

**NEXT-GEN SOLAR
OASIS: EMPOWERING
ZENÚ HERITAGE
THROUGH CLEAN
ENERGY, WATER
SOVEREIGNTY, AND
RESILIENCE**



ECOCEANOS
FOUNDATION

2026

1. RESUMEN

The Ecoceanos Foundation has been working with the Zenú indigenous people in Colombia since 2021, on energy transition initiatives with a focus on rights, gender and food security. Between 2024 and 2025, with funding from the Honnold Foundation, 20 solar panels were installed to power a hydraulic pump capable of extracting water from an aquifer located 45 meters away and provide irrigation to community food production plots for about 300 Zenú indigenous families.

The results have been overwhelming: production went from 3 to 15 tons per month (five times more), and a sustainability strategy was designed in which part of what is produced is managed by the indigenous secretariat and sold to the community at a fifth of the market price, generating funds to maintain the photovoltaic system and the aqueduct for at least 30 years.

However, the water extracted from the deep well is also used for human consumption and the current infrastructure does not have a drinking water treatment system. This exposes children, young people and women to water-borne diseases, such as diarrhoea and leptospirosis in children, and toxoplasmosis in pregnant women, with effects on the health of the mother and the newborn.

This preliminary study supports the need to incorporate a reverse osmosis water treatment plant with the capacity to produce at least 10,000 liters of drinking water per day, describes its preliminary technical scope, its articulation with the existing infrastructure, the sustainability scheme, the work plan, the risks and the monitoring indicators.

Executing entity	Ecoceanos Foundation
Territory	Zenú Indigenous Reservation, Colombia
Beneficiaries	≈ 300 Zenú indigenous families; priority in children, youth, women and pregnant women
Existing infrastructure	20 solar panels, hydraulic pump, deep well (aquifer at 45 m), aqueduct and community irrigation plots
Proposed Object	Reverse osmosis water treatment plant, minimum 10,000 L/day, with storage and distribution points
Proposed duration	12 months (6 months of execution and 6 months of accompaniment and monitoring)



2. BACKGROUND

2.1 The Zenú people

The Zenú people live mainly in the Colombian Caribbean region, in the departments of Córdoba and Sucre, and also in some areas of the Urabá region of Antioquia. Their ancestral territory, located on the Caribbean coast, has been significantly reduced by colonization processes and development projects. The largest Zenú settlement center is located in the San Andrés de Sotavento reservation, in Córdoba.

As documented in the 2021 work of Ecoceanos, the reservation faces a lack of basic needs, including access to electricity, essential to access social, professional, and cultural opportunities. There, climate alterations (droughts and periods of extreme rainfall) reduce the availability of water and food and increase diseases. These impacts are not homogeneous: the most vulnerable sectors are women, children, and the elderly. Despite pressures, such as the illegal economy, the community generates forms of resistance based on tradition and the collective, and women artisans play a central role in community organization and in the daily use of resources.

2.2 Ecoceanos' previous experience in the territory

Between 2024 and 2025, the Ecoceanos Foundation, funded by the Honnold Foundation, implemented a solar energy project to ensure food security for approximately 300 Zenú indigenous families. The initiative included the installation of 20 solar panels that drive a hydraulic pump to extract water from an aquifer located 45 meters deep and distribute it in community plots. Thanks to constant irrigation, agricultural production increased from 3 to 15 tons per month. To ensure long-term sustainability, the Indigenous Secretariat manages the marketing of part of the harvest, selling it to the community at

only one-fifth of its market price. This scheme generates income for the maintenance of the photovoltaic and aqueduct system for an estimated period of 30 years, especially benefiting children, young people and women. Although the water extracted is used for both crops and human consumption, the current infrastructure lacks drinking water. Therefore, it is necessary to incorporate a reverse osmosis treatment plant with a capacity of 10,000 liters per day. This will prevent diseases such as leptospirosis, diarrhea in childhood and toxoplasmosis in pregnant women, safeguarding the health of the entire community.

Indicator	Before	After	Variation
Food production	3 t/mes	15 t/m	5 times (+400%)
Families with food security supported	—	≈ 300	—
Pickup depth	—	45 m (aquifer)	—
Maintenance Horizon Financed	—	≥ 30 years old	—

2.3 Sustainability strategy implemented

A percentage of the food produced is taken and managed by the indigenous secretariat for marketing and to improve the economic conditions of the community. The food is sold to the community itself at 1/5 of the market price, so that access to food is improved and, at the same time, the necessary funds are guaranteed for the maintenance of the photovoltaic system and the

aqueduct for at least 30 years. The most impacted beneficiaries have been the children, young people and women of the reservation.



