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Master Thesis

Safe Water and Saved CO_2: CO_2 Reductions and SDG Impacts of Solar Water Disinfection (SODIS) with WADI

submitted by

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Safe Water and Saved CO_2

CO_2 Reductions and SDG Impacts of Solar Water Disinfection (SODIS) with WADI

Project Evaluation of 'Clean Air and Safe Drinking Water for Soroti' – an Empirical Study in Uganda

Photo by Helioz 2019

by Max Reisinger

Affidavit

I hereby declare that I have authored this master thesis independently, and that I have not used any assistance other than that which is permitted. The work contained herein is my own except where explicitly stated otherwise. All ideas taken in wording or in basic content from unpublished sources or from published literature are duly identified and cited, and the precise references included.

I further declare that this master thesis has not been submitted, in whole or in part, in the same or a similar form, to any other educational institution as part of the requirements for an academic degree.

I hereby confirm that I am familiar with the standards of Scientific Integrity and with the guidelines of Good Scientific Practice, and that this work fully complies with these standards and guidelines.

Vienna, 30.09.2022 Max REISINGER *(manu propria)*

“Ich denke vieles von dem, was zwischen Himmel und Erde ist, lebt, stattfindet, wissen wir nicht. Manche wissen vielleicht etwas mehr, manche gar nichts und insgesamt wird es aber wohl gut sein, nicht allzu viel zu wissen!“

Dominik Schmitz, 2021

“We live in a strange world where children must sacrifice their own education in order to protest against the destruction of their future. Where the people who have contributed the least to this crisis are the ones who are going to be affected the most.”

Greta Thunberg, 2019

“You cannot get through a single day without having an impact on the world around you. What you do makes a difference, and you have to decide what kind of difference you want to make.”

Jane Goodall, 2019

Acknowledgements

This thesis was written out of my optimistic belief in humanity and our power to change the world for the better, in times of climate and social crisis. My intrinsic motivation to conduct this study is, to contribute at least a bit to safeguarding the beauty of life of all forms on this amazing planet on which we are guests on. I want to dedicate this thesis to all people who have no sufficient access to safe drinking water and wish for improvements for all of them. This thesis aims for being at least a small contribution on the way to come there.

One of my personal motivations was to dive deeper into the controversial topic of CO_2 offsetting and its chances and limitations to reduce emissions and improve the quality of life for humans and all other species on this planet. By looking at an existing climate project financed by carbon credits, I wanted to specify my own positioning towards this controversy.

I would like to thank my main supervisor Ao.Univ.Prof. Dipl.-Ing. Dr.nat.techn. Maria Fürhacker for her guidance and for giving me freedom to unfold my ideas. I would also like to thank my co-supervisor BSc Hons. PhD Lin Roberts for her support from the other side of the globe, her detailed feedback and her inspiring values. I also want to say thank you to my friend and mentor Dominik Schmitz who accompanied me to grow my roots in field of climate action and gave me his trust and the chance for visiting my very first climate project in Bangladesh. I further want to thank all the people in Soroti, who have participated in the SODIS project and offered their time to share their personal stories in the interviews of the empirical study. A huge `Thanks!' to Water School Uganda to reliably assist me in the data collection during the field visit, enabling me to get authentic project insights and for their precious project activities. Furthermore, I want to thank Helioz for the good collaboration and their engagement for safe drinking water around the globe. Thanks to my colleague Anabell who conducted the baseline study as a foundation of my thesis and thanks to BOKU for being such a grat university.

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Abstract

The latest IPCC report shows that we only have 3 years left to change from annually increasing CO_2 emissions to rapidly decreasing them to stay able to reach our global climate goals. Deep and systemic change is needed. Solutions like Solar Water Disinfection (SODIS), the SDGs and ambitious climate mitigation projects can be important stepping stones in that transformation. A combination of these solutions is found in an ongoing drinking water project in Uganda financed by carbon credits. Nevertheless, there is a research gap in the emission reduction potential and SDG impacts of SODIS on project level. This study aims for quantifying the impacts of SODIS with WADI within the project 'Clean Air and Safe Drinking Water for Soroti' – an empirical case study in rural Uganda. A mixed-methods approach combines quantitative and qualitative research. Relevant literature was analyzed and a Project Study delivered current data from 223 local households. This data have been compared to the 'Baseline Study' (before the project activities started) through a pre- and post-analysis. The results show that the people have taken on the new water disinfection method. They have changed from boiling the water with firewood to practicing SODIS with WADI. The average results between two calculated scenarios give a CO_2 reduction of 2.12 t per WADI annually which is leading to a total project impact of 21,200 t CO_2 reduction over the 2000 HH within the five years of project duration. Furthermore impacts on 9 affected SDGs have been quantified. Benefits of the project have not only included improvements to people´s health due to a reduction of water-borne diseases, but also time savings, increased autonomy, strengthened sense of community, more school attendance and a regeneration of surrounding trees and ecosystems. The findings show how interconnected safe water, improved livelihood and climate mitigation are. To solve global problems like climate change, many local solutions are needed.

Keywords:

SODIS, clean drinking water, WADI, water disinfection, CO_2, CO_2 reduction, SDG impact measurement, carbon credits, climate project, sustainable development, Uganda, Soroti

Kurzfassung

Laut dem neuesten IPCC Bericht bleiben uns nur noch drei Jahre, um von jährlichem Anstieg an CO_2 Emissionen zu einer rapiden Reduktion zu kommen, damit wir noch Chancen haben, unsere globalen Klimaziele zu erreichen. Ein Systemwandel ist notwendig! Lösungen wie Solare Wasserdesinfektion (SODIS), die SDGs und ambitionierte Klimaschutzprojekte, können wichtige Puzzlesteine dafür sein. Diese Lösungen werden in einem laufenden Trinkwasserprojekt in Uganda, finanziert durch Emissionszertifikate, verflochten. Es fehlt die Forschung rund um das Potential von SODIS in Bezug auf die CO_2 Einsparungen und die SDG-Wirkung auf Projektebene. Diese Arbeit soll die Quantifizierung der Wirkungen von SODIS mit dem WADI anhand des Projekts „Sicheres Trinkwasser und saubere Luft für Soroti“ darstellen. Methodisch wurde eine Kombination aus quantitativer und qualitativer Forschung gewählt. Relevante Fachliteratur wurde analysiert und eine eigene Projektstudie lieferte neueste Daten aus 223 lokalen Haushalten. Diese wurden mit früheren Daten aus der „Baseline-Erhebung“ (vor Projektstart) verglichen und analysiert. Die Ergebnisse zeigen, die Leute haben die neue Wasseraufbereitungsmethode in ihren Alltag integriert. Sie kochen ihr Wasser nicht mehr am Feuer ab, sondern praktizieren SODIS mit dem WADI. Das bewirkt laut Durchschnittsszenario eine CO_2 Reduktion von 2,12 t pro WADI / Jahr, die eine Gesamteinsparung des Projekts von 21.200 t CO_2 der 2000 Haushalte über die Laufzeit von 5 Jahren ergibt. Außerdem wurde die Wirkung auf 9 relevante SDGs quantifiziert. Neben der gestiegenen Gesundheit wurden durch das Projekt Zeitersparnisse, erhöhte Autonomie, gestärktes Gemeinschaftsgefühl, vermehrte Schulanwesenheit, und eine Erholung der lokalen Ökosysteme erreicht. Die Ergebnisse zeigen auf, wie sehr sauberes Wasser, gestiegene Lebensqualität und Klimaschutz miteinander verbunden sind. Globale Probleme wie der Klimawandel, brauchen viele lokale Lösungen.

Schlagwörter:

SODIS, sauberes Trinkwasser, WADI ,Wasserdesinfektion, CO_2 ,CO_2 Reduktion, SDG Impact, CO_2 Kompensation, Klimaschutzprojekt, Nachhaltige Entwicklung, Uganda, Soroti

List of abbreviations

BOKU = University of Natural Resources and Life Sciences Vienna

CO_2 = Carbon dioxide

(The) GS = (The) Gold Standard

HH/s = Household/s

HWTS = Household Water Treatment and Storage

NGO(s) = Non-Governmental Organization(s)

PET = Polyethylene terephthalate

SDG(s) = Sustainable Development Goal(s)

SODIS = Solar Disinfection

SSI(s) = Semi-structured Interview(s)

t CO_2 e = tons of CO_2 equivalents

UV = Ultraviolet

UN = United Nations

UNFCCC = United Nations Framework Convention on Climate Change

VHT = Village Health Team

WADI = Device for Solar Water Disinfection

WASH = Water, Sanitation, Hygiene

WHO = World Health Organization

WSU = Water School Uganda

WWF = World Wide Fund for Nature

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1. Introduction and context

1.1. The global climate challenge

The latest IPCC report shows that we as humanity only have three years left to completely change our behavior on this planet. By 2025 at the latest, we have to reach 'peak carbon' in order to have a chance to stabilize the global climate at around + 1.5°C as agreed in the Paris Agreement (IPCC Press Office, 2022b). Reaching this goal is essential to nothing less than our own future and the life of countless other species on earth.

