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Final Report:

LaundReCycle

A Water- and Energy Self-sufficient Laundromat

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1. Summary

The LaundReCycle project aimed to address water and energy shortages and provide laundry services to communities in Cape Town, South Africa, with limited access to these resources. The project successfully demonstrated the technical feasibility of the LaundReCycle system through pilot tests and adaptations of core technologies. In terms of operational feasibility and acceptance, the pilot plant in Cape Town achieved an energy self-sufficiency rate of 92% and a water self-sufficiency rate of 92%. Only 8% of the water used for washing came from an external supply (tap water), with greywater reuse accounting for 43% and rainwater collection contributing 49%. Expanding the rainwater collection area by just 6m^2 could potentially achieve complete water self-sufficiency. The project conducted a survey to assess the acceptance of LaundReCycle in Switzerland and South Africa. South Africans displayed a more positive attitude, with 57% in favour of greywater reuse for laundry compared to 35% in Switzerland. The survey revealed that the positive environmental impact held greater importance than cost savings for users, with the assurance of human health through greywater reuse being a critical aspect.

In terms of financial feasibility and business development, the LaundReCycle system generated a total income of 40,000 ZAR from customers utilizing the laundromat services, while costs amounted to 30,000 ZAR. The project also created new jobs and provided training to personnel, contributing to local employment opportunities and skills development. Preparatory work for multiplication and replication involved conducting market surveys and analysing consumer preferences. The project developed a scalable business model and explored financing options for establishing a spin-off organization. Efforts were made to develop a self-sufficient water system capable of addressing larger water challenges.

The project's impacts include the installation of 4.32 kWp renewable energy capacity, resulting in the annual production of 7030 kWh of renewable energy and a reduction of greenhouse gas emissions by 3.4 tons per year. The project also saves 25'000 litres of freshwater annually and reduces wastewater discharge by 23'500 litres per year. The project generated economic benefits through third-party funding, local income, and job creation.

The next planned steps involve testing the flow-through system in a pilot installation in South Africa and establishing a spin-off company. Efforts will be made to promote multiplication and replication through market development and partnerships with local stakeholders. Lessons learned include the importance of integrating technological and socio-economic perspectives, interdisciplinary collaboration, thorough staff training, and addressing context-specific challenges. The project's findings and recommendations can guide similar projects in maximizing their impact.

2. Starting Point

In the past, Cape Town in South Africa had experienced one of the most severe water crises in its history. Water management strategies had failed to provide sufficient water to span the dry summer months. To this day, the city continues to endure the persistent pressure of anticipating the next drought. At the same time, rapid growth of informal settlements is placing additional pressure on local water resources. In these settlements, washing clothes is mostly practiced by hand and bucket at government-installed communal water points. After washing, the water is usually disposed in the street, creating ponds with standing water, which are an ideal basis for pathogens to spread.

However, washing clothes by hand is not as effective as with machine washing, which can result in hygiene-related health issues. Moreover, washing by hand is not only time-consuming but also a hard and inconvenient task. Many of the residents, who are predominantly young and leading busy urban lives, do not have the time to wash their laundry by hand. This has created a growing demand and affordability for laundry services. However, the use of washing machines is often limited due to the lack of access to household water services and stable electricity supply. As a result, wherever there are water and electricity available, small informal laundry businesses are opening across the informal settlements. However, these businesses still rely on freshwater and sewer connections, limiting their implementation in locations without mains infrastructure. In case of a water shutdown or strong water restrictions, these businesses can no longer operate. The rising demand for laundry services, coupled with restricted availability of water and energy resources in informal settlements, calls for innovations in the laundry sector.

3. Objectives

The objectives of the LaundReCycle project were to address water and energy shortages and provide laundry services to communities with limited access to these resources. The project proposed the implementation of an innovative Laundromat system that aimed to be nearly self-sufficient in terms of water and energy usage. It was designed to be installed in areas without direct freshwater, sewer, or grid connections, with the potential for mobile installation. The key objectives were:

1. Achieving technical feasibility: The project aimed to demonstrate the technical feasibility of the LaundReCycle system by testing and adapting core technologies, such as the biofilter for water treatment and the stand-alone photovoltaic energy generation system. This involved conducting pilot tests in Switzerland and adapting the technologies to suit South African conditions.

2. Achieving operational feasibility and acceptance: The project aimed to assess the operational and financial feasibility of the LaundReCycle system in the demonstration site in Cape Town. This included evaluating the costs associated with components, installation, and operation, as well as analysing the system's performance. Additionally, the project aimed to analyse the acceptance of the system within South African communities and implement awareness-raising activities.

3. Achieving financial feasibility and business development: The project aimed to assess the financial feasibility of the LaundReCycle system and develop an investment model based on factors such as economies of scale and demand pricing. The objective was to explore financing options for establishing a South African spin-off organization and micro-enterprises to introduce the product to the market.