Figure 1. Solar-Irrigated Lettuce Crops in the Zenú Community Plot

3. DESCRIPTION OF THE PROBLEM AND NEED FOR INTERVENTION IN PUBLIC HEALTH AND WATER INFRASTRUCTURE

3.1 Diagnosis of the current water situation in the zenú indigenous reservation

The execution of the solar energy project carried out by the Ecoceanos Foundation, with funding from the Honnold Foundation between 2024 and 2025, represented an unprecedented technical, social and economic advance for the Zenú indigenous community of San Andrés de Sotavento. The installation of a photovoltaic array composed of 20 solar panels made it possible to activate a submersible hydraulic pump capable of extracting groundwater from a deep aquifer located 45 meters deep. This infrastructure immediately solved the problem of water scarcity that limited community agricultural production, managing to quintuple the yield of the plots by going

from 3 to 15 tons of food per month, directly benefiting approximately 300 families.

However, the productive success and availability of water resources have revealed a critical structural paradox in the reservation: the current infrastructure was conceived primarily as a collection and pumping system for agricultural irrigation and mass storage, it completely lacks a component or plant for purification and physicochemical and microbiological treatment.

In the daily practice of the community, the water extracted from the deep well at 45 meters is not only channeled to the canals and irrigation itineraries of the crops, but is also captured, transported and stored by the community members to meet the essential domestic needs of direct human consumption, food preparation, personal hygiene and hygiene at home. Children, young people, pregnant women and older adults depend on this same source to quench their thirst and cook their food on a daily basis.

As it has not been subjected to any standardised filtration, disinfection or purification process that guarantees compliance with water quality standards for human consumption, the liquid that reaches homes retains intact the loads of dissolved micropollutants, heavy minerals, sediments, organic matter and, fundamentally, microbiological pathogens (bacteria, viruses, parasites and spores). Therefore, the direct use of this untreated water resource represents a permanent health risk and of very high severity for the collective health of the population.



Figure 2. Indigenous Woman Carrying Water Containers, Highlighting the Unpaid Care Burden in the Community

3.2 Detailed assessment of the effects on public health and social welfare

The chronic lack of access to safe drinking water within the indigenous territory triggers a range of infectious and contagious pathologies and socioeconomic repercussions that hit the most vulnerable sectors of the Zenú social structure particularly hard. Sustained exposure to non-potable water has established itself as the main social determinant of the disease within the 300 beneficiary families.

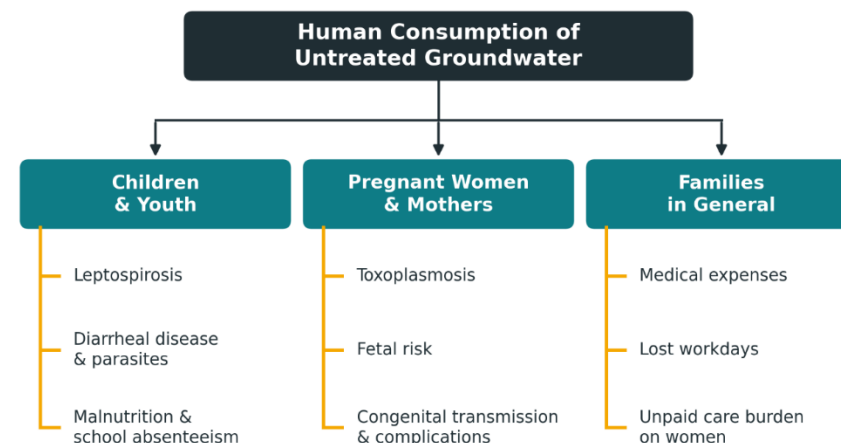


Figure 3. Health and Socioeconomic Impacts of Untreated Groundwater Consumption in the Zenú Community

A. Epidemiological Impact on Children and Youth (Children and Youth)

Children and young people from the Zenú reservation constitute the population group with the highest degree of exposure and fragility to the ingestion of contaminated water. Epidemiologically, the continued ingestion of pathogens present in the water source translates into two dominant clinical conditions:

1. **Leptospirosis:** This bacterial zoonosis, usually transmitted by the contamination of water sources with urine from rodents or farm animals that orbit wells and aquifers not adequately protected on the surface, finds in untreated water a direct vector of transmission. In children, leptospirosis generates acute fever, severe muscle pain, jaundice, kidney and liver compromise that, if not treated in time, puts the lives of minors at imminent risk.

