopus (48%); squid (38%); fish (14%)
Electricity access	None
Distance to markets	~111.5 km on average
Solutions dimensioned	40 m³ hub (9 kWh/day); 45 L cold rooms; 600 kg/day ice unit
Recommended solution	Ice unit + passive coolers - viable (positive IRR; ~3-year ROI)

Figure 18: Sakariaka site



Site 6 - Talaky Bas (Tsihombe district, Androy)

Talaky Bas comprises 547 households, 82 percent of which are fishing households, with catches dominated by fish alongside spiny lobster and crabs, and a highly seasonal production profile. The site has no grid access, and around 114.3 tons of the catch per year requires cold storage. Despite still-negative financial indicators, the community solar refrigeration hub integrating cold storage and ice production is the most coherent solution, thanks to the pooling of equipment and the diversification of services, recommended under a CaaS model.

INDICATOR	VALUE
Households (fishing)	547 (82% fishing)
Annual production	261.6 t (236.4 / 25.2; seasonality 9.3)
Requiring cold storage	114.3 t/year (43.7% of production)
Main species	Fish (80%); spiny lobster (15%); crabs (8%)
Electricity access	None
Furthest market	~33 km
Solutions dimensioned	258 m³ hub (55 kWh/day); 377 L cold rooms; 1.5 t/day ice unit
Recommended solution	Community hub with ice production - CaaS (not yet viable)

Figure 19: Talaky Bas site



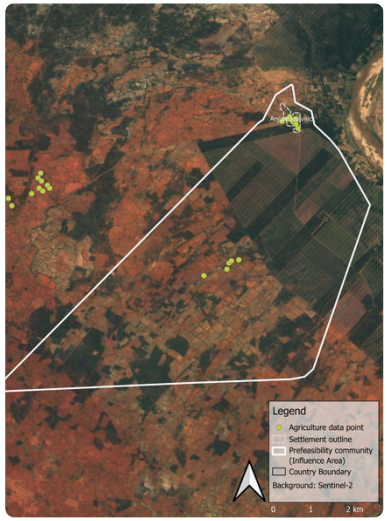
PRE-FEASIBILITY RESULTS: AGRICULTURE SITES (1 | 2)

Site 7 - Anjamahavelo (Amboasary Atsimo district, Anosy)

Anjamahavelo is an agricultural site of 1,038 households – nearly all farming – with 169 milk producers growing tubers and pulses alongside perishable market garden crops with a March–June peak season. The site is not electrified but hosts an RRT solar station supplying a food store and a smart village, directly illustrating the off-grid productive use logic of case study 2. No solution is financially viable on commercial terms at current volumes; if pursued as grant-funded rural development infrastructure, a refrigerated hub would be the most suitable configuration.

INDICATOR	VALUE
Households (farming / milk)	1,038 (1,035 farming; 169 milk)
Main perishable volumes	Leafy greens 89,183 kg; tomatoes 84,422 kg; watermelon 65,619 kg; milk 9,464 L/year
Estimated crop losses	~10% typical (up to 40%); median MGA 50,000
Electricity access	Not electrified; RRT solar station on site
Solutions dimensioned	2,414 m³ hub (229 kWh/day); 600 L cold rooms
Recommended approach	No financially viable solution; grant-funded hub as development infrastructure

Figure 20: Anjamahavelo site

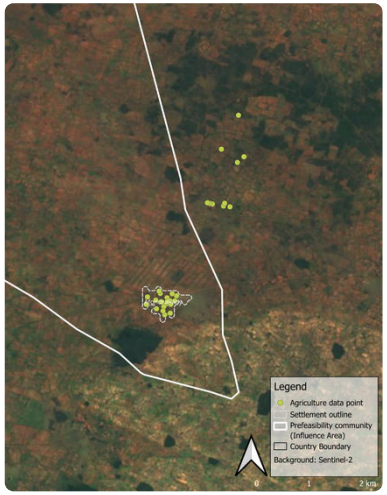


Site 8 - Afondrakady (Ambovombe Androy district, Androy)

The Afondrakady influence areas spans 25 fokontany and comprises 3,171 households, nearly all of which engage in farming. This includes 296 dairy farmers who produce cow and goat milk year-round. The site has no public electricity access and no modern storage infrastructure, and post-harvest losses are driven primarily by animal pests and poor storage. The collective solar milk cooling tank is the most coherent solution technically, sanitarily and socio-economically, recommended as a grant-funded pilot with pay-as-you-go tariffs calibrated to farmers' capacity to pay.