4. Project Review

4.1 Project Implementation

As a first step, the LaundReCycle prototype was developed, built, and tested at Zurich University of Applied Sciences (ZHAW) in Wädenswil, Switzerland during the year 2019 (Figures 1-3). The final set-up was tested in a 10-week pilot operation including water quality testing, as well as analysis of the energy and water balance. To ensure standardized wastewater conditions, a set of new textiles were intentionally soiled with a standardized soiling solution prior to being washed in the prototype. Thus, the prototype was tested within an experimental setup without real laundry.

In order to facilitate knowledge exchange with the South African partners regarding the construction and operation of the prototype, a five-day technology transfer workshop took place from 16 to 20 December 2019 at ZHAW in Wädenswil (Figures 4-6). The program consisted of workshops conducted by relevant experts in water treatment, solar energy, and design. It also allowed time for independent work to adapt the design to South African conditions and included visits to informative comparative projects and technologies.

Figure 1: Prototype of the LaundReCycle on ZHAW Campus Grüental in Wädenswil, Switzerland

Figure 2: Interior of the LaundReCycle prototype including washing machine and installations for the water treatment

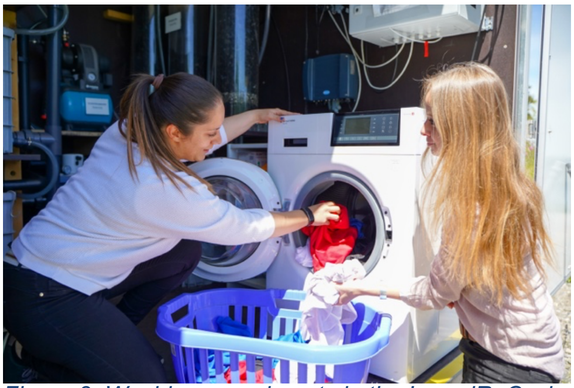

Figure 3: Washing experiments in the LaundReCycle prototype

Figure 4: Project team meeting during the technology transfer workshop for the South African partners. From left: Matthias Frei, Bernard Wessels, Devi Bühler, Bobby Mabe

Figure 5: Visit to a bio pool to show analogies to greywater treatment to the South African partners

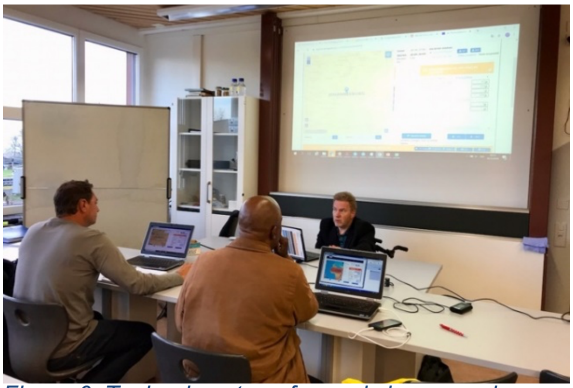

Figure 6: Technology transfer workshop on solar energy with Christoph Koller, lecturer for solar energy at ZHAW

In January 2021, the LaundReCycle pilot plant was finally installed and operationalized in Cape Town by the project team, experiencing a one-year delay due to the pandemic. The facility's opening was organized together with the Swiss embassy and officially launched to the local media (Figure 7). On-site, the team of Khulisa received training on how to operate and monitor the LaundReCycle and collaborated to establish SOPs (Standard Operating Procedures) for monitoring and operational processes. Technical analysis equipment was acquired, and a small field laboratory was established within the pilot plant. The local team started to build a customer base and integrated the LaundReCycle into their daily routines (Figures 9-12). An online survey was conducted to assess the acceptance of the technology.

Both the prototype at ZHAW and the pilot plant in South Africa were initially designed as batch systems. However, their operation revealed that such a batch system required a complex control mechanisms or manual oversight by experts, making it unsuitable for large-scale implementation. Additionally, the batch system consumed excessive energy due to multiple pumps. Consequently, at ZHAW, the treatment system was further developed into a system with flow-through operational mode, with all cleaning stages housed in a single box. Simultaneously, the technology's further development was tested at KREIS-Haus in Switzerland alongside the pilot operation in South Africa. The name KREIS-Haus stands for the German term “Klima- und Ressourcen-Effizientes Suffizienz-Haus“, which is means in English “climate and resource efficient sufficiency house”. KREIS-Haus is a living lab where new technologies are tested and further developed in practice.

The final phase of the project focused on the business development part. The project team engaged in several sessions with a business consultant to establish a scalable business model.