2. **Acute Diarrheal Disease (ADD) and Parasitic Infections:** The presence of enteropathogenic bacteria (such as *Escherichia coli*, *Salmonella spp.* and *Shigella spp.*) and protozoa (*Giardia lamblia*, *Entamoeba histolytica*) in the water produces recurrent episodes of profuse diarrhea and vomiting. These repetitive episodes lead rapidly to **severe dehydration and intestinal malabsorption of nutrients**.

In turn, the recurrence of acute diarrheal diseases acts as a primary driver of **chronic child malnutrition** and delayed pondostatureal development of Zenú children. From an educational perspective, constant episodes of morbidity cause high rates of **school absenteeism**, interrupting the formative process of childhood and perpetuating intergenerational circles of poverty and social vulnerability. In situations of greater clinical complication, families are forced to transfer children to health centers or hospitals of greater complexity in neighboring municipalities, adding anxiety and emotional exhaustion.

B. Impact on Maternal and Child Health and Pregnant Women

Pregnant women represent a group of special biological vulnerability to water-borne infections. The most alarming risk documented in the territory is exposure to the parasite *Toxoplasma gondii*, which causes **toxoplasmosis**.

When a pregnant woman consumes unpurified water or food washed with water contaminated by cysts of the parasite, she is exposed to a primary infection that can cross the placental barrier. **Congenital toxoplasmosis** directly compromises the health and systemic development of the fetus and newborn, and can cause:

1. Stillbirth or miscarriages.

2. Severe congenital malformations, with emphasis on hydrocephalus, intracranial calcifications, and microcephaly.
3. Irreversible damage to the baby's retina and central nervous system, resulting in blindness, deafness, seizures, or permanent cognitive impairment.

The general state of malnutrition or anemia derived from intestinal infections associated with poor quality water degrades the overall health of the pregnant mother, substantially increasing the chances of premature births and low birth weight.

C. Socioeconomic Repercussions and Care Burden for Families

The consequences of the lack of drinking water go beyond the strictly medical level and have a devastating impact on the household economy:

1. **Erosion of Family Income:** Families in the reservation must allocate scarce economic resources to pay for medicines, rehydration supplies, laboratory tests and transportation costs to health centers to care for their patients.
2. **Loss of Labor Productivity:** The need to care for the sick or the personal suffering of adults results in the recurrent loss of days of agricultural or artisanal work, reducing the household's income-generating capacity.
3. **Inequitable Overload of Care Work:** Culturally and socially, the care of sick children, the elderly, and convalescents falls primarily on the women of the community. This overload of unpaid work absorbs the available time of Zenú women, severely limiting their

opportunities to participate in productive activities, training spaces, artisanal enterprises, or community leadership roles.

3.3 Technical analysis and solution proposal: reverse osmosis purification and multi-barrier approach

Faced with this serious public health problem, it is essential to complement the water infrastructure of the reserve with the installation and integration of a Reverse Osmosis (RO) Water Treatment Plant capable of processing and delivering a minimum flow of 10,000 liters per day of high-quality purified water for direct human consumption.

A. Technical Basis of Reverse Osmosis

Reverse osmosis technology works by passing water through semipermeable membranes with tiny pores (around 0.0001 microns) under pressure. This process constitutes a highly effective barrier against dissolved contaminants, salts, heavy salts, viruses, bacteria, protozoa and microparasites, retaining up to 99% of the microbiological and physicochemical impurities in the water.

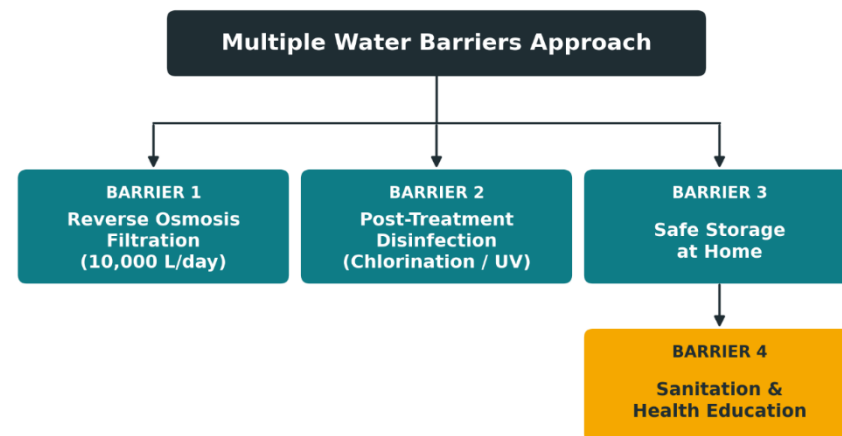


Figure 4. Comprehensive Water Quality Strategy: From Reverse Osmosis to Health Education