INDICATOR	VALUE
Households (farming / milk)	3,171 (3,166 farming; 296 milk)
Main perishable volumes	Tomatoes 67,752 kg; watermelon 47,490 kg; milk 42,506 L/year
Estimated crop losses	~8% typical (up to 16%); MGA 20,000-50,000
Electricity access	Not electrified; RRT solar station on site
Solutions dimensioned	166 m³ hub (23 kWh/day); 14 L cold rooms; 1,164 L solar milk tank
Recommended solution	Collective solar milk cooling tank - grant-funded pilot

Figure 21: Afondrakady site



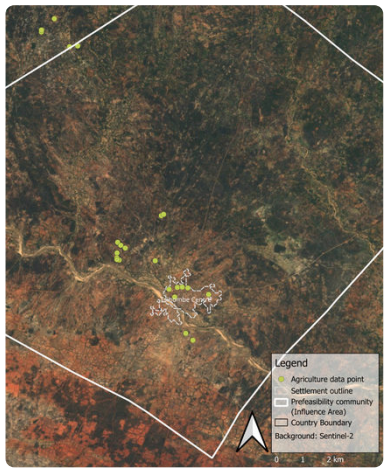
PRE-FEASIBILITY RESULTS: AGRICULTURE SITES (2 | 2)

Site 9 - Tsihombe Centre (Tsihombe district, Androy)

Tsihombe Centre is the largest influence area studied, spanning 28 fokontany with 4,534 households and a substantial annual milk volume of nearly 192,000 litres, three-quarters of which is sold. The site is 50 percent electrified by JIRAMA at comparatively low tariffs, but has no modern storage infrastructure. Modular positive cold rooms are the most suitable solution thanks to their flexibility, low investment cost and better fit with current production volumes, recommended under a CAPEX grant and OPEX recovery model with pay-as-you-go user fees.

INDICATOR	VALUE
Households (farming / milk)	4,534 (3,630 farming; 349 milk); 24,892 inhabitants
Main perishable volumes	Milk 191,985 L; watermelon 91,355 kg; tomatoes 42,350 kg/year
Estimated crop losses	10-20% typical (up to 75%); average MGA 41,600
Electricity access	50% electrified (JIRAMA; 130-140 MGA/kWh)
Solutions dimensioned	300 m³ hub (40 kWh/day); 18 L cold rooms
Recommended solution	Modular positive cold rooms - CAPEX grant + OPEX recovery

Figure 22: Tsihombe Centre site

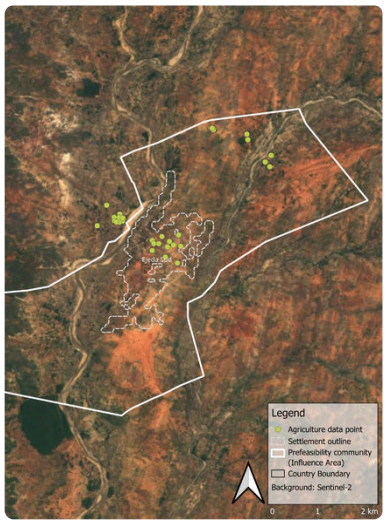


Site 10 - Ejeda Sud (Ampanihy district, Atsimo Andrefana)

Ejeda Sud comprises 3,777 households and stands out due to its comparatively developed local infrastructure: 50 percent electrification by a private operator, full drinking water supply, and an existing cold store and fresh produce market at the site centre. A multi-purpose collective refrigeration hub, pooling production volumes around the active local market, is the most coherent long-term solution but is not yet viable site-wide; a phased implementation is recommended, prioritizing the fokontany of Bekinana and Antsevaseva Besavoa as pilot sites.

INDICATOR	VALUE
Households (farming / milk)	3,777 (2,675 farming; 411 milk); 11,314 inhabitants
Main perishable volumes	Milk 174,839 L; watermelon 115,917 kg; tomatoes 22,292 kg/year
Estimated crop losses	~12% typical (up to 20%); median MGA 150,000
Electricity access	50% electrified (private operator; 1,900-3,000 MGA/kWh)
Solutions dimensioned	1,708 m³ hub (90 kWh/day); 630 L cold rooms
Recommended approach	Phased collective hub; pilots in Bekinana and Antsevaseva Besavoa

Figure 23: Ejeda Sud site





CHAPTER FOUR

WHAT COMES NEXT?