Figure 7: Launch of the LaundReCycle pilot plant in Cape Town in January 2021

Figure 8: Interior of the LaundReCycle pilot plant including washing machine and installations for the water treatment

Figure 9: Clothes drying in the garden of the LaundReCycle

Figure 10: Instructions for the local staff on how to do the water testing

Figure 11: Staff member working in the LaundReCycle

Figure 12: The LaundReCycle in the Streetscapes Urban Farm in Cape Town in 2022

4.2 Achievements of Objectives and Results

Objective 1: Achieving technical feasibility

The technical feasibility of the LaundReCycle system was successfully demonstrated through pilot tests and adaptations of core technologies. The pilot operation in Switzerland achieved a 69% water reuse rate, with potential to increase it to 90%. The solar system achieved 80% self-consumption, but only 30% self-sufficiency. Under the given testing conditions, the desired water quality was achieved. The complete results of the pilot operation were published by Buehler et al. (2021). The learnings from the pilot operation of the prototype were used for the development of the pilot plant in South Africa.

Objective 2: Achieving operational feasibility and acceptance

The pilot plant in Cape Town was successfully constructed and underwent continuous development efforts over a two-year period. In its final configuration, the system achieved an energy self-sufficiency rate of 92%. This result is based on an average of 11 wash cycles per week. The water balance analysis demonstrated a water self-sufficiency rate of 92%, meaning that only 8% of the water used for washing came from an external supply (tap water). Greywater reuse accounted for 43% of the supply, while rainwater collection contributed 49% (Figure 13). Expanding the rainwater collection area by just $6m^2$ could potentially achieve complete water self-sufficiency.

Water quality parameters were monitored over time and compared to values from literature and regulatory standards. The LaundReCycle system achieved good removal rates for turbidity, COD and microbial parameters, and met all requirements for low-quality washing water according to the guideline from VITO (n.d.) (Table 1). COD stands for Chemical Oxygen Demand and is a main indicator for the presence of organic matter and hence the degree of pollution in the water.

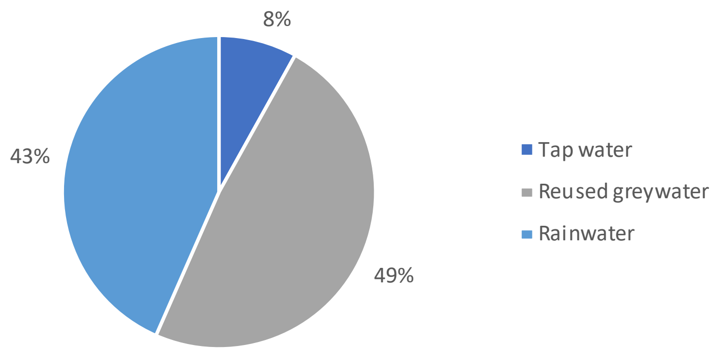

Figure 13: Water balance for the LaundReCycle. 100% corresponds to the freshwater used for the washing machine.

Table 1: Overview of water quality parameters before and after the treatment, removal rate of the system, and comparison to limit values

Parameter	Unit	n	Laundry effluent	Treated water*	Removal rate (%)	Limit value (VITO, n.d.)
pH	-	19 / 25	8.4	8.3		6 - 8
EC	µS/cm	22 / 30	985	655	34%	3000
Turbidity	FNU	22 / 29	202.6	2.6	99%	5
COD	mg/l	21 / 20	506	36	93%	35
TN	mg/l	13 / 13	14.7	7.7	47%	
TP	mg/l	20 / 20	0.64	0.54	16%	
Coliforms	CFU/100ml	9 / 20	4.30E+07	16123	100%	
Aerobic count	CFU/ml	11 / 17	3.52E+06	39225	99%	
Enterobacteriaceae	CFU/ml	8 / 19	1.85E+05	206	100%	
Total Dissolved Solids	mg/l	4		495		2000
Total Suspended Solids	mg/l	4		2.0		30
Calcium	mg/l	4		8.1		20
Nitrate	mg/l	4		3.4		50
Nitrite	mg/l	4		<0.05		5
Sulphate	mg/l	4		24.9		300
Copper	µg/l	4		<10		10
Iron	µg/l	4		179.8		300
Manganese	µg/l	4		<20		50

* Treated water mixed with tap water from refill

The project involved a survey to assess the acceptance of LaundReCycle. 237 individuals from South Africa and Switzerland completed the survey, consisting of 35 questions. The comparison of the two samples revealed cultural differences in water attitudes. South Africans displayed a more positive attitude, with 57% in favour of greywater reuse for laundry, compared to only 35% in Switzerland (Figure 14). However, both countries exhibited higher acceptance for other applications such as toilet flushing and irrigation. Figure 15 provides potential explanations for the differences between the two countries, including South Africans' experience of water scarcity, exposure to government communication on water issues, and personal experience with greywater reuse. The findings highlight the potential of the LaundReCycle in the South African market and suggest tailored strategies for promoting adoption in different regions.