B. The Comprehensive Multi-Barrier Approach

Despite the high technical effectiveness of reverse osmosis, scientific evidence and experience in socio-technical projects show that the installation of the machine alone does not automatically eradicate communicable diseases if a multi-barrier approach is not adopted. For this reason, the infrastructure improvement project proposes a holistic strategy articulated in four operational axes:

1. **Advanced Primary Treatment (Reverse Osmosis):** Removal of dissolved contaminants, solids and microorganisms at the aquifer catchment point.
2. **Residual Subsequent Disinfection:** Application of a secondary disinfection system (such as controlled chlorination or ultraviolet light

disinfection) that prevents bacterial recontamination of purified water during transit or transport.

3. **Hygienic Storage and Handling at Home:** Provision and implementation of clean, airtight and safe containers for water collection, avoiding contact with dirty hands or uncovered containers inside homes.
4. **Basic Sanitation, Zoonotic Control and Health Education:** Comprehensive community accompaniment through health education workshops, proper hand washing, safe handling of excreta, hygienic management of domestic/livestock animals and continuous epidemiological monitoring.

3.4 Affected population and prioritization of beneficiaries

The affected population and direct beneficiary of this intervention includes the 300 Zenú indigenous families that are part of the reserve's water system network.

Within this universal coverage, the project establishes a focused prioritization on the most vulnerable population groups:

1. **Children and Youth:** As they are the most likely to suffer from dehydration, stunting and school absenteeism due to diarrhea and parasitosis, the provision of 10,000 L/day of pure water guarantees their healthy physical and cognitive development.
2. **Pregnant and Lactating Women:** Prioritized to radically eliminate the risk of toxoplasmosis and water pathologies that compromise intrauterine life or maternal-neonatal health.

3. **Women Artisans and Leaders:** By drastically reducing cases of illness in the home, Zenú women are freed from the overwhelming burden of informal health care, allowing them to redirect their time and energy towards productive agricultural activities, artisanal manufacturing, and community governance.

The integration of the 10,000-liter daily reverse osmosis treatment plant, supported by the 20-panel solar infrastructure installed by Ecoceanos and the Honnold Foundation, will not only close the gap in access to drinking water, but will also definitively consolidate food security, public health and dignity of the Zenú indigenous community.

4. JUSTIFICATION

The installation of the reverse osmosis water treatment plant represents the strategic link that completes the value chain of the social and technical investment already executed in the Zenú indigenous reservation. While the first phase of the project – developed by the Ecoceanos Foundation with funding from the Honnold Foundation – managed to resolve the amount of available water and food security through the solar pumping system at a depth of 45 meters, this proposal addresses and definitively resolves the quality of the water resource intended for human consumption.

The relevance, viability and transformative impact of this intervention are based on the following six fundamental pillars:

I. Continuity and Efficiency of Prior Investment

The project makes the most of the physical, technical, and social infrastructure previously consolidated in the territory. Currently, the reservation already has

the deep well fully operational, the array of photovoltaic panels, the storage and distribution network, as well as an organized community structure with proven territorial management capacity. Therefore, the marginal cost of integrating the reverse osmosis purification module is substantially lower than that of building an independent aqueduct system from scratch, optimizing every dollar invested and guaranteeing a high cost-benefit ratio.

II. Comprehensive Health Protection in Vulnerable Populations

The direct consumption of groundwater without microbiological treatment represents the primary cause of serious pathologies in the community, such as leptospirosis, parasitic infections and acute diarrheal disease (ADD) in children and young people, as well as toxoplasmosis in pregnant women. Eradicating these health risks through the delivery of 10,000 liters of purified water per day generates a direct and immediate impact on public health, community well-being and child development, drastically reducing hospitalization rates, associated malnutrition and school absenteeism.

III. Economic Model and Demonstrated Financial Sustainability

Unlike welfare projects that collapse due to lack of operational funds, the Zenú community has demonstrated the effectiveness of its economic self-management mechanism. Through the social commercialization of agricultural food at one-fifth () of its commercial market price, a reserve fund administered by the Indigenous Secretariat is collected for the maintenance of the water and solar system for a horizon of 30 years. This same financial sustainability scheme can 1/5be expanded in a scalable manner to comfortably cover the

costs of operation, replacement of filters, and maintenance of the reverse osmosis plant.

