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From Idea to Impact: Engineering KeepTheSun, an Innovative Circular Startup delivering Energy Access

In collaboration with Coesa Srl

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Summary

1. Introduction

1.1 Global context: energy and energy poverty

After twenty years of progress, there has been the first regression in terms of access to electricity globally and this is reflected in the 2022 data released by the global leaders of Sustainable Development Goal 7 (SDG 7) [1]. Population growth is outpacing progress and as many as 685 million people live in energy poverty, but what is worse is that without immediate interventions 660 million people will still lack electricity services by 2030. This data points to a worrying situation, but for which solutions exist.

Among the most effective and sustainable solutions to address the energy emergency in rural and fragile contexts are off-grid solar systems (OGS), recognized as the most economical method to electrify isolated areas, as it is estimated that OGS are the most cost-effective approach to provide energy to the 40% of the population currently disconnected. Indeed, it is important to note that most individuals without energy access belong to low-income populations and live in vulnerable areas. In addition to those without energy at all, there are also 1.6 billion people whose energy is intermittent, with frequent blackouts, for whom OGS would represent an important backup and an improvement in their lifestyle [2].

According to the latest data, off-grid solar systems have already provided basic electricity to over 250 million people (Tier 1) and advanced access (Tier 2 or above) to around 130 million, for a total of more than 560 million beneficiaries [3]. The sector, in fact, has continued to grow even in recent years (characterized by an unfavorable economy with high sales and currency devaluation, wars and pandemics), especially for use in manufacturing, schools and hospitals [2]. Companies producing solar technologies of this type have proven resilient and above all able to adapt.

Overall, the sector has also received greater consideration and recognition, with many governments implementing this innovative solution in their electrification plans. Furthermore, there has been a growth in private investment, especially results-based investments, which are currently successful. A key driver has been "Mission 300," launched by the World Bank and the African Development Bank to electrify an additional 300 million people by 2030, which has further boosted the sector [4].

Despite the sector's significant progress, it's clear that limited economic accessibility is the main obstacle. Even by adopting deferred payment formulas such as Pay-As-You-Go, only a minority of low-income families can afford a basic kit: the percentage is estimated to be around 22% and even lower in the most remote areas [2]. The sector requires financing and organization to achieve the desired impact; data estimates that $3.6 billion would be needed annually until 2030 to reach 398 million people. Forecasts call for 60% private capital and 40% public subsidies. The current problem is that only $0.6 billion per year is currently invested in the sector, leaving a gap of $3 billion [2].

1.2 The importance of off-grid energy in developing countries

Fragile, Conflict-affected, and Vulnerable contexts (FCV)

Contexts defined as fragile, conflict-affected, or vulnerable (FCV) encompass a wide range of situations, from humanitarian crises to protracted emergencies and even armed conflicts. These countries are characterized by severe institutional and social weaknesses, often accompanied by political instability or widespread violence. The classification is typically based on two main criteria: first, the quality of institutions and public policies, assessed through specific indicators; and second, conflict-related mortality rates relative to the population.

In FCV contexts, infrastructure development, including electrification, is particularly challenging due to the high risk of disruptions, the scarcity of logistical resources, and the presence of urgent humanitarian needs. In such scenarios, off-grid solar (OGS) solutions represent a valuable alternative, as they are easily deployable, autonomous, and capable of ensuring access to energy even in the absence of traditional grids, which are often damaged or non-existent.

Without accelerated action, the world is unlikely to achieve Sustainable Development Goal 7 (SDG 7) by 2030, potentially leaving 660 million people still without access to electricity [1] [2].

Multi-Tier Framework (MTF)

Access to electricity is not only measured by the presence of a connection, but also assessed based on the quality of service, the continuity of energy, and its adequacy for daily needs. The Multi-Tier Framework (MTF) classifies electricity access into six levels, from 0 (total absence) to 5 (complete and reliable access). Minimal solutions, such as solar lanterns, fall into the lowest levels (Tier 1), while small home systems that power multiple lights and light devices fully meet this level. More powerful systems that support additional appliances such as TVs or fans belong to Tier 2. This approach allows for a more accurate assessment of energy access, going beyond the simple distinction between "connected" and "not connected." [3].

The strategic role of Off-Grid Solar Systems in addressing global energy poverty

According to the World Bank current data, approximately 660 million people will not even reach the minimum level of Tier 1 by 2030. In fact, in 2022 the number of people without access to electricity increased after two decades and reached the exorbitant number of 685 million [1]. The percentage of people without energy and living in fragile contexts exceeds 60% and in this scenario off-grid systems are already playing an important role, improving the lives of millions of people by electrifying schools, public institutions and hospitals, where the connection is absent or highly unstable. By 2023, the off-grid sector had provided electricity access to approximately 561 million people, contributing to 55% of the new electricity connections built in sub-Saharan Africa between 2020 and 2022. An estimated 969 million people worldwide will need to be connected by 2030, and off-grid systems are the most advantageous solution for approximately 40% of them. They are also a valid alternative to diesel generators and allow significant savings on fuel subsidies for both households and governments. [2] [5].

OGS not only provide access to energy, but also to its productive uses, thus enabling families, small businesses, and farmers to generate income and improve their living conditions. It's important to note that they also improve the functioning of essential services such as healthcare facilities and schools, which is crucial for inclusive and sustainable development in marginalized areas [5].

If current trends continue, an estimated 660 million people are still at risk of remaining without access to electricity by 2030, and it is estimated that over 85% of them will live in sub-Saharan Africa [1] [6]. From 2005 to 2021, there was a significant reduction in the number of people without access to electricity, falling from over 1.2 billion to 675 million. However, between 2021 and 2022, this positive trend was interrupted, with a renewed increase in the number of people without access. Increased population growth is partly responsible, but factors such as the global pandemic and the energy sector disruptions caused by the war in Ukraine have also hindered progress. In the sub-Saharan Africa region specifically, extreme weather events have exacerbated existing vulnerabilities and compromised electrification efforts [1] [7].

OGS appear to work particularly well in low-income per capita settings, low population density, and therefore in rural areas and fragile contexts due to conflict and institutional weakness. In these cases, OGS appears to be the most economically accessible solution and also technically more feasible than traditional alternatives [2].

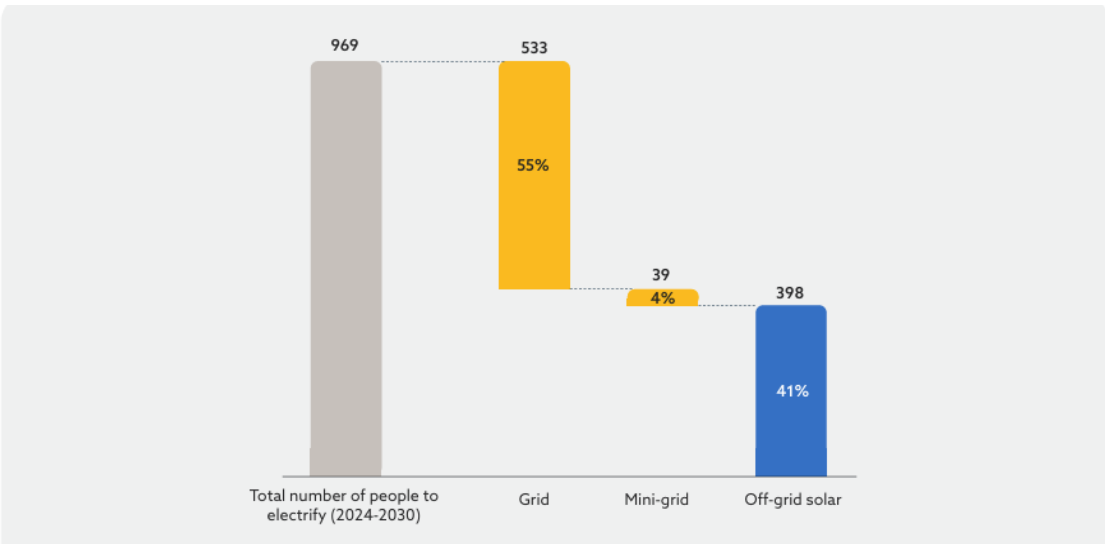

Figure 1 - Number of people that need to be electrified between 2024 and 2030 to achieve universal access accounting for population growth (millions).

The big difference compared to building a new electricity grid is that OGS are an immediate and more cost-effective solution that meets the consumption levels needed by currently unserved communities. OGS is more suitable than ever in remote locations, as extending the grid would be too costly. It is also one of the few viable options in fragile, conflict-affected, or vulnerable (FCV) countries, where infrastructure and affordability constraints are more severe. According to data collected by the World Bank, in 2023, the off-grid sector enabled over 560 million people to be connected, or 55% of the new connections built in sub-Saharan Africa in the three-year period 2020-2022. In the same period, OGS solutions provided initial access to electricity to 42.4 million people, approximately a third of whom lived in countries classified as FCV [2].

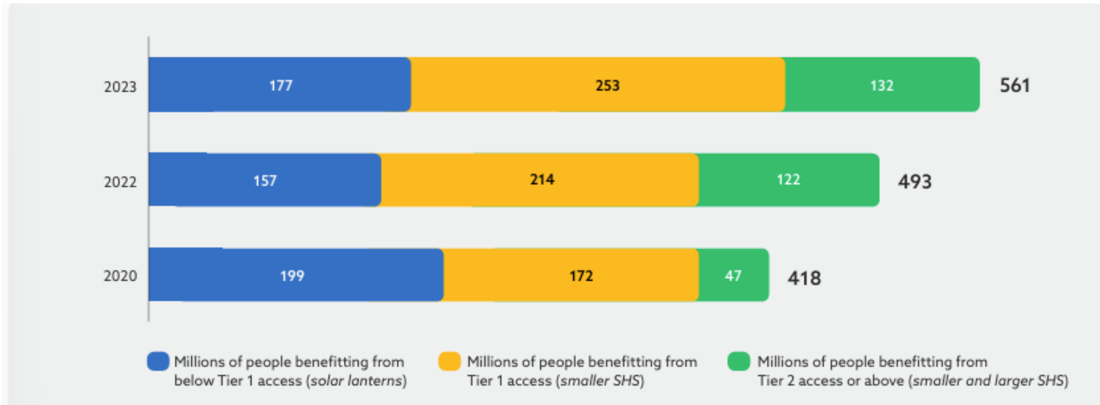

Figure 2 - Total number of people benefitting from off-grid solar energy kits by tier of electricity access (millions)

OGS can also represent a temporary solution for populations that will hopefully connect to the grid in the future, or to a mini-grid. Governments investing in OGS, in addition to meeting a population need, can also make a strategic investment in integrating these solutions into long-term development plans for grids or mini-grids. This strategy could also stimulate energy demand, so that in the future, when the population is perhaps connected to the grid, their consumption will be sufficient to guarantee a sustainable energy service, without incurring significant losses that would require continued public subsidies [2].

Insufficient electricity often forces families to go without power entirely or resort to diesel generators, which are expensive, must run for many hours a day, and are polluting. Nearly 10% of electricity consumption in sub-Saharan Africa comes from generators, with annual household fuel costs reaching up to $50 billion, not to mention maintenance costs. Switching to OGS solutions could significantly reduce government spending on fossil fuel subsidies, eliminating recurring fuel costs definitely [5].

A 2021 survey of over 79,000 off-grid users in 31 countries found that 86% of solar water pump (SWP) users saw an increase in productivity, while 60% expanded their cultivation area. As a result, 88% reported an increase in income. Additionally, 88% of solar refrigerator users used them for productive purposes, with 81% reporting an overall improvement in their quality of life. In 2023, over 3 million people used their solar home systems (SHS) to run businesses. These data clearly outline how off-grid solutions can help increase income through various productive activities. In many schools, the level of education is being lowered by the lack of a stable connection, with reduced teaching hours and the inability of students to learn exclusively during daylight hours. In health centers without reliable electricity, it becomes difficult to manage medical devices, adequately treat patients, and safely store vaccines. It is therefore argued that OGS improves the local economy and promotes community engagement [2] [5].

Energy poverty and fragility: The emerging epicenter in Sub-Saharan Africa

Progress in electrification has been uneven over the years: South Asia has seen progress, while sub-Saharan Africa has not seen significant improvements. South Asia has contributed approximately 75 percent of the global reduction in the number of people without access to electricity, thanks to large-scale infrastructure expansion and favorable policies [1].

In fact, approximately 85% of the world's population without access to electricity lives in sub-Saharan Africa, and the situation is exacerbated by population growth, economic hardship, political instability, and the increasingly severe and violent effects of climate change, making progress more difficult, especially in rural areas. Electrification efforts in sub-Saharan Africa are primarily concentrated in urban centers and areas where conditions are relatively stable. This geographic focus increases the need for urgent interventions to prevent rural and vulnerable communities from being permanently excluded and the gap from widening [7].

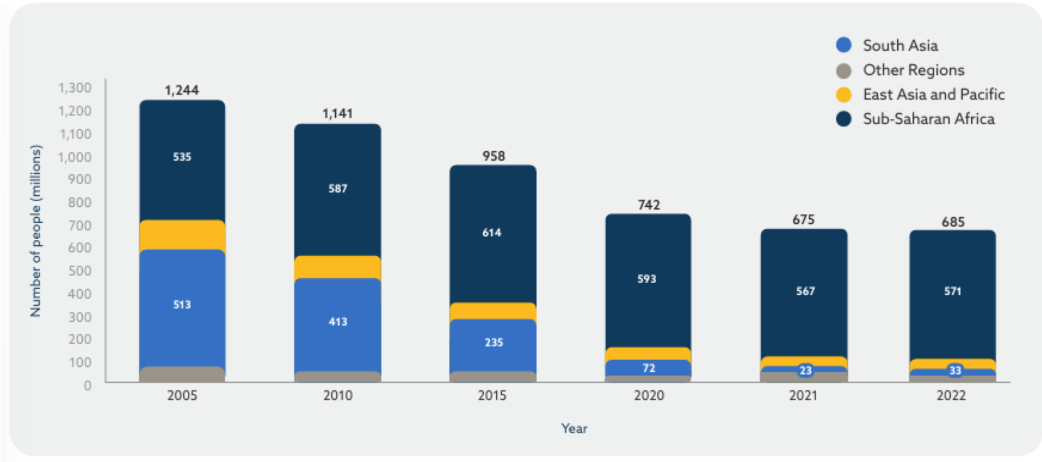

Figure 3 - Total number of people lacking access by region, 2005 – 2022 (millions)

Nearly half of the population without access to electricity in sub-Saharan Africa lives in just five countries: Nigeria, the Democratic Republic of the Congo (DRC), Ethiopia, Tanzania, and Uganda. [5] In 2018, 57% of the population without access to energy lived in FCVs, while today this figure has increased to 67% and symbolizes great difficulty in electrifying areas characterized by weak governance, insecurity and limited fiscal capacity that leads to chronic underinvestment in the energy sector. Traditional energy development approaches and strategies implemented by national governments, including policies for the growth of off-grid solar markets, are not sufficient to improve the situation [2] [7].

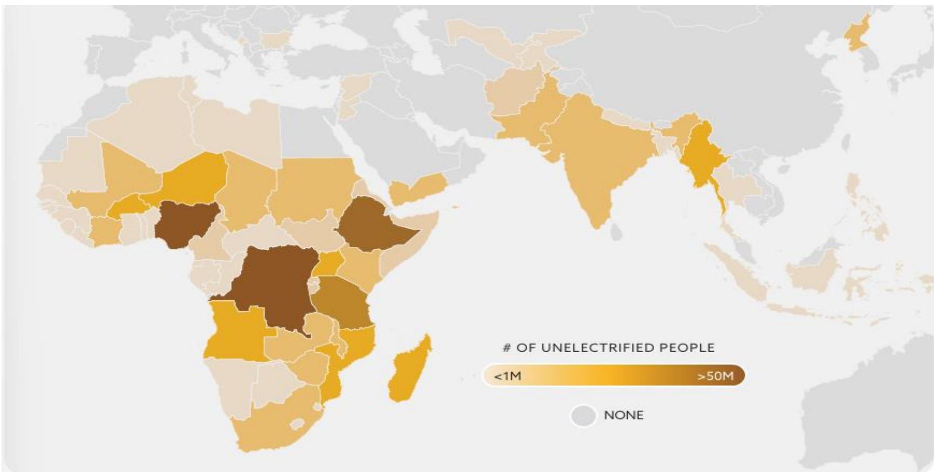

Figure 4 - Heatmap of access deficit countries with the number of people without electricity access by country

1.3 Thesis objectives and methodology

Definition of objectives and research questions

This thesis is centered on the research, development, and validation of KeepTheSun, an innovative circular economy-based energy solution designed to aid the challenge of energy poverty through repurposing second-life photovoltaic components. Central to this effort is Juakit, a modular, portable, and plug-and-play off-grid solar system, which I am developing, in collaboration with Coesa S.r.l., from the initial conceptualization to the technical, economic, and strategic design phases, up to its market launch.

The objective of the research is to establish a strong foundation (theoretical and practical) for scaling Juakit across Sub-Saharan Africa, with an initial pilot project scheduled to be deployed in Uganda. As such, the thesis is not strictly an academic review; it is more a practice-based endeavour to structure and validate a real-world energy startup project, which has the potential for, and aspiration towards, deep social and environmental impact.

In this context, the research aims to answer the following key questions:

1. How do I create a circular business model based on the reuse of second-life solar panels to enhance affordability, scalability, and sustainability within off-grid energy markets?
2. What are the main tech, economic, and logistical factors to consider when designing and rolling out a product like Juakit in rural and fragile spaces, like those in Uganda?
3. What financial mechanisms (e.g., Pay-As-You-Go, microcredit, donor support), and local partnerships are best able to support widespread adoption and economic viability?
4. What kind of demonstrable impact can Juakit offer around energy access, fossil fuel reduction, and socio-economic empowerment, particularly for low-income households and small businesses?

Through these questions, the thesis is contributing to the broader conversation about sustainable innovation to the Global South and shaping the operational roadmap for Juakit’s field deployment.

Methodologies used

In order to effectively research these questions, the thesis utilizes a holistic, multi-disciplinary research model that includes methodologies appropriate to management engineering, and includes strategic analysis, business modeling, impact evaluation and planning of intervention pilots in the process, among other research methods. The research process is divided into three methodological pillars:

1. Case development and project-based research

The thesis is developed as an embedded case study, in which I play a dual role as both researcher and project lead. This allows for a deep and practical exploration of Juakit's development lifecycle, including product design, supply chain configuration, stakeholder engagement, and the iterative refinement of features based on technical and contextual requirements. The case study encompasses some of the firsthand documentation relating to both the planning and preparation phases for the pilot in Uganda, which is the pilot we are using as a testbed for validating the solution in a real-world environment.