Within these three years the global carbon emission need to turn around from further annual increases to constantly decreasing. That means rapid and deep systemic change from today on. From 2025 till 2030 carbon emissions have to fall by 43%, and we should live as carbon neutral societies from 2050 onwards (IPCC Press Office, 2022b). Only if we manage to do so, are the UN climate goals of "*…staying well below 2°C, preferably 1.5°C of global warming.*" (UNFCCC, 2016, p. 4) still realistic. If we don´t, severe changes could destabilize our known ecosystems leading to many catastrophes around the globe (Pörtner et al., 2022; Vaughan, 2022).

We need to accelerate the climate transition dramatically. Emissions need to be reduced by several percentage points per year.

> "*We do not have time to pick only the low-hanging fruits; we need to start picking all the fruits. The whole of society needs to engage, in all sectors and at all levels, including policymakers, firms, municipalities and citizens. The decisions and actions taken this decade will have a critical impact on our ability to reach zero emissions […]*" (Zetterberg et al., 2021, p. 4).

That urgency leads to many questions: How are we going to reduce our carbon emissions that drastically? How can we ensure that we simultaneously develop decarbonized systems and behaviors? In which ways can we walk alongside low-income societies of the global south and assist them to strengthen their resilience and sustainable development? How can we as high polluting continent (next to trying our best to reduce our own emissions radically) honestly and genuinely help people that contributed the least to, but will suffer the most from the climate crisis? How can sustainable development projects and climate mitigation projects have a beneficial impact?

For the transition to a carbon neutral world many changes are needed: alternative production processes need to be possible without carbon emissions and sustainable consumption patterns have to follow, the energy sector should be mainly renewable, the whole agricultural sector needs to shift towards regenerative agriculture, land use patterns can no longer be exploitive but should repair and heal degraded land, construction & housing should be based on natural materials and mobility and transport patterns should be fossil fuel independent. That is a huge transition and needs to be done step by step.

For the transition phase climate mitigation projects financed by carbon credits, could be one of the useful stepping stones contributing to that important change (Broekhoff et al., 2019; Streck, 2021). These projects, often also called 'sustainable development projects' or 'carbon offsetting projects', try to build a bridge between helping vulnerable, low-income communities to reach better health and wellbeing and at the same time reducing carbon emissions (BOKU Competence Centre for Climate Neutrality, n.d.). One of these projects is going to be in the spotlight in this thesis: 'Clean Air and Safe Drinking Water for Soroti' – a case study in Uganda.

1.2. Attempts to address this challenge

There is still hope. We have a few years left to address this challenge and learn from our past mistakes. The latest IPCC report says that we can still stabilize the global climate system by ambitions and fast actions (IPCC Press Office, 2022a). The momentum of the climate movement around 'Fridays for future' shows how heavily civil society is demanding a system change.

Many countries, organizations and companies therefore have set their climate goals and want to reach carbon neutrality. Pledges like reaching net zero by the end of the decade are heard more often these days, meaning that the CO_2 emissions shall be avoided and reduced to a minimum and the remaining emissions shall be compensated elsewhere via carbon credits enabling equivalent carbon reductions often in countries of the global south (UN, n.d.).

Uganda, like many other global south countries, already suffers from the consequences of climate change, which is impacting not only the nation's environment but also the national human health. Countless Ugandans on a personal level suffer from prolonged dry seasons, water shortages, crop failure, famine and heavy rainfalls causing flooding and soil erosion. Direct impacts are more water-borne diseases and more fevers and coughs (United Nations - Environment Programme, 2018).

SODIS (=Solar Water Disinfection) could be one of many little solutions in addressing not only the climate but also the upcoming water and human health challenges. It enables people to turn unsafe water into safe drinking water. Water is a precious resource on earth´s surface. The following graph (Water Science School, 2018) highlights how rare freshwater is, by showing the distribution of the planet's water resources. The graph is based on the data of Shiklomanov (1993).

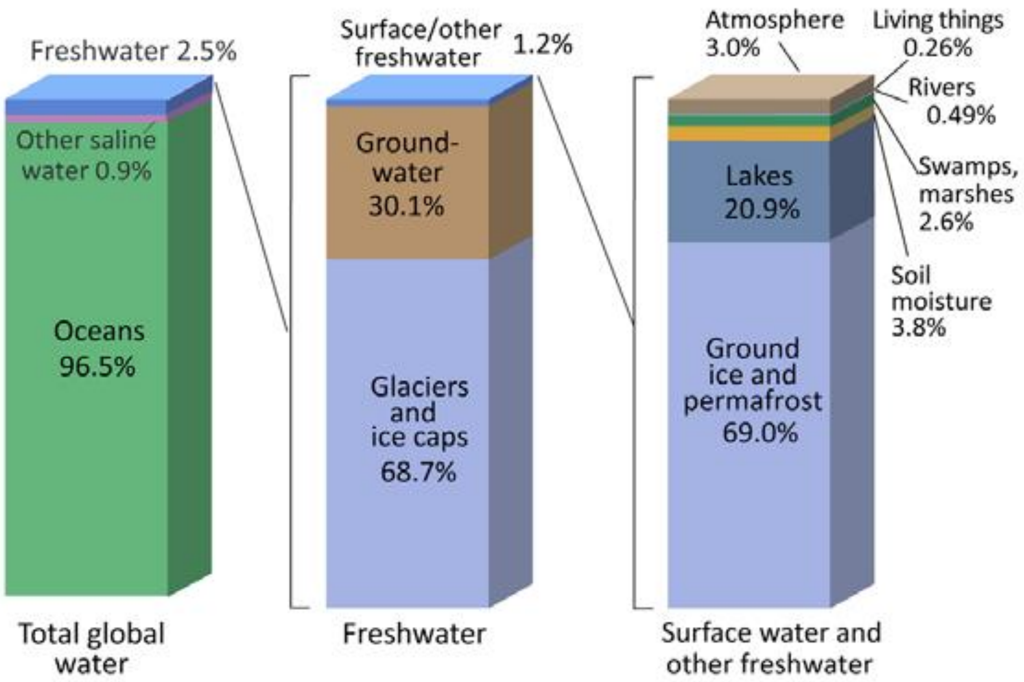

Fig. 1: Water distribution on earth (Shiklomanov, 1993, p. 2; Water Science School, 2018)

The figure is showing that only 2.5% of the world's water is freshwater and of this, only 1.2% is directly available on the surface. From that tiny remaining percentage only ~ 21.5% is water in rivers and lakes, which are drinkable only very occasionally. Perlman et al. (n.d.) visualized the earth's water distribution in another figure by repainting the picture of our blue planet. It shows the water distribution in volume relatively sized to the planets volume. All the planet's water according to the 3 bars from Fig. 1 (Shiklomanov, 1993, p. 13) is packed into the three blue balls. The smallest ball is hard to spot, showing how small the river and lake water resources are compared to the rest of the planet's water.

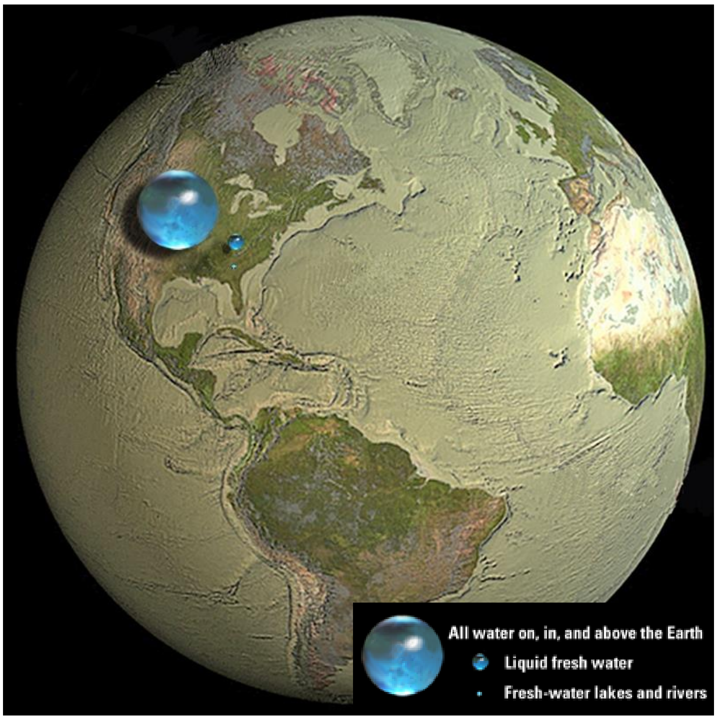

Fig. 2: The volume of the world´s water relative to the total volume of the planet (Perlman et al., n.d.)