IV. Human Rights and Gender Equality Approach

Access to drinking water is not a privilege, but a fundamental and inalienable human right. In the social dynamics of the reservation, Zenú indigenous women suffer disproportionately from the scarcity and poor quality of water, as they historically assume the overload of caring for the sick at home and collecting the resource. Providing safe water dignifies women's work, promotes gender equity, and frees up valuable time for them to lead productive, artisanal and territorial governance initiatives.

V. Direct Contribution to the Sustainable Development Goals (SDGs)

The proposal is comprehensively aligned with the United Nations 2030 Agenda, simultaneously impacting six global goals:

1. **SDG 2 (Zero Hunger):** By consolidating agricultural production with quality water for washing and processing food.
2. **SDG 3 (Good Health and Well-being):** By drastically reducing mortality and morbidity from water-borne diseases.
3. **SDG 5 (Gender Equality):** By empowering indigenous women and reducing the unpaid burden of care work.
4. **SDG 6 (Clean Water and Sanitation):** By ensuring equitable and universal access to safe and affordable drinking water.
5. **SDG 7 (Affordable and Clean Energy):** By operating the system with clean and renewable sources.

6. **SDG 13 (Climate Action):** By mitigating the carbon footprint and strengthening community resilience to climate change.

VI. Consolidating the Just Energy Transition with Clean Energy

Faithful to the vision of the Ecoceanos Foundation, the treatment plant will operate coupled to the photovoltaic energy system, avoiding the emission of greenhouse gases and dependence on fossil fuels. This design reaffirms the commitment to a just and sovereign energy transition, demonstrating that clean technology can and should be the engine to simultaneously solve the challenges of health, food and the environment in Colombia's indigenous territories.



Figure 5. Drip Irrigation System Installed in Zenú Community Farming Plots

5. OBJECTIVES

5.1 General objective

Guarantee access to safe water for human consumption to the approximately 300 Zenú indigenous families of the San Andrés de Sotavento reservation, through the implementation of a reverse osmosis treatment plant with a minimum capacity of 10,000 liters per day, integrated into the existing solar pumping system.

5.2 Specific objectives

- Characterize the physicochemical and microbiological quality of the well water to define the final treatment design.
- Design, supply and install the reverse osmosis plant and its complementary works (pre-treatment, post-treatment, storage and distribution points).
- Verify and, if necessary, expand the solar generation and storage capacity to meet the plant's energy demand.
- Train community operators, with the participation of women and youth, and form a water committee to manage the plant.

- Integrate the operation and maintenance costs of the plant into the sustainability strategy managed by the indigenous secretariat.
- Develop education activities in hygiene, safe water management and disease prevention, and monitor water quality and health indicators.



Design observation

With 10,000 L/day, the supply is equivalent to about 33 liters per family. If the average household is five people (data to be confirmed in the field), it is about 7 L per person per day, enough for drinking and cooking, but not for all domestic uses. It is recommended to design the plant in a modular and expandable way, and to use this water exclusively for human consumption (drinking and food preparation).

6. Scope and technical description of the solution

This section presents a preliminary sizing. The final parameters will be confirmed with the water characterization, the field survey and the offers of suppliers.

6.1 Preliminary sizing

Parameter	Reference value
Minimum production of treated water	10,000 L/day (10 m ³ /day)
Hours of operation (assumption)	8 to 10 hours/day, preferably at times of maximum solar irradiation
Equivalent product flow rate	≈ 1.0 to 1.25 m ³ /hr
Typical system recovery	50% to 70% (depending on feedwater quality)
Required raw water flow rate	≈ 1,4 a 2,5 m ³ /h
Reference energy consumption	≈ 1 to 3 kWh per m ³ produced (≈ 10 to 30 kWh/day); to be validated with the supplier
≈ 1 to 3 kWh per m ³ produced (≈ 10 to 30 kWh/day); to be validated with the supplier	≈ 33 L/family/day (10,000 L ÷ 300 families)

6.2 Proposed treatment scheme

N.º	Stage	Function
1	Raw water collection and storage	Water intake from the existing system and regulation tank.
2	Pre-treatment	Sediment filtration, multimedia filter and activated carbon; antifouling dosing if analysis requires it; cartridge filters.
3	Reverse osmosis	High-pressure pump and membranes that remove dissolved salts, metals and a large part of contaminants and microorganisms.
4	After-treatment and disinfection	Disinfection (ultraviolet light and/or residual chlorination) and pH adjustment or remineralization if required.
5	Treated water storage	Tanks for exclusive use, in sanitary material and protected from light and pollution.
6	Distribution	Community supply points (and, depending on the design, connection to schools or health centres), with sanitary taps.
7	Monitoring and control	Flow, conductivity and pressure meters; operation and maintenance record.