2. Business model design and evaluation

The business model of Juakit is analyzed using the Business Model Canvas and Circular Economy frameworks, specifically addressing:

- The value proposition testing in the off-grid solar areas;
- The revenue arrangements including PAYG and donor co-finance;
- The life cycle extension of reused solar PV components;
- Risk and resilience in fragile and conflict-affected contexts.

This evaluation is informed by benchmark analyses of comparable initiatives, as well as by contextual data from Uganda and Sub-Saharan Africa more broadly.

3. Impact and feasibility assessment

A forward-looking impact assessment will explore the potential outcomes of the Juakit as it relates to social inclusion, environmental sustainability, and economic empowerment. This includes:

- Scenario modeling for electricity access and reduced costs;
- Environmental analysis of emissions avoided from switching from diesel generators;
- Socio-economic indicators related to job creation, income generating activities, and improvements in users' quality of life.

The Uganda pilot has been pivotal for the impact assessment by providing an anchoring reference so that the analysis can explore the logistical, regulatory, and financial aspects to get the project into the field successfully.

This thesis is focus purely on the design, design, and practical validation of Juakit. In this case, management engineering competences are applied not as a means in themselves, but rather as a strategic and methodological foundation for supporting the structurization of the initiative, ultimately allowing for effective planning, scalable business models, and rigorous impact assessment within constraints and opportunities of the real world.

2. The KeepTheSun project: From initial idea to evolved model

2.1 Origins of the project and European context

The KeepTheSun project was born out of the convergence of two challenges in the energy landscape across Europe: the increasing number of end-of-life photovoltaic (PV) panels on the market and the lack of a structured market with transparent protocols for reuse. KeepTheSun grew out of the entrepreneurial efforts of Coesa S.r.l., an Energy Services Company (ESCO) based in Turin, Italy, and was launched in 2024 as the first online marketplace in Italy for the resale and responsible disposal of used solar modules. What could only be described as a sharp observation of the Italian PV ecosystem formed the basis of KeepTheSun. As a result of a generous government benefit program (Conto Energia) between 2005 through 2012, installers deployed vast quantities of solar systems. In this case, many of these systems are now at the end of the subsidized operational life of 20 years [8].

Feed-in tariff scheme	Number of installations	Capacity (MW)
First	5,725	163.4
Second	203,785	6,801.8
Third	38,595	1,566.2
Fourth	200,565	7,370.5
Fifth	28,234	448.5
Total	476,904	16,350.4

Table 1 - Plants and capacity in operation as of December 31, 2012 (cumulative)

Feed-in tariff scheme	Certified installations	Capacity (MW)	Incentivized energy (GWh)	Recognized incentives (€M)
First	5,724	163.4	974.6	482.1
Second	203,290	6,781.0	18,389.2	7,111.7
Third	38,388	1,561.9	3,380.8	1,105.1
Fourth	189,070	6,873.3	7,911.2	2,197.5
Fifth	1,943	27.7	6.2	0.9
Total	438,415	15,407.3	30,662.0	10,897.3

Table 2 - Incentivized energy and recognized incentives as of December 31, 2012 (cumulative)

By 2033, it is projected that up to 48 million panels will be decommissioned in Italy [9]. While many of these photovoltaic modules are still fully operational (as indicated by degradation rates as low as 15% after 12 to 15 years of operation) and have capacity to generate significant energy, they are typically replaced at this point because of a combination of economic and technological reasons. Essentially, under the Conto Energia incentive in Italy (which guarantees feed-in tariffs for a 20-year period) system owners want to maximize performance before the end of the tariffs. At this stage, significant advancements in panel efficiency and decreased costs of new high-efficiency modules make economically advantageous to undertake a system revamp. This would allow operators to increase overall energy generation and return on investment. However, despite their utility, many of the decommissioned panels could be disposed of or exported via informal channels, typically without sufficient oversight from regulations [8] [9].

KeepTheSun wanted to fill this market gap by creating an online marketplace that would be able to create artificial supply and demand for used PV modules in a traceable, regulated and quality-checked manner. The platform incorporated innovations to professionalize the secondary market: technical data sheets with over 95,000 panel models, expert-backed listings and a partnership with other companies for panel testing, certification and environmentally-sound recycling.

The business model, grounded in circular economy principles, offers multiple value propositions: it enables plant owners to monetize decommissioned assets, reduces the demand for new resource-intensive modules, and supports the broader goal of a more sustainable European PV supply chain. Within a year, the platform supported the sale of approximately 12,000 solar panels and hosted listings for over 40,000 panels, confirming the existence of a previously underserved market segment and attracting both private users and professional operators.

However, the strategic vision underpinning KeepTheSun was never confined to the European secondary market. From its inception, the project's founders recognized the untapped potential of repurposed solar modules as a tool to address global energy poverty. Indeed, what in Europe is considered an end-of-life component may, in another context, represent a lifeline to modern energy services.

This stage represents a major shift in the journey of KeepTheSun, transitioning from an entirely digital marketplace to now providing a material solution. Although the project retains the principles of circularity from the original platform, it is now more focused on delivering broader global impact in off-grid and underserved areas. This evolution is embodied in the development of Juakit, an innovative portable solar kit created to deliver decentralized, affordable electricity access. Juakit is built using second-life photovoltaic panels sourced directly through the marketplace, upholding the platform's sustainability aspect, while addressing energy poverty through applied technology. This phase represents a substantial shift toward digital infrastructure and product innovation, which is the main focus of analysis in this thesis.

2.2 Evolution towards KeepTheSun and the birth of Juakit

Motivations for moving towards a physical product

Following the launch and early success of KeepTheSun, it became increasingly evident that the platform's potential extended far beyond the European context. While the initial model efficiently addressed inefficiencies in the domestic secondary PV market, the abundance of functional but underutilized solar modules also highlighted a broader, global opportunity: the redirection of these components towards regions suffering from chronic energy poverty.

The decision to introduce a product-oriented extension of KeepTheSun emerged from the convergence of two key insights, reflecting an evolution in the project’s mission and scope. The idea to implement a product-oriented extension of KeepTheSun arose from the combination of two important ideas, which represented a transition to the project's shape and mission. First, second-life panels, while not qualifying for a national incentive scheme or considered the worst option for grid-connected systems, still provide clean and reliable electricity. Second, an off-grid area in the Global South (especially Sub-Saharan Africa) has an ongoing and critical energy deficit; there are still more than 600 million people without access to electricity. These two asymmetries (excess in the North; scarcity in the South) provided a motivating brain tickler for innovation [2] [9].

A strategic shift was thus launched toward designing a modular, portable, and plug-and-play solar solution to valorize second-life panels in a standardized off-grid product. The resulting project is Juakit, a small solar generator that is capable of meeting the decentralized energy needs of rural households, schools, health facilities, and micro-enterprises. Juakit represents a material manifestation of KeepTheSun's circular mission: converting waste into a product of empowerment and resilience.

Introduction of a social impact component

The launch of a product was also a significant enlargement of the product's intended purpose, from a platform to optimize resource flows across Europe to a scalable solution for essential development problems in energy-poor contexts. KeepTheSun, via Juakit, has embedded a strong social impact element in its value proposition. An impact-driven approach is a response to the increasing global imperative of extending energy access as a prerequisite for sustainable development. As documented in recent reports from the International Energy Agency and the World Bank, the most cost-effective route to electrification for remote, low-income areas is often through off-grid solar systems [2]. In this context, Juakit provides a reliable and portable system that can deliver clean electricity to remote areas where grid extension is not practical or economical. The Juakit system was developed not only as a technical solution for off-grid electricity access, but also as enabling infrastructure for essential services in under-served communities. While there can potentially be many more applications, the project is focused on three key areas: education; access to clean water; and food security. These priority areas were selected based on evidence of local need, and for their potential to demonstrate significant social impact with limited energy input but directed in a friendly and meaningful way.

especially for rural and remote schools. Access to reliable lighting can improve learning through afternoon/evening study, decreasing reliance on dangerous kerosene lamps, and providing opportunities to use digital tools for teaching. The International Energy Agency states that there are still nearly 770 million people worldwide without access to electricity, and research shows that targeted school electrification is beneficial in terms of student access to schools, attendance and academic outcomes [10].

Provision of clean water is another essential area where Juakit can make a positive difference. With solar-powered water pumps, Juakit can access safe groundwater from deep wells reducing the incidence of water-borne diseases and improving hygiene conditions. Over 400 million people in Sub-Saharan Africa do not have access to basic drinking water services [11]. Moreover, the state of freedom from the time picking ragweed in order to obtain water, which stands amount to over 200 million hours of time worldwide, can liberate time for women and children to spend on education or economic opportunities [12].

The third thematic area is food security. In many agricultural communities, cold storage is unavailable and unavailability leads to considerable post-harvest losses. This problem is particularly serious, for rural economies that rely on perishable crops where access to refrigeration is non-existent. The FAO estimaged that up to 30 percent of food produced is lost before is put into the mouths of consumers in Sub-Saharan Africa [13]. By powering solar refrigeration units, Juakit contributes to preserving agricultural goods, reducing spoilage, and improving the economic resilience of smallholder farmers, who account for more than 60 percent of the rural labor force [14].

By prioritizing these three application areas, the project is intended to consider the appropriate technical innovation within the parameters of social development objectives. Each of these areas is then associated with internationally recognized priority issues such as; Sustainable Development Goal 2 on zero hunger, Goal 4 on quality education, and Goal 6 on clean water and sanitation. Juakit then presents a system that can be presented as flexible and adaptable for further applications in supporting inclusive and sustainable economic growth in energy poor regions. In order to facilitate affordability in energy-poor settings, Juakit structure is intended to apply Pay-As-You-Go (PAYG) financing. Combining other PAYG uses within off-grid community solar, allows for an incremental payment process, based on usage, that helps lower entry barriers and maximizes ownership. In addition to this, the next major milestone will be the pilot implementation in Uganda which was designed as part of this thesis, as a field based validation for Juakit; noting that this pilot will allow data to evaluate and measure system performance, collect user feedback for continuous improvements and measure aspects of social impact that are necessary to justify, to scale and to prepare for investment towards further implementation efforts.

KeepTheSun through Juakit demonstrates how engineering, entrepreneurship, and social purpose can converge to create circular, inclusive solutions for one of the most pressing global challenges such as universal access to sustainable energy.

2.3 Towards an impact-driven startup: entrepreneurial and innovative elements

Team structure

KeepTheSun 2.0 and its core innovation Juakit arose through an iterative and collaborative impact-orientated entrepreneurial process. The project is both conceptualized and developed jointly by a small but multidisciplinary team of myself as a master's student's Management Engineering, and Matteo Stoppa as Chief Innovation Officer at Coesa S.r.l, who is also the company mentor and supervisor of the thesis project. This dual structure allows for complementary skill sets to effectively integrate. On one hand, I have a strong academic and analytical background in the field while applying tools and methods from management engineering in business modelling, financial planning, supply chain design, and impact evaluation. On the other hand, Matteo Stoppa's broad startup experiences in the field of renewable energy and innovation provide strategic focus and direction, the technical validation of both the innovation and its potential impacts, access to Coesa's operational capabilities, and an ecosystem of partners. Together, this has enabled us to move beyond the ideation pieces into the operationalization of real-world impact innovation by effectively blending theory with practice; a necessary trait of any new-stage impact startup.

Innovation potential

Juakit exemplifies a high-impact innovation at the nexus of circular economy principles and off-grid renewable energy deployment. It was developed in the face of a dual-pronged challenge: an abundance of second-life photovoltaic components and the increasing urgency of energy access in off-grid settings. Juakit is the embodiment of innovation-as-technology simplification and innovation-as-systemic inclusivity.

Juakit's design accepts the revalorization of under-exploited resources (specifically, used solar panels) and introduces them into an accessible, easily replicable, and adaptive solution to local socio-environmental settings. This design ethos has the additional benefit of reducing environmental externalities and reducing upfront capital costs, that allow for deployment in a space where investment in traditional infrastructure is dangerous or predetermined as economically unjustifiable.

From a business perspective, the project integrates unique financing strategies for affordability and user empowerment. It utilizes innovative payment models that accommodate low-income communities and thus enhance greater financial inclusion and sustainable consumption of energy.

Taken together, Juakit shows how product and service innovation can merge in a seamless, impact-driven solution capable of accomplishing global sustainability objectives and local development.

Scalability and strategic vision

The project is being developed with scalability as a core design principle. Thanks to standardized modular components and containerized logistics, Juakit can be mass-distributed across various geographies, particularly in Sub-Saharan Africa where electricity deficits remain critical. The pilot project in Uganda, is currently in the proposal design stage. This will be the first time the system will be tested outside the lab. The prototype piloting in Uganda will provide an opportunity to validate the system in the real-world, for which this field validation will:

- Evaluate robustness and usability in various environments
- Collect feedback/input from the users regarding further technical development and optimization process and service
- Quantify actual social impacts and economic benefits to users.
- Iteratively refine the operational model and the distribution plan.

Beyond this initial deployment, KeepTheSun aims to develop strategic partnerships with NGOs, local cooperatives, and community-based organizations, to design a decentralized delivery and distribution service enabling local deployment maintenance and scaleup.

KeepTheSun with Juakit represents the transition from academic and environmental study to a scalable social impact venture. The alignment of a team dedicated to testing their ideas into the real world, styles of innovation that fit with their mission, created an environment where there was a viable technological start-up, but even more it is a social venture. Management engineering provides the tools to structure, measure, and scale, to propel an initiative that will challenge the current relationships between the circular economy, renewable energy, and inclusive development.

2.4 Objectives and technical features of the system

Composition and functionality of Juakit

The Juakit system's main aim is to constitute a trustworthy, modular, and deployable off-grid energy option best suited for the energy needs of homes, schools, health centers, and small businesses in disadvantaged and remote areas. Juakit's design is rooted on the principles of affordability, resilience, and circularity by using second-life photovoltaic modules bundled into a standard, user-friendly power management unit. The physical core of Juakit is being developed with Photon Solar System, a startup company that developed the platform which acts as the technical backbone of the in Juakit solar generator and is designed with safety and modularity in mind, whilst ensuring compatibility to energy components available at a local level in low-resource contexts.

The Juakit unit incorporates:

- A pure sine wave inverter;
- An integrated control board with user interface for basic diagnostics;
- Multiple universal AC outputs;
- Compatibility with 12V external batteries (50–100Ah), commonly available in local markets;
- Modular architecture to support different use cases and energy profiles.

This arrangement gives users the flexibility to create or grow their systems without the dangers associated with improvised electrical configurations, which commonly occurs in off-grid applications.

Technological specifications overview

Below is a summary of the main technical features of the Juakit solar generator based on the Photon Solar System platform:

Feature	Specification
Inverter type	Pure Sine Wave
Power output	1500W continuous / 2500W peak
AC Outputs	2× 220V universal sockets
Compatible battery	12V, 50–100Ah (external, user-selectable)
Dimensions	60 × 48 × 22 cm
Design	One-person portable; military-grade casing
User interface	Integrated control board with display
Modularity	Supports integration with external components
Advanced option	Communication module (GPS + remote tracking)

Table 3 - Technological features of the Juakit solar generator

The configuration was purposefully designed to be flexible and scalable so end users or implementation partners could tailor the system to local demands without sacrificing safety or efficacy. The Juakit system is an engineering challenge, and the Juakit engineering design uses practical design choices to alleviate energy poverty without sacrificing utility and safety through decentralization and user control. The technical specifications in Juakit are suitable for field operating conditions, while modularity in design allows for emergent changes based on community demands.

3. Market analysis and business strategy

3.1 Demand and supply in the used photovoltaic market

Availability of second-hand panels in Europe

The progressive decommissioning of older solar installations, especially those installed during the early incentive phases of the 2000s, is driving a structural transformation in the European photovoltaic industry. Newer and more efficient technologies are replacing many of these systems, which are still operational but no longer competitive in terms of efficiency. This change is creating a rapidly growing inventory of used panels, which are frequently thrown away even though they still function between 70 and 85 percent of the time.

In countries like Italy, Germany, and Spain, thousands of tons of photovoltaic modules are becoming waste each year, even though many could be repaired and reused. For example, Italy had an installed capacity of over 20 GW by 2012. Most of this will reach the end of its incentive period by the end of this decade [8] [9]. This scenario provides a unique opportunity to recover and redeploy functional modules, aligning environmental sustainability with circular economy principles.

Despite the increasing supply, the market for second-life panels is still fragmented and poorly regulated. Challenges include the absence of standardized testing and certification for reused modules, logistical issues, and a poor match between supply chains and actual global energy needs. However, new players, including startups and social enterprises, are starting to shape this emerging market. They are collecting used panels and giving them a second life through careful testing, sorting, and integration into new energy solutions like Juakit.

On the demand side, the situation is marked by urgent, unmet needs. As of 2023, more than 660 million people around the world still do not have access to basic electricity. Sub-Saharan Africa is home to nearly 85% of this group. Additionally, about 1.6 billion people live in places with very unreliable electricity infrastructure. This situation forces them to rely on expensive and polluting options like diesel generators. The off-grid solar sector has become the most practical solution for many of these communities, especially in rural and fragile areas where extending the grid is not financially or technically possible. From 2020 to 2022, 55% of new electricity connections in Sub-Saharan Africa came from off-grid solar technologies. Demand is particularly strong in countries such as Nigeria, the Democratic Republic of the Congo, Ethiopia, and Uganda, where many people still lack reliable energy access [2]. Furthermore, off-grid solar goes beyond basic lighting and phone charging. The demand is increasingly shifting toward productive energy uses, like running agricultural machinery, refrigeration units, and small businesses. These uses are vital for economic growth and reducing poverty. This rising demand creates a major opportunity for second-life solar technologies. By cutting down the costs of new installations, refurbished systems can make decentralized energy cheaper and more accessible.

Dimension	Europe (Supply side)	Emerging economies (Demand side)
Photovoltaic stock	> 200 GW installed capacity (EU), large share aging	< 10% rural electrification in many Sub-Saharan countries
Second-life panel availability	Thousands of tons/year entering end-of-life phase	Limited local PV manufacturing capacity
Average residual efficiency	70–85% after 15–20 years of use	Low-income households need low-cost, functional systems
Infrastructure maturity	Advanced recycling/logistics infrastructure emerging	Weak infrastructure, especially in FCV and rural areas
Energy demand characteristics	Saturated residential market, shift to storage and grid services	High off-grid demand; need for standalone and modular solutions
Cost constraints	High disposal and recycling costs for producers	Affordability gap: < 25% of households can afford entry-level systems without subsidy
Potential for circular solutions	High if supported by regulation and certification standards	High particularly when linked to local assembly, training, and service networks

Table 4 - Comparative overview - Supply vs. Demand

3.2 Benchmarking with similar models

The off-grid solar market in Sub-Saharan Africa is highly dynamic, characterized by a growing number of players offering a diverse array of solutions aimed at bridging the electricity access gap. Among the most established companies are d.light and Sun King, whose business models provide valuable reference points for benchmarking the KeepTheSun initiative.

d.light uses PAYG to provide new solar home systems (SHS) that come with lights, power banks, and televisions. The company prioritizes affordability and accessibility, backed by microfinance partnerships and a wide distribution network. Despite this, it shows limited innovation concerning the circular economy since its attention is mainly on new product deployment, with little reuse of components [15].