Freshwaters in Africa are often not of drinking water quality (Conway & Vincent, 2021; Uganda Ministry of Water and Environment, 2020). SODIS has the potential to help people around the globe to turn this unsafe water into safe drinking water, using the power of the UV-radiation of the sunlight.

1.3. A gap in SODIS CO_2 monitoring

While providing safe drinking water, SODIS brings many additional co-benefits to its users. One of them is that it makes boiling of water for disinfection redundant and therefore saves a lot of wood, which doesn´t have to be burned. That again reduces CO_2 emissions of many households (HHs), which have previously been dependent on boiling. Summed up globally among all SODIS users, this has an essential positive impact on the climate. How much climate potential there is in SODIS globally can only be estimated. Little attention has been given to the CO_2 impact of SODIS by the scientific community so far. While it´s technical and chemical process and the water quality requirements and the health benefits are well described, there is a gap in precise quantitative CO_2 monitoring and it´s CO_2 reduction potential. Almost no scientific literature can be found. This thesis is aiming to address this gap.

2. Research Objectives

This thesis acts as an evaluation study by measuring the impacts of the ongoing project 'Clean Air and Safe Drinking Water for Soroti' in Uganda. It aims to scientifically assess and quantify the effect of the project activities on relevant SDGs, with special focus on the calculation of the achieved CO_2 emission reductions. Furthermore, this thesis aims for improving the understanding of the positive impact that SODIS has on climate action (SDG 13) and other SDGs as this would add a new aspect to the science around SODIS. Therefore different ways of evaluation should be applied and compared. Using the internationally standardized calculation methodology 'Gold Standard' as a basis shall ensure environmental integrity and transparency in the verification of the results achieved. Also experiences and expertise from the existing BOKU-CO_2 Offsetting system can be taken into account to ensure BOKU standards are complied with, improve the methodology and make the project results comparable. The results will give a realistic impact assessment updating the findings of an earlier baseline study (Wornig, 2021) by analyzing recent data gathered in a followed-up project study. Overall the study can be seen as a detailed empirical report on the impact of the climate project 'Clean Air and Safe Drinking Water for Soroti'. It is incorporating the relevant state of the art science literature to critically examine the role of climate projects like this in the framework of the SDGs and Carbon Crediting Schemes.

2.1. Research Question

The central research question is:

What benefits and co-benefits can be described through the application of SODIS with WADI within the project 'Clean Air and Safe Drinking Water for Soroti (Uganda)'?

Two sub-questions help to break down the research question:

1. How many tons of CO_2 emission reduction can be achieved through the project in total?
2. What is the impact of the project's first three years on the relevant SDGs, with special focus on SDG 13 (Climate Action)?

These research questions will be answered by conducting an empirical 'project study' and comparing the derived results to the 'baseline study' which was done by Wornig (2021) at the beginning of the project. This piece of work acts as a reference study. In addition, a literature review about the SODIS method and different methodologies for assessing the SDG impacts and the CO2 reductions via carbon credits, was conducted to understand the scientific context. Relevant publications were found through different search engines like Boku LitSearch, Google Scholar and Karlsruhe Virtual Catalogue by using keywords like 'SODIS' / 'Solar water disinfection', 'Carbon emission reduction' / 'CO_2 emission reduction', 'drinking water', 'Uganda', 'SDG impact measurement', 'carbon credits', 'Gold Standard Methodology', ´firewood´, '3 stone stove' and ´climate change´. These terms were used in different combinations. Additional publications were found through reference lists of relevant papers.

2.2. Scope and Limitations

The Soroti SODIS project involves 2000 HHs in 10 different villages of the district 'Soroti' in rural Uganda. With a HH size of 8.12 persons in average, the project activities reach over 16,000 people directly day by day. The empirical part of this study involved 223 randomly selected households from across the 10 different villages, with the aim of generating a representative understanding of all 2000 HH participating in the project.

The thesis gives a detailed zoom-in into this specific project. It should be a reference study for all upcoming studies measuring the impacts of SODIS especially on carbon reduction potential on HH level. So far, there is not much scientific literature around to compare and benchmark these results to. A major limitation is, that due to the travel restrictions during the COVID-19 pandemic the field visit couldn´t take place as planned. The survey had to be conducted by the local field team on their own without the presence of the researcher himself. To still ensure a successful field visit, a training of the field team, regular updates via mail and a debriefing meeting have been taking place together with the researcher. The data was collected successfully, but there were no on-site observations. To attempt to address this gap, three days of online interviews and a focus group (accompanied by technical problems) with different stakeholders of the project took place. Nevertheless these impressions are just not the same as being on site for oneself. (On the plus side, inability to travel to Soroti and return did, reduce the overall carbon emissions of the project by about 2.2 t of CO_2 e (BOKU Competence Centre for Climate Neutrality, n.d.)). Furthermore the local effects of the pandemic on the project activities and beneficiaries are only assessed to a small extent.

To truly assess the impacts that SODIS has on the people´s lives in Soroti from afar, with a completely different cultural background and based on very simplified data in comparison to the complexity of influencing factors and motivations, is enormously ambitious. The situation in the project area is non-static as people, weather, climate, politics, pandemics and all their interrelations influence the actions, motivations, needs and behaviors of the people day by day. Therefore to put this living complex system into numbers only ever can be a rough best estimate approach to describe the situation quantitatively in some numbers. Clear and narrow system boundaries are needed. These are further described in Chapter 5. To get a 360-degree insight, many things like historical cultural backgrounds, sociologic research, policy observations and market analyses outside these boundaries would also have to be looked at. As this exceeds the frames of this thesis, further research on those details is recommended.

Even when trying to be as reflective as possible, this is still a study from a researcher socialized in a scientific and Eurocentric society, who has never experienced water scarcity or severe climate change impacts at all. This fact might be the biggest limitation.

2.3. Structure of the thesis

The thesis starts with Chapter 1 in which the context of the global challenges of climate urgency is set. Chapter 2 outlines the objectives of the work, its research focus, the scope and structure of the thesis. In Chapter 3, the fundamental scientific background is given by a review of the state of the art scientific literature. The topics of SODIS, the SDG framework and carbon crediting built up the thematic frame. Chapter 4 continues with the description of the investigated case study project 'Clean Air and Safe Drinking Water for Soroti'. Here all the background information and previous findings from the baseline study conducted within the same project is given. This background project information is essential as this thesis builds up upon it. In Chapter 5, the materials and methods of the empiric approach are explained. This is divided into the quantitative research part, the qualitative approaches, the CO_2 reduction calculations and the SDG impact assessment. Chapter 6 is presenting the results and discussion of the findings on CO_2 reduction and other SDG impacts. The thesis closes with a conclusion and outlook in Chapter 7.

3. Fundamentals – a literature review

This chapter presents a literature based overview on the topic of SODIS, SGDs and carbon credits and how they are interconnected.

3.1. SODIS – Solar Water Disinfection

3.1.1. The basic SODIS method

> "*Solar water disinfection (SODIS) is one [of] the cheapest and most suitable treatments to produce safe drinking water at the household level in resource-poor settings.*" (García-Gil et al., 2021, p. 1).

Millions of people rely on surface waters for their daily water supply. About 11% (844 million people) of the world's population still has no access to basic water services at all. Another 2.1 billion people only have access to unsafe or insufficient amounts of water (UN, 2018). Often this water has to be disinfected due to bacterial contamination. Fig. 3 shows the most common disinfection practices at the HH level and their characterizations.

García-Gil et al. (2021) state that boiling unsafe water is accepted by users around the world as a method of making drinking water safe, and that boiling is highly effective in removing microbial contamination. In simple financial terms, it may be the cheapest way of disinfection as long as the fuel used is free of cost. In many cases therefore firewood is used. Its collection may be for free but is very time consuming and can have negative effects on the biosphere due to deforestation.

SODIS is a more sustainable option. People just need to fill a suitable PET or glass bottle with unsafe water and place it horizontally in the sunlight. The UV radiation in combination with the heat of the sun kills bacteria and can even be effective against viruses and protozoa due to its germicidal effect (García-Gil et al., 2021; Luzi et al., 2016). This effect has been proven repeatedly by many studies over the last 30 years. Exposure times required to kill the pathogens vary between 6h and 48h, depending on the intensity of the sunlight and the pathogen structure (McGuigan et al. 2012). Countries closer to the equator are more suitable for SODIS as the effectiveness of the method is all about solar exposure and the resulting penetrations depth of the UV radiation (Luzi et al., 2016). About 5 million people in over 50 different countries spread across the globe daily depend on SODIS (McGuigan et al., 2012). The WHO (2013) recommends SODIS for low-income countries as well as for emergency situations.