6.3 Solar System Integration

The operational success and economic viability of the new reverse osmosis water treatment plant depend on a harmonious integration with the previous PV generation infrastructure. Before starting the purchase or acquisition of the new filtration equipment and components, it is essential to carry out a detailed technical diagnosis on site. This study will accurately assess the actual operational capacity and degradation status of the existing solar infrastructure, installed in the initial phase of the project for pumping water to a depth of 45 meters.

The central purpose of this energy audit is to determine whether the photovoltaic array composed of the 20 current solar panels, together with their respective battery storage bank and charge controllers, has sufficient power margin to meet the new thermal and electrical requirements. The technical goal is to verify whether the existing system can simultaneously feed, and without voltage drops, both the submersible deep well extraction pump and the high-pressure subsystems of the reverse osmosis purification plant.

In the event that the energy balance reveals an insufficient load, restriction in peak power or an inability to respond at times of high hydrological demand, the engineering plan foresees a modular expansion strategy. This design contemplates the projected expansion of the photovoltaic field through the addition of new solar modules and/or the scaling of the battery bank. In this way, it will be guaranteed that the supplementary electricity demand of the drinking water treatment plant is absorbed comfortably, protecting community agricultural irrigation routines and avoiding unforeseen cuts in food production.

For reasons of hydraulic efficiency and financial profitability, the operating scheme has been structured to operate mainly during the daytime window of greatest irradiance. It has been established that operation during the hours of maximum solar radiation constitutes the most economical and sustainable technical alternative for the indigenous reservation.

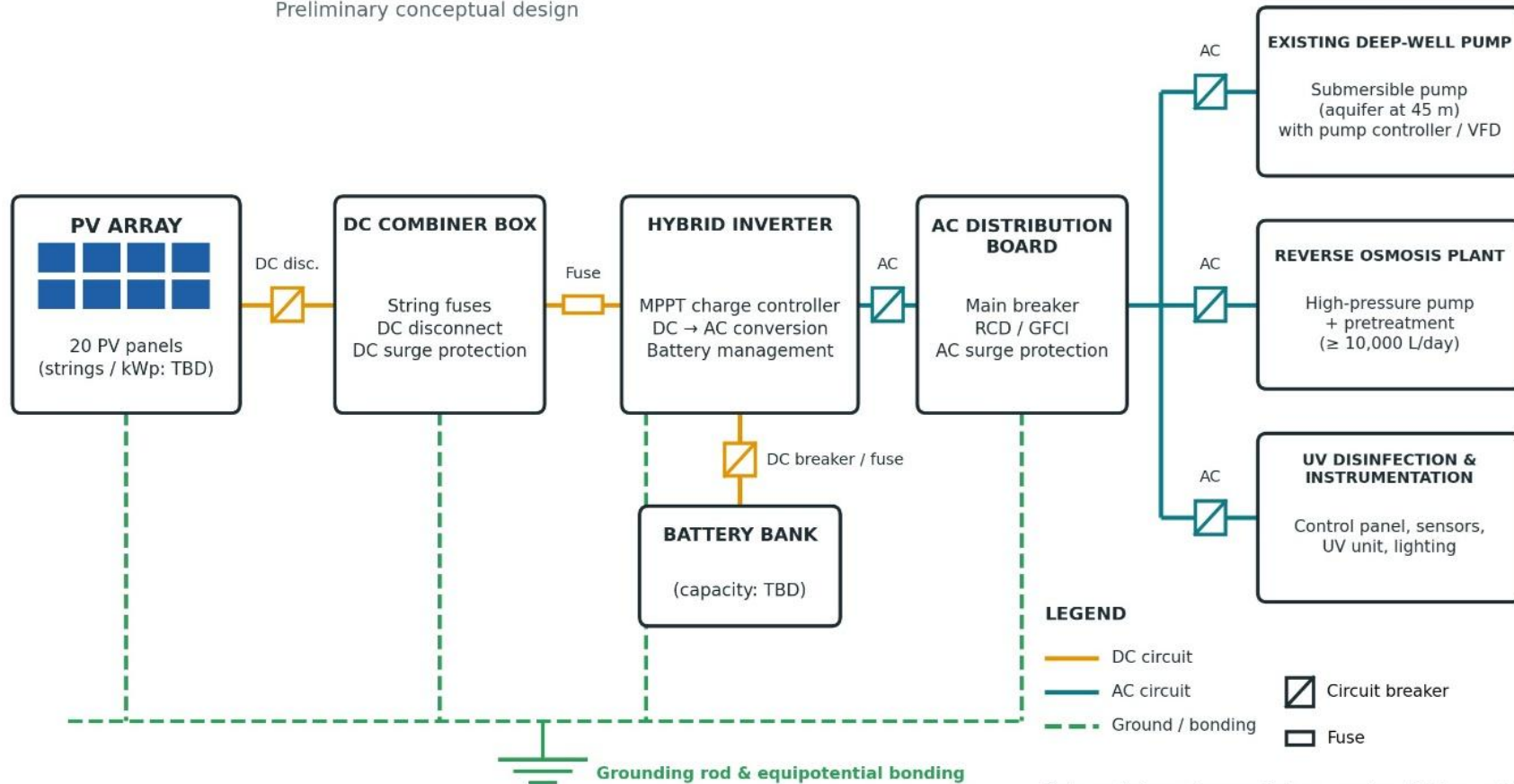
By coupling and energizing the treatment plant directly with instantaneous solar generation during the day, electrical current will flow from the panels to the motors without requiring deep discharge cycles in the batteries. This direct consumption mode dramatically reduces reliance on chemical storage, minimizing wear and tear on the storage bank, extending its operational life, and substantially lowering both the initial investment costs of the project and future expenses for battery replacement and maintenance.