Sun King, which used to be part of Greenlight Planet, operates in over 40 countries. It combines solar home systems with after-sales services and a strong PAYG model. It focuses on modularity and scalability, allowing users the flexibility to expand their systems. Like d.light, it has not adopted circular design principles and continues to depend on newly manufactured systems and virgin materials [16].

In contrast, KeepTheSun sets itself apart by incorporating a circular economy approach. It reuses second-life photovoltaic panels collected through its European marketplace. This strategy greatly reduces both environmental impact and production costs, while improving affordability for users. The product, JuaKit, merges this reused infrastructure with an efficient energy storage system and PAYG-enabled access. Additionally, its design focuses on ease of deployment, local reparability, and modular scalability, making it particularly suitable for fragile or low-infrastructure settings.

To provide a clear visual comparison, the following table summarizes key differentiators among the main actors:

Feature / Company	Juakit	d.light	Sun King
Product model	Refurbished kit (JuaKit) + PAYG	New SHS (TV, lights) + PAYG	Modular SHS + PAYG
Circular strategy	Second-life panels	Limited (partial battery reuse)	None
Target price range considering power offered	Low (reuse reduces costs)	Medium	Medium-high
Target market	B2C + B2B (NGOs, schools)	B2C (households)	B2C + SMEs, schools
Deployment model	NGO partnerships in Uganda	Local agent network	Extensive distribution
Differentiators	Circular economy + high-power 230W panels + local adaptability	Mass-market new systems	Modularity, scale

Table 5 - Key differentiators among the main competitors in the market

What stands out from this comparison is that KeepTheSun uses its innovation in reuse, local adaptability, and affordability to address a market gap that traditional companies overlook. Its combination of technical strength, circular business model, and social mission allows it to make a significant impact in regions like Uganda, where the pilot is currently supposed to be sent.

While d.light and Sun King have helped develop the off-grid solar market through extensive distribution and financing options, KeepTheSun sets itself apart with a sustainable, locally focused, and impact-driven model designed for the challenges of energy poverty in emerging markets.

We will focus on mainstream off-grid solar companies such as d.light and Sun King that have achieved significant market penetration in Sub-Saharan Africa by offering low-cost, plug-and-play solar home systems (SHS), often financed through Pay-As-You-Go (PAYGo) schemes. However, this affordability frequently comes at the expense of long-term performance, modularity, and perceived reliability. According to field data collected in Gulu (Uganda), typical systems from these providers offer limited solar generation capacity, generally ranging from 40 Wp (e.g., d.light X1000) to a maximum of 400 Wp in higher-end kits like the d.light IMax 10 Pro and battery capacities from approximately 141 Wh to 960 Wh, often based on sealed lithium iron phosphate (LFP) or nickel manganese cobalt (NMC) chemistries.

Retail prices for these kits vary from 1.5 to 3.8 million UGX (approximately $400–$950), depending on integrated appliances (such as televisions, LED lights, and fans) and service bundles. Despite offering short-term energy relief, such systems exhibit a limited lifespan, typically estimated at three to four years, with minimal opportunities for repair, component replacement, or system upgrading. Their sealed architecture, especially concerning battery packs, restricts user autonomy and increases replacement friction. These limitations are particularly relevant in rural and underserved contexts, where durability, reparability, and long-term support are essential for technology acceptance.

In contrast, Juakit has been specifically engineered to address the limitations of existing entry-level SHS solutions. The system integrates a high-power 230/400 Wp refurbished solar module with an external, user-replaceable 12V battery bank, typically sized between 50 and 100 Ah (translating to 600–1,200 Wh usable capacity). The prototype version tested during the pilot includes a 5.4 kWh LFP storage unit, allowing sustained energy supply for both household and productive uses.

Juakit delivers both AC (1,200 W pure sine wave) and DC outputs, enabling the safe operation of a wide range of appliances including refrigerators, TVs, sewing machines, and barber tools. Its modular suitcase design (60×48×22 cm), military-grade casing, and remote monitoring capabilities via a mobile application distinguish it from traditional SHS models. These features enhance both usability and maintenance in harsh environments. Furthermore, Juakit's compatibility with locally available 12V batteries and its reconfigurability for community or enterprise use represent key advantages in fragile, off-grid contexts, where resilience, repairability, and trust in technology are vital for long-term adoption [17] [15] [16].

To remain competitive with existing market players, Juakit aims to maintain a price point around 3,200,000 UGX ($ 800), positioning itself within the affordability range of mainstream solar kits while offering significantly higher power and durability. While this might seem high at first, it is much more cost-effective when considering energy output, lifespan, and versatility. The cost per watt of usable energy and per year of operation is very competitive, especially with financing options like Pay-As-You-Go (PAYG) and support from grants or NGO partnerships. Additionally, Juakit's circular production model, which uses second-life solar panels sourced in Europe, significantly lowers capital costs while also improving environmental sustainability. This combination of technical strength and affordability through reuse puts Juakit as a solution that can last longer and perform better than many cheaper alternatives.

Feature	**d.light / Sun King**	**Juakit**
Solar panel power	40–400 Wp (depending on model)	230–800 Wp (refurbished, e.g. 2×400 W)
Battery storage capacity	141–960 Wh (sealed LFP/NMC)	960 Wh (GEL) up to 5.4 kWh (external LFP, modular and replaceable)
Output	DC only (USB, LED, small TV)	AC + DC (1,200 W pure sine wave, suitable for appliances and tools)
Retail price range	1.5M–3.8M UGX (≈ $400–950)	≤ 3.3M UGX (≈ $800 target)
Lifespan	2-3 years (average battery/system lifespan)	8–10 years (panels + modular battery replacement)
Circular design	None or very limited	Full reuse of second-life PV panels + recyclable battery bank
Monitoring	Limited or none	Integrated mobile app with remote diagnostics and usage tracking
Suitability for productive use	Low (basic lighting/charging only)	High: refrigeration, ICT tools, sewing machines, agricultural equipment
Trust / Perceived reliability	Medium (low durability, sealed systems)	High (robust design, locally repairable, tested by technicians)

Table 6 - Summary of technical-economic comparison

Thanks to its robust design, dependable performance, and high energy output, Juakit is well-suited not only for individual households but for entire communities. Its modular structure and power capacity allow multiple users to benefit simultaneously. This is particularly valuable in rural settings, where shared access to energy can strengthen community ties, support local economic activity, and reduce reliance on costly or unstable energy sources over time.

Analytical commentary

Power and capacity

Juakit is designed to deliver between 230 Wp and 800 Wp of photovoltaic power, depending on the configuration, with the pilot version integrating two 400 W second-life panels. This output level is significantly higher than mainstream PAYGo kits such as those from d.light, whose most powerful offerings range from 100 Wp to 400 Wp. When compared to entry-level systems like the Sun King Home 200X or d.light X-series (often limited to 40–80 Wp) Juakit delivers up to 10–20 times more generation capacity, making it suitable not only for basic household use but also for micro-enterprises requiring sustained AC power.

Cost per Watt

Although Juakit's target retail price is around 3,000,000 UGX (approximately €730), it remains cost-effective in terms of energy output. With a photovoltaic capacity of 800 Wp (2×400 W refurbished modules), the system yields a cost-per-watt of approximately €0.91/Wp, which is highly competitive compared to mainstream off-grid solar kits currently available in Uganda.

For instance, the d.light IMax 10 Pro, priced at 2.8 million UGX for a 400 W system, results in a cost of around €1.71/Wp, while the Sun King Home 500X, delivering only 50 Wp at a typical price of 3 million UGX, reaches an extremely high €14.63/Wp. Despite Juakit's higher upfront cost, its superior power output, modular design, and longer operational lifespan offer a much lower lifetime cost of ownership. This makes Juakit a more sustainable and economically rational investment, especially in contexts where long-term affordability and performance matter more than entry-level price alone.

Reliability and trust

Juakit has an estimated useful life of 8 to 10 years due to the use of industrial-grade second-life panels. This significantly surpasses the typical warranties of around 3 years and this aspect is vital in African markets, where trust in products and their longevity is key to acceptance.

Modularity and repairability

One of the main differences between Juakit and typical off-grid solar kits is the level of modularity and repairability in the system design. Most solar home systems (SHS) from companies like d.light and Sun King are sold as "all-in-one" plug-and-play kits. Our kit is also ready to use, simplifying the initial setup, but it has something extra to not significantly limit the possibility of maintenance, component replacement, and system upgrades after purchase. The batteries in major competitors, usually lithium (LFP or NMC), are sealed and not intended for user replacement or on-site maintenance. Therefore, when a battery fails (usually within 3 years), you risk throwing away the entire device, even wasting the still-functioning elements. Juakit is different because it adopts a modular architecture that allows each component (solar panel, charge controller, inverter, and battery) to be accessed, replaced, or upgraded independently and easily. This feature reduces long-term costs by allowing for gradual refurbishment rather than a much more expensive complete system replacement. Furthermore, the system's mechanical casing is designed for durability and field maintenance, allowing qualified technicians to repair or upgrade the hardware on-site. This results in strong technical resilience and stimulates local value creation by enabling partnerships with regional installers and technicians for after-sales support. It also increases user confidence, making the adoption of such a product certainly more compelling. In this regard, Juakit offers not simply a product, but a platform that can evolve over time with user needs, a key feature for inclusive and sustainable energy access.

Sustainability and circularity

Juakit is the only solution in this comparison that operates on a circular economy model, using second-hand components from the European solar decommissioning market. This approach reduces environmental impact and costs while promoting a repeatable system for sustainable electrification.

Durability

When looking at the durability of off-grid solar products on the market today, it is clear that most entry-level systems are not very durable. This lack of longevity can harm trust and hinder adoption, especially in vulnerable or underserved communities.

For example, d.light is estimated to have a lifespan of about 2-3 years, which aligns with the standard warranty provided by the manufacturer [18] [19]. Similarly, the Sun King Home 40 Plus, another popular entry-level system, has a battery life of about 2-3 years, according to the data from its maker, Greenlight Planet [20]. While some of their advanced models have longer warranties, this does not apply to their basic kits.

In contrast, the Juakit system uses second-life industrial-grade photovoltaic panels sourced from the European market. These panels still have a residual lifespan of at least eight years, based on technical evaluations and durability records. The internal battery is designed for long-term use, and the entire system is expected to function reliably for eight to ten years in optimal conditions. It combines reused high-quality components with newly integrated electronics, remote monitoring features, and strong protective casing, which gives it a product lifecycle that greatly exceeds market standards. This longer durability makes Juakit not only a more sustainable and cost-effective choice over time, but it also serves as a more reliable and impactful energy source for communities that rely on solid infrastructure.

Feature	Juakit	d.light IMax 10 Pro	Sun King Home 500X
Solar Panel	800 W (2×400 W)	400 W	50 W
AC Output	1,200 W (pure sine wave)	500 W (pure sine)	—
Battery	External, 12V 50–100Ah	960 Wh (LFP)	141 Wh (NMC)
Price in Gulu	≤ 3.3 M UGX (target)	2.80 M UGX	2.74–3.86 M UGX
Portability	Suitcase 60×48×22 cm	24 kg box	Console + panel
Expected Lifespan	Over 5 years (target)	~ 2 years	~ 2 years

Table 7 - Technical and commercial comparison

3.3 The circular and scalable model

The KeepTheSun project is based on a new business model that combines environmental sustainability with social impact through two main operations: first, a European digital marketplace for second-life photovoltaic panels, and second, a deployment platform for off-grid solar kits (Juakit) in areas with limited access in Sub-Saharan Africa. This dual approach allows the model to be circular and scalable. It tackles two main problems at once: the growing issue of solar panel waste in developed countries and ongoing energy poverty in emerging economies.

The first part of the business model is a digital marketplace that collects, tests, and redistributes used photovoltaic panels that are no longer eligible for government incentives but are still functional. This marketplace emerged within KeepTheSun to address the increasing number of decommissioned solar modules across Europe, where older generations of PV installations are nearing the end of their subsidized lifespans. It provides a clear way to extend the useful life of these panels, promoting reuse instead of disposal and reducing the environmental impact. It also offers transparency and traceability in the supply chain, which is essential for assembling off-grid energy solutions later.

The second and most innovative part of this model is Juakit, that is made from these recovered panels. It is perfect to meet the energy needs of off-grid and fragile communities in Africa. Juakit can adapt a high-capacity energy storage system, it has both AC and DC outputs, and an easy-to-repair design suitable for difficult conditions. It also comes with a pay-as-you-go system and remote monitoring, making it affordable and easy for users and operators. Unlike many off-grid solar products that focus only on individual households, Juakit is also designed for community use. Its performance and durability make it ideal for shared settings such as schools, health centers, small farms, or micro-enterprise clusters. This choice not only improves energy access but also strengthens social bonds and boosts economic productivity.

At the core of this business model is the idea of a circular economy. By giving a second life to photovoltaic components that would otherwise be thrown away, KeepTheSun cuts down on waste, reduces production costs, and lowers the carbon footprint of its products. At the same time, it creates local value in areas facing severe energy shortages, transforming an environmental problem into a chance for development. This focus on reuse allows for a sustainable cost structure, making clean energy available to low-income communities without sacrificing quality or long-term functionality. In addition, the system's modularity and the flexible supply chain, supported by the European marketplace, allow the model to be easily scaled up in different locations and for various applications.

SDG	Contribution
SDG 7 – Affordable and clean energy	Juakit provides decentralized, renewable energy to off-grid communities.
SDG 12 – Responsible consumption and production	The model promotes reuse of solar panels, extending product life cycles.
SDG 13 – Climate action	By replacing diesel generators, Juakit cuts emissions and supports low-carbon energy access.
SDG 9 – Industry, innovation and infrastructure	Supports resilient infrastructure and inclusive innovation through circular design.
SDG 17 – Partnerships for the goals	Builds cross-continental partnerships between European suppliers and African communities.

Table 8 - Contribution to the Sustainable Development Goals (SDGs)

3.4 Commercial strategy and market entry plan for Africa

The commercial strategy of KeepTheSun aims to successfully and effectively introduce the Juakit solution in Sub-Saharan Africa, beginning with a pilot deployment in Uganda. This approach focuses on prioritizing markets, building local partnerships, using inclusive sales channels, and following a phased roadmap that guides the project from initial testing to regional expansion.

Target countries

The first target country is Uganda. It was chosen because of its high level of energy poverty, with only about 42% of the population having access to electricity. Uganda has a stable regulatory framework for off-grid electrification and active networks of NGOs and micro-entrepreneurs. It also acts as a gateway to the East African market, where countries like Kenya, Tanzania, and Ethiopia have similar socio-economic conditions and energy access issues. In West Africa, Nigeria and Ghana are also recognized as strong second-stage markets due to their large populations, off-grid demand, and experience with pay-as-you-go models [2].

Country	Population (millions)	Electrification rate (%)	Off-grid population (millions)	PAYG penetration	Off-grid market maturity
Uganda	48.6	42%	~28	High (mobile money widespread)	Medium-High
Kenya	55.1	75%	~14	Very High (MPESA integration)	High
Tanzania	67.4	40%	~40	Medium	Medium
Nigeria	223.8	55%	~100	Medium-High	High
Ghana	34.1	85%	~5	Medium	Medium
Ethiopia	126.5	50%	~63	Low	Low-Medium

Table 9 - Comparative energy access and market potential in selected countries

This table shows the varied energy access conditions in Sub-Saharan Africa. Uganda, where KeepTheSun first started, has over 28 million people without electricity and a strong PAYG system. This makes it a great place to enter the market. Countries like Kenya and Nigeria also offer good opportunities because they have large off-grid populations and developed digital payment systems. Tanzania and Ethiopia have high unmet demand but deal with some infrastructure and regulatory issues. Ghana, though more electrified, is still a useful place to test partnerships thanks to its stable governance and supportive energy policies.

Partner networks

The success of Juakit's commercial rollout will mainly rely on the strength of the partnerships formed on the ground. These collaborations are crucial for ensuring that the project can grow sustainably and meet the specific needs of off-grid communities.

First, local NGOs and solar distributors will be vital in managing logistics and last-mile delivery, especially in rural and hard-to-reach areas. Their understanding of the local landscape and existing networks will be essential for installing the kits effectively and building trust within the community.

Second, local technicians will guarantee customer support and long-term maintenance. They will be trained through specific capacity-building programs. This approach not only provides ongoing technical help but also creates jobs and encourages local ownership of the technology.

Third, access to funding will come from involving microfinance institutions and development banks. These organizations will support the Pay-As-You-Go (PAYG) payment system, which allows users to pay for Juakit gradually instead of all at once. This is ideal for making it affordable for low-income households.

To advance this strategy, KeepTheSun has started building a network of partnerships in Uganda. This includes connections with local energy cooperatives, collaborations with local researchers and European technology partners like Photon Solar System, which helps with hardware components and kit integration. These initial relationships create a strong base for the pilot phase and future market growth.

Sales channels

At this initial stage, the project is focusing on a B2C strategy. This means that Juakit will be offered directly to end users, mainly households and small businesses, through channels like mobile agents, rural retailers, and targeted community events. This approach aims to maximize user engagement and adaptability, allowing for flexible payment through PAYG micro-installments using mobile money, which is already widely used in many countries of Sub-Saharan Africa. The decision to prioritize the B2C route comes from the belief that direct interaction with users will provide clear insights into their real energy needs, usability issues, and long-term adoption behavior, especially during the pilot phase. It also fits with Juakit's modular and portable design, which is perfect and comfort for individual or small group.

That said, B2B and B2G options, such as partnerships with NGOs, cooperatives, and public institutions, are still viable. These channels could allow for wider deployments in schools, health centers, and agricultural cooperatives once the product and model have been confirmed at the consumer level. A digital platform is also in development to support this strategy, enabling centralized management of inventory, payments, kit performance, and social impact data.

3.5 SWOT Analysis

To assess the position of Juakit in the off-grid energy market, a SWOT analysis was performed. This framework helps identify strengths and weaknesses within the company, along with opportunities and threats from outside. It guides both short-term actions and long-term growth plans.