CONCLUSIONS

- The AgCAP pilot has produced Madagascar's first settlement-level analysis of agricultural and fisheries cooling potential. It translates the opportunity identified in the IEP (USD 230 million in preventable annual losses at 20 percent penetration) into concrete, identifiable sites. Of the more than 14,500 settlements characterized, approximately 2,900 show strong post-harvest cooling potential.
- The analysis confirms the need for an energy-agriculture nexus approach. Currently, only about 15 percent of high-farming-activity settlements are electrified, indicating substantial latent off-grid potential for cooling, while roughly one in 10 settlements shows high fishing activity.
- The analysis confirms the potential for local-level cooling investments close to production areas and at landing sites, addressing a critical but still underdeveloped link in Madagascar's cold chains. The pre-feasibility study reinforces this finding, identifying clear perishable volumes at all 10 assessed sites.
- However, large community refrigeration hubs and individual cold rooms, have limited financial viability at most sites at current volumes, due to production seasonality, distance to markets, energy constraints and the limited financial capacity of local actors. The most suitable solutions are tailored, modular and shared by the community.
- Food-grade ice production at small fisheries sites is one of the most viable solutions today. Three of the six fisheries sites assessed present positive financial returns, confirming the IEP's finding that returns are fastest for fish cooling.
- These results constitute a first-level prioritization to guide investments, rather than final investment decisions. Site-level deployment must be confirmed through the assessments the pre-feasibility approach demonstrated.



Cooling as a productive use of energy has the opportunity to strengthen the economic case for rural electrification, and electrification unlocks cooling in turn.



Equipment alone is not enough: viability depends on pairing cooling infrastructure with training, market structuring and adapted business models.



Solar ice production for small fisheries offers the fastest, most viable entry point for cold chain investment in southern Madagascar.



Community cold storage close to harvesting and landing sites has the greatest potential to cut losses and improve rural livelihoods.

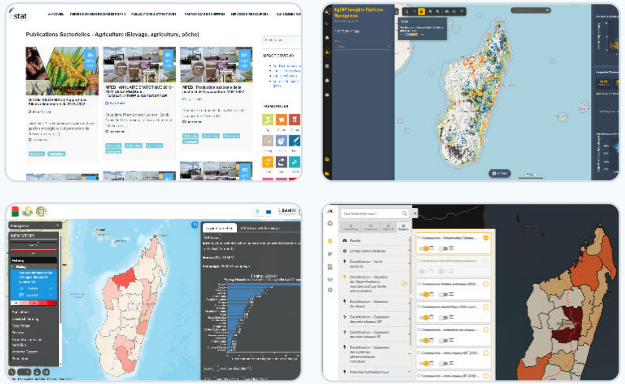
RECOMMENDATIONS

- **Incorporate AgCAP results and data of this analysis into existing national data platforms.** The settlement-level dataset and cooling potential indices should be published on the Madagascar IEP visualization platform, and relevant layers can be shared on the Stat SANOI and INSTAT portals. Upcoming national data initiatives should enhance future iterations of the model.
- **Strengthen and extend the agriculture-fisheries-industry-energy nexus approach.** Institutionalize joint planning across the agriculture, fisheries and energy sectors through a standing coordination mechanism among relevant ministries and development partners. In that way agricultural and fisheries needs, including cooling, are systematically considered in electrification planning, and energy availability is factored into agricultural development programmes. Future work should extend the analysis to other productive uses of energy.
- **Deploy sustainable business models and strengthen their viability.** Combine grant-funded initial investment with cost recovery through tariffs calibrated to users' capacity to pay. Select operators according to their technical and commercial capacity: structured cooperatives or producers' organizations where governance is strong; otherwise, private operators or rural entrepreneurs. Support the structuring of producers' and fishers' organizations, including women's groups that dominate post-harvest fisheries activities, through training in handling, hygiene and management, as well as improved logistics and market access. Maintain targeted public support for sites with high socio-economic impact but limited financial return.
- **Adopt a progressive approach matched to the context of each site.** Start with simple solutions adapted to local realities, such as solar ice production and short-term preservation where fish cooling potential is high but reliable electricity is lacking, and scale to modular cold rooms or community refrigeration hubs only where volumes, value chain organization and market linkages are sufficiently mature.