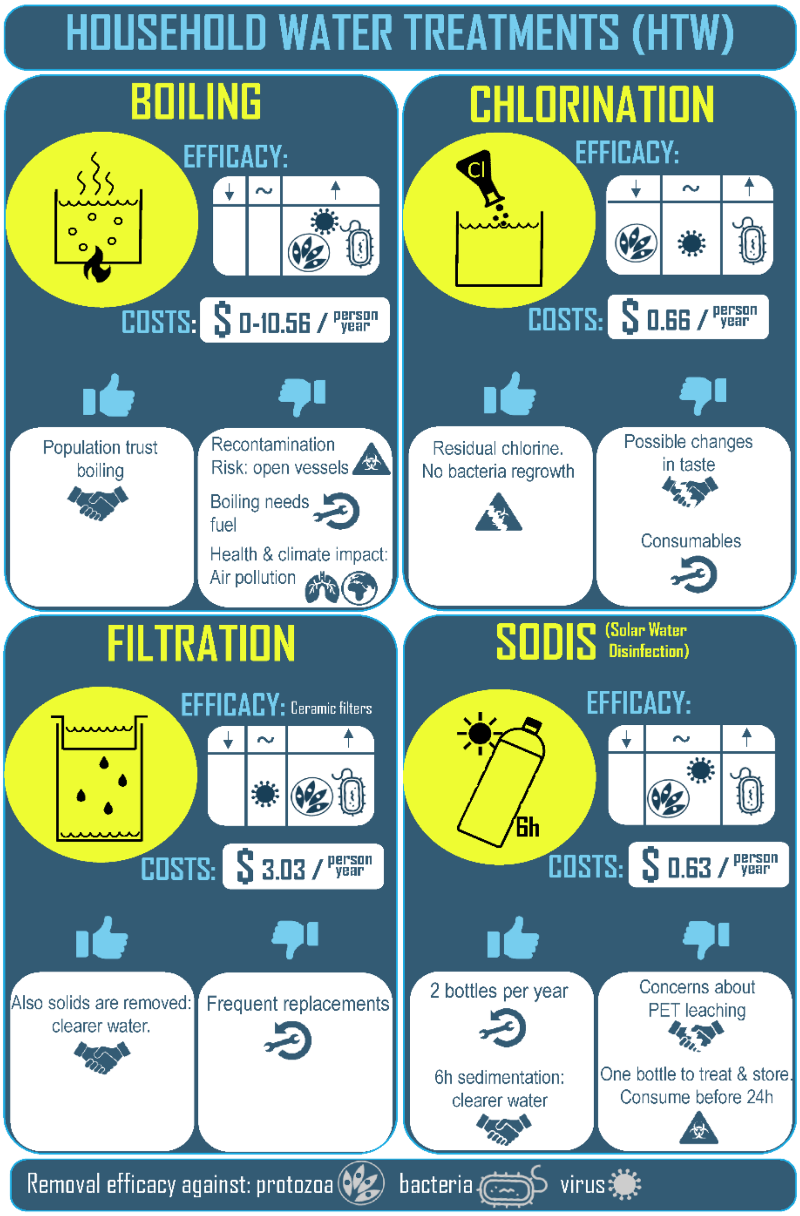

Fig. 3: Common HH water treatments(García-Gil et al., 2021, p. 4, Fig.1)

For a HWTS (=HH water treatment and storage) system to be culturally acceptable and replace traditional methods like boiling, it needs to be easy to use, cheap and sustainable. As SODIS combines these properties, it became more popular within the last decade (McGuigan et al., 2012).

A standard 'SODIS method' has been developed by 'Eawag', the Swiss Federal Institute of Aquatic Science and Technology (Luzi et al., 2016). The process of disinfection is quite simple but the pre-treatment before applying SODIS is essential to remove suspended matter. Different methods like aeration, sedimentation and filtration are endorsed (WHO, 2013). For example the water is filtered through a cloth in a first step and then poured into a transparent bottle or container. Glass bottles and PET-bottles are both UV permeable and work for SODIS. PET bottles are usually favoured. They are easier to access in low-income countries and they are also more durable, as they don´t break as easily (McGuigan et al., 2012).

Nevertheless, it is still a common psychological barrier to consume water from a PET bottle which was continuously exposed to direct sunlight. There prevails the fear that toxic substances from micro plastics could leach into the water and be dangerous for human health. It is true that glass in comparison to PET is totally inert to sunlight and does not release any photoproducts. Luzi et al. (2016) argued that because of that material safety of PET, it is used for all kinds of food and drinks packaging and many studies found that PET bottles do not leach considerable amounts of substances dangerous for human health (McGuigan et al., 2012; Wegelin et al., 2001). Sometimes terephthalate can be found but it stays at the surface of the bottle without leaching into the water (Wegelin et al., 2001). Other substances like plasticizers or carbonyls that could be found in marginal amounts are far below the limits for classifying safe drinking water. Only when the same PET bottle is used 6 months or longer, negative genotoxicity can occur (Ubomba-Jaswa et al., 2010). Therefore, the SODIS water out of PET bottles can be consumed unhesitatingly, if bottles are renewed at least every half a year (McGuigan et al., 2012). The minimal health risk in consuming drinks out of them with or without exposure to sunlight is comparable. Bottles made out of other plastic materials like polycarbonate (PC) or polyvinylchloride (PVC) are not suitable for SODIS. They can release bisphenol A (BPA) which is carcinogenic and can harm the hormone balance. These harmful substances are not used in PET bottles (Luzi et al., 2016).

Since the 1980s ongoing research around the SODIS application has made it safer and easier to use and many technical advances have increased its effectiveness:

- Solar reflectors focus more sunlight at the point of application
- Dark surfaces beneath the bottles increase the absorption of heat and sunlight
- Optimized bottle designs and bottle positioning increase the UV penetration depth
- Indicators for UV radiation (e.g. WADI device) increase the user's confidence and the SODIS image.

Most of these advanced designs of the SODIS method have not been scaled up through widespread commercial products (Luzi et al., 2016), but recently a device was developed which incorporates a UV radiation indication. The 'WADI' as an essential technology in this thesis is explained in the next sub-chapter.

3.1.2. SODIS method with WADI

The WADI, developed the Austrian company 'Helioz' aims to increase people's confidence in practicing SODIS. It is a little solar powered device, which runs by a photovoltaic cell and stores some energy in a battery. This enables its use regardless of any additional power supply or electric infrastructure. The WADI is put next to the bottles at the start of a standard SODIS process where it is exposed to the same amount of sunlight as the water. There it just measures the UV-radiation of the placed spot with a sensor. It does not do any disinfection of the water itself, but using an emoji that gradually changes from a frowning face to a smiling one, plus a line that moves from one bar to five, it visually depicts the progress of the solar disinfection (Helioz, n.d.–b). Fig. 4 is a schematic illustration of the WADI application.

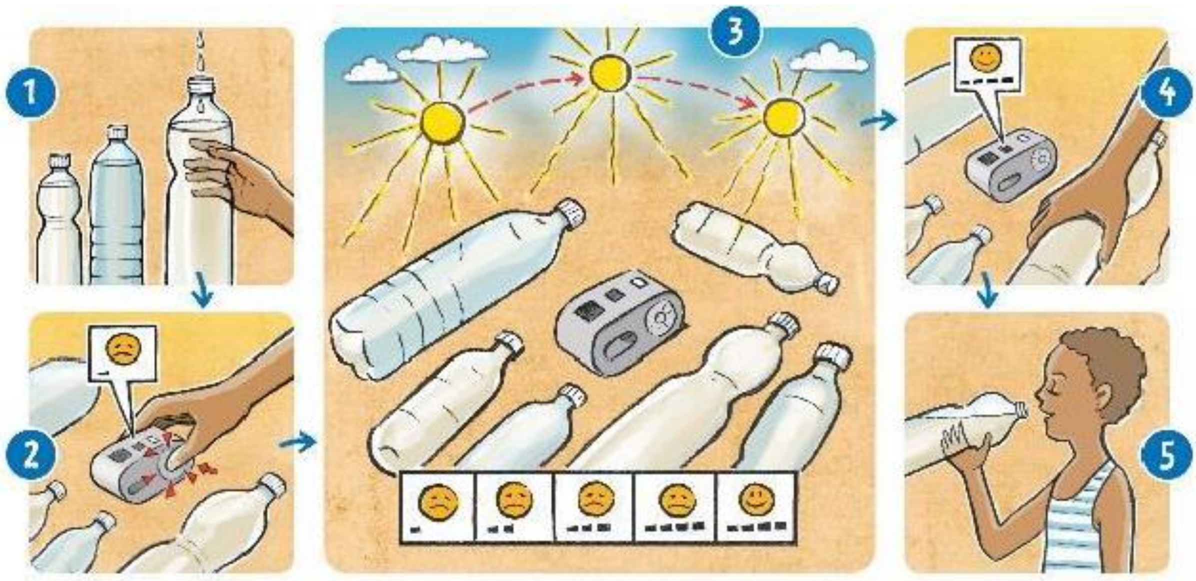

Fig. 4: WADI application in SODIS process (Helioz & BOKU, 2018, p. 3)

The WADI tackles two of the standard SODIS disadvantages named by Luzi et al. (2016). Firstly there normally is no visual indicator, of when the water is entirely disinfected and safe to drink. People often are unsure when the SODIS process is finished, as the water looks the same before and after disinfection. The WADI overcomes this challenge by measuring the UV radiation and duration and displays a laughing smiley, when the water is finished. Before, the WADI just shows a sad smiley. Therefore people (whether literate or not) have a clear indication when the water is ready to drink (Helioz, n.d.–b). This is especially useful on cloudy days, as the radiation intensity is difficult to estimate. As the disinfection process is highly dependent on the weather, the WADI can bring additional clarity. Furthermore it increases the efficiency of the whole SODIS process, by securing the water safety and minimizibg unnecessary waiting time (Helioz & BOKU, 2018). Secondly the standard SODIS method often has the image of being a 'poor-peoples' thing'. The advantage of being a trivial low-tec solution, only requiring PET bottles and sunlight, often is a barrier to people's acceptance. The bottles are often collected from the bins or landfills, as there they are accessible for free. This is causing SODIS´s needy image. The WADI adds a more technological and modern image, which can increase the beneficiaries' acceptance and SODIS usage rate (Luzi et al., 2016).