Strengths

Juakit is known for its strong design and long lifespan, which greatly surpasses most entry-level off-grid kits. By using second-life photovoltaic panels along with new, modular electronics, the system achieves both technological and system improvements. Its design supports multiple users and shared access to energy, making it ideal for schools, clinics, and small communities. The project is aided by a real-world pilot being developed in Uganda and has strong support from Coesa Srl and PhotonSolarSystem. Additionally, Juakit directly supports Sustainable Development Goal 7, which aims to provide universal access to affordable, reliable, and modern energy.

Weaknesses

Despite its strengths, Juakit faces challenges mainly because of its higher initial cost and the complicated logistics of sourcing, testing, and reusing second-hand panels. The product has limited data from the field. A reliable after-sales support system needs to be set up to maintain its long operational lifespan. Additionally, the project relies on external partners for key hardware components, which increases risk when trying to scale.

Opportunities

The market is favorable for Juakit. There is growing demand for reliable off-grid energy solutions in Sub-Saharan Africa, especially in fragile or underserved areas. At the same time, global policies are encouraging circular innovation and climate finance. Juakit's mid-range pricing allows it to serve a currently neglected segment of the market. Future growth could be boosted through partnerships with NGOs, local distributors, and government institutions.

Threats

Juakit may face tough price competition from cheap, low-quality products that dominate entry-level markets. Regulatory uncertainty, especially in fragile or conflict-affected areas, could make market entry more difficult. Global supply chain issues and increasing transportation costs are also risks. Finally, as a circular solution, Juakit may struggle with recovering panels at the end of their life and could have conflicts with established energy companies.

Category	Key Element
Strengths	Robust and long-lasting design (8–10 years)
	Circular architecture using second-life PV
	Strong industrial backing (e.g., Coesa, PhotonSS)
Weaknesses	Higher upfront cost compared to basic competitors
	Logistical complexity (collection, transport, delivery)
	Dependence on external suppliers and partners
Opportunities	Growing demand for reliable off-grid energy
	Global trend toward green and circular models
	Expanding local networks and partnerships
Threats	Low-cost competitors with inferior quality
	Political instability in target countries
	Supply chain volatility and rising component costs

Table 10 - SWOT Analysis

3.6 Risk analysis and risk mitigation strategy

When launching and scaling a circular, impactful solution like Juakit, it's crucial to understand the market risks involved. These include institutional, economic, regulatory, operational, and perceptual factors. Special care is needed since the project plans to work in fragile and disadvantaged areas of sub-Saharan Africa.

Entry barriers and institutional complexity

Target countries have regulatory and bureaucratic systems that create significant challenges. Importing solar technologies, especially those made with second-life components, often encounters scattered procedures, inconsistent standards, and unpredictable customs delays. For instance, several countries in West and Central Africa do not have efficient customs clearance procedures for off-grid kits at ports and may require expensive compliance certifications depending on the country [2]. Furthermore, in places without clear rules for reused modules, entering the market can take longer. Juakit focuses on reuse and circularity by using refurbished photovoltaic modules from the European secondary market. However, many Sub-Saharan African countries still do not have clear legal guidelines or certification processes for second-life solar components [2]. This situation poses two risks: (1) refurbished systems may not qualify for national energy access programs or climate finance, and (2) possible bans or rejection of used products could occur after deployment, threatening business continuity. To reduce these risks, the modules will be pre-certified in Europe according to international standards to simplify customs procedures and expedite customs clearance. KeepTheSun will collaborate closely with NGOs and development partners to raise institutional awareness of circular solutions and advocate for acceptance of European testing standards at the national level in the target countries.

Operational and logistical risks

Operational complexity affects both the upstream and downstream logistics chains. Upstream, collecting, testing, and reprocessing used PV modules needs technical infrastructure and quality control processes that are not yet standardized in Europe. Downstream, transporting kits to rural Africa involves risks like poor roads, political checkpoints, and seasonal access problems in remote areas. Additionally, a lack of local technicians could impede installation, maintenance, and user training, particularly without strong local partnerships. The project will set up regional logistics hubs and partner with local distributors and technicians to boost last-mile delivery and maintenance capabilities. Technical training programs will be introduced to build local capacity and lessen reliance on external support.

User trust and product perception

Consumer perception is crucial for the adoption of off-grid energy solutions. In key target markets like Uganda, previous experiences with low-quality solar kits, especially those tied to unclear PAYGO contracts or early device failures, have led to widespread mistrust of solar technologies [21]. Anyway, in many Sub-Saharan African settings, high-quality second-hand equipment is often perceived positively, especially when associated with industrial-grade durability and European manufacturing. This presents a clear opportunity for Juakit. Nonetheless, it is essential to communicate the principles of circularity and component reuse in a way that is clear and accessible. Juakit must offer a transparent and compelling narrative that conveys the value, safety, and long-term reliability of refurbished modules. This message should be reinforced by tangible local infrastructure, such as trained agents, distribution networks, and responsive customer support. Building trust will depend not only on product performance but also on the credibility of the broader ecosystem around it. Strong emphasis will be on community engagement, open communication, and user education. The pilot project in Uganda will be a key demonstration of Juakit's effectiveness. It will help build credibility through a local presence and trusted agents.

Macroeconomic volatility and political risk

Currency instability, inflation, and global supply chain disruptions (intensified by pandemics, geopolitical conflicts, and resource scarcity) pose serious threats to off-grid energy initiatives. In recent years, inflation has reduced the buying power of end-users and the financial stability of distributors. Key hardware components, like batteries, charge controllers, and inverters, are experiencing global shortages. This makes basic freight capacity more uncertain and expensive [2]. For a circular product like Juakit, which uses both refurbished and new parts from various sources, this results in higher operational risks and more complex planning. Juakit's deployment model focuses on FCV areas, including remote rural locations with poor infrastructure and unstable governance. In these regions, operations may face disruptions from logistical problems, cost issues, security incidents, sudden regulatory changes, or civil unrest. These risks are real and reflect the current geopolitical landscape [2]. While FCV regions are high-need, high-impact zones for energy access efforts, they also require tailored risk management strategies. To tackle these challenges, the project will widen its supplier network, add financial buffers to its pricing models, and pursue long-term agreements with important component suppliers. Risk mapping will guide the selection of countries, focusing on regions with relative stability for pilot deployment. Working with humanitarian organizations will help maintain service continuity, even in high-risk areas.

Risk	Description	Mitigation strategy
Regulatory	Absence of clear certification frameworks for second-life panels; inconsistent import regulations	Collaborate with local authorities and NGOs to build acceptance; pre-certify panels in Europe
Operational logistics	High costs and delays in panel recovery, shipping, and rural distribution	Set up regional logistics hubs; partner with local distributors and technicians for last-mile delivery and maintenance
User perception	Negative bias due to prior low-quality PAYGO products;	Community engagement campaigns; pilot in Uganda as demonstration
Financial / Supply Chain	Exchange rate volatility; inflation in transport and battery prices; delays in component sourcing	Diversify suppliers; adopt price buffers in financial planning; secure long-term contracts with key hardware providers
Political and legal	Sudden policy changes, political unrest, or conflicts in FCV regions	Risk mapping for each country; choose pilot zones with relative political stability; adapt strategy

Table 11 - Strategic and operational risk matrix

4. The pilot project in Uganda – Supply chain

4.1 Geographical and socio-energy context of Uganda

Uganda, situated in the center of East Africa, is a landlocked country with a population of over 48 million people. Although the nation has seen consistent economic growth and better social indicators in the past decade, getting reliable electricity is still a significant challenge, particularly in rural and peri-urban areas. According to the International Energy Agency, only 42% of the population has access to electricity, with electrification rates in rural areas dropping below 25% in several districts [1].

The lack of access to energy greatly affects poverty, education, health, and local economic growth. Households and small businesses often depend on dirty and unreliable energy sources, such as diesel generators, kerosene lamps, and disposable batteries. This reliance raises costs and health risks. It also restricts opportunities for communities and worsens social inequalities.

Uganda's energy landscape relies mainly on hydroelectric power. This power source is vulnerable to climate changes and seasonal variations. The government has set ambitious goals to increase electricity access by developing the grid and mini-grids. However, progress is slow because of high infrastructure costs, financial challenges, and governance issues, particularly in remote areas. In this scenario, decentralized solar options present a practical and scalable solution. Off-grid solar systems have become one of the most promising ways to advance Sustainable Development Goal 7 (SDG 7 – Affordable and Clean Energy). Uganda has turned into one of the fastest-growing markets for Solar Home Systems (SHS) and Pay-As-You-Go (PAYG) models in Sub-Saharan Africa [22].

The pilot project for Juakit is closely aligned with Uganda's national electrification goals and broader international sustainability aims. By reusing second-life photovoltaic panels and incorporating battery storage and modular electronics, Juakit provides a cost-effective, circular, and scalable energy solution. Its plug-and-play design is well suited for local schools, rural clinics, and community centers, where energy needs surpass the capacity of traditional entry-level SHS kits. Furthermore, Uganda is experiencing significant population growth and urban pressures, which are likely to increase energy demand in the coming years. Uganda ranks among the top ten African countries for SHS sales and boasts a lively network of NGOs, last-mile distributors, and microfinance institutions [2]. This environment is ideal for introducing Juakit and validating it through real-world field tests.

The pilot project, coordinated by Coesa S.r.l. in partnership with local groups, will collect important data on performance, usability, and socio-economic impact. It will also serve as a testing ground to assess the solution's circularity potential in one of the world's most energy-vulnerable areas. This will help link sustainability, innovation, and inclusive development.

4.2 Specific objectives of the pilot and stakeholders involved

The pilot project in Uganda represents a crucial step in field-testing the Juakit system under realistic operational and environmental conditions. The aim is to validate the technical, social, and economic feasibility of deploying a circular off-grid energy solution in a rural, low-income context characterized by limited infrastructure and basic energy needs. The plan for this initial stage is to install one Juakit unit on a small dairy farm in a rural area of Uganda.

Pilot's objectives

The system will serve two main purposes:

1. Power refrigeration units to keep milk and dairy products fresh before transport and sale.
2. Provide light with eight LED bulbs for use in the farmer's home.

This setup is designed to meet the actual energy needs of rural Uganda, which are much lower than those in Europe. For context, the average yearly electricity consumption per person is about 6,000 kWh in Europe, while in Sub-Saharan Africa, it often falls below 200 kWh per person [2]. This difference shows why it's crucial to have appropriately sized, modular technologies like Juakit. They provide essential energy services without going beyond actual needs or causing excessive costs.

In this context, energy isn't viewed as a way to support high-consumption lifestyles. Rather, it serves as a tool for basic services that can help people earn income, preserve food, and improve safety and quality of life. For example, the ability to keep milk fresh with solar refrigeration reduces spoilage, boosts bargaining power, and strengthens involvement in local agricultural value chains.

The pilot project in Uganda is an important test to see how well Juakit works in areas with high temperatures, rural isolation, and limited access to the power grid. One main goal is to check how consistently the system runs in tropical conditions and with changing energy demand. Using remote telemetry, the pilot will allow for ongoing tracking of both energy production and consumption. This will provide useful insights into usage patterns and system efficiency over time. Gathering direct feedback from users is also essential. We need to know how easy the system is to use, its maintenance requirements, and overall satisfaction. This information will help improve both the technical setup and the user interface, so they better suit the needs and abilities of rural households. Additionally, the pilot will examine the economic and productivity effects of Juakit by looking at how access to reliable electricity improves lives. For example, keeping milk from spoiling for more than a day may lead to higher sales and better financial stability. The pilot aims to confirm the system’s technical viability and show its role in empowering communities economically.

Roles and stakeholders

The pilot project is led by Coesa S.r.l., which plays a key role in both developing the technology and guiding Juakit's strategy. Coesa is in charge of integrating system components, customizing the kit for local needs, managing logistics, and sourcing refurbished solar panels. It also handles installation planning and sets up the remote monitoring system. At the same time, Coesa leads the evaluation phase, defining and tracking key performance indicators to ensure the pilot provides useful feedback for future expansions.

A main technical partner is Photon Solar System, an Italian startup that focuses on solar innovation. Photon takes care of the hardware development and physical construction of the Juakit suitcase. Their skill ensures the system is durable, portable, and works well with reused components; important features that make Juakit different from other off-grid products. In Uganda, a team of local partners will manage field operations. They are currently being selected. Their tasks include picking and preparing the pilot site, connecting with the beneficiary household (the smallholder dairy farmer), and managing community logistics. They will also give basic technical support, monitor how the system is used, and assist with data collection and community engagement activities.

This small-scale but impactful deployment serves as proof of concept. It shows that even a small amount of energy can lead to real improvements in rural lives when provided through a reliable, affordable, simple system. By addressing actual needs with a circular and scalable solution, Juakit shows how inclusive energy innovation can offer lasting benefits to communities. Insights from this initial pilot will be crucial in improving the system and planning for a wider rollout in Uganda and other underserved areas.

4.3 Understanding the end user: Customer exploration strategy

The success of a technology like Juakit isn't just about how well it works or its cost. In off-grid areas, where access to electricity relates to social, economic, and cultural factors, knowing the end user is essential. In Uganda, as in many Sub-Saharan countries, energy needs are often overlooked in traditional data sources. These needs vary greatly among urban, peri-urban, and rural areas, and even more in unstable regions. That's why the pilot phase in Uganda has a specific customer exploration strategy. This strategy aims to study the behaviors, expectations, and challenges of the real people who will use Juakit. The goal is not only to validate a product but also to design a solution that fits people's real experiences, routines, and financial situations. Grasping how people currently access energy, what they use it for, how much they can pay, and how they view technology is crucial.

This exploratory process focuses on three main questions: What do local households and smallholders really need from an energy system? How are they currently meeting those needs? What would encourage them to trust and adopt a new solution like Juakit?

The research will take place in the field, not behind a desk. It will include interviews, observations, and surveys. In areas with limited or unreliable electricity access, and where distrust of poorly performing products is common, especially in the PAYGO market, listening to people is the only way to design something useful, desirable, and sustainable. One delicate aspect to look into is the perception of refurbished solar components. While used items can be accepted and even valued when they are durable and functional, clear communication about their origin and performance will be crucial to build trust. The customer exploration phase will also guide important decisions about pricing models, technical setups, and after-sales strategies. For instance, although Juakit aims to power multiple devices for more than one user at a time, this assumption needs to be validated in real communities. Shared use may be common in some areas, while energy management can occur at the household level in others. Payment options also need to be flexible and clear, especially in communities with limited cash flow or unpredictable income.

To finish this phase, the project team will send out a standardized survey to a representative sample of rural households in Uganda. They will target smallholder farmers and communities that have no or unreliable access to the grid. The survey will be done in collaboration with local partners and translated into local languages when needed.

Proposed survey instrument

Title: Household and community energy needs survey – Juakit Pilot Project

Section	**Questions**
1. Household profile	1.1 How many people live in your household? 1.2 What are the main sources of income? 1.3 Do you own or rent your home?
2. Current energy access	2.1 Do you currently have access to electricity? (Yes/No) 2.2 If yes, what type of source? (National grid / Generator / Solar lamp / None / Other) 2.3 How many hours per day is electricity available? 2.4 What appliances do you currently use at home?
3. Energy needs and priorities	3.1 Which energy services are most important to you? (Lighting / Phone charging / Refrigeration / TV / Agricultural use / Other) 3.2 Have you ever used solar products before? (Yes/No) 3.3 What challenges did you experience, if any?
4. Affordability & payment	4.1 How much do you currently spend on energy per month (fuel, phone charging, etc.)? 4.2 Would you prefer to pay a fixed amount each month or pay only for what you use? 4.3 What is a reasonable monthly amount you could afford for a reliable energy service?
5. Perception and trust	5.1 Would you trust a product made from reused solar components? 5.2 What concerns would you have, if any? 5.3 What would make you more confident in adopting such a solution?
6. Feedback on Juakit	6.1 After seeing the system, do you believe it would meet your household's needs? 6.2 What features do you find most useful? 6.3 What could be improved?

Table 12 - Energy need survey used to understand the end user

This survey is not only a tool for information gathering but also a way to start a conversation with the community. The answers will guide both the short-term adaptation of the pilot and the long-term business and deployment strategy of Juakit across Uganda and similar regions. Ultimately, customer exploration is not just about understanding the market, it’s about making sure the innovation we deliver is truly relevant, inclusive, and capable of generating lasting impact.

4.4 Operational process and technical feasibility: from pickup to redistribution

The operational workflow of Juakit shows the complexity and goals of a circular, decentralized energy solution. Unlike traditional solar systems that depend on new parts and centralized distribution, Juakit offers a modular, reuse-based system. This approach combines environmental sustainability with affordability. The whole process, from sourcing to deployment, is carefully designed to guarantee technical reliability and replicability in off-grid settings.

Each Juakit system starts with collecting second-life photovoltaic panels. These panels still retain at least 80% of their original performance and come from decommissioned solar installations in Europe, mainly from rooftop systems replaced after 10 to 15 years. For example, Italy had over 20 GW of installed capacity by 2012 [8]. This means thousands of panels are gradually entering the secondary market. Many of these components are often thrown away or recycled badly, even though they can still work well for another decade or more. After collection, the panels go through testing and certification to check their functionality and safety. This step happens at certified facilities, where each module's electrical performance, insulation, and physical integrity is verified. Only panels that meet strict durability and efficiency standards are chosen for Juakit. The testing process includes electrical profiling to ensure consistency within the kits and to make remote monitoring easier after installation.

Following inspection for quality Photon Solar System will put the Juakit kit's hardware together. The battery, charge controller, DC/AC ports, and remote monitoring systems are all included in the robust suitcase-style design of the solar panel. Since each kit is made to be plug-and-play and requires little on-site setup, fewer skilled technicians are needed.

Coesa S.r.l. is responsible for logistics and transportation. They oversee international shipping and by employing efficient container strategies, they lower expenses and guarantee adherence to customs regulations. The portability of Juakit's modular design is one of its main advantages. In fact, for routine cargo transportation, the entire system is adequate in size; this simplicity helps with delivery to rural areas in countries like Uganda.

Local partners supervise operations on the ground after the kit reaches the destination country. They set up the website, install the system, and instruct users in basic maintenance and use. The platform for remote monitoring is also turned on at the same time. The project team can now monitor energy production and consumption in real time thanks to this. This system facilitates prompt remote support when required and aids in the early detection of any problems.

This organized yet flexible process shows Juakit's technical feasibility across the entire value chain. By connecting European circular supply streams with local resources in the Global South, the model bridges two worlds, turning possible waste into a means for social impact. This method is both environmentally and economically sustainable, and it stays practical, even in fragile and resource-limited environments.

4.5 Project management and Work Packages (WPs)

Work Packages (WPs)

Five interconnected Work Packages (WPs) with distinct goals, deadlines, and deliverables make up the schedule of the KeepTheSun project. Proactive risk mitigation, adaptive resource management, and systematic progress tracking are made possible by this modular organization's alignment with a comprehensive month-by-month planning framework.