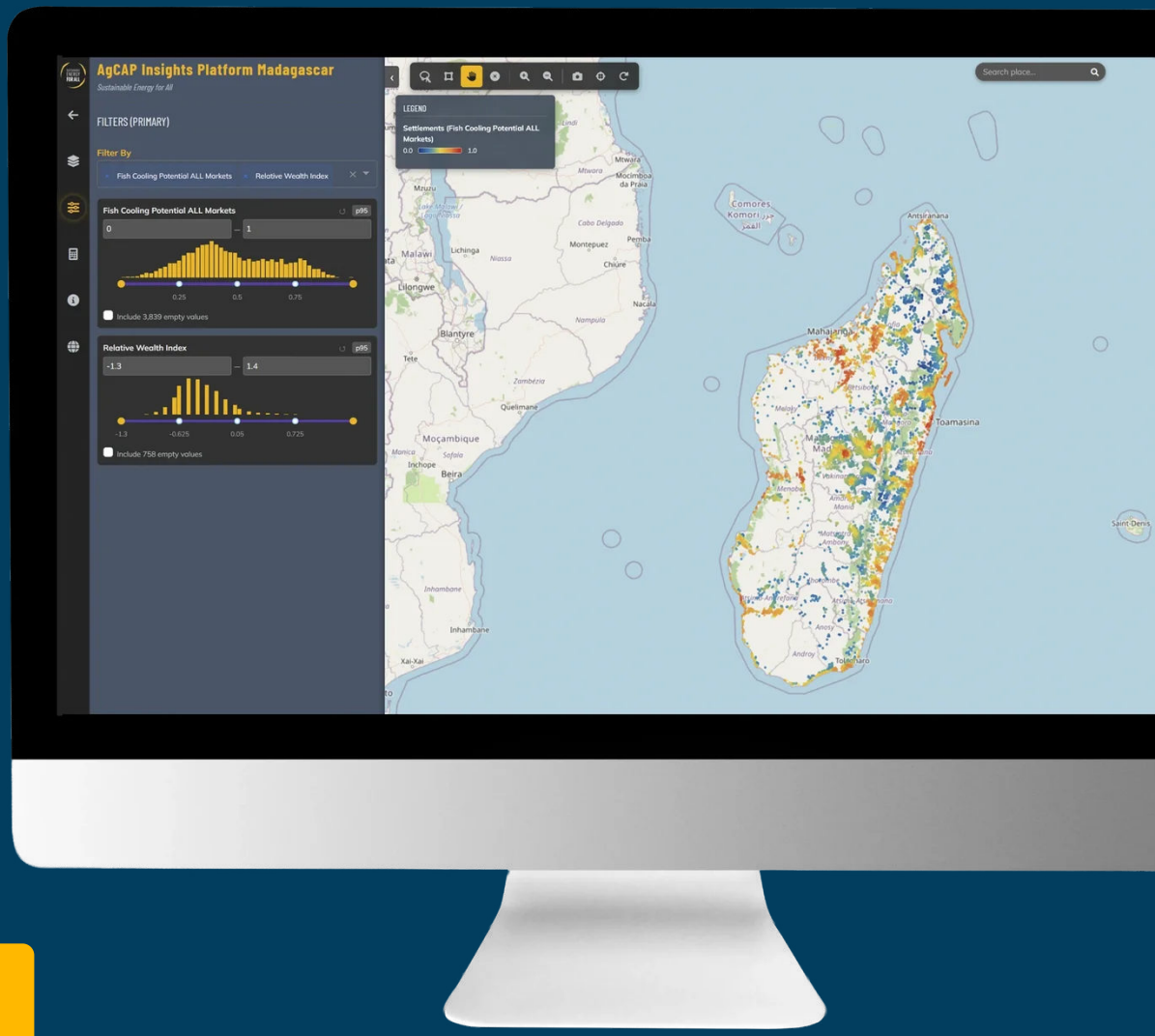
PUTTING THE DATA TO WORK:

- Building on the AgCAP results, a series of matchmaking gatherings are envisaged to define specific project opportunities. These will initially convene public sector stakeholders and development partners, donors and private sector players to turn mapped cooling potential into an investment-guiding project pipeline.

