ZAKAWZAY

PILOT TECHNICAL LABORATORY FOR APPLIED ENVIRONMENTAL RESEARCH

VALORIZATION OF GLASS WASTE IN INSULAR TERRITORY

SAN CRISTÓBAL ISLAND – GALÁPAGOS ISLANDS – ECUADOR

TYPE OF INTERVENTION
Applied environmental research – Pilot technical infrastructure

ESTIMATED PROJECT DURATION
8 effective months of execution
(Starting from the availability of funding and commissioning of equipment)

PROJECT LEAD
Arq. Lic. José Antonio Díaz Valiente

TOTAL ESTIMATED BUDGET
USD 34.000

DATE
San Cristóbal, Galápagos – February 11, 2026

ZAKAWZAY

Contenido

1. EXECUTIVE SUMMARY

The Zakawsay – Pilot project proposes the implementation of a Pilot Technical Laboratory for Applied Environmental Research in the Valorization of Glass Waste in the Galápagos Islands, based on San Cristóbal Island, Galápagos Province, Ecuador.

The initiative responds to the need to generate local technical knowledge on the behavior, transformation, and potential reuse of discarded glass, in a context where logistical costs, energy limitations, and territorial regulations require solutions that are both adapted and technically verifiable.

Currently, although glass is theoretically considered a 100% recyclable material, in insular contexts such as the Galápagos its management faces structural constraints related to transportation, storage, classification, and the economic feasibility of transfer to the mainland (continental Ecuador). This reality highlights the need to evaluate in situ valorization alternatives that reduce dependence on external logistics and provide technical information for future public policy or private investment decisions.

The project includes the implementation of minimum operational technical infrastructure for applied research, including:

- A 36-liter programmable front-loading glass fusing kiln (6.6 kW, 220V), with digital thermal curve controller.
- A basic crushing system adapted for granulometric classification.
- Thermal and electrical monitoring instrumentation (energy consumption measurement per cycle).
- Dedicated electrical installation with industrial safety standards.
- Technical recording and experimental documentation equipment.

During eight effective months of execution —starting from the availability of funding and commissioning of equipment— progressive trials will be carried out aimed at:

- Determining fusion and annealing thermal curves adapted to locally recovered glass.
- Evaluating structural stability, bubble behavior, internal stresses, and final resistance of the transformed material.
- Measuring real energy consumption per experimental cycle under insular conditions.
- Systematizing reproducible technical protocols.

This phase does not include commercial purposes or training activities, maintaining a strictly research-oriented nature. The objective is to produce verifiable technical evidence to determine the future feasibility of glass valorization models in insular territory.

The total estimated budget amounts to USD 34,000, covering specialized electrical installation and setup, acquisition of technical equipment, insular transport of machinery, monitoring instrumentation, initial operational costs, and certified technical labor for installation and commissioning.

Zakawsay – Pilot constitutes a strategic exploratory phase aimed at establishing solid technical foundations for future initiatives of circular economy applied to glass in the Galápagos, under criteria of sustainability, traceability, and experimental rigor. The project does not involve direct intervention in the municipal solid waste management system, but rather the generation of complementary technical information.

2. INTRODUCTION

The province of Galápagos constitutes a special regime territory primarily oriented toward environmental conservation, internationally recognized by UNESCO as a Natural World Heritage Site since 1978 due to its unique biodiversity and high level of endemism (UNESCO, 1978). This condition imposes additional responsibilities in environmental management, particularly in solid waste management, considering the fragility of its ecosystems and the limited territorial carrying capacity.

Population growth and the tourism dynamics of the archipelago have increased waste generation in the inhabited islands, representing a structural challenge for decentralized autonomous municipal governments responsible for the comprehensive management of solid waste, in accordance with their competencies established under national regulations (National Competencies Council [CNC], 2012). Municipal waste management plans in Isabela, Santa Cruz, and San Cristóbal highlight the need to strengthen classification, recycling, and source reduction processes as priority strategies to reduce pressure on landfills and minimize environmental impacts (Decentralized Autonomous Government of San Cristóbal, n.d.; Decentralized Autonomous Government of Santa Cruz, n.d.; Decentralized Autonomous Government of Isabela, n.d.).