WP1 – Prototype requirements and use case definition (Months 1–2)

The primary objective of this initial phase is to define the operational and technical requirements of the Juakit prototype. Several potential use cases are identified, including the implementation of off-grid electrification for rural households, schools, and microenterprises, and a thorough assessment of the planned implementation contexts in Uganda is conducted. A structured survey will be distributed to local stakeholders to gather information on priorities, affordability, and energy consumption patterns, ensuring the solution meets actual user needs and that the market study is thorough. The final result will be a functional and technical report outlining the product and user specifications, both of which are essential to guide Juakit's development.

Deliverable: Technical and functional specification report.

WP2 – Prototype development and In-house testing (Months 3–4)

This second stage involves the physical assembly of the first Juakit prototype, which combines modular hardware components with second-life solar panels. The kit is put through a rigorous testing process in the lab to assess its environmental resilience, durability, safety standards, and energy performance. The digital monitoring platform, which will allow for remote diagnostics and usage data monitoring, is being developed concurrently.

Deliverable: Assembled and tested prototype, ready for field deployment.

WP3 – Field pilot and market validation (Months 5–7)

The prototype is used in a real-world pilot venture in Uganda, where its functionality is observed in real-world settings. Data on energy generation, consumption trends, and user satisfaction are gathered both quantitatively and qualitatively. The Pay-As-You-Go model's implementation is also tested, providing information on behavioral acceptability and affordability.

Deliverable: Pilot evaluation report with field data and user feedback.

WP4 – Product refinement and platform integration (Months 8–10)

The hardware and software components of the Juakit design are improved in response to the pilot's findings. The Juakit is incorporated into the KeepTheSun digital platform, which enables assets, performance, and lifecycle management, and the supply chain procedure for locating and assembling extra units is optimized.

Deliverable: Optimized bill of materials (BOM), and platform integration demo.

WP5 – Commercial rollout & circularity dissemination (Months 11–12)

The last stage prepares the ground for scaling. The project's circular and social value will be promoted through communication campaigns. Moreover, a local sales and support network will be established, and the certification path for carbon credits linked to avoided emissions will be prepared.

Deliverable: Commercial rollout roadmap and dissemination materials.

With the help of field-tested data and a foundation in sustainability and the circular economy, this phased structure guarantees that technical development, user-centered design, logistical planning, and business strategy all advance simultaneously.

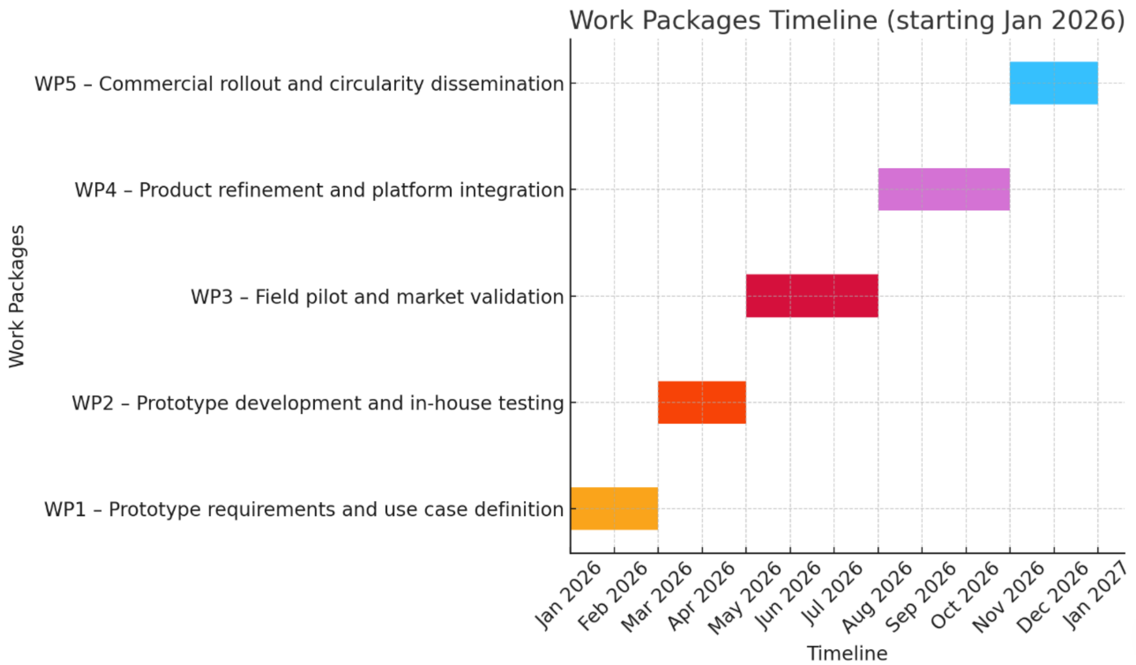

Figure 5 - GANTT chart

WBS (Work Breakdown Structure)

Each Work Package (WP) will be divided into smaller tasks using the Work Breakdown Structure (WBS) methodology in order to organize the project in an understandable and controllable manner. WBS is a popular management tool for breaking down complicated projects into smaller, easier-to-manage parts. By making task assignment, resource allocation, scheduling, and monitoring easier, this hierarchical framework guarantees that every project phase is precisely defined and practically achievable.

WP1 – Prototype requirements and use case definition

By relating the technical design to the requirements of target communities, this first stage lays the foundation for Juakit's future development. There are three primary steps in the process:

- Context analysis in pilot areas: This entails a thorough assessment of the physical, social, and economic circumstances in a few chosen rural Ugandan communities. The analysis seeks to determine the primary obstacles to energy access as well as the baseline requirements for electrification of homes and public buildings.
- User needs survey and demand mapping: Data collection occurs through structured questionnaires and field surveys distributed locally. The goal is to gather insights into energy usage patterns, user expectations, affordability limits, and priorities related to off-grid solutions.
- Definition of technical and functional specifications: The insights from the previous activities are combined into a technical requirements document that outlines the Minimum Viable Product (MVP). This includes key details such as expected power output, system modularity, ease of use, and compatibility with local conditions and user profiles.

WP2 – Prototype development and in-house testing

The goal of this work package is to construct Juakit's first working prototype and validate it in a controlled setting. The following activities are part of it:

- Juakit prototype assembly: It entails combining new electronic components with repurposed photovoltaic panels into a small, robust suitcase-like design. Strength, portability, and appropriateness for off-grid use in rural areas are highlighted in the design.

- Lab testing and performance validation: This entails evaluating the assembled prototype under simulated environmental and load conditions. The main performance indicators are energy conversion efficiency, system durability, and adherence to electrical safety standards.
- Development of remote monitoring system: This means creating and putting into use a mobile-based digital interface that enables real-time tracking of energy production, storage conditions, and consumption trends. This system facilitates user interaction, diagnostics, and potential future integration with more extensive platform infrastructures..

WP3 – Field pilot and market validation

This stage starts the Juakit system's practical testing in a rural area of Uganda. Its technical performance and user acceptability are to be assessed. Among the activities are:

- Installing the pilot unit: It entails putting up a fully functional Juakit prototype in a rural farming area. The system will provide energy for important needs like milk refrigeration and home lighting.
- Monitoring of usage data and user feedback: This includes collecting usage data along with conducting interviews and observations. The aim is to evaluate usability, maintenance needs, and how useful the system seems to the end-users.
- Evaluation of economic benefits and PAYGO model: This looks at how well the Pay-As-You-Go (PAYGO) payment model works. The focus is on its impact on household productivity, energy reliability, and the overall economic sustainability of the solution.

WP4 – Product refinement and platform integration

This stage aims to improve the Juakit system based on insights from the field pilot. It also prepares the system for large-scale deployment by connecting it to the digital infrastructure. The activities include:

- Design optimization and technical adjustments: This involves making repeated improvements to hardware and software components to boost system performance, make assembly easier, and lower production costs.

- Supply chain structuring and sourcing procedures: This focuses on developing a clear supply chain framework, including logistics workflows and quality assurance steps for sourcing, testing, and qualifying second-life components.
- Integration into the KeepTheSun digital platform: This ensures Juakit is fully integrated into the wider KeepTheSun digital ecosystem. It allows for centralized tracking of inventory, monitoring of impact indicators, and evaluation of circularity metrics throughout the product lifecycle.

WP5 – Commercial rollout and circularity dissemination

The final phase focuses on getting the Juakit system ready for the local market and promoting its environmental and social impact. The key activities are as follows:

- Development of a local distribution network: Identify, select, and onboard key implementation partners, including NGOs, local PAYGO agents, and technical service providers, to support product distribution, maintenance, and customer engagement in the community.
- Awareness and trust-building campaign: Create and disseminate instructional and marketing materials to increase knowledge of the Juakit solution. The campaign emphasizes the system's social significance and environmental advantages while focusing on institutional actors and local communities.
- Carbon credit modeling and dissemination strategy: Calculate the avoided greenhouse gas emissions associated with the implementation of Juakit. Enabling certification under carbon finance mechanisms is the aim. To encourage stakeholder participation and possible funding opportunities, the results will be disseminated via focused outreach materials and communication channels.

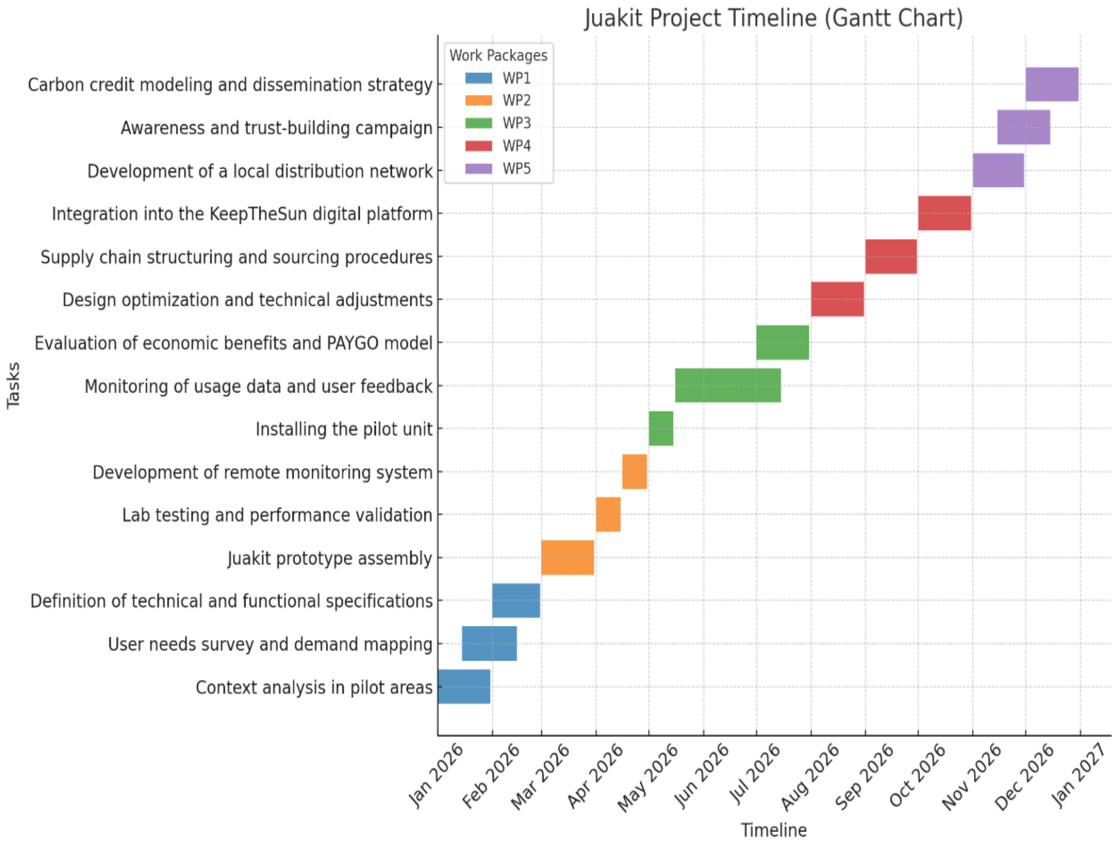

Figure 6 - Detailed GANTT Chart overview

KPIs

KeepTheSun's performance has been measured in three main areas: supply chain efficiency, user adoption, and environmental impact. We have set up Key Performance Indicators (KPIs) to ensure effective project monitoring and ongoing improvement. During and after the pilot phase, these KPIs help guide decision-making and act as metrics for evaluating progress.

1. Environmental impact KPIs

These indicators assess how well Juakit aligns with circular economy principles and contributes to climate goals:

Indicator	**Definition**	**Target / Notes**
CO_2 emissions avoided ($kgCO_2$/year)	Estimated emissions saved by replacing diesel generators with solar energy	Based on conservative fuel displacement assumptions
Reuse rate of PV panels (%)	Share of refurbished panels in each deployed Juakit kit	Should remain ≥ 90% to maintain circularity goals
Waste diverted from landfill (tons)	Total amount of e-waste (mainly panels) repurposed instead of discarded	Monitored per shipping batch from Europe to Africa

Table 13 - Environmental impact KPIs

The environmental dimension of the KeepTheSun project is intrinsically linked to its circular design philosophy, which emphasizes reuse, waste reduction, and greenhouse gas mitigation. The KeepTheSun project's circular design approach, which emphasizes reuse, waste reduction, and greenhouse gas emission decreasing, is closely linked to its environmental component. The set of environmental KPIs above has been developed in order to quantify this impact.

The quantity of CO_2 emissions avoided is among the most significant indicators, replacing fossil-fuel-based generators with solar energy benefits the climate. This KPI is crucial not just for assessing the project’s climate benefit but also for possible future carbon credit certification. Other indicators include the reuse rate of photovoltaic modules, which indicates how well second-life panels are used in each Juakit unit. Also important is the total weight of e-waste kept out of landfills, providing clear evidence of resource circularity. Together, these indicators help confirm the project's environmental validity and show its support for Sustainable Development Goals, especially SDG 7 (affordable and clean energy) and SDG 12 (responsible consumption and production).

2. Adoption and social impact KPIs

These track how well Juakit is accepted by users and whether it delivers tangible improvements in quality of life:

Indicator	Definition	Target / Notes
User satisfaction rate (%)	Share of users reporting positive experience (post-installation surveys)	Target ≥ 85%
Daily energy usage (Wh/day)	Actual consumption per household vs. expected capacity	Benchmark for system adequacy
Economic uplift indicators	Number of users reporting increased income due to energy access	Based on survey and qualitative interviews
Retention rate after 6 months (%)	Share of users still using the system after 6 months	Key for long-term sustainability and business model validation

Table 14 - Adoption and social impact KPIs

Beyond whether the technology works, Juakit's success depends on how well rural users in Sub-Saharan Africa accept and continue using it. To measure this, we have created a set of key performance indicators focused on user adoption, usability, and socio-economic benefits.

The user satisfaction rate, gathered through structured surveys after installation, will give us immediate feedback on the quality, ease of use, and adequacy of the service. We will also track daily energy usage per household and retention rates after six months. These metrics will show if the product meets user expectations over time and stays integrated into their daily routines. Additionally, we will look at economic indicators, such as increases in productivity or income generation through services like refrigeration or mobile charging. This data will help confirm the broader impact of the intervention. These KPIs are vital for creating a user-centered business model and for adjusting future versions of the system to fit real-world needs.

3. Supply chain and operational KPIs

These indicators focus on the efficiency and scalability of logistics and operations:

Indicator	Definition	Target / Notes
Cost per kit delivered (€)	End-to-end cost including sourcing, assembly, transport, and installation	Used to refine pricing strategy and identify bottlenecks
Lead time (days)	Time from order confirmation to final installation	Target: < 45 days from Italy to rural site
On-time delivery rate (%)	Percentage of shipments arriving within planned timeframe	Should exceed 90%
Number of local technicians trained	Capacity building metric for local support	Tied to long-term sustainability of the project

Table 15 - Supply chain and operational KPIs

From the perspective of management engineering, KeepTheSun's logistical and operational performance is just as important as its social and technological components. Given the complexity of operating between Europe and Africa, the KPIs in this area are centered on monitoring the system's supply chain's resilience, scalability, and efficiency.

Key metrics include the cost per unit delivered, which covers the whole value chain from sourcing refurbished components to final on-site installation. Lead time measures how quickly Juakit can be deployed in remote locations. The on-time delivery rate is also a key metric, showing logistical reliability. Finally, since developing local capacity is essential to growing deployment without depending on outside assistance, the quantity of trained local technicians is a sign of long-term project sustainability as well as an operational indicator. In addition to enhancing internal procedures, these KPIs set up the project for successful expansion under a flexible and lean management style.

5. Economic and financial business plan

Hardware procurement, design iterations, technical testing, and final assembly are all phases of Juakit's development. These also include the various steps for storage, transportation, and on-site sales, as well as marketing, sales, and after-sales plans. Based on internal estimates, partner quotes, and cost projections, the main cost categories are broken down according to the following structured method.

5.1 Cost analysis of Juakit's pilot

A. Bill of Materials (BoM)

The foundation of Juakit's prototyping process is the component procurement and testing phase. With an emphasis on guaranteeing both functionality and durability in field settings, this stage entails acquiring the essential structural and electronic components required to construct and validate the system. The bill of materials was created to maintain technical robustness while striking a balance between affordability and performance. According to the procurement plan, five test units will be built, some of which will be used for functional trials and others for design validation, failure testing, and backup purposes. Below is a summary of the key elements:

- Rugged suitcase (5 units, €50 each, €250 total): This is the main casing for Juakit. Its durability is important for withstanding transportation and rough handling.
- Solar charge controller (40A, 5 units at €35, €175 total): This device manages the energy flow between the solar panels, battery, and load, ensuring safe and efficient charging.
- Inverter (500W, 5 units at €100, €500 total): This converts the DC energy stored in the battery into usable AC power. It allows for compatibility with standard appliances.
- 12V batteries (3 units at €60, €180 total): These are meant for testing purposes only. They enable the simulation of actual usage cycles and system behavior under load.
- 12V chargers (5 units at €25, €125 total): These are essential for initial charging and testing of the battery systems in controlled conditions.

- Display modules (GUI/SOC, 3 units at €7, €21 total): These small screens provide basic information on state-of-charge and power status. They facilitate user interaction.
- 220V outlets (2 units at €10, €20 total): These are used to replicate typical household use scenarios and ensure safety compliance for end users.
- Connectors and wiring (10 sets at €2, €20 total): These are critical for internal connections and system modularity.
- Spare parts and contingency margin (€50): This amount is included to cover unexpected component failures or replacements during testing.