Figure 6. Existing Solar Panel Infrastructure Under Evaluation for RO Plant Integration

Single-Line Diagram: Solar PV System Integrated with Reverse Osmosis Plant

Preliminary conceptual design



Note: preliminary diagram. Ratings, number of strings, cable sizing and protection settings (TBD) will be defined in the detailed engineering design.

6.4 Handling Rejection (Concentrated)

The purification process by reverse osmosis inevitably generates a stream of reject or concentrated water, which contains a higher density of salts and total dissolved solids retained by the membranes. To guarantee the environmental sustainability of the project and avoid negative impacts on the environment of the reservation, a safe disposal protocol will be established based on the initial physicochemical characterization of the water and strict compliance with the applicable environmental regulations.

Under no circumstances will the indiscriminate discharge of this flow be allowed into surface water sources or agricultural soils sensitive to salinization. Instead, the technical team will evaluate alternatives for circular use and impact with specialized technical endorsement, such as:

- Controlled reuse for cleaning, disinfection and washing of community infrastructure.
- Evaluation of the use in targeted irrigation of plant species or crops with high tolerance to salinity.
- Infiltration conducted in technically delimited areas that do not put at risk the vegetation layer or the recharge of the aquifer.

6.5 Pre-Employment Studies and Verifications

In order to ensure an efficient execution, free of cost overruns and technically supported, a rigorous phase of field diagnostics will be carried out before proceeding with the acquisition of the plant or the contracting of the civil works:

- **Physicochemical and Microbiological Analysis of Well Water:** Representative samples will be taken at the collection point at a depth of 45 meters to be analyzed by a certified and accredited laboratory. The characterization will determine the exact concentration of total dissolved solids (TDS), hardness, iron, manganese, nitrates, arsenic and other heavy metals, as well as microbiological indicators such as total coliforms and *E. coli*.
- **Water Verification (Flow and Well Levels):** Pumping tests will be carried out to monitor the dynamic flow, static level and recharge capacity of the aquifer, ensuring that the supplementary extraction required by the treatment plant does not compromise the availability of water for agricultural irrigation or generate overexploitation of the aquifer.
- **Energy Balance of the Existing Solar System:** The photovoltaic production of the array of 20 solar panels and the state of battery storage will be audited to accurately size the necessary expansions in generation or accumulation, guaranteeing the simultaneous operation of pumping and purification.
- **Site Survey and Civil Works Design:** The exact location of the treatment plant will be defined, including the space for the protection booth, the safety enclosure, the foundation, the drainage system for reject water and the purified water distribution connections.
- **Community Census and Characterization of Beneficiaries:** An updated registry of the 300 families dependent on the system will be prepared to record the number of members per household and identify critical priority delivery points, prioritizing educational centers, households with pregnant and lactating mothers, and children in early childhood.