In the insular context, waste management presents technical and logistical particularities. The Organic Law of the Special Regime of the Province of Galápagos establishes a regulatory framework aimed at strict environmental protection of the territory, including provisions related to pollution prevention and the special management of waste generated within the province (LOREG, 2015). Among the applied mechanisms is the periodic transfer of recyclable inorganic waste to the mainland, which helps prevent critical accumulation but at the same time reflects a structural dependence on external transport for material valorization.

In terms of global sustainability, the 2030 Agenda for Sustainable Development recognizes in its Objective 12 the need to substantially reduce waste generation through prevention, recycling, and reuse (United Nations, 2015). Within this framework, the transition toward circular economy models is particularly relevant in insular territories where land availability and final disposal capacity are limited.

Glass represents a material with high potential within circular economy schemes, as it can be recycled indefinitely without significant loss of quality when processed under appropriate conditions (European Container Glass Federation [FEVE], 2022). However, the implementation of local transformation processes requires technical evidence to assess their energy, operational, and structural feasibility under specific conditions such as those present in the Galápagos archipelago.

Currently, there are no documented studies that analyze in an applied manner the transformation of recycled glass under insular conditions within the province. The lack of local technical data on thermal behavior, energy consumption, and post-fusion and annealing structural stability limits the possibility of designing territorial valorization alternatives based on verifiable information.

In this context, it is pertinent to develop applied environmental research aimed at generating local technical evidence on the feasibility of transforming recycled glass in San Cristóbal, aligned with the sustainability principles established under the special regime of Galápagos and the international commitments assumed by Ecuador.

3. THE PROBLEM

The province of Galápagos faces structural challenges in the comprehensive management of solid waste derived from its insular condition, its special conservation regime, and its tourism-based economic dynamics. Decentralized autonomous municipal governments exercise direct responsibility over waste management in accordance with the national regulatory framework (National Competencies Council [CNC], 2012); however, limited land availability, high logistical costs, and the need to minimize environmental impacts constrain the implementation of conventional disposal and valorization solutions.

The Organic Law of the Special Regime of the Province of Galápagos establishes an environmental protection framework that restricts pollutant discharges within the territory and includes mechanisms for the periodic transfer of recyclable inorganic waste outside the archipelago (LOREG, 2015). This system has helped prevent critical waste accumulation, but at the same time has reinforced a structural dependence on transportation to mainland Ecuador as the primary means of material valorization.

Municipal waste management plans in the inhabited islands recognize the need to strengthen reduction, classification, and recycling processes at the source (GAD San Cristóbal, n.d.; GAD Santa Cruz, n.d.; GAD Isabela, n.d.). However, these instruments are predominantly focused on operational aspects of collection and final disposal, without developing technical lines aimed at the local transformation of specific materials such as glass.

Glass, although technically recyclable indefinitely without significant loss of quality (European Container Glass Federation [FEVE], 2022), does not have documented transformation processes within the insular territory. In practice, classified material is periodically transported to the mainland, implying recurring logistical costs, energy consumption associated with transport, and the absence of locally generated technical information regarding its potential in situ valorization.

This situation constitutes a concrete technical gap: there are no applied studies in Galápagos that evaluate the energy, structural, and operational feasibility of transforming recycled glass under specific insular conditions. There is no available local data on thermal behavior in small-scale kilns, annealing curves adapted to the environment, real electrical consumption per experimental cycle, or minimum operational safety parameters for such processes.

The absence of technical evidence limits informed decision-making regarding the possible implementation of territorial circular economy models and restricts the capacity to evaluate local valorization alternatives aligned with Objective 12 of the 2030 Agenda, which promotes the substantial reduction of waste generation through prevention, recycling, and reuse (United Nations, 2015).

Consequently, the central problem does not lie exclusively in the generation of glass waste, but in the lack of verifiable technical information to determine whether it is feasible to implement processes for transforming recycled glass in San Cristóbal under criteria of environmental sustainability, operational safety, and energy efficiency. This knowledge gap sustains dependence on the current external transport model and hinders the exploration of alternatives based on experimental data.