3.1.3. SODIS outlook

SODIS is a niche solution designed for decentralized and equatorial low-income areas, which are currently not supplied reliably with safe drinking water and won´t be supplied in the short and mid-term either. Its independence of supply chains other than PET bottles makes it a universally applicable HWTS method. Its benefits and success vary significantly from one area to another. At its core acceptance of SODIS is a challenge of achieving a specific behavioral change within the supported communities. The long-term success of SODIS is assessed by the continuous usage rates. Studies by 'Eawag' show different long-term usage results (Luzi et al., 2016):

- In Indonesia about 21% of the people still practice SODIS 5 years after the first promotion.
- In Nepal usage rates have decreased about 60%, two to four years after the last promotion
- In Bolivia about 62% of the people still practiced SODIS many years after promotion
- In Peru this number was 32% (observed) – 42% (self-reported)

These numbers show how important continuous promotion is. Knowledge transfer and continuous ownership of the method is even better for a long-term change. Other HWTS methods face the same challenges, when something fundamental like a culturally learned and lifelong water consumption or disinfection pattern needs to be changed (Luzi et al., 2016).

With the WADI device, 'Helioz' wants to achieve a high long-term usage rate through ownership and women's empowerment. Many improvements on different SDGs other than 'Safe Water' will motivate families and communities to practice SODIS. Training of trainers in the project area, continuous HH visits by local partners and close collaboration with local and national political institutions will help to achieve this (Helioz & BOKU, 2018).

3.2. The SDGs and their implementation

3.2.1. History

The Sustainable Development Goals (SDGs) are the core framework of the 2030 Agenda for Sustainable Development. The 2030 Agenda was resolved by all member states of the United Nations in the General Assembly in September 2015. The official document starts with the sentence "*This Agenda is a plan of action for people, planet and prosperity*" (UN, 2015, p. 5). The 17 SDGs help to break down this holistic plan into interwoven categories. They aim for global partnerships of all countries to end poverty, increase health and wellbeing, protect and restore marine and land ecosystems, stabilize the global climate and reduce inequalities worldwide. In other words: aiming to solve global problems with global goals. These goals can only be reached when they are tackled together and simultaneously by all countries, adjusted to their development progress. Many milestones of UN work within the last decades, like the Agenda 21 in 1992, the Millennium Development Goals in 2000 and the Conference on Sustainable Development in 2012 have laid the ground for the SDGs (UN - Department of Economic and Social Affairs, n.d.).

The 17 SDGs (see Fig. 5) are divided into 169 specifying targets and 248 indicators, which will help to monitor their implementation progress. The countries have been asked to make their own pledges to reach the goals according to their possibilities (UN, 2015).

Fig. 5: The 17 SDGs (UN, 2019)

From their agreement onwards, the SDGs were celebrated by people and governments around the globe for setting the most ambitions and large-scale goals of global politics ever (Crossette, 2015). What is a big hope on one side is criticized for its vagueness on the other. Some scientists argue that the SDG follow a too linear approach. Different weighting of the goals is emphasized (see 6.1.3) like in the Wedding Cake Model (Stockholm Resilience Center, 2016). Through the interrelation of the goals also synergies and trade-offs are described. A former UN Special Rapporteur on extreme poverty points out that for example the SDG 8 (Economic Growth) has counter-productive effects on other SDGs like SDG 13 (Climate Action). His critique is that the SDGs still follow the same neo-liberal logic and growth glorification that caused many of the current global problems that the SDGs are actually aiming to solve (Alston, 2020).

3.2.2. Impact measurement of the SDGs

The countries are required to report their SDG progress through government authorities on a national level. The UN Statistical Division collects the data that relate to the official indicator framework. Annually a SDG impact report is presented by the UN. Already in 2020, the report showed that the world was not on track to reach the SDGs by 2030 (UN, 2020). The latest report is even more discouraging. The COVID-19 pandemic, climate change and wars have dangerous impacts on the goals. The number of violent conflicts is at a record high since the Second World War leaving 100 million people displaced from their home globally. From a climate perspective, emissions are still rising, up to 14% with the current national pledges, instead of drastically declining which actually would be needed till 2030. This threatens the survival of the human species (UN, 2022).

The UN reports a big gap in underlying data. For example, only 20% of the countries have reported data on SDG 13 Climate Action. Only for about half of the SDGs does comparable national data exist. Missing gender information and disability status compromise the degree of complete information even further (UN, 2022). Based on the information that is available, the following interpretations can be made:

- Four years of progress in ending poverty has vanished due to the pandemic
- Various health and education cuts happed due to the pandemic
- To reach the WASH (='Water, Sanitation and Hygiene') goals, progress would need to be four times faster

- The climate catastrophe is human's biggest warning with energy related emissions reaching highest levels ever in 2021
- Anxiety and depression is on the rise, especially among youth and women (UN, 2022)

The SDG success on a global level therefore seems to be heavily threatened.

Still the SDGs are a popular framework also inspiring project developers and organizations on more local levels. Due to their big scale and global nature, it is a challenge to apply the indicators to single projects on sub-national scale, even though important contributions to the SDGs are happening on a project level (Mansell et al., 2020). Moreover, project activities can play an essential role not only to reach the SDGs but also the Goals of the Paris Agreement (Gold Standard, 2022). The 'Gold Standard' (see 3.3.5) tries to close this gap by making its climate project impacts on the SDGs measurable, quantifiable and verifiable. Their SDG Impact Tool was developed for listed Gold Standard projects. It enables consistent and significant impact measurement across different types of activities and contexts (Gold Standard, 2022). Approaches like this are valuable in breaking down the global SDG indicators to local level. More information on the individual SDGs and the impacts on them of the case study project of this research can be found in chapter 6.1.3.

3.3. Carbon crediting – a controversial issue

> *"Carbon credits, or offsets, are a market-based method for reducing the amount of greenhouse gas (GHG) emissions into the atmosphere. A carbon credit represents the removal of one ton of carbon dioxide or its equivalent from the atmosphere"* (Summers et al., 2015, 2).

Carbon credits are based on the idea of compensating for the same amount of CO_2 that is produced somewhere else. Carbon offsets are only possible because climate change is an international problem and greenhouse gases are accumulating in the atmosphere regardless of national borders. Therefore, reducing them anywhere is helpful for the overall climate goals (Carbon Offset Guide, n.d.–g). Carbon offsetting has received a lot of criticism. It is often seen as greenwashing, because polluters are allowed to keep polluting, yet can still reach carbon reduction goals by cheap offsetting rather than investing in the reduction of their own carbon footprints (Broekhoff et al., 2019).

Carbon Credits can be generated by a variety of actions that either reduce GHG emissions or sequester carbon. Typical offsetting projects are mostly about:

- Displacing fossil fuels by encouraging renewable energy practices (e.g. efficient cook stoves)
- Afforestation, forest protection or avoided deforestation (e.g. planting trees)
- GHG capture and destruction (e.g. decentralized biogas power plants)

Thus projects can vary in size, meaning the amount of carbon credits produced can also vary. ‘Small scale projects’ reduce about a few hundred tons of CO_2 e per year while ‘large scale projects’ may reduce millions of tons per year (Broekhoff et al., 2019, p. 7).

3.3.1. History

Carbon Crediting became relevant when the Kyoto Protocol came into force in 2005. The Kyoto Protocol is an international treaty of the UN to fight climate change where binding emission reduction targets were resolved for the first time in history. It consists of three main flexibility mechanisms: the ‘International Emission Trading’ (IET), the ‘Clean Development Mechanism’ (CDM) and ‘Joint Implementation’ (JI). These aim for giving the ratifying industrialized countries (‘Annex 1 countries’), which had the highest emissions, some flexibility in how to reach their binding reduction targets. At the same time they aim for clean development possibilities for low- and middle-income countries (not Annex 1 countries), with a reduced need for fossil fuels (Umweltbundesamt, 2013).