- **Final Assessment of Technological Alternatives:** Although reverse osmosis remains the reference solution in the face of high salinity scenarios or the presence of complex dissolved contaminants, if the laboratory demonstrates low salinity, the feasibility of implementing an ultrafiltration train complemented with disinfection (UV or chlorination) will be evaluated, as a technical alternative with a lower investment and maintenance cost.

7. RISK ANALYSIS

Risk	Level	Mitigation measure
Raw water quality different from expected (salinity, iron, hardness)	Medium	Previous characterization and design of the pretreatment based on results.
Insufficient solar power for the new load	Medium	Previous energy balance; photovoltaic expansion and operation during daylight hours.
Lack of resources to replace membranes and filters	High	Incorporate costs into the sustainability scheme; specific fund; maintenance contract.
Poor operation or lack of training	Medium	Trained operators, illustrated manuals and 6-month technical support.
Subsequent contamination in storage or at home	Medium	Waste disinfection, sanitary tanks, education in safe water management.
Impact on the aquifer or irrigation	Low	Pumping tests, level monitoring and use of water for human consumption with controlled volumes.
Vandalism or theft of equipment	Medium	Enclosure, community surveillance and inventory registration.

Risk	Level	Mitigation measure
Logistical delays and weather conditions	Medium	Schedule with slack; early purchases; planning for the rainy season.
Community tensions or disagreements over water use	Medium	Prior consultation, clear rules and a committee with broad representation.

8. CONCLUSIONS

Based on the technical, social and epidemiological diagnosis carried out in the territory, it is concluded that:

1. **Clear Identification of a Critical Public Health Need:** It has been fully documented that water extracted from the aquifer at a depth of 45 meters is used for human consumption without any prior purification process. This situation exposes the inhabitants to severe health risks, manifested in recurrent episodes of leptospirosis, acute diarrheal disease (ADD) and malnutrition in childhood, as well as the latent danger of toxoplasmosis in pregnant women.
2. **Technical Feasibility and Use of Installed Infrastructure:** The proposed solution consisting of the installation of a reverse osmosis treatment plant with the capacity to produce at least 10,000 liters per day of purified water powered by solar energy is technically feasible. This proposal does not start from scratch, but is based on the previous infrastructure (well, photovoltaic array of 20 panels, networks) and on

the organizational operational capacities already developed in the community, which minimizes the marginal costs of implementation.

3. **Guarantee of Economic Sustainability:** The financial viability for the continued operation, replacement of inputs, and preventive maintenance of the water treatment plant can be ensured through the expansion of the existing economic model. This agricultural marketing mechanism at one-fifth () of its commercial price, transparently managed by the Indigenous Secretariat, provides a solid and self-managed financial platform for the long-term sustainability of the water system. 1/5.



Figure 8. Indigenous Secretariat and Community Meeting Managing the Monthly Maintenance Fund for the Existing Energy System

9. RECOMMENDATIONS

In order to proceed with the safe, efficient and concerted implementation of this second phase, the following strategic recommendations were made:

1. **Immediate Realization of Technical Diagnoses:** Advance as a priority with the physicochemical and microbiological characterization of the well water in an accredited laboratory, while executing the detailed energy balance of the solar system. These inputs are essential to ratify or adjust the design of the plant and define whether the expansion of the photovoltaic field or the battery bank is required.
2. **Consultation and Governance Protocols with Traditional Authorities:** Establish formal spaces for dialogue and prior consultation with the Indigenous Secretariat and the Cabildo Mayor to agree in a concerted manner on the scope of the project, the physical location of the civil works, the rules of operation and the quotas for the redistribution of drinking water.
3. **Modular and Scalable Engineering Design:** Project the construction of the water treatment plant under a modular architecture. This will facilitate future expansions of processing and storage capacity as the demand of the population increases, without the need to redesign the base infrastructure.
4. **Holistic Strategy with Health Education and Health Indicators:** Accompany the physical installation of the technology with a continuous technical training program for local operators, education

workshops on domestic hygiene and the handling of safe containers. It is also recommended to agree on a follow-up system together with health entities to monitor the reduction in cases of diarrhea, leptospirosis and toxoplasmosis in the reservation.

5. Complementary Financing Management: Leverage the search for new funds and international cooperation alliances by taking as a letter of introduction the successful and verifiable results obtained in the 2024–2025 project. Demonstrating the effectiveness of the previous model will facilitate the attraction of investment to guarantee the right to drinking water of the Zenú community.

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