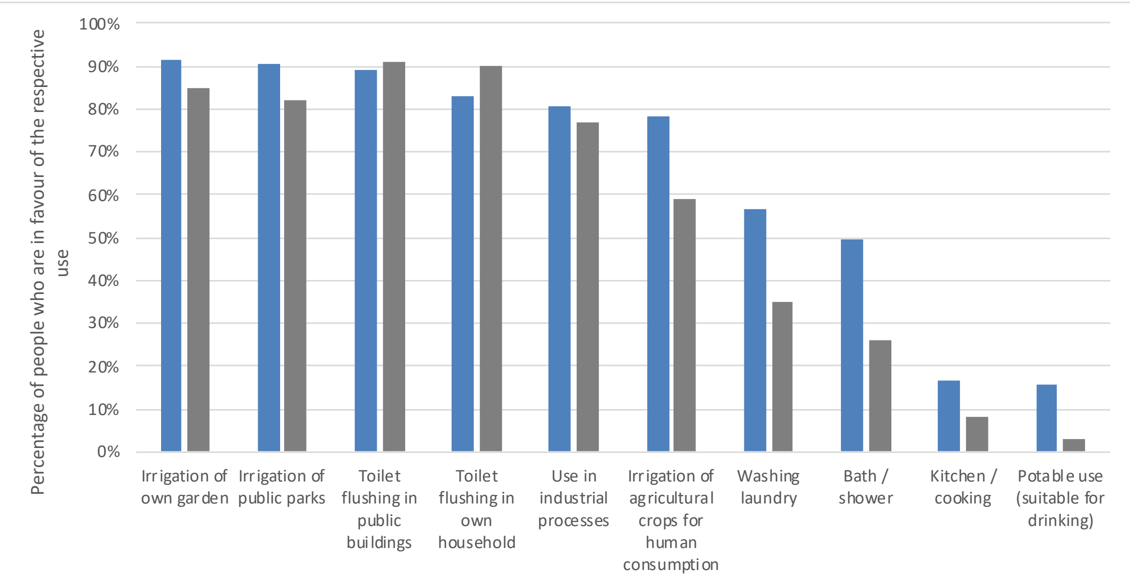

Figure 14: Acceptance of greywater reuse for different applications in South Africa and Switzerland

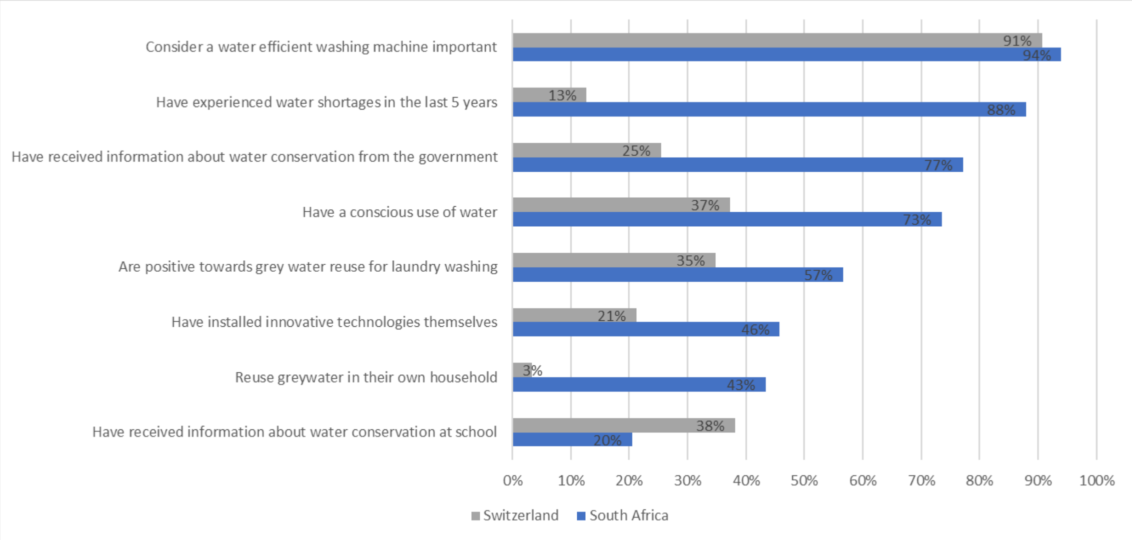

Figure 15: Comparison of user's characteristics, experiences, and attitudes towards water efficiency and reuse in South Africa and Switzerland

Objective 3: Achieving financial feasibility and business development

As part of the financial assessment, monitoring of both costs and generated income was conducted. The initial investment costs for the LaundReCycle system amounted to 440'000 ZAR. Over the course of the two-year trial period, the LaundReCycle generated a total income of 40'000 ZAR from customers utilizing the laundromat services. On the expenditure side, costs amounted to 30'000 ZAR, covering regular running expenses such as detergent and technical system maintenance, but not including staff costs.

Comparing the pilot plant in South Africa to the newer system in Switzerland revealed a significant reduction in energy, maintenance, and running costs. This finding highlights the potential for improved cost efficiency and long-term savings for the South African system.