Every Annex 1 country was given an emission target and the corresponding number of carbon emission allowances. The legally binding emission targets had to be reached in a certain period of time. The countries should reach their goals predominantly by reducing own emissions. If they couldn´t, they were allowed to trade emission allowances with other countries that had a surplus of allowances (IET) or to buy carbon credits. The CDM made it possible that industrialized countries could reach their emission reduction targets by implementing projects in developing countries (Carbon Offset Guide, n.d.–f). Out of Kyoto’s mechanisms the world’s first international carbon crediting scheme emerged. CDM’s goal was to enhance sustainable development and at the same time CO_2 reductions (UNFCCC, n.d.). Industrialized countries were allowed to invest their money in emission mitigation measures in other countries and account this to as their emission reduction (Carbon Offset Guide, n.d.–c). In the meantime the CDM marked faded out, due to a crash in prices (see 3.3.3).

Nevertheless, the signing of the Kyoto Protocol provided the impetus to establish internationally agreed standards for measuring carbon emissions and carbon offsets, and to establish regulated carbon markets. National governmental authorities regulate them and the carbon credits can be traded between countries. Emission trading schemes (ETS) are the market instrument to finance and trade carbon credits. By putting a price on CO_2, these become tradable among different participants in the scheme (Environmental Protection Authority, 2022). In most ETS the total amount of emissions is capped by a permitted authority and the participants are allowed to trade their proportioned emission allowances in order to meet their reduction targets (Cap and Trade System). Many different ETS on the compliance carbon market exist. The most important ones are discussed in Chapter 3.3.4. In 2012 the price for one credit crashed and fell below 0.5$ per t CO_2 e, which was the collapse of CDM and ended its era (Kazunari, 2022).

Next to the compliance markets also voluntary carbon offset markets have developed and are literally booming in the last years (Milne, 2020). From 2018 to 2019 the volume of carbon credits traded there doubled to 140 million t CO_2 e. Voluntary markets allow companies and individuals without binding emission reduction targets to also offset their CO_2 emissions by buying carbon credits. Offsetting personal flight emissions and producing 'climate neutral' products are well-known nowadays. These voluntary markets are more unregulated than the compliance markets. Therefore many organizations and standards, also called 'offsetting programs', who professionally validate and verify the voluntary credits emerged (Summers et al., 2015). One of these is the Gold Standard (GS), further described in chapter 3.3.5.

3.3.2. What makes a 'good' carbon credit

Carbon credits traded within this compliance and voluntary schemes differ in quality. In general it is much easier to measure real emissions than to measure emission reductions to predict the impact of offsetting projects. The quality therefore describes the precision of the emission reduction description. If some company buys a carbon credit, this always should be an equal supplement for the reduction of its own emissions by the same amount of CO_2. So the world should be as well off in both cases, regarding the emission reduction and also all other social and environmental consequences. The quality therefore describes the trust one can have, that this principle will be met by the credit (Broekhoff et al., 2019). In other words overall carbon credits and trading them on the market, shall preserve 'environmental integrity' defined by Schneider and La Hoz Theuer (2019).

According to Broekhoff et al. (2019, p. 18), the two main criteria for quality offset credits are:

> *"[First] a quality offset credit must represent at least one metric tonne of additional, permanent, and otherwise unclaimed CO_2 emission reductions or removals. Second, a quality offset credit should come from activities that do not significantly contribute to social or environmental harms."*
>
> Furthermore the GHG reductions or savings must be "*…additional, not overestimated, permanent, not claimed by another entity and not associated with significant social or environmental harms…*" to be high quality (Broekhoff et al., 2019, p. 18).

These 5 criteria (Broekhoff et al., 2019, pp. 19–30) are described in detail below.

Additionality:

Carbon offsets that ensure additionality mean that the GHG reductions /saving that they are claiming would not have occurred without the specified carbon offset project. So in the absence of these carbon credits, no emission savings would have happened. If the reductions would have happened anyway, additionality is not given. In other words: only because of the money paid for the carbon credits on the carbon market, the project activities and corresponding GHG reductions are enabled. Of course it is in the interest of project developers to argue and find ways to display that their projects are additional. The challenge with additionality however is that it is always subjective and therefore shall be critically questioned and investigated from one project to another (Broekhoff et al., 2019).

Avoiding overestimation:

There is the risk that project developers report higher emission reductions than actually will happen, because they have an incentive to do so. In the case that the offsetting program believes and validates these numbers, more credits than actually reduced can be sold. Overestimation can occur in different stages of the project. A subtle way to overestimate emission reduction is during the baseline estimation, which is the status quo reference situation in the project area against which the actual project emission are calculated in the long run. Some critical parameters within the baseline are based on assumptions and future predictions.

Another way is to underestimate project emissions. Most of the projects reduce but don´t completely remove GHG emissions in comparison to the baseline. Furthermore the indirect and unforeseen emissions caused by project interventions, also called 'Leakage Effect' are often not included. Verification by third parties to ensure scientific monitoring and robust fit to the methodologies requirements is essential to avoid overestimation (Broekhoff et al., 2019).

Permanence:

GHG reductions or removals need to be long-term. CO_2 emitted today, stays in the atmosphere for hundreds of years, so reductions/removals should work the same way. The classic example of the limitation of permanence are tree plantings in afforestation projects. What if the trees that have been planted burn down in a wildfire or get harvested illegally some years after project implementation? Then they can´t sequester CO_2 any longer and even worse, the stored carbon gets reemitted or reversed into the atmosphere. In these projects the risk for reversal in the long run is nearly 100%. "*[…] Scientifically, anything less than a full guarantee against reversals into the indefinite future is not 'permanent'*.", due to Broekhoff et al. (2019, p. 26). Project developers therefore often build buffer reserves as an insurance mechanism. The duration of permanence varies significantly from the end of the projects lifetime, which mostly is below 10 years, up to 100 years and longer (Broekhoff et al., 2019).

Exclusive claim to GHG reductions:

It is very important that emission reductions/savings are just claimed once by one entity. Otherwise 'double counting' could occur, leading to falsified overall emission reductions and worsening climate change. Double counting can happen, if more than one credit is assigned for the same emission reduction (= double issuance), if two different entities count the same credits as theirs (=double use), or if a project developer as well as a nation call for the same credits for their reduction goals (=double claiming). Most programs have control measures and precise carbon credit registries in place to avoid these typical mistakes of double counting. Nevertheless even the Paris Agreement is unprecise about this issue (Broekhoff et al., 2019).

Avoid significant social and environmental harms:

What is good for the climate, doesn't have to be good for the local population or ecosystem at the same time. High quality projects should consciously deal with local circumstances and treat them with care within the legal frameworks of the region. Most programs therefore require honest stakeholder participation and verify the compliance with legal requirements. In many cases not just harms can be avoided but also social and environmental co-benefits can be created (Broekhoff et al., 2019).

If high quality is ensured, carbon credits can play an essential role in climate change mitigation as they may channel huge amounts of money for climate projects. These projects have the potential to support local communities in the global south in their climate mitigation or climate action, which they wouldn´t be able to do otherwise (Streck, 2021). Furthermore carbon projects can even increase health in low-income countries through financing HHWT systems (Pickering et al., 2017). This and other co-benefits are a great chance of carbon credits.

3.3.3. Common criticism

Even if the highest quality is ensured by a program, healthy scepticism about its pledges and its effectiveness in reducing the global emissions is absolutely valid. Also the carbon crediting and carbon trading per se have been seen as very controversial from the beginning.

To start with the criticism about how carbon credits are set up, the "*perverse incentives*" (Broekhoff et al., 2019, p. 16) need to be mentioned. The carbon market allows organisations to keep polluting while outsourcing emission reductions by purchasing credits from carbon projects. This distracts them from actually starting by themselves to reduce and avoid CO_2 emission in their companies. Buying credits is often the easier way. Even more it enables them to greenwash their image, claiming to be climate friendly or carbon neutral by doing so. The counterproductive effect can happen, that they keep investing in fossil fuel technologies and cheap high-carbon infrastructure and therefore actually locking in high GHG production in the long-term. This is seen as the opposite of ambitious climate action. Another perverse incentive given by carbon markets is to avoid needed legislative regulations on certain industries or production patterns. If for example a certain forest becomes protected by law, a project developer couldn't use the forest for his forest protection carbon project anymore, because it would not serve the additionality criterion. This is bad for the country's economy in the short run as no financial flow is created (Broekhoff et al., 2019).