Figure 24: Potential national data platforms for publication of the AgCAP results (INSTAT, AgCAP Insights Platform, Stat SANOI, IEP)



AGCAP INSIGHTS PLATFORM



EXPLORE THE RESULTS FOR YOURSELF

www.agcap-insights.org/mdg/en

ANY QUESTIONS:

uiep@seforall.org

About SEforALL

Sustainable Energy for All has a global mandate to accelerate progress on the energy transition in emerging and developing countries. Hosted by UNOPS, we work at the intersection of energy, climate and development, partnering with governments and organizations worldwide to end energy poverty, double energy efficiency, significantly expand renewable energy and combat climate change.

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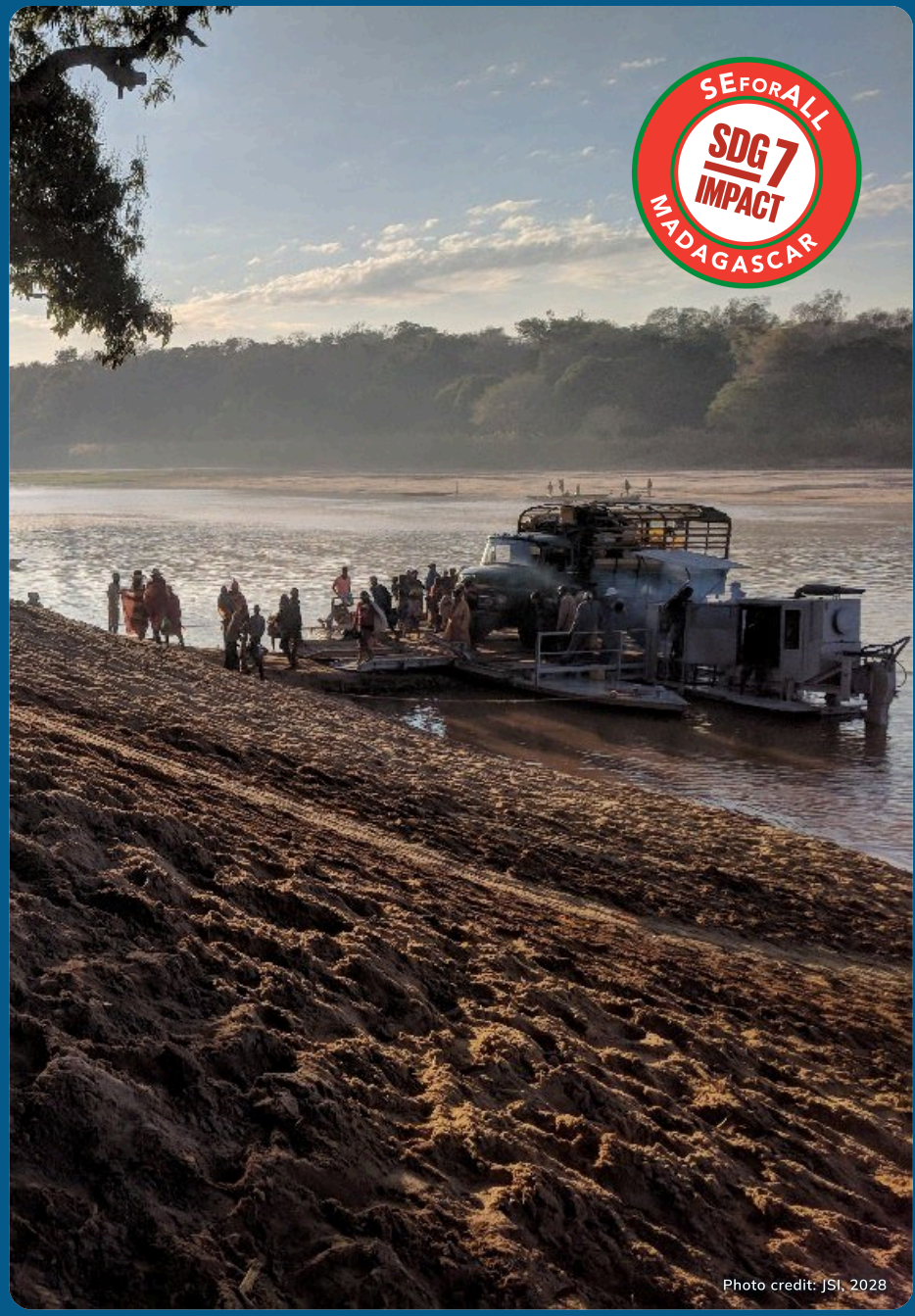

Photo credit: JSI, 2028