The absence of documented experimental studies on glass transformation under insular conditions therefore constitutes the core problem that the present Zakawsay – Pilot Program for Applied Environmental Research seeks to address through applied environmental research.

4. PROJECT OBJECTIVES

4.1. General Objective

To evaluate the technical, energy, and operational feasibility of the local transformation of recycled glass on San Cristóbal Island through the implementation of a pilot technical laboratory for applied environmental research over a period of eight effective months, with the purpose of generating verifiable technical evidence to support future strategic decisions in territorial circular economy within an insular context.

4.2. Objetivos específicos

a) To analyze the thermal behavior of locally recovered recycled glass through controlled trials of crushing, fusion, and annealing, determining preliminary operational parameters adapted to insular energy and environmental conditions.

b) To measure real energy consumption per experimental cycle and estimate the operational costs associated with transformation processes, in order to evaluate their technical feasibility and energy efficiency in the context of San Cristóbal.

c) To systematically document experimental results, including structural stability, deformations, thermal failures, and minimum operational safety conditions, with the objective of developing a preliminary protocol for the transformation of recycled glass applicable to insular territory.

5. PROJECT SCOPE

The present Zakawsay – Pilot Program for Applied Environmental Research will be carried out exclusively on San Cristóbal Island, Galápagos Province, and will have a total duration of eight (8) effective months of technical operation.

The execution period will begin only once the availability of the required financial resources has been confirmed and the operational installation of the pilot laboratory has been completed, including the preparation of the physical space, the dedicated electrical installation, and the commissioning of the technical equipment. Consequently, the eight-month timeline is not counted from the project submission date, but from the formal start of experimental activities.

The scope of this phase is strictly limited to applied environmental research aimed at generating verifiable technical evidence on the local transformation of recycled glass under specific insular conditions. This stage does not include:

- Commercial production
- Product commercialization
- Supply contracts
- Industrial implementation
- Mass waste processing
- Replacement of existing mechanisms for the transfer of recyclable waste

Activities are limited to controlled experimental trials, measurement of technical variables, systematic documentation of results, and the development of a preliminary protocol adapted to the energy and operational context of San Cristóbal.

The program does not replace municipal competencies in solid waste management nor does it modify the mechanisms for the transfer of recyclable waste established under the current regulatory framework, particularly the Organic Law of the Special Regime of the Province of Galápagos (LOREG, 2015). Its nature is complementary and exploratory, aimed exclusively at evaluating the technical feasibility of potential future local valorization.

Likewise, the project does not commit to productive, commercial, or financial outcomes during this initial phase. Its nature is experimental, and results will be conditioned by the technical behavior of the material, the actual energy conditions of the territory, and the findings derived from the documented trials.

6. METHODOLOGY

The methodology of the Zakawsay – Pilot Program for Applied Environmental Research is based on a controlled experimental approach, aimed at generating verifiable technical evidence on the transformation of recycled glass under specific insular conditions.

The pilot laboratory will operate under a progressive testing scheme structured in interrelated technical phases, allowing the evaluation of material behavior from its initial preparation to the production of experimental prototypes and the measurement of energy and structural variables.

Phase 1. Material Classification and Preparation

Recovered glass will be selected based on:

- Type (containers, flat glass, others)
- Color
- Approximate thickness
- Physical condition

The absence of contaminants (metals, labels, organic residues) will be verified, and when possible, the origin of the material will be recorded. Each batch will be identified through internal coding to ensure traceability throughout the experimental process.

Estimated minimum target:

- Classification and preparation of at least 250 kg of recovered glass over eight months

Phase 2. Crushing and Granulometric Control

Controlled crushing tests will be carried out, classifying the material into differentiated granulometries (fine, medium, and coarse). The following will be evaluated:

- Fragmentation uniformity
- Presence of unwanted particles
- Material behavior during compaction

Each sample will be labeled and recorded in the technical log.