Also the reported quality of credits and the underlying projects can always be doubted. Currently project developers may be allowed to monitor their own project data. This data is later on reported to the programs and acts as the base for the amount of credits to be issued (Pickering et al., 2017). This is a weakness, where buyers would be naive to think that every project does honest and accurate monitoring. Broekhoff et al. (2019, p. 17) named several studies which have found that there are serious distortions in some carbon programs. For example, up to 60-70% of all CDM credits may not represent validated emission reductions. The reason is that the most of CDM´s projects were found to be not additional. Because of such misinformation large scale offsetting schemes like CDM are a threat to real climate change action in the upcoming years (Haya, 2009). Due to this critique, an UN report admitted CDM´s weaknesses and its potential for improvement. In 2012 the price for one credit crashed and fell below 0.5$ per t CO_2 e, which was the collapse of CDM and ended its era (Kazunari, 2022). National ETS and voluntary markets took over.

Other studies showed that specific projects harmed local communities and caused additional environmental destruction. In the study of Pickering et al. (2017) where HHWT was practiced in Kenya, unprecise usage rate and supressed demand reporting led to questionable emission reductions. Over 60% of claimed reductions were found to no be invalid. In a clean energy project in Cambodia, where a hydro power plant earned carbon credits, illegal logging started to occur on the project area. Furthermore, environmentalists were killed, who wanted to reveal that the government was involved in this illegality (Milne, 2020). These examples are just a small selection of many dubious carbon credit projects out there.

Observers of the carbon market also criticise the whole logic of the offsetting system per se. McAfee (2016) argues, that carbon credits are misusing the economic powers and the rules of the market to hide the biggest damages to the environment and the climate of globalized capitalism. At the same time, they are causing a revival of economic growth in the global north, promoting development in the global south and try to decouple growth from ecosystem destruction. Two decades of climate negotiations, which haven´t resulted in declining emissions yet, have made clear that climate change cannot be separated from the issue of inequality and the paradox of economic growth. Degrowth movements should get more attention in the whole discussion (McAfee, 2016).

A completely different approach to carbon projects, away from natural solutions to people-centred solutions, is suggested by Fleischman et al. (2020):

> "*Such a shift in focus, away from tree planting and toward people and ecosystems, must be rooted in the understanding that natural climate solutions can only be effective if they respond to the needs of the rural and indigenous people who manage ecosystems for their livelihoods.*" (Fleischman et al., 2020, p. 947).

All of these examples legitimize the scepticism about the current carbon credit boom.

3.3.4. Different accounting and monitoring methods

Basically carbon credits are about some kind of measured and quantified behavioral change (Milne, 2020). The organizations verifying the carbon credits have to prove, that the change and the resulting emission reductions claimed by project developers actually have been accomplished. An overview of the major compliance and voluntary offset programs is given in Table 1.

Table 1: Overview of the major carbon offsetting programs (Broekhoff et al., 2019, p. 9 see Table 1)

"Compliance" carbon offset programs (run by governmental bodies)	Geographic Coverage	Label used for offset credits
Clean Development Mechanism (CDM)[6]	Low & middle income countries	Certified Emission Reduction (CER)
California Compliance Offset Program	United States	Air Resources Board Offset Credit (ARBOC)
Joint Implementation (JI)[7]	High income countries	Emission Reduction Unit (ERU)
Regional Greenhouse Gas Initiative (RGGI)	Northeast United States	RGGI CO_2 Offset Allowance (ROA)
Alberta Emission Offset Program (AEOP)	Alberta, Canada	Alberta Emissions Offset Credit (AEOC)
"Voluntary" carbon offset programs (run by NGOs)	**Geographic Coverage**	**Label used for offset credits**
American Carbon Registry	United States, some international	Emission Reduction Tonne (ERT)
Climate Action Reserve (CAR)	United States, Mexico	Climate Reserve Tonne (CRT)
The Gold Standard	International	Verified Emission Reduction (VER)
Plan Vivo	International	Plan Vivo Certificate (PVC)
The Verified Carbon Standard	International	Verified Carbon Unit (VCU)

All of these programs are using specialized monitoring methods and CO_2 accounting standards according due the type of carbon project, the main focus of the program and national circumstances. Some operate internationally, some only in specific continents or countries. Every program has its own label/name for the generated offset credits, like currencies have.

Moreover all programs have their own eligibility requirements for projects offered. Table 2 shows the differences.

Table 2: Offset project eligibility (Carbon Offset Guide, n.d.–d)

Name of Program	Eligible Project Locations	Eligible Project Types
Kyoto offset mechanisms		
Clean Development Mechanism	Low and middle income (non-Annex 1) countries where Designated National Authorities (DNAs) are established	All eligible except nuclear energy, new HCFC-22 facilities or avoided deforestation (REDD)
Voluntary programs		
American Carbon Registry	No restrictions on project location.	No restrictions. All projects that meet the ACR Technical Standard are eligible for registration.
Climate Action Reserve	United States	Current eligible projects: conservation-based forest management; reforestation; avoided conversion; tree planting projects by municipalities, utilities, and universities; livestock and landfill methane capture.
Gold Standard	All locations, except in countries with emission caps unless Gold Standard (GS) Verified Emission Reductions (VERs) are backed by permanently retiring assigned amount units (AAUs)	Renewable energy and energy efficiency projects. Additional rules and requirements for hydropower larger than 20 MW
Verified Carbon Standard	All locations, except in countries with emission caps unless voluntary carbon units (VCUs) are backed by permanently retiring AAUs.	All project types eligible with VCS approved methodology, except projects from new industrial gas facilities
Plan Vivo	Low and middle income countries	Bio-sequestration projects: • forest restoration; • agroforestry/small plantations; • forest protection and management; • soil conservation and agricultural improvement.
Social Carbon Methodology	Low and middle income countries	Eligible project types not defined.

Table 2 above shows how programs differ in their project locations and types. For example, Climate Action Reserve and Plan Vivo are including forest and agricultural projects, while Gold Standard focuses on energy efficiency projects. Some programs are allowing all kind of projects, accepting also new project methodologies by project developers (=bottom-up) as long as they meet the program's standards. Others however just provide their own methodologies for specific project types, without opening up for new project types (=top-down) (Carbon Offset Guide, n.d.–d).

Every offset project methodology defines GHG accounting rules and how to monitor, report verify and certify the project. Basically, they include the rules and procedures to assess eligibility, additionality, and baseline as well as project studies for different project types (Carbon Offset Guide, n.d.–e). For example, the carbon credits of a forest protection project follow a completely different methodology and CO_2 savings calculation logic than a drinking water project with SODIS. A direct comparison between different methodologies would go far beyond the extent of this thesis. Nevertheless, a comparison of different programs by category was made by Schmidt and Gerber (2016). The main programs, including the Verified Carbon Standard (VCS), American Carbon Registry (ACR), the Natural Forest Standard, the Rainforest Standard, the Gold Standard Foundation (GSF), Plan Vivo, the Climate, Community & Biodiversity Standard (CCBS) and Social Carbon, were rated, ranked and compared with respect to 'climate integrity', 'biodiversity conservation' and 'human and community rights, stakeholder participation & sustainable community development'. The results are shown in the Fig. 6, Fig. 7, and Fig. 8 below.

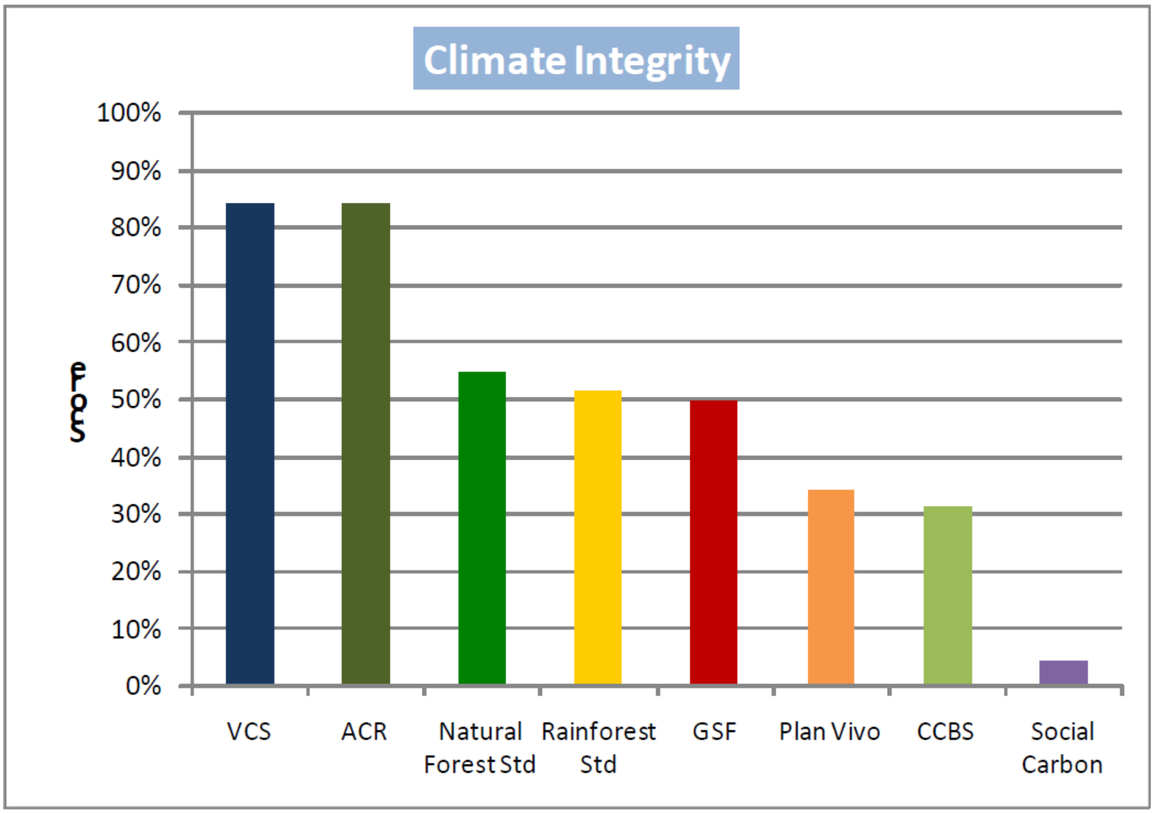

Fig. 6: Score for the criterion 'climate integrity' of selected carbon offset programs (Schmidt & Gerber, 2016, p. 22, see Fig.4)