The customer base of the LaundReCycle in South Africa was also analysed throughout the project period. The evaluation demonstrated that the facility is utilized by a diverse range of customers. The customer segments included employees of Khulisa (16%), homeless individuals and clients of Khulisa (41%), as well as external customers (43%) such as private customers, restaurants, or other businesses.

External customers paid 20 ZAR per kilogram of laundry, while employees and homeless/clients paid 10 ZAR per kilogram. On average, customers brought 5 kg of laundry. External customers contributed the most laundry, often including larger quantities such as bedding. In the future, the composition of the customer base will vary depending on the deployment area of LaundReCycle. However, the current usage by diverse customers at the current location demonstrates the potential for the facility's success in other locations as well.

The project team collaborated with a business consultant to establish a scalable business model, and plans are currently being discussed to establish a spin-off following the project's completion. Furthermore, the survey conducted as part of the project yielded valuable insights into effective marketing strategies and further technological advancements, as elaborated in section 4.3.

4.3 Multiplication / Replication Preparation

In order to facilitate the expansion and replication of the project, preparatory work has been undertaken. This included conducting a survey on the market situation, analysing consumer preferences, identifying potential markets, and assessing the technical requirements for further development. Efforts have also been made towards the development of a business framework.

The survey results regarding installation costs indicated an average willingness to pay of $9565 USD for the LaundReCycle. This is lower than the investment costs of LaundReCycle pilot plant. Therefore, further cost reductions through technical improvements and economies of scale need to be pursued. Interestingly, the survey also revealed that, from the user's perspective, the positive environmental impact held greater importance than cost savings. The assurance of human health through the reuse of greywater was identified as the most critical aspect (Figure 16).

Feedback from users and the results of the market research highlighted a demand for energy- and water-independent laundromats in South Africa, particularly in areas lacking basic infrastructure for water and energy. However, it is crucial to acknowledge that these areas often face more complex and extensive water-related challenges that cannot be fully addressed by a single laundromat alone. Therefore, the project has taken steps to develop a self-sufficient water system capable of addressing larger water challenges in these areas. As part of this effort, a shower has been incorporated into the laundromat in Cape Town, and initial experiments have been conducted to explore greywater use for irrigation (Figure 17, Figure 18). In addition, ongoing testing of the treatment system in KREIS-Haus, Switzerland, utilizing total greywater, has provided insights on how to integrate the technology into a completely off-grid water system.

Based on the project's findings and the market potential, discussions are underway to establish a spin-off for the commercial continuation of the project. A scalable business model has been developed, with a focus on the water treatment unit as the primary intellectual property. The versatility of the treatment unit allows for various applications, such as laundry or total greywater treatment, opening doors to multiple markets. To support replication efforts, a business structure based on local partners was developed. These local partners would be responsible for activities such as assembly, commissioning, monitoring, and maintenance of the technology. Involving local stakeholders will aim to enhance the technology’s sustainability, create employment opportunities, and ensure the effective operation of the system.

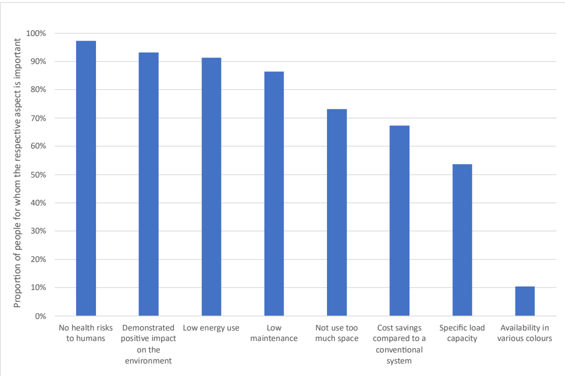

Figure 16: Ranking of the importance of aspects in the purchase/operation of the LaundReCycle

Figure 17: Expansion of the LaundReCycle with a shower and hydroponic system with the aim to explore wider greywater reuse applications