Component	**Quantity for prototyping**	**Unit price (€)**	**Total (€)**
Rugged suitcase	5	50	250
Solar charge controller (40A)	5	35	175
Inverter (500W)	5	100	500
12V Battery (for testing)	3	60	180
Charger 12V	5	25	125
Display (GUI/SOC)	3	7	21
220V outlets	2	10	20
Connectors and wiring	10	2	20
Spare parts and margin for failures	—	—	50
Subtotal (hardware)	—	—	**€1,341**

Table 16 - Estimated hardware costs for Juakit prototype development

The estimated subtotal for this hardware purchase is €1,341. This sum covers every component required to construct and verify the initial iterations of Juakit. As the project moves closer to larger-scale production and improved sourcing, these numbers, which reflect pre-industrial costs, should decrease.

Testing Juakit's performance and resilience in tropical, off-grid environments is made possible by this initial investment in high-quality, modular components. Before the system is put into use, it makes sure that it satisfies user expectations and technical standards.

B. Engineering and validation effort

Given the technical complexity and accuracy needed to design, assemble, and test a reliable, modular off-grid energy system, a significant amount of the initial investment in the Juakit pilot phase went toward engineering and validation. The entire estimated effort comes to 200 hours, or €8,000 in direct labor costs, assuming a labor cost of €40 per hour. Each phase is explained in detail below.

Development phase	**Estimated hours**	**Cost (€ 40/h)**
Component research and sourcing	50	2,000
Bench testing and setup	40	1,600
Field testing under real conditions	20	800
Prototype 3D design and assembly (2 kits)	80	3,200
Final validation and documentation	10	400
Subtotal (labor)	**200**	**€8,000**

Table 17 - Estimation of labor hours and costs for Juakit development phase

- Component research and sourcing (50 hours → €2,000)
  This entails locating compatible, long-lasting, and reasonably priced parts, especially used photovoltaics and related electronics. In order to fulfill MVP requirements, supplier dependability and component interoperability must be guaranteed.
- Bench testing and setup (40 hours → €1,600)
  This includes assembling the system in the lab and testing its functionality under controlled conditions. We will check the electrical performance, thermal behavior, and fault handling before taking prototypes into the field.
- Field testing under real conditions (20 hours → €800)

We will conduct tests in simulated off-grid environments, such as varying temperature, humidity, and dust conditions. This is to evaluate actual performance in Uganda with an emphasis on durability, battery charge/discharge cycles, and solar generation efficiency.

- Prototype 3D design and assembly (2 units, 80 hours → €3,200)

  This covers the mechanical design needed for fitting components into the rugged suitcase.In order to guarantee usability and serviceability in the field, iterative testing is conducted in addition to wiring and integrating the panels, inverter, and monitoring systems.

- Final validation and documentation (10 hours → €400)

  Clear technical documentation, such as component specifications, test reports, maintenance manuals, and electrical diagrams, will be created by us. Training, knowledge sharing, and possible future certification or replication will all be aided by this.

These numbers represent the amount of money required during the pilot stage to guarantee Juakit's dependability, safety, and capacity to withstand real-world circumstances. We anticipate that labor time and expenses will decrease as the project expands because of streamlined procedures and mass production efficiencies.

C. Logistics and deployment – Pilot mission (1 unit)

The necessity of close field participation and direct technical supervision is demonstrated by this pilot deployment scenario. The best course of action is to manually transport the Juakit unit using the luggage allowance of two team members going to Uganda, as only one will be installed during the initial pilot phase.

	Details	Estimated cost (€)
Air transport of 1 Juakit unit	As additional checked-in luggage (oversize/special baggage fee)	~150
Travel & field mission (2 people)	Flights, local transport, accommodation, meals (10 days, Uganda) *(see bando)*	~3,000
Customs, duties and clearance	Entry tax estimate based on solar equipment declaration	~60
Local installation and logistics	On-site delivery, setup support, basic user training	~50
Subtotal (logistics and deployment)	Includes full field mission and delivery	**~3,260**

Table 18 - Estimated logistics and deployment costs for field pilot in Uganda

A huge amount of the cost comes from the 10-day field mission. This covers round-trip airfare, local transport, food, and accommodation for two people. It must be considered that large or heavy technical equipment usually requires a special baggage fee. Being on-site is crucial for proper installation and monitoring of the system. It also helps with community engagement, gathering baseline user feedback, and starting the first phase of the Pay-As-You-Go user interface. Customs and duties have been estimated based on usual charges for solar equipment entering Uganda. These could change depending on how the second-life hardware is classified. Local logistics, such as last-mile transport, physical setup, and basic training, are included. However, these costs are small compared to the overall mission expenses. This high-cost-per-unit pilot model makes sense for the early stages of the project, where learning, impact assessment, and feedback are key. Future large-scale deployments will probably use container shipping and local partners to lower costs significantly.

Total unit-level estimation (pilot phase)

I decided not to include R&D overhead costs in the prototyping analysis. These expenses relate to more general costs that are not directly related to a single Juakit unit, like shared laboratory equipment, general project coordination, administrative support, or documentation. I concentrated on direct and traceable costs, particularly hardware components, engineering labor, and deployment logistics, for the sake of clarity and transparency. These expenses more accurately represent the monetary requirements for scaling and reproducing the pilot in practical settings, so they will be considered in the scale-up analysis in the following pages.

Category	**Per unit cost estimate (€)**
Components (bill of materials)	€1,340
Labor (design + testing)	€8,000
Logistics & deployment	€3,260
Total per Juakit prototype	**€12,600**

Table 19 - Estimated total cost per Juakit prototype (All-Inclusive)

The unit-level cost estimation outlines the expected expenses needed to deploy a Juakit prototype during the pilot phase in Uganda. This phase covers the physical assembly and shipping of the product, along with the necessary research, development, and field engagement. Verifying its functionality, assessing user acceptance, and refining the business model for future expansion all depend on these activities.

While this amount is high for a consumer product, it accounts for the complete costs of product development, deployment, and evaluation in a fragile, off-grid setting. It is crucial to remember that these numbers only pertain to the pilot stage and do not account for Juakit's long-term commercial costs. It is anticipated that bulk purchasing, better logistics, and a reduction in labor time per unit will result in a significant reduction in overall costs once the design is complete and production ramps up.

5.2 Cost analysis and scale-up

Sales prediction, CoA and target selling price

Field data collection revealed strong growth in systems similar to Juakit, which is why the following sales forecasts were made, which are ambitious but decidedly realistic. The product will be in its launch phase in 2026, with an initial prototyping period in Gulu and subsequent market penetration. Sales are estimated at 100 units, reflecting a realistic but cautious entry strategy. Based on the results of this first year and thanks to advertising and improvements, sales are expected to increase to 500 units in 2027, which represents a credible growth path. From 2028 onwards, the goal is to consolidate and increase visibility, which will lead to a further increase in sales to approximately 1,000 units, thus confirming the project's sustainable scalability.

As shown in the following table, sales targets are aligned with a progressively optimized marketing budget and decreasing Customer Acquisition Cost (CoA), reflecting growing market efficiency, brand awareness, and local partner engagement.

	Revenue (€)	Budget marketing (%)	Marketing (€)	Sales	CoA (€ / clients)
2026	80.000,00 €	3%	2.400,00 €	100	24,00 €
2027	415.000,00 €	2%	6.225,00 €	500	12,45 €
2028	850.000,00 €	1%	8.500,00 €	1.000	8,50 €

Table 20 - Cost of Acquisition

The estimation of production costs for the Juakit system is grounded on a direct quotation obtained from Photon Solar System, the project's selected supplier. This external reference provides a reliable market-based benchmark for hardware expenditures, ensuring that the financial model reflects realistic procurement conditions. The unit cost decreases consistently over the three-year horizon, from €395 in 2026 to €314 in 2028, as a direct result of economies of scale associated with higher production volumes (100, 500, and 1,000 units, respectively). This trend highlights how progressive scaling not only supports market expansion but also improves cost efficiency, ultimately strengthening the project's long-term financial sustainability.

Production costs	2026	2027	2028
Units	100	500	1000
Hardware cost/unit	395,00 €	353,00 €	314,00 €
Total cost	39.500,00 €	176.500,00 €	314.000,00 €

Table 21 - Production costs

Just as hardware costs will decrease as orders increase, other costs will also benefit from economies of scale and decrease. An important cost to consider is the purchase of used photovoltaic panels. Thanks to KeepTheSun's consolidated network, it will be possible to purchase panels suitable for composing Juakit at the favorable price of approximately €15.00 per unit on average, making the reuse of decommissioned modules a cost-effective and sustainable sourcing strategy. It's also worth considering that each kit will include an IoT SIM card that allows for remote monitoring, and its annual cost ranges from €6.00 per kit in the pilot phase to €4.20 in the consolidation phase, reflecting negotiated local M2M rates and the impact of volume-based discounts.

Cost of materials	2026	2027	2028
Units of Juakit	100	500	1000
Total hardware cost PSS	€ 39.500,00	€ 176.500,00	€ 314.000,00
Units of used moduls	200	1000	2000
Used modules purchase	€ 3.000,00	€ 15.000,00	€ 30.000,00
Remote monitoring / IoT SIM	€ 600,00	€ 2.400,00	€ 4.200,00
Total	**€ 43.100,00**	**€ 193.900,00**	**€ 348.200,00**

Table 22 - Cost of maretials

The target selling price for each Juakit unit has been set at approximately €800, corresponding to about UGX 3,300,000. This pricing strategy stems from an in-depth field analysis, using both survey data and benchmarking comparable products offered by local and international competitors. The chosen price positions Juakit competitively; it's not a low-cost product, but it significantly outperforms similarly priced products, reflecting its added value in terms of modularity, reliability, and circular design.

5.3 Logistics structure and costs from Italy to Africa

Domestic transport and preparation in Italy

Juakit's deployment logistics guarantee the economical and effective transportation of materials from Italy to destinations in Africa, beginning with Uganda. Delivering the product and maintaining Juakit's circular business model depend heavily on this transcontinental supply chain.

The upstream logistics cycle of Juakit begins in Italy, where second-life photovoltaic panels are sourced, transported and prepared for integration into the final system. Leveraging the growing volume of decommissioned modules (especially from solar installations commissioned between 2005 and 2010) represents a cost-effective and circular strategy for component acquisition. These panels are perfect for our application, as they are not only affordable for companies in Italy, but are ideal for off-grid applications.

Procurement focuses on three main macro-regions: Northern, Central, and Southern Italy (including the islands). Based on historical installation data from the incentivized feed-in tariff period, it is estimated that approximately 50% of eligible used panels are located in Northern Italy, 30% in Central regions, and 20% in Southern areas [8]. Transport to the logistics hub in Turin is calculated using average round-trip distances: approximately 500 km from the North, 1,000 km from Central Italy, and 2,000 km from the South. Assuming a transport capacity of 500 panels per truck and a standard industrial shipping cost of €1.20 per km, the total transport cost for collecting 1,000 panels is estimated at around €2,200 for 1000 panels. This includes fuel, highway tolls, and driver labor across three partial truckloads.

Upon arrival in Turin, the panels are temporarily stored in a dedicated warehouse where they are tested, sorted, and matched with Juakit suitcases. A batch of 1,000 panels typically requires 50 standard pallets, each containing 20 modules. The estimated cost of warehousing and internal handling (including pallet storage, picking, and relabeling) is around €1,100–1,200 per month, based on average commercial warehouse rates in the Turin metropolitan area.

The domestic transport phase concludes with the transfer of the kits to the port of Genoa, where international shipment is organized. The kit is modular, allowing the panels and case to be optimally arranged in the container, optimizing space and reducing the risk of damage to the product during transport.

Maritime transport: Genoa to East Africa

Currently, the average cost of shipping a single 20-foot container (internal volume is 33 m³) from Italy to East Africa ranges from €5,000 to €7,500. The cost is affected by fuel prices, port traffic, and political stability along the maritime routes. According to the calculations that follow, the container is convenient if filled to its full capacity, to optimize costs.

Each Juakit unit is composed of:

- A solar suitcase (60 × 48 × 22 cm), weighing 20–25 kg, and occupying ~ 0.063 m^3.
- Two standard 400 Wp photovoltaic panels, each with an average dimension of 1.72 × 1.14 × 0.035 m, equivalent to ~ 0.068 m^3 per panel.

Assuming tight and protective stacking of the panels in bundles and vertical arrangement of the suitcases, the estimated total volume required per complete Juakit is approximately 0.2 m^3. We can conclude that 120 Juakit units would require approximately:

- 7.6 m^3 for 120 suitcases
- 16.3 m^3 for 240 solar panels
- Total ≈ 23.9 m^3 out of a usable 33 m^3 in a standard 20-foot container

This configuration is ideal to allows for the transportation of at least 120 complete kits per container, but also provides space flexibility for accessories, spare parts, or support materials (e.g., mounting hardware, documentation). The modular design of Juakit and the physical independence between energy generation (panels) and energy management (suitcase) support this logistical flexibility and makes this strategy particularly advantageous for scaling deployment and optimizing cost-per-kit logistics, especially when coordinating bulk shipments from Europe to off-grid regions in the future.

Customs procedures and import taxes in Uganda

One of the most critical and complex phases in the Juakit logistics chain involves customs clearance and taxation upon arrival in Uganda. Although many African countries formally encourage the import of renewable energy products, the relevant laws and regulations are often vague and unclear. The situation is similar in Uganda, where product approval for import follows poorly defined procedures, especially if the product in question is modular and composed of multiple components, like Juakit.

Import duties in Uganda are calculated based on the CIF value (Cost, Insurance, and Freight) of the shipment. This figure includes the value of the goods themselves (such as solar panels, suitcases, batteries, and inverters) and also the costs of international insurance and freight up to the port of entry (typically Mombasa or Dar es Salaam). For a standard 20-foot container carrying approximately 120 Juakit units, a realistic CIF estimate is around €48,000. This figure is derived from an average cost of €350 per kit and shipping and insurance costs of roughly €6,000.

Based on this CIF value, four main taxes and levies are typically applied. The import duty, amounting to 25%, is levied on the majority of imported electronics unless explicitly exempt. The Value Added Tax (VAT), at 18%, is then applied to the combined value of the goods plus the import duty. Additionally, a Withholding Tax of 6% is charged directly on the CIF value as an advance payment of income tax, while an Infrastructure Levy of 1.5% contributes to the national transportation and energy infrastructure fund.

Tax category	Calculation basis	Rate	Amount (€)
Import duty per container	CIF (€48,000)	25%	12.000,00 €
VAT	CIF + Duty (€60,000)	18%	10.800,00 €
Withholding Tax	CIF (€48,000)	6%	2.880,00 €
Infrastructure Levy	CIF (€48,000)	1.5%	720,00 €
Total estimated Taxes			**26.400,00 €**

Table 23 - Estimated import duties and taxes on CIF value

For solar technology projects with a high social impact or that improve community development, Ugandan customs could provide partial or even total exemptions that would make the project even more economically viable. However, obtaining these benefits is not easy and requires advance clearance through the Uganda Revenue Authority (URA). Exemptions are more likely to be obtained when imported by registered NGOs or public sector entities, in addition to submitting supporting documentation such as letters of endorsement from ministries, technical datasheets, and proof of intended use. Moreover, since Juakit is a modular system composed of multiple subcomponents (panels, cables, batteries, LEDs), there is a substantial risk that the customs authority will classify each item separately rather than recognizing the product as a unified solar kit. In such cases, only certain elements (typically the panels) may qualify for exemption, while others remain fully taxable.

Given the above, it is prudent for the present analysis to assume the standard tax regime in estimating operational costs. This results in a cumulative tax burden of approximately €26,400, or 55% of the CIF value. Anyway, the project's social impact potential and alignment with rural electrification objectives make it a promising candidate for exemption in future phases, so it is fundamental to establish partnerships with institutional stakeholders and applying through formal URA procedures in order to unlock significant savings and improve the project's economic sustainability on a scale.

Inland transportation and last-mile distribution in Uganda

Following customs clearance at East African entry ports kits are transported inland to their final distribution points, primarily located in northern Uganda, with a focus on the city of Gulu.

At this stage, the region's infrastructure weaknesses are the main risk, such as disused roads, seasonal floods, and traffic delays that can create bottlenecks. The overland route from the port to Gulu spans an estimated 900 to 1,200 kilometers, typically requiring medium- to large-capacity trucks with an estimated cost at approximately €700 per 20-foot container.

The distribution strategy is designed according to lean logistics principles, with the aim of minimizing intermediate warehousing and ensuring fast, direct delivery. Even before their arrival, the kits will be assigned to selected local distributors, such as electronics and solar product retailers, who will serve as the final point of sale for direct sales to customers. These partners are already embedded in the Ugandan economic and social fabric and will be responsible for direct sales, after-sales support, and PAYG plan activation, as well as providing support for technical demonstrations and promotional campaigns. Partnerships with local logistics and retail operators are essential to ensuring territorial reach, operational continuity, contextual adaptation, and field-based feedback collection.

Juakit's physical structure once again facilitates work, being easily transportable, and the solar panels have simplified assembly instructions. These simplifications are essential in fragile contexts where logistical reliability must offset limited infrastructure and constrained resources.

Total transportation costs

The following table reflects a progressive scaling scenario over the first three years of Juakit's deployment. Unlike the single-container example previously illustrated, which served to detail the calculation method, the following table incorporates economies of scale and logistical efficiencies that emerge as volumes increase. In particular, maritime transport and customs duties are expressed as average values per container, which gradually decrease as higher shipment volumes improve bargaining power with carriers and allow for more favorable tax treatment. The resulting estimates therefore provide a more realistic picture of the medium-term cost structure, moving from the pilot phase (2026) to consolidated distribution (2028).

Key value	2026	2027	2028
Units transported	120	480	1000
Containers required	1	4	8
Transport to Turin warehouse	€1,000	€2,200	€4,000
Maritime transport / container	€6,000	€5,000	€4,000
Total maritime transport	€6,000	€20,000	€32,000
Inland transport in Uganda / container	€700	€600	€500
Total inland transport in Uganda	€700	€2,400	€4,000
Total logistics	€7,700	€24,600	€40,000
Customs duties (on CIF Value €48,000 / container)	€26,400	€23,100	€20,000
Total duties	€26,400	€92,400	€160,000
Total transport costs + customs fees	**€34,100**	**€117,000**	**€200,000**

Table 24 - Logistics cost summary

5.4 Other variable costs and fixed expeditures

Adv, marketing and retail costs

The projected costs for advertising, marketing, and retail/after-sales services are calculated as a percentage of revenues over the 2026–2028 horizon. The allocation of resources follows a top-down method, with advertising costs estimated at around 2% of revenues in the initial phase and progressively decreasing over time, reflecting the expectation of growing brand awareness and reduced need for paid promotion. Marketing costs follow a similar trajectory starting with 3% of revenues in the first year, designed to support visibility during the pilot and early expansion phases, before stabilizing once Juakit achieves market consolidation.