Estimated minimum target:

- Generation of at least 3 standardized granulometric categories
- Experimental processing of at least 200 kg of crushed material

Phase 3. Thermal Fusion Testing

Stepwise temperature tests will be conducted within technically appropriate ranges for recycled glass. Controlled variables will include:

- Maximum temperature reached
- Holding time
- Heating rate

- Configuration of the programmed thermal curve

During this phase, the following will be evaluated:

- Level of deformation
- Presence of bubbles
- Material homogeneity
- Surface stability
- Preliminary structural integrity

Applied thermal curves will be systematically recorded.

Estimated minimum target:

- Execution of 30 to 45 documented experimental cycles over eight months
- Evaluation of at least 5 differentiated thermal configurations

Phase 4. Annealing and Stabilization

Controlled annealing processes will be applied to reduce internal stresses in the material. The following will be documented:

- Annealing temperature
- Holding time
- Progressive cooling rate

Subsequently, potential delayed fractures, visible microcracks, and basic handling resistance will be evaluated to identify minimum structural stability parameters under experimental conditions.

Estimated minimum target:

- Comparative structural evaluation of executed cycles
- Identification of functional thermal ranges
- Post-annealing behavior recording

Phase 5. Energy Measurement and Operational Evaluation

During each experimental cycle, real energy consumption will be measured using dedicated instrumentation, recording:

- Energy consumption (kWh) per cycle
- Total process duration
- Relationship between material load and energy used

This information will allow estimation of operational feasibility under insular conditions, considering that energy is a critical variable in territories distant from the mainland.

Estimated minimum target:

- Individual energy recording in 100% of experimental cycles
- Estimation of average consumption per cycle and per kilogram processed

Technical Recording System

Throughout the process, a structured technical log will be maintained, including:

- Test code
- Date and time
- Material type and granulometry
- Applied thermal parameters
- Measured energy consumption
- Technical observations
- Photographic record
- Basic post-process structural evaluation

Results Analysis

Data obtained will be compared across tests to identify:

- Reproducible thermal configurations

- Acceptable energy ranges
- Minimum safety conditions
- Identified technical limitations

The methodological approach does not seek immediate industrial optimization, but rather to establish preliminary parameters adapted to the territorial reality of San Cristóbal.

Safety and Prevention

The methodology will be carried out under occupational risk prevention principles, using appropriate personal protective equipment, controlled ventilation, and safe handling of glass material and thermal equipment.

Final Systematization

At the end of the experimental period, a consolidated technical report will be prepared, including:

- Obtained results
- Comparative analysis
- Identified limitations
- Technical recommendations for a potential scaling phase

7. EXPECTED RESULTS

At the end of the eight effective months of experimental operation, the Zakawsay – Pilot Program will have generated verifiable technical evidence aimed at reducing the existing knowledge gap in the province of Galápagos regarding the local transformation of recycled glass under specific insular conditions.

The results of the program are structured at the following levels:

7.1. Operational Technical Infrastructure

- Implementation and commissioning of a pilot laboratory with dedicated electrical installation, minimum safety conditions, and standardized basic procedures for controlled testing.
- Structured technical recording system with material traceability and photographic documentation.

7.2. Experimental Technical Results

- Documented execution of 30 to 45 controlled experimental cycles.
- Comparative evaluation of at least 5 differentiated thermal configurations.
- Preliminary determination of functional temperature ranges and holding times.
- Identification of minimum structural stability parameters after annealing.
- Recording of material behavior according to granulometry.

7.3. Energy and Operational Results

- Measurement of real energy consumption in 100% of experimental cycles.
- Estimation of average consumption per cycle and per kilogram processed.
- Identification of critical variables affecting energy efficiency.
- Preliminary evaluation of operational feasibility under local tariff conditions.

7.4. Documentary and Methodological Results

- Structured experimental database.

- Complete technical logbook.
- Development of a preliminary transformation protocol adapted to insular conditions, including functional technical parameters and identified limitations.
- Development of experimental prototypes for technical validation purposes, not commercial use.

7.5 Strategic Outcome of the Program

The main outcome of the pilot will not be a commercial product, but the production of applied technical knowledge under real insular conditions. This evidence will help reduce uncertainty regarding the operational feasibility of transforming recycled glass in San Cristóbal and will provide objective inputs for future institutional decision-making in territorial circular economy, in alignment with Objective 12 of the 2030 Agenda (United Nations, 2015).