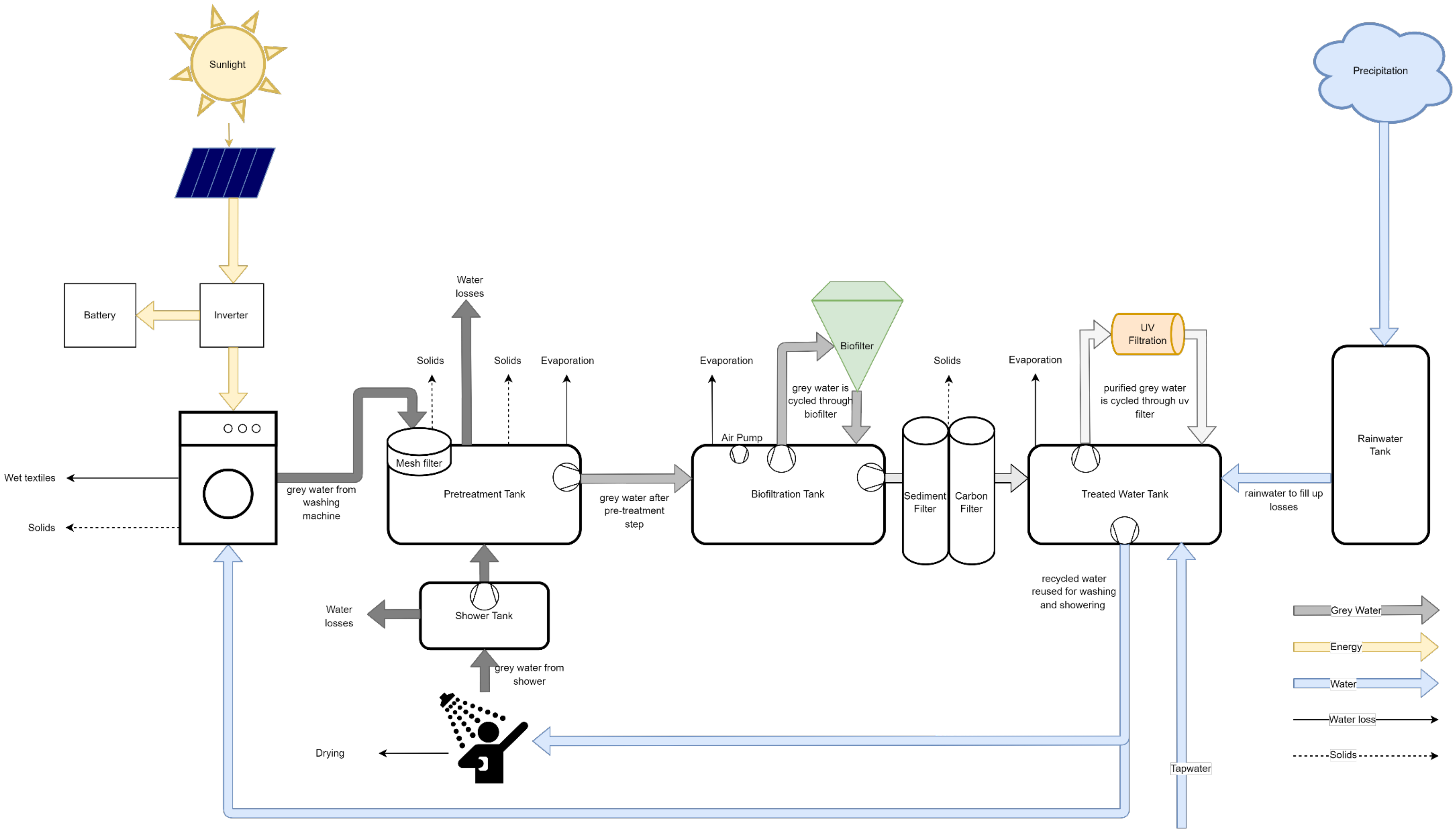

Figure 18: Technical overview of the components and flows in the LaundReCycle

4.4 Impact / Sustainability

The LaundReCycle project has generated impacts in the areas of ecology, economy, and society. In terms of ecology, the installation of a 4.32 kWp (12*360W) renewable energy capacity has resulted in the annual production of 7030 kWh of renewable energy (Figures 19, 20). This has reduced reliance on fossil fuels and resulted in a reduction of greenhouse gas emissions of 3.4 tons per year. Water management efforts leaded to the conservation of 25’000 litres of freshwater annually through greywater reuse and rainwater harvesting. Wastewater discharge was reduced by 23’500 litres per year. From an economic perspective, the project showed a levelized cost of energy (LCOE) of 13 ZAR/kWh (0.62 CHF/kWh*) for the complete LaundReCycle, including container, water treatment, washing machine and solar power system, and 3.3 ZAR/kWh (0.16 CHF/kWh*) for the solar power system only. For comparison, the current energy price in Cape Town is 2.78 ZAR/kWh. Furthermore, the project has attracted third-party funding and investments, including a contribution of CHF 3500.- from the Swiss Embassy. This funding has been allocated for various purposes such as organizing the opening event, conducting dissemination activities, and expanding the LaundReCycle with the shower and hydroponic system. To promote the project and engage with the community, several dissemination activities were organized, including a high-level event and a children's art workshop held in the LaundReCycle's garden. Additionally, the Laundromat container was artistically painted by a local artist, highlighting themes of water, nature, and the collaboration between Switzerland and South Africa. Moreover, the project attracted third-party funding of ZAR 600’000 from an international foundation for a follow-up project of Khulisa. This funding will allow Khulisa to further explore water and energy cycles in a setting of a farm. The project has not only achieved environmental goals but has also made a positive social impact. It has benefited the local community as well as individuals directly involved. With an estimated 274 customers per year, the project has provided a valuable service to the community. Furthermore, the creation of two new jobs and the training provided to eight personnel have contributed to local employment opportunities and skills development, empowering individuals within the community.