Based on empirical evidence collected from local retailers in the field in the city of Gulu, they typically charge a commission ranging from 5% to 15% of the product price when acting as PAYGo distribution partners. A conservative estimate of 10% commission is therefore applied in the pilot phase, with a reduction to 8% in 2027 and 5% in subsequent years. With this in mind, retailers primarily provide customer support, handover, and post-sale assistance. This cost structure confirms both the realism of the financial assumptions and the efficiency of the model, which avoids overestimating retailer involvement or imposing excessive margin pressure while ensuring adequate support for end-users.

	2026	2027	2028
Revenues	80.000,00 €	415.000,00 €	850.000,00 €
Sales	100	500	1000
Price per unit	800,00 €	830,00 €	850,00 €
Advertising	1.600,00 €	3.320,00 €	4.250,00 €
Marketing	2.400,00 €	6.225,00 €	8.500,00 €
Retail + After Sales service	8.000,00 €	33.200,00 €	42.500,00 €
Total	**12.000,00 €**	**42.745,00 €**	**55.250,00 €**

Table 25 - Adv, marketing and retail overview

Returned goods

The impact of returns must also be considered, an increase in the expected sales volumes and a declining rate of return has been estimated, which is assumed to decrease from 4% in 2026 to 2% in 2028. This progressive reduction reflects learning effects, improvements in product quality assurance, and the establishment of more efficient after-sales support mechanisms. In absolute terms, the number of returned units is projected to rise from 4 in 2026 to 20 in 2028, as a direct consequence of higher sales volumes. However, the relative weight of returns on total sales decreases over time, confirming the effectiveness of scaling and quality control. The financial impact of returned goods is quantified at €3,200 in the pilot year, increasing to €12,450 in 2027 and €17,000 in 2028, the calculation was estimated as the cost of the returned product and therefore the lost collection. It is essential to consider these costs both as a contingency factor and as a measure of long-term customer satisfaction and product reliability.

Returned goods	2026	2027	2028
Sales	100	500	1000
Price	800,00 €	830,00 €	850,00 €
Rate of returne	4%	3%	2%
Returned goods	4	15	20
Total cost	**3.200,00 €**	**12.450,00 €**	**17.000,00 €**

Table 26 - Returned goods prediction

Fixed costs

The fixed costs associated with Juakit's deployment, as reported in the following tables, comprise both infrastructure-related expenses and personnel costs. Warehousing represents a significant share, with expenditures ranging from €13,200 in 2026 to €21,600 in 2028, reflecting the need to store and test increasing volumes of second-life panels. The reference values (approximately €1,100–1,200 per month for 1,000 panels and up to €1,800 for 2,000 panels) are consistent with commercial warehouse rental rates in the Turin area.

R&D activities are budgeted at €20,000, to be split over the three years, linked respectively to field testing and feedback collection during 2026, optimization of system components in 2027 and the development and establishment of an evolutionary prototype in the following year. Another one-time cost is a professional I–V curve tracer, available on the market for around €13,000. This is essential for testing and certifying the performance of the second-life panel. A certificate that ensures compliance with safety and quality standards costs €5,000.

	2026	2027	2028
Werahouse	13.200,00 €	14.400,00 €	21.600,00 €
R&D	5.000,00 €	7.000,00 €	8.000,00 €
Test I-V Curve Tracer professional	13.000,00 €	\	\
Certification	5.000,00 €	\	\
Prototyping	12.600,00 €	\	\
Total	**48.800,00 €**	**21.400,00 €**	**29.600,00 €**

Table 27 - Principal fixed costs

Personnel costs account for the project's managerial and operational backbone varies during the first three years, consistently with the business growth perspective. In 2026, a full-time project manager is complemented by a part-time sales manager, with a company-side cost of approximately €50,000 and €15,000 respectively. With the scale-up in 2027, the sales role is extended to full-time so the cost becomes €30,000, and in 2028 also an after-sales technician is introduced part-time with a cost of €15,000, ensuring adequate customer support and claims management. By 2028, the structure consolidates with three dedicated roles: project manager, sales manager, and after-sales expert, for a total annual personnel cost of €95,000. This staffing trajectory reflects the progressive need for coordination, market presence, and technical support as the initiative moves from pilot phase to market consolidation.

HR	2026	2027	2028
Project Manager	50.000,00 €	50.000,00 €	50.000,00 €
Sales Manager 1	15.000,00 €	30.000,00 €	30.000,00 €
Sales Manager 2	- €	- €	- €
After Sales Expert	- €	- €	15.000,00 €
Total	**65.000,00 €**	**80.000,00 €**	**95.000,00 €**

Table 28 - HR costs

5.5 Financial plan

In 2026, revenues are expected to reach €80,000, based on the sale of 100 units at a target price of €800. However, variable costs slightly exceed revenues, resulting in a negative gross profit. The imbalance is explained by the small production scale, the relatively high unit cost of hardware during the pilot phase, and the incidence of initial setup expenses. Fixed costs are particularly significant in this first year, with a strong impact from human resources, warehousing and one-off items such as certifications and prototyping. Consequently, total costs amount to €209,506.80, generating a negative EBIT of –€129,506.80.

In 2027, scaling up to 500 units sold and increasing the price to €830 per kit, thanks to the trust gained, saw a significant increase in revenues. Variable costs also rose, but economies of scale began to emerge, reducing their incidence from 101% to 78% of revenues. Gross profit became positive, and fixed costs remained relatively stable, despite some costs not being repeated in the previous year, with a modest increase in personnel expenses and distribution and marketing.

As a result, the EBIT loss was reduced (–15%), confirming the financial improvement brought by higher volumes.

By 2028, with the sale of 1,000 units at €850 each, revenues are projected at €850,000. The trend continues and proves successful with variable costs decreasing, confirming stronger cost efficiency and gross profit increases significantly. Fixed costs rise moderately, driven mainly by human resources and warehousing. At this stage, the business achieves a positive EBIT of €92,155.60 (11%), marking the transition from an initial loss-making phase to operational profitability.

Overall, the financial plan demonstrates a classic scaling trajectory: negative results in the pilot stage due to limited sales and high fixed cost incidence and progressive cost absorption with a significant margin recovery during expansion. Profitability comes together with a sustainable sales volume. This highlights the critical role of scale economies, lean distribution, and controlled fixed expenditures in ensuring the long-term financial sustainability of Juakit.

	Absolute value			% value		
Financial highlights	**2026**	**2027**	**2028**	**2026**	**2027**	**2028**
Revenues	**80.000,00 €**	**415.000,00 €**	**850.000,00 €**	100%	100 %	100 %
Price	800,00 €	830,00 €	850,00 €	\	\	\
Units sold	100	500	1000	\	\	\
Variable costs	**80.400,00 €**	**323.350,00 €**	**565.200,00 €**	**101%**	**78%**	**66%**
Gross Profit	**- 400,00 €**	**91.650,00 €**	**284.800,00 €**	**-1%**	**22%**	**34%**
HR	65.000,00 €	80.000,00 €	95.000,00 €	81%	19%	11%
Distribution and Marketing	12.000,00 €	42.745,00 €	55.250,00 €	15%	10%	7%
R&D costs	5.000,00 €	7.000,00 €	8.000,00 €	6%	2%	1%
Warehouse costs	13.200,00 €	14.400,00 €	21.600,00 €	17%	3%	3%
Other costs	33.906,80 €	7.931,46 €	12.794,40 €	42%	2%	2%
Fixed Costs	**129.106,80 €**	**152.076,46 €**	**192.644,40 €**	**161%**	**37%**	**23%**
Total costs	**209.506,80 €**	**475.426,46 €**	**757.844,40 €**	**262%**	**115 %**	**89%**
EBIT	**- 129.506,80 €**	**- 60.426,46 €**	**92.155,60 €**	**-162%**	**-15%**	**11%**

Table 29 - The main financial highlights of Juakit over the first three years of deployment (2026 - 2028).

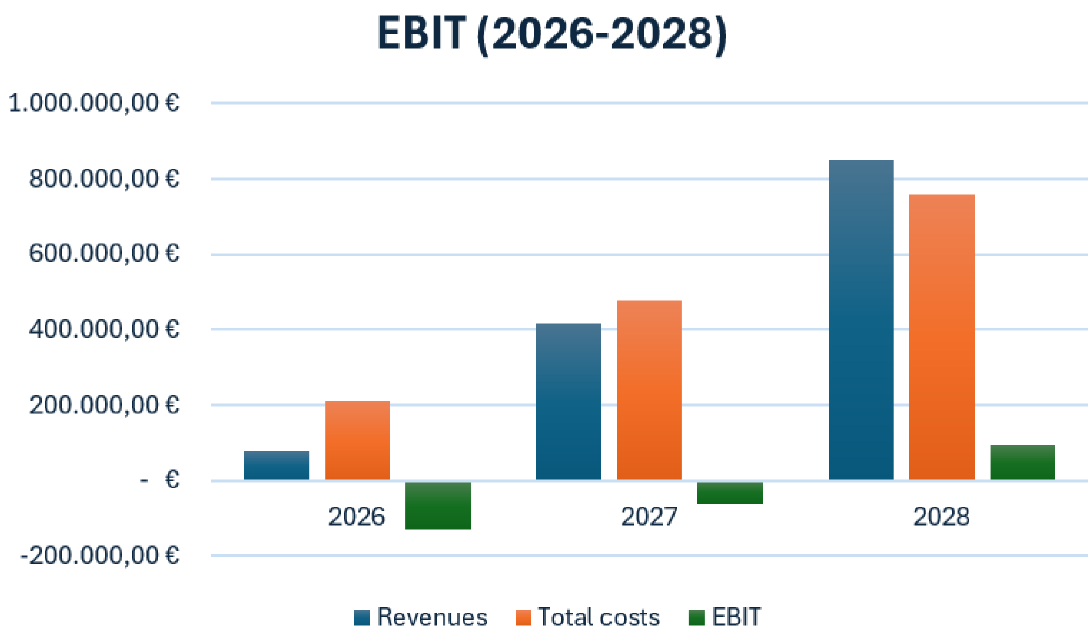

Figure 7 - EBIT bar chart (2026 - 2028)

5.6 Profit and loss

It highlights an initial phase characterized by structural losses, followed by progressive financial stabilization and after that it builds profitability. In the first year, the net margin is strongly negative, but this is due both to the limited revenues given by the small number of sales and to the large, fixed costs required to start the business and to establish the operational and technical foundations of the project.

In the expansion phase, although the company is still loss-making, the financial outlook improves significantly. The increase in sales volumes enhances gross profitability, while the relative incidence of variable and fixed costs on revenues begins to decline. Winning economies of scale are therefore evident, even though marketing and retail costs remain substantial due to the need to support market entry and build customer trust in a new technological solution.

In the third year, the business model shows a positive net profit with a sustainable margin. This demonstrates that as sales increase, fixed costs are absorbed and logistics/customs expenditures are balanced, making the initiative financially viable. The Profit and Loss account therefore highlights the importance of scaling up as a precondition for economic sustainability:

initial losses are normal, but the long-term trajectory is what establishes the business's cost-efficiency and profitability, as well as demonstrating the successful implementation of lean distribution strategies.

Profit and Loss account	2026	2027	2028
Revenue	**80.000,00 €**	**415.000,00 €**	**850.000,00 €**
Materials and component costs	43.100,00 €	193.900,00 €	348.200,00 €
Logistic costs	7.700,00 €	24.600,00 €	40.000,00 €
Custom duties	26.400,00 €	92.400,00 €	160.000,00 €
Returned goods	3.200,00 €	12.450,00 €	17.000,00 €
Total variable costs	**80.400,00 €**	**323.350,00 €**	**565.200,00 €**
Gross Profit	**- 400,00 €**	**91.650,00 €**	**284.800,00 €**
Warehouse	13.200,00 €	14.400,00 €	21.600,00 €
R&D	5.000,00 €	7.000,00 €	8.000,00 €
Setup & Validation Costs	30.600,00 €	\	\
Salaries	65.000,00 €	80.000,00 €	95.000,00 €
Marketing & Adv	4.000,00 €	9.545,00 €	12.750,00 €
Retail & After sales	8.000,00 €	33.200,00 €	42.500,00 €
Accounting e legal fees	1.942,00 €	4.247,50 €	6.898,00 €
Overheads	853,00 €	2.302,48 €	3.685,25 €
Sundry expenses	511,80 €	1.381,49 €	2.211,15 €
Total expenses	**129.106,80 €**	**152.076,46 €**	**192.644,40 €**
Net Profit	**- 129.506,80 €**	**- 60.426,46 €**	**92.155,60 €**
Net Profit %	-162%	-15%	11%

Table 30 - Profit and loss account

5.7 Cash Flow and payback period

Cash Flow Analysis

Cash flow projections are the clearest way to gain a dynamic view of Juakit's financial trajectory over the 2026-2028 horizon, and for greater detail, each year is divided into four quarters. This clearly illustrates the structural evolution of the project's liquidity position, the scalability of operations, and the interaction between inflows and outflows.

In the initial phase, it's essential to support the project with non-dilutive funding to ensure initial financial sustainability during a pilot phase without high sales. This reliance on external funding decreases over time, once the project begins to benefit from economies of scale and increase sales.

Outflows are characterized by a diversified structure, including materials and component purchases, logistics and customs duties, personnel expenses, R&D investments, and marketing and after-sales costs. Initially, there are significant fixed costs that weigh heavily, such as wages and inventory, but these lay the foundation for the business's stability. Variable costs are significant, especially in the initial phase, since small production doesn't allow for full exploitation of economies of scale, but they will be significantly reduced in subsequent years. Importantly, the projections also account for returned goods, overheads, and legal/accounting expenses, demonstrating the comprehensiveness of the financial model.

From a financial management perspective, the quarterly cash flow evolution reveals the dynamics of cash flow in each quarter. The values are initially negative or close to zero, while progressive growth is evident from the second half of the time horizon. This outlines an initial phase of financial stress with negative cash flow and cumulative cash flow values, but this trend changes after just a year and a half, when quarterly cash flows become positive and consequently the cumulative cash flow benefits, growing. This trajectory underscores the financial viability of the business model, showing that initial negative pressures can be absorbed thanks to a combination of external funding and scale-driven efficiency gains.

To achieve these results, an injection of €250,000 is planned, spread over the first few years, to provide a funding boost for the project. This is a realistic amount, and not difficult to obtain for a high-impact project like Juakit. The study illustrates how the project transitions from a funding-dependent pilot initiative into a revenue-sustained business, with clear evidence of improved cash generation capacity and growing resilience over time.

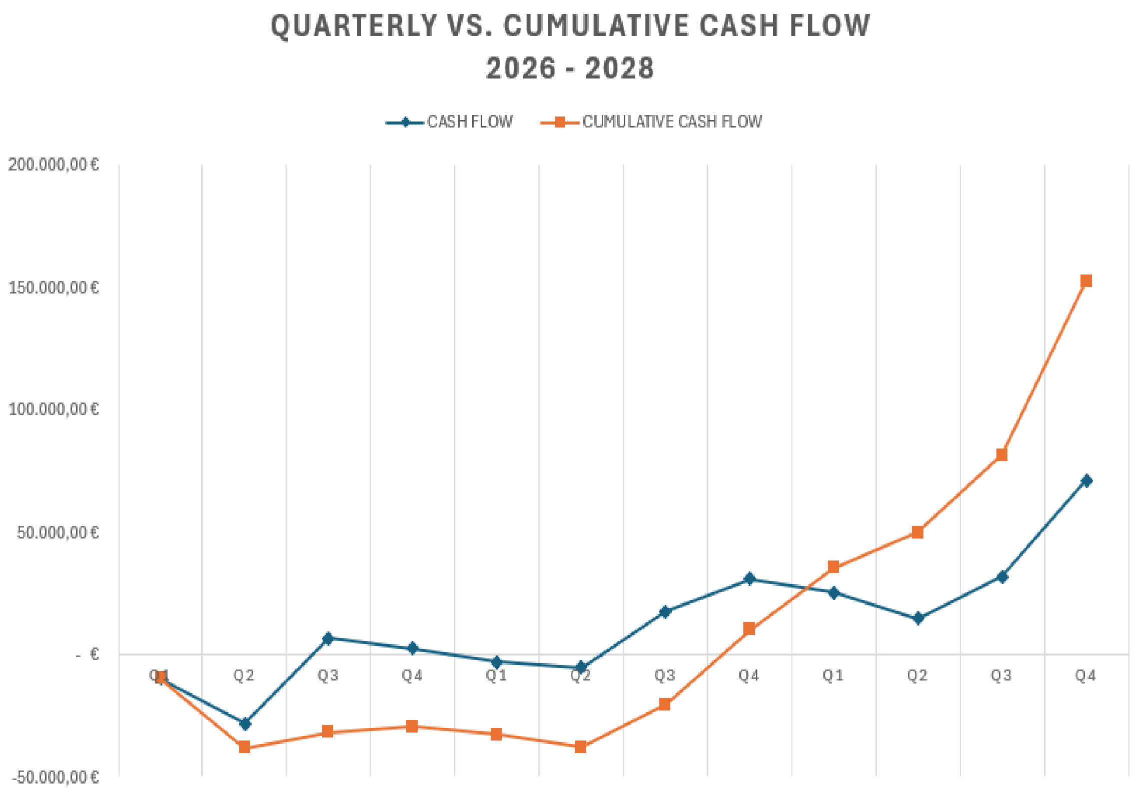

Figure 8 - Quarterly vs. Cumulative Cash Flow

The graph above clearly illustrates what has been explained: that is, how, despite an initial phase of financial difficulty, there is a clear recovery, and in the fourth quarter of the second year, cash flow is broken, meaning the company has not only covered its initial losses but is also starting to generate positive net cash. Therefore, the business is sustainable and able to generate sufficient resources to finance itself. This demonstrates that the initial financing was only needed to cover the typical start-up deficit.

Break Even Analysis

The following chart provides a dynamic representation of the relationship between total inflows and outflow and cumulative cash flow throughout the 2026–2028 period.