8. DURATION AND IMPLEMENTATION SCHEDULE

The Zakawsay – Pilot Program for Applied Environmental Research will have a total duration of eight (8) effective months of experimental operation.

The execution period will begin only upon confirmed availability of the required financial resources and the operational setup of the pilot laboratory, including the leasing of the physical space, installation of a dedicated 220V–32A electrical system, acquisition of technical equipment, and compliance with basic industrial safety conditions. Consequently, the timeline is not counted from the project submission date, but from the commissioning of the laboratory.

The preliminary implementation schedule is structured into four consecutive phases:

Phase 1 – Installation and Setup (Month 1)

- Preparation of the leased physical space
- Installation of dedicated electrical system and certified technical verification
- Delivery and installation of the kiln and complementary equipment
- Implementation of the experimental recording system
- Empty technical tests to verify operational functionality

Expected outcome: A fully operational and safe technical laboratory ready to begin testing.

Phase 2 – Initial Testing and Calibration (Months 2 and 3)

- Preliminary crushing and granulometric classification tests
- Exploratory fusion tests with small loads
- Progressive adjustment of thermal curves
- Preliminary evaluation of energy consumption
- Identification of initial operational parameters

Target: Execution of 8 to 12 initial experimental cycles.

Phase 3 – Systematic Documented Testing (Months 4, 5, and 6)

- Development of controlled tests under defined parameters
- Comparison of thermal configurations
- Systematic measurement of energy consumption in each cycle
- Evaluation of post-annealing structural stability
- Comprehensive recording through coded technical logs

Target: Cumulative execution of 20 to 30 additional documented cycles.

Phase 4 – Analysis, Systematization, and Reporting (Months 7 and 8)

- Comparative processing of experimental results

- Identification of reproducible configurations
- Development of the preliminary operational protocol
- Preparation of the final technical report
- Formulation of recommendations for a potential scaling phase

Delivery of the consolidated technical report and structured experimental database.

The schedule may be technically adjusted based on experimental findings, without altering the total duration of the program, provided that operational conditions remain within the established period..

9. BUDGET

The budget of the Zakawsay – Pilot Program is presented as an estimated reference amount of up to USD 34,000 (thirty-four thousand United States dollars), considering the logistical, technical, and energy-related particularities of the insular territory of Galápagos.

This amount covers the minimum costs required for the implementation and operation of the pilot laboratory during eight effective months of experimental execution. Due to the insular nature of the project, costs associated with mainland–insular transport, specialized technical labor, and certified technical assistance may vary depending on availability, current rates, and the need for relocation of technical personnel.

If the transfer of specialists from the mainland is required, the costs of airfare, accommodation, and food must be incorporated within the specialized technical labor category, potentially generating adjustments within the established budget ceiling.

The budget is presented as a projected maximum amount and may be technically adjusted within this limit according to duly justified operational needs.

9.1. ESTABLISHED BUDGET

	Category	General Description	Amount (USD
1	Laboratory setup and installation	8-month lease (40–60 m^2), deposit, dedicated 220V–32A electrical installation (industrial breaker, 8 AWG wiring, independent panel), technical ventilation, signage, and space conditioning	5.500
2	Main technical equipment	36L programmable front-loading glass fusing kiln (6.6 kW), refractory accessories, molds, thermal tools, and basic crushing system	6.200
3	Instrumentation and technical monitoring	Thermal and electrical measurement equipment, digital scale, energy monitoring, and complementary control systems	2.000
4	Technical recording systems	Laptop/technical tablet, digital storage, documentation camera, and basic software	1.400
5	Industrial safety	Certified thermal PPE, fire extinguisher, first aid kit, and signage	1.300
6	Insular transport and specialized logistics	Mainland–insular freight, reinforced packaging, technical handling	4.200
7	Initial operational costs (8 months)	Experimental energy consumption, supplies, preventive maintenance	2.200
8	Specialized technical labor	Certified electrical installation, assembly, calibration, safety testing, initial technical assistance	10.000
9	Technical contingency	Electrical adjustments, component replacement, operational contingencies	1.200
		TOTAL	**34.000 USD**

10. TRANSPARENCY AND MONITORING

The Zakawsay – Pilot Program will adopt principles of transparency, technical traceability, and financial accountability throughout its execution, consistent with its experimental nature and the use of resources exclusively allocated to applied environmental research.