Ecological	**Unit**	**At the REPIC Project’s Completion**
Installed renewable energy capacity	[kW]	4.32
Renewable energy produced	[kWh]/year	7030
Amount of fossil fuel energy saved	[kWh]/year	7030
Greenhouse gas reduction	[t CO_2-eq]/year	3.4
Saved freshwater	[L]/year	25'000
Reduced wastewater	[L]/year	23’500
Economic		
Energy costs (LCOE)	[ZAR/kWh]	LaundReCycle complete system: 13 ZAR/kWh (0.64 CHF/kWh*) Only photovoltaic: 3.3 ZAR/kWh (0.16 CHF/kWh*)
Triggered third-party funding/investments	[CHF]	Swiss Embassy: CHF 3500.- Foundation: 600’000 ZAR
Local income generated	[CHF]	10’000 ZAR
Social		
Number of beneficiaries	[Number/a]	Total: 274 customers/a - 43% external customers - 16% own staff - 41% homeless/clients
Number of new jobs	[Number]	2
Number of trained personnel	[Number]	8

**Calculated with the exchange rate on 25 July 2023: 1 CHF = 20.36 ZAR*

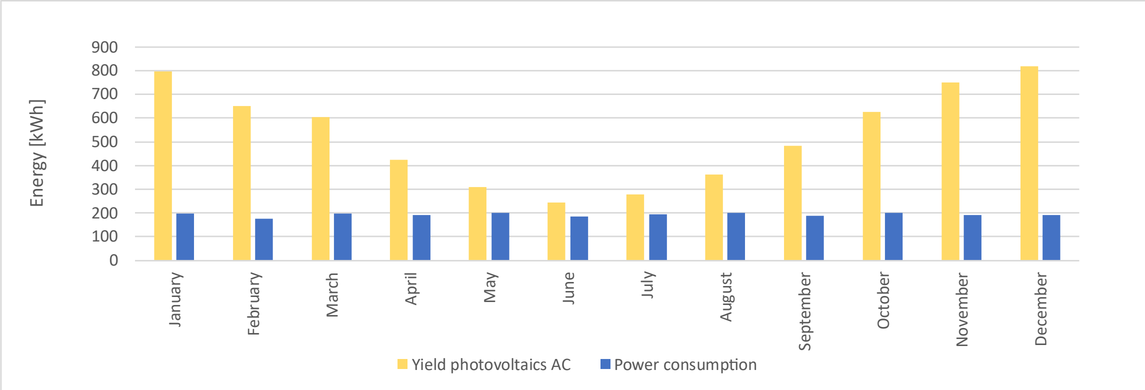

Figure 19: Monthly kWh produced and consumed by the LaundReCycle based on an average of 11 wash cycles per week

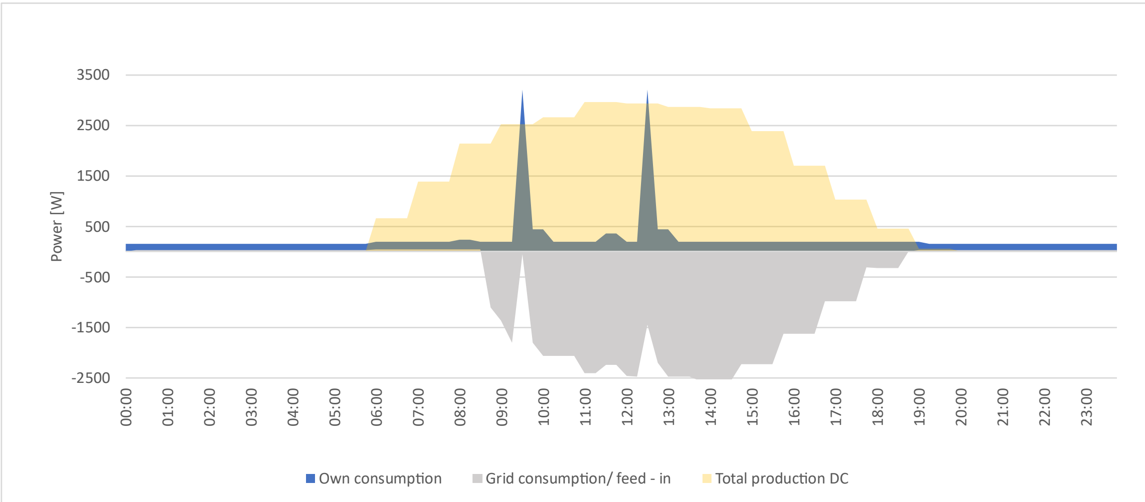

Figure 20: Example of a daily profile in summer with two wash cycles, PV production and grid consumption/ feed-in of the solar system of the LaundReCycle together including a battery

5. Outlook / Further Actions

5.1 Multiplication / Replication

The LaundReCycle pilot facility will remain at its current location in Cape Town and will continue to be operated and monitored by Khulisa. This arrangement offers the opportunity to gather valuable insights into the long-term operation of the facility. Moreover, it enables the provision of training and job opportunities for the beneficiaries associated with Khulisa, fostering skill development and empowerment within the community.