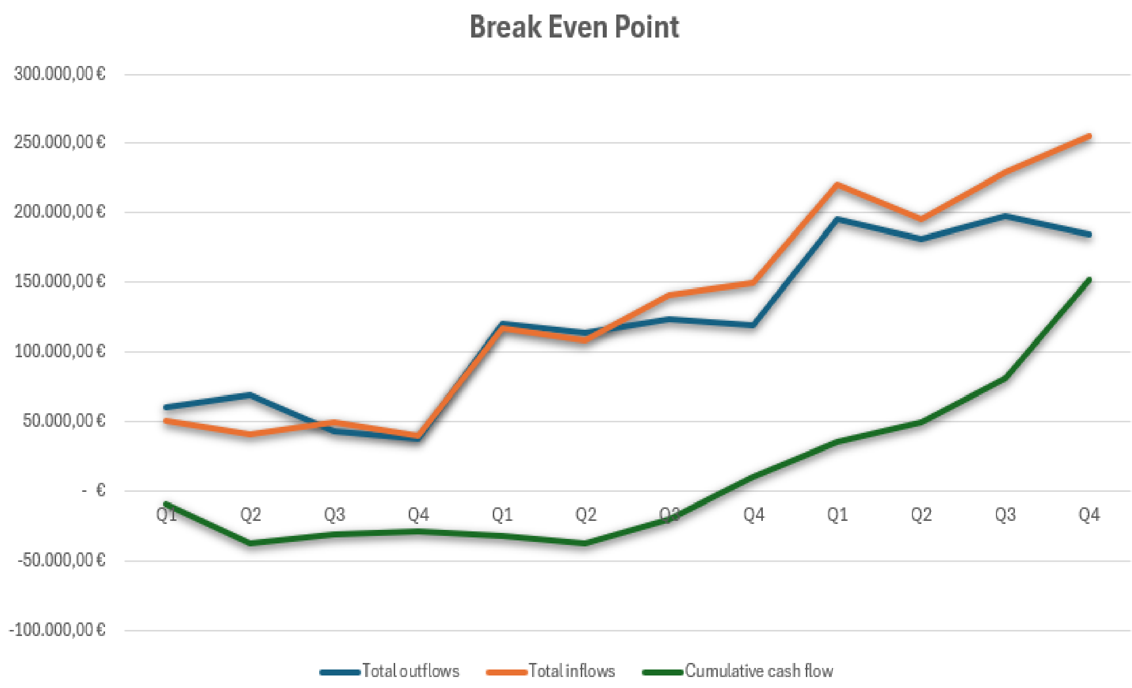

Figure 9 - Break Even Point

Particular attention is paid to the lines representing total inflows and total cash flows. Initially, the values are low, but starting in the first year, they show progressive growth over time, with some fluctuations but an underlying upward trend. It is therefore clear when inflows exceed cash outflows, thus generating positive cash margins. By the second half of the first year, inflows and outflows are balanced, and this trend continues for about a year, stabilizing. Midway through the second year, inflows exceed outflows, marking an upward trend that gradually distances itself from the underlying outflow line.

The green line, which depicts cumulative cash flow, clearly shows the implications of this trend: in the initial phases, the indicator remains negative, highlighting a deficit. However, as inflows progressively increase relative to outflows, the cumulative curve reverses its trend and reaches zero in the third quarter of the second year. This is the point at which the sum of cash flows generated since the beginning of the period equals the total outflows incurred**.**

Subsequently, the cumulative curve continues to grow steadily, reaching a value above €150,000 in the final fourth quarter. This evolution signals not only the overcoming of the imbalance phase, but also the financial model's ability to generate liquidity on an increasing and sustainable scale. This is due to the improvement and stabilization of the business over time. The break-even point thus not only signals the end of the loss-making phase but also validates the underlying assumptions about scalability and efficiency embedded in the business model.

6. Funding strategies for impact startups

6.1 Funding options

As is typical for early-stage startups, securing funding is essential to launching the business solidly. Even more so if the model is a convergence of technology, energy access, and social equity. Juakit's hybrid nature, balancing a commercially viable product and a development-focused initiative, allows it to tap into various funding sources: public grants, investors, environmental finance options, and public participation models, such as crowdfunding. The following funding options are particularly relevant for the pilot and scale-up stages.

Public and institutional funding

Initial product development goes through development, field testing, and market penetration phases. These steps can typically be supported by grants and non-dilutive funding provided by public bodies and international cooperation agencies. In particular, resources for startups supporting the Sustainable Development Goals (especially Goal 7, which focuses on universal access to clean energy) are available through programs from institutions such as the African Development Bank, Enabel, AICS, SEforALL, and the European Union. This funding reduces the risk associated with private investments and can finance, for example, technical prototyping, local implementation, community engagement, and capacity building.

Impact investors and blended finance

In developing markets, access to off-grid energy is a hot topic, attracting attention from many investors and offering blended financing options. Venture capital funds such as Acumen, Global Innovation Fund, and SunFunder seek investment opportunities that offer both monetary returns and measurable development benefits. Juakit is ideally suited to attract these sources of financing due to its potential for long-term sustainability, the inclusive access it offers, and the positive environmental impact resulting from emissions reductions. To reduce capital costs during the expansion phase, multilateral banks and development finance institutions (DFIs) can provide credit guarantees, counterpart funds, or concessional loans [23].

Carbon credits and environmental finance

Juakit, being a high-impact circular innovation, also significantly reduces CO_2 emissions, replacing diesel generators in areas off the grid. These positive emissions can be sold on the voluntary carbon market after certification using recognized methods such as Verra or Gold Standard [24]. Furthermore, this would be an additional source of credit with multiple advantages: first, it could reduce the price and thus make the product even more accessible; a further consequence is that it could attract climate-conscious investors and open the door to long-term environmental financing.

Crowdfunding and community-based finance

Crowdfunding can help build a community of supporters with shared goals, generate initial revenue, and validate market interest. With Juakit, for example, one could consider pre-selling units, raising awareness about energy poverty, and engaging with eco-conscious consumers or the African diaspora through platforms like Kickstarter, StartSomeGood, or LITA.co. However, it's important to consider that this method may not be sufficient for large-scale operations, but it is effective in raising visibility and financing initial production. This is why a multi-pronged approach should guide Juakit's funding strategy: using public and institutional grants for product development and piloting, seeking blended or impact investments for scaling, and leveraging crowdfunding and carbon credits to improve long-term profitability and support disadvantaged customers. Only through a diverse strategy can the project's goal of becoming a scalable, circular, and inclusive energy solution be more quickly achieved, while also ensuring financial stability [25].

6.2 Impact measurement and reporting

Juakit aims to be a high-impact initiative, seeking funding and support based on all the positive aspects it brings. However, long-term sustainability depends not only on financial viability, but also on the ability to demonstrate measurable social and environmental results. Demand for proof of impact from investors, donors, and institutional partners has increased, especially in recent times. This is because projects aligned with the Sustainable Development Goals (SDGs) must combine financial returns with tangible contributions to sustainable development. Juakit directly addresses SDG 7 (Affordable and Clean Energy) by expanding access to reliable and renewable energy, while simultaneously generating indirect benefits that resonate with SDG 3 (Good Health and Well-Being), SDG 4 (Quality Education), and SDG 13 (Climate Action).

From an environmental perspective, Juakit achieves a goal by reducing dependence on fossil fuels by replacing diesel generators, still common in remote areas of sub-Saharan Africa, thanks to its clean solar technology. This reduces CO_2 emissions generated by older energy generation methods such as kerosene lamps or diesel generators. Using second-hand solar panels also extends the lifespan of electronic components and reduces waste. These aspects can be certified through avoided emissions certifications for voluntary carbon markets, creating an additional revenue stream while reducing the actual costs for low-income users. The data regarding reused second-hand solar panels would be clear and meaningful for potential investors.

The social impact is also particularly significant, especially considering the potential for ensuring access to electricity for thousands of families and businesses, significantly improving their lifestyles. Students of all ages would also benefit, as it promotes evening study and digital inclusion. Furthermore, it reduces the health risks associated with traditional fuels and supports small businesses. The modular design also facilitates integration with production applications, such as food refrigeration, further enhancing its development potential. Sales through local retailers would generate employment growth in the sector, also considering the deployment of field technicians to manage after-sales services.

To ensure credible and reliable impact measurement, specific international frameworks such as IRIS+ (developed by the Global Impact Investing Network) and the SDG Impact Standards can be used [26]. These tools enable the use of specific standardized indicators, such as those used to monitor energy access, avoided greenhouse gas emissions, and the socioeconomic benefits of adopting clean energy. Some key KPIs to report to make the project more attractive to potential investors include the number of households reached, tons of CO_2 emissions avoided, or the number of local jobs created. These provide quantifiable value to the project's performance and are easily understandable. Indeed, providing transparent and robust reporting strengthens donor confidence, reassures impact investors about the overall value generated, and builds trust among stakeholders and local communities.

From this perspective, impact measurement is a crucial aspect; indeed, it's crucial within the governance framework for project development. Only by integrating well-structured measurement concepts from the outset can we ensure the continued validity of the circularity, inclusion, and sustainability objectives. Furthermore, measuring well means communicating data effectively, thus conveying a clean and reliable image. This approach consolidates Juakit's positioning within the ecosystem of clean energy access solutions and increases its attractiveness for future investments .

7. Discussion and future perspectives

7.1 Limitations of the study

While the analysis presented in this thesis offers a comprehensive assessment of Juakit’s financial and operational prospects, several limitations must be acknowledged in order to ensure a balanced and critical interpretation of the results.

One limitation worth highlighting is the nature of some of the data derived from the collected data. Indeed, all data is derived from field studies, expert estimates, and indicative supplier quotes, all of which are reliable but may be subject to change depending on seasonal demand, regional economic conditions, and evolving market trends. For example, warehouse costs are derived from an industry estimate in the Turin area, but may be subject to change; similarly, customs costs, which were taken as a whole in a pessimistic perspective, could be reduced thanks to exemptions. Sales forecasts are based on in-depth market and end-user analysis, but do not yet take into account the complexity of consumer behavior. Therefore, it is important to emphasize that the data should be interpreted as projections rather than precise results, requiring validation through pilot implementation and continuous feedback loops.

Another issue that cannot be overlooked is the uncertainty of the institutional and regulatory environment. Customs and tax regimes in sub-Saharan Africa, particularly in Uganda, are often inconsistent due to a discrepancy between formal legislation and practical implementation. The customs clearance process itself may be subject to discretionary decisions by officials rather than enforcement, resulting in a high level of variability in tariff considerations (which, pessimistically, have been considered maximum considerations). Customs clearance times could also be delayed, thus compromising the reliability of the supply chain. Solar products are eligible for tax exemptions, but since these are not applied automatically, the level of unpredictability remains high.

The Ugandan region is also characterized by significant infrastructural fragility. Inland transport from East African ports to northern Uganda is subject to risks related to the condition of the roads: unpaved, often flooded by seasonal rains, and administrative bottlenecks. These factors can create transport bottlenecks and extend delivery times. This is a difficult factor to integrate ex ante into the financial model, despite our significant impact.

The study's timeframe is relatively short (2026–2028). In a project with long-term scalability ambitions, it will be important to consider equipment replacement cycles, technological obsolescence, or the evolution of the competitive landscape in the coming years, which have not been analyzed at this time. To provide greater robustness, the timeframe could be extended and a scenario analysis could be integrated to provide a broader view of future risks and opportunities.

While caution and adaptability are needed, the study provides a solid foundation for decision-making. Future iterations of the business model should be based on iterative testing, local partnerships, and ongoing monitoring to validate and refine the hypotheses presented in the thesis.

7.2 Future challenges

Looking ahead, Juakit will face a series of structural challenges that will determine the success of its implementation, scalability, and long-term sustainability. The most obvious challenge is scalability and replicability. The business model demonstrates economic viability, growing from 100, 500, and even 1,000 units sold in the third year. However, reaching these volumes requires overcoming many barriers. Market demand is present, but it depends heavily on affordability, which is why Juakit is integrating the PAYG model. Trust must also be considered, which must be developed over time through reliability and customer education about the product. Replicating the model in other sub-Saharan African countries adds another layer of complexity, as regulatory frameworks, consumer preferences, and local market structures vary greatly. The business model must therefore not be rigid, but adaptable to local contexts.

Establishing public-private partnerships isn't a given. Local resellers and distributors can certainly be relied upon for last-mile delivery, but broader collaboration with NGOs, international development agencies, and government programs will be essential to ensure their legitimacy. This is essential to broaden market reach and facilitate access to subsidies or tax incentives, as well as integrating Juakit into national rural electrification strategies, ensuring the project isn't perceived as an isolated initiative, but as part of a broader policy framework for access to sustainable energy.

Juakit is a project we already know will require continuous technological evolution. While Juakite's modular design allows for flexibility, rapid advances in photovoltaic and storage technologies could quickly redefine benchmarks in terms of efficiency and cost-effectiveness. This is significant, as the Project must invest in research and development to maintain competitiveness, especially considering that, along with technologies, customer expectations are also evolving, requiring the system to be adaptable to productive energy uses, such as refrigeration, small-scale agricultural processing, or digital connectivity. Agile management ensures that it doesn't remain in a blind and stagnant environment, but rather remains innovative and capable of sustainable investment.

Finally, institutional and financial challenges must be considered. Although the financial plan outlines a path to profitability, securing the necessary initial funding remains an obstacle. Careful negotiation can result in blended financing mechanisms, which reduce the risks of private investment, but require meeting the expectations of donors and investors. The use of second-life photovoltaic panels as a key cost-saving strategy could be limited by future changes in European recycling policies, although a move toward incentivizing reuse is likely.

These challenges do not diminish Juakit's potential, but they highlight areas where strategic foresight, resilience, and adaptability will be most crucial.

7.3 Managerial and policy implications

The findings of this study extend beyond the specific case of Juakit, offering insights with broader managerial and policy relevance.

The project illustrates how early-stage social impact startups can reconcile financial sustainability with social and environmental objectives by adopting favorable mechanisms: lean cost structures, modular product design, and diversified financing strategies. Iterative experimentation can offer many lessons to startups like Juakit that combine technology and social inclusion; for example, leveraging second-life resources to reduce costs and integrating circularity into their value propositions. Impact is a key theme, and Juakit demonstrates how impact reporting is strategic not only as a reporting tool, but also as a lever for attracting investment and building community trust.

For ESG investors and funds, the project highlights the growing importance of blended value creation, combining financial returns with quantifiable development outcomes. This study highlights the importance of using standardized impact metrics (e.g., IRIS+, SDG-aligned KPIs) that can convey credibility to their readers. In this sense, the project contributes to the ongoing debate on how to integrate sustainability into the investment decision-making process, and also demonstrates how, even on a relatively small scale, interventions can generate significant impact when strategically aligned with market demand and global policy frameworks.

From a political perspective, Juakit demonstrates how promoters of clean energy access are not crucial enablers. Governments and regional institutions can support such initiatives by simplifying the entire supply chain. For example, they can facilitate procedures by offering tax exemptions for renewable technologies and incentivizing the local assembly or recycling of photovoltaic modules. Policies that promote public-private collaboration and electrification strategies are supportive of Juakit's goals and are fundamental to ensuring the long-term sustainability of environmental-impact-oriented business models. We can therefore say that by aligning regulatory frameworks with Sustainable Development Goal 7, policymakers can create the conditions for initiatives like Juakit to thrive and multiply their impact on multiple fronts.

In summary, the implications of this study are twofold: for managers, they underscore the need for strategic agility and lean innovation; for policymakers and investors, they highlight the systemic conditions necessary to enable an inclusive and sustainable energy access business to thrive.

8. Conclusions

8.1 Summary of results and expected impacts

The analysis conducted in this thesis explored Juakit as an innovative business model that brings together access to clean energy, the circular economy, and social impact. Starting from the technical and logistical feasibility of reusing second-life photovoltaic panels, the study demonstrated how a streamlined, modular design can enable the creation of affordable solar kits, specifically adapted to the off-grid conditions of sub-Saharan Africa.

The business plan highlighted the potential feasibility, highlighting that the initial phases of the project are the most fragile, characterized by high start-up costs and negative margins. Scalability, however, plays a crucial role and leads to profitable results with a sales volume of 500 units after just a year and a half of operation, as shown in the break-even analysis. Profitability over time is increasingly supported by cost efficiencies and a reduced dependence on fixed expenses.

Not only will Juakit generate financial gains, but it is expected to generate significant social and environmental impacts. From a social perspective, each unit can provide energy services to families otherwise excluded from reliable access to electricity, thus enabling improvements in education, health, and micro-entrepreneurship. From an environmental perspective, Juakit encourages the replacement of diesel generators, supports the recycling and waste reduction of used but functioning panels, and is perfectly aligned with global climate goals and the circular economy. Overall, the results demonstrate Juakit's ability to combine financial sustainability and development outcomes, making it a promising example of inclusive innovation.

8.2 Challenges and improvement proposals

Despite these encouraging results, several challenges have been identified that require careful consideration. As discussed in detail in previous chapters, particular attention must be paid to regulatory and infrastructure uncertainty in the target country, which could jeopardize the project. Strong partnerships with local institutions, NGOs, and logistics service providers help successfully manage these challenges, but political dialogue should also not be overlooked to ensure tax exemptions and regulatory clarity.

The main weakness lies in the financial sustainability of the initial phases. The pilot phase, in fact, involves negative margins that can discourage potential investors, especially private ones. This is why blended financing is needed, as it reduces the risk of private participation by combining public grants, subsidized loans, and impact capital. Furthermore, crowdfunding and the monetization of carbon credits can provide complementary revenue streams and visibility. To maintain competitiveness and attract new investors, it is also crucial not to neglect technological innovation, as well as ensuring reliable quality, since are used photovoltaic panels. Investing in reliable testing equipment and certification procedures is essential to guarantee performance and build investor and customer trust, just as the R&D budget must remain consistent.

These improvement proposals highlight the need for a **phased strategy**, in which early risks are mitigated through institutional support, innovation is embedded in the business model, and financial sustainability is progressively consolidated.

8.3 Future prospects

Looking to the future, Juakit has strong scalability and replicability potential, making it an attractive project. Expansion in Uganda begins in Gulu, with expansion to surrounding districts planned in the medium term. In other sub-Saharan African countries, it will be possible in the long term, provided local adaptations are made to account for regulatory and cultural contexts.

Digital innovation will play an increasingly central role in this journey. Juakit plans to integrate IoT-based monitoring, which not only ensures technical reliability but also opens up opportunities for pay-as-you-go business models. It also enables predictive maintenance and real-time impact reporting. These capabilities enable the collection of important data to improve both operational efficiency and investor confidence.

Finally, the evolution of Juakit could involve the addition of complementary services. An example could be transforming the kit from a basic electrification tool into a platform for rural development. Another option could be productive energy uses (e.g., refrigeration, irrigation, small-scale agricultural processing), integration with microfinance services, and the provision of digital connectivity. The value created will thus be significantly increased, and the project itself will acquire greater relevance and importance.

In conclusion, Juakit emerges as a scalable and innovative solution for energy access in Africa, capable of aligning financial sustainability with environmental circularity and social inclusion. By addressing its challenges and leveraging future opportunities, the project can become a benchmark for impact entrepreneurship and a concrete contributor to the achievement of the Sustainable Development Goals, demonstrating how innovation can translate into lasting social and environmental value.

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