10.1. Technical Monitoring

During the eight months of execution, a technical control system will be implemented, including:

- Coded record of each experimental test
- Technical log updated per cycle
- Digital archive of energy data and thermal parameters
- Systematic photographic record of results
- Periodic digital backup of the experimental database

Results will be organized in a structured manner to allow subsequent technical review and methodological verification.

10.2. Financial Monitoring

The use of allocated resources will be documented through:

- Record of acquisitions with valid invoices or receipts
- Identification of the corresponding budget category
- Internal record of financial execution
- Organized digital archive of accounting support documentation

The budget will be executed within the estimated maximum limit, prioritizing efficiency in resource use and avoiding unjustified deviations.

10.3. Progress Reports

The preparation of the following reports is planned:

- An interim technical report (approximately in month 4), describing methodological progress and adjustments made
- A final technical report at the end of the eight effective months of operation

These reports will include experimental progress, preliminary analyses, and overall budget execution.

10.4. Publication of Results

Given the research nature of the program, the final technical report may be published in digital format, with the aim of:

- Contributing to local technical knowledge
- Facilitating institutional analysis
- Serving as input for future decision-making in territorial circular economy

10.5. Principle of Responsibility

The program does not commit to commercial results or profits during this phase. Its objective is to generate verifiable technical information. All investment will be exclusively directed toward achieving the experimental objectives defined in this document.

11. FUTURE SUSTAINABILITY PROJECTION (CONDITIONAL ON RESULTS)

The present Zakawsay – Pilot Program for Applied Environmental Research is strictly experimental in nature and does not include commercial activities during its execution. However, if the technical results obtained demonstrate operational, energy, and structural feasibility under insular conditions, a subsequent phase oriented toward the progressive scaling of the model may be evaluated.

Any potential continuation will be conditioned on the achievement of reproducible results, a favorable energy evaluation in terms of efficiency, compliance with minimum operational safety conditions, and analysis of the current regulatory framework in the province of Galápagos.

In a scenario of verified feasibility, alternatives may be explored such as the development of controlled micro-scale local valorization processes, the production of demonstrative prototypes for technical purposes, collaboration with institutional or private stakeholders interested in territorial circular economy models, and the pursuit of complementary funding to expand installed technical capacity.

However, any expansion decision will require additional studies, specific regulatory evaluation, and an independent financial sustainability analysis. The present program does not assume or guarantee the automatic implementation of a subsequent productive phase. Its purpose is to reduce technical uncertainty through the generation of verifiable evidence that supports future decisions based on real data obtained within the insular territory.

12. REFERENCES

National Assembly of Ecuador.. (2015). *Ley Orgánica de Régimen Especial de la Provincia de Galápagos*. Registro Oficial Segundo Suplemento No. 11, 11 de junio de 2015. https://www.galapagos.gob.ec/wp-content/uploads/downloads/2017/01/Ley_organica_de_regimen_especial_de_la_provincia_de_galapagos_ro_2do_s_11_06_2015.pdf

Consejo Nacional de Competencias (CNC). (2012). *Resolución sobre competencias de los gobiernos autónomos descentralizados en gestión de residuos sólidos*. Quito, Ecuador.

European Container Glass Federation (FEVE). (2022). *Glass recycling facts*. https://feve.org/about-glass/glass-recycling/

Gobierno Autónomo Descentralizado de San Cristóbal, Santa Cruz, Isabela (s.f.). *Plan de manejo de desechos sólidos*, https://cursos.gobiernogalapagos.gob.ec/moodle/pluginfile.php/39/mod_folder/content/0/Manejo_desechos_Isabela.pdf?forcedownload=1

Naciones Unidas. (2015). *Transformar nuestro mundo: la Agenda 2030 para el Desarrollo Sostenible*. https://sdgs.un.org/2030agenda

UNESCO. (1978). *Galápagos Islands – World Heritage List*. https://whc.unesco.org/en/list/1/