The next step towards multiplication and replication will be to test one final pilot installation of the new flow-through system in South Africa. This testing will involve higher loads than in KREIS-Haus and will be established in one of the target markets. The aim is to gather valuable data and feedback to further refine the system and ensure its suitability for upscaling. After a successful pilot operation, the aim would be to produce the first zero series of the flow-through system. To promote the multiplication and replication of the technology, the team will continue to explore the market and develop a comprehensive plan for market development. This will involve identifying which markets to access first and with which product. It may also require adaptations to the product to meet specific market requirements.

Additionally, the further development will focus on the development of low-cost monitoring technology. Such a technology will play a crucial role in ensuring the safe and efficient operation of the system. By implementing effective monitoring, the project can maintain high performance standards and address any issues promptly. Furthermore, a training program needs to be developed to build the capacity of individuals in operating and maintaining the system. This program will equip local stakeholders with the necessary skills and knowledge to ensure the long-term sustainability and success of the project.

5.2 Impact / Sustainability

During the multiplication phase in the medium term, the project expects to generate sustainable effects in terms of environmental and socio-economic aspects, as well as resource efficiency and CO_2 relevance. One of the key environmental benefits of the project's multiplication is the conservation of freshwater resources. Each new installation will contribute to saving freshwater by reducing water consumption. Additionally, the system's ability to treat and reuse greywater will help minimize wastewater discharge and its associated environmental impacts. By implementing renewable energy sources in conjunction with the installations, the technology will also contribute to reducing CO_2 emissions that typically arise from conventional water treatment and the use of fossil fuels.

The multiplication of the project could enable the establishment of completely water self-sufficient systems in communities, eliminating the need for centralized infrastructures and extensive piping networks. This decentralization enhances resource efficiency by avoiding energy-intensive water transportation and reducing water losses. Furthermore, the project's focus on reducing freshwater demand and wastewater discharge can have secondary positive effects, such as decreasing the energy required for pumping, treating, and distributing freshwater.

In socio-economic terms, the replication of the project could bring benefits through the decentralization of water treatment, energy generation and recycling processes. By doing so, a significant part of the value chain would be moved into the local communities. This decentralization creates opportunities for capacity building, education, and job creation within those communities. As a result, the replication phase is projected to generate employment opportunities, stimulate economic growth, and enhance local livelihoods in the regions where the system is implemented.

Furthermore, by providing access to safe and sustainable water resources, the project has the potential to enhance the overall health and well-being of the local population. Clean water plays a vital role in preventing waterborne diseases and promoting good hygiene practices, leading to improved community health outcomes.

6. Lessons Learned / Conclusions

Thanks to the project, some key findings and conclusions have emerged. The positive feedback and high acceptance received for bringing green innovations to a water and energy stressed country have been noteworthy. This indicated the willingness of the community to embrace sustainable solutions.

A crucial lesson learned is the importance of integrating technological development with the socio-economic perspective. By understanding target markets, consumer preferences, and adapting the technology accordingly, the project was able to meet the needs of the local communities effectively.

Interdisciplinary and transdisciplinary collaboration has proven to be vital in the project's context. Partners had to bridge their expertise and work together to develop suitable solutions. This required time, conscious effort, and effective teamwork to ensure successful outcomes. Also, creating space for trial and error and providing adequate training for the local staff was crucial. Actively involving the local staff ensured the long-term viability of the project. Staff members had to be trained and made aware of the unique requirements of operating the LaundReCycle facility. For example, sensible dosing of detergents and finding alternative solutions when certain chemical products cannot be used were essential aspects to be addressed.

The operation of the LaundReCycle can be limited by electricity availability, especially during the installation of a dryer and in winter. Balancing the need for reliable business operation with water and energy self-sufficiency is essential. Backup systems may be required to ensure continuous operation. Therefore, the development of water and energy conservation technologies should align with the economic goals of the operator.

In comparison to Switzerland, certain tasks were more challenging in the South African context. For instance, water sample analysis proved to be difficult due to unreliable or expensive external labs, leading to the establishment of an on-site field lab in the LaundReCycle. Sourcing the components for the field lab and technical components for the further development of the technology, presented to be challenging.

In conclusion, the project's findings emphasize the importance of integrating technological and socio-economic perspectives, fostering interdisciplinary collaboration, providing thorough staff training, and addressing challenges specific to the project's context. These lessons can serve as valuable recommendations for similar projects, guiding their implementation and maximizing their impact.

7. References

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8. Annex

All press articles, news and reports are published on www.zhaw.ch/iunr/laundrecycle/en