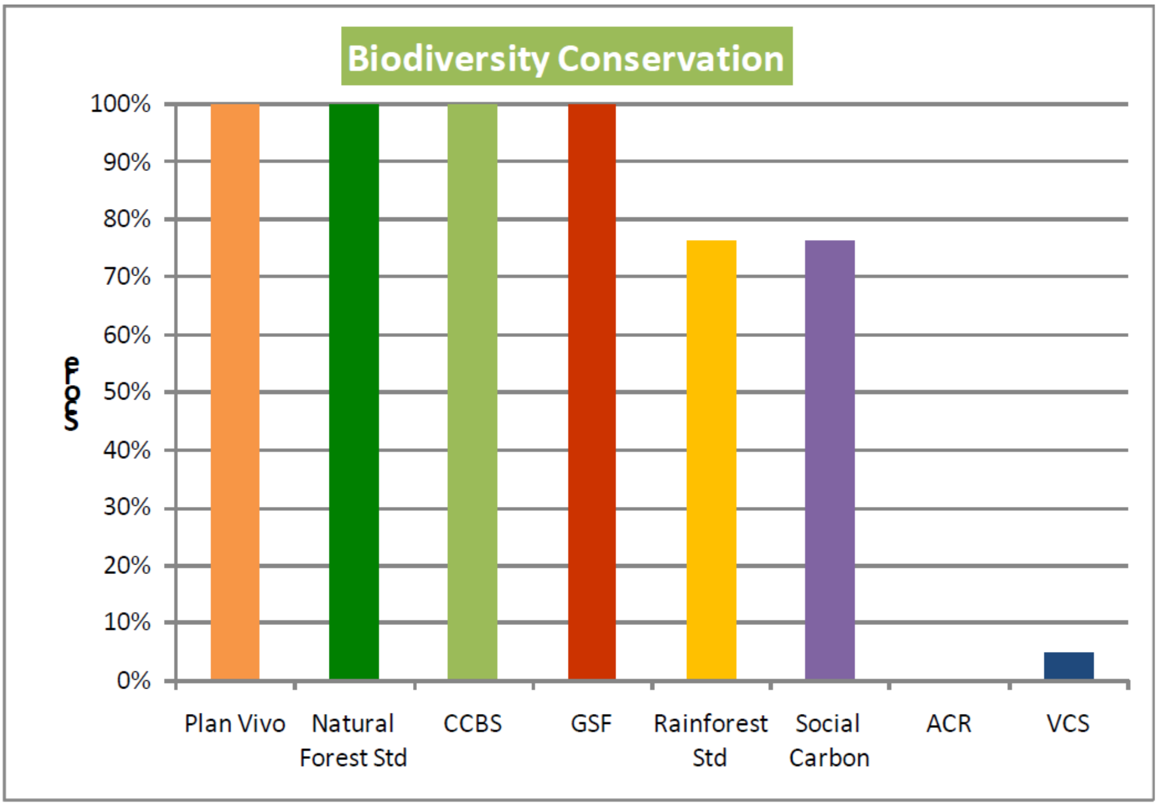

Fig. 7: Score for the criterion 'biodiversity conservation' of selected carbon offset programs (Schmidt & Gerber, 2016, p. 22, see Fig.5)

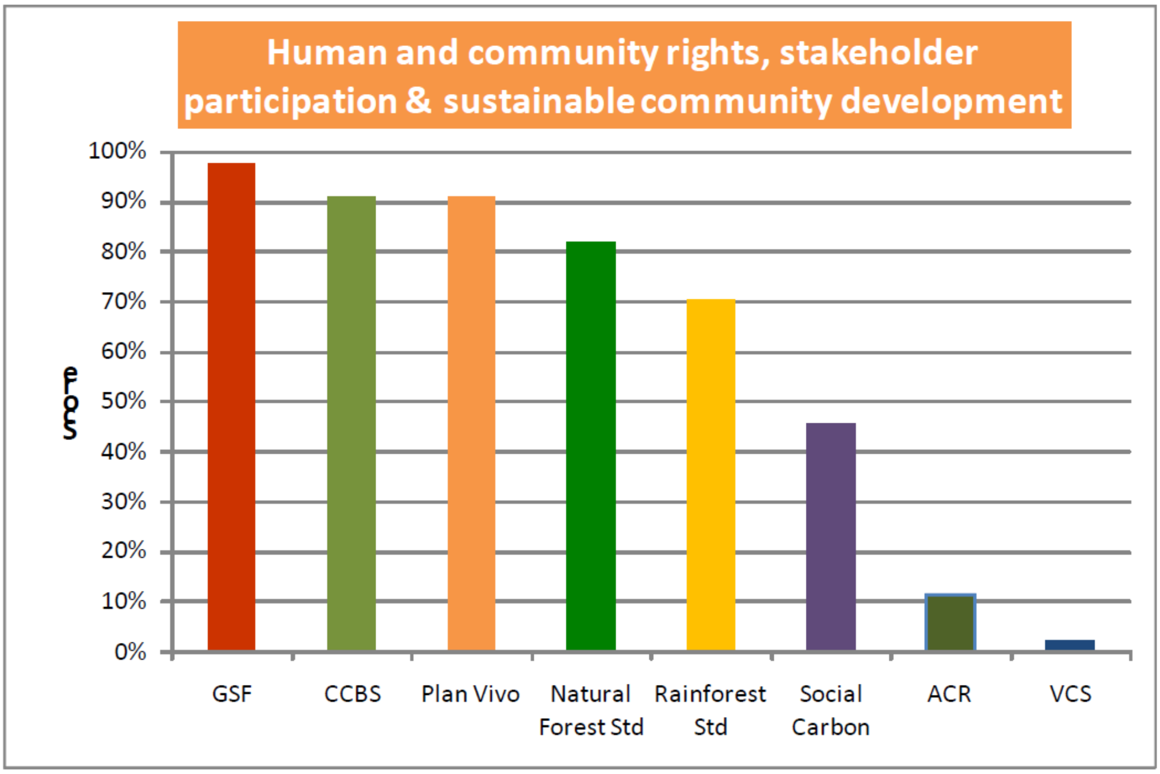

Fig. 8: Score for the criterion 'human and community rights, stakeholder participation & sustainable community development of selected carbon offset programs (Schmidt & Gerber, 2016, p. 23, see Fig.6)

The authors aim was to assess different standards for the carbon portfolio decisions of the German government. In 'climate integrity', the VCS and the ACR both reach the highest score with 85% while the Gold Standard just reaches 50%. In the human and sustainable development criterion the GS scores top with almost 100% and VCS and ACR are comparatively very weak with just about 3% and 12%. GS again scores 100% in 'biodiversity conservation' while VCS and ACR don´t include this criterion in their projects at all (Schmidt & Gerber, 2016). This can be explained as projects which are aiming for highest carbon credits typically score lowest in integrating the so called 'co-benefits' (= sustainable development benefits additional to only CO_2 reduction) and vice versa (Broekhoff et al., 2019). The following chapter is going to examine the Gold Standard in more detail, as this was chosen as a foundation for the emission reduction calculation in the case study in Soroti (see 5.3.1).

3.3.5. The Gold Standard & the concept of 'Suppressed Demand'

The GS was developed by the WWF, SouthSouthNorth and other environmental and climate NGOs in 2003, with a focus on carbon offsetting projects that ensure long-lasting environmental, social and economic benefits. Its projects contribute to the SDGs and benefit the local communities in the project region (Carbon Offset Guide, n.d.–b). The SDGs are so central to GS´s approach that since March 2022, the use of a SDG impact tool enabling to monitor, quantify and verify a project's contributions to the SDGs has become a mandatory part of the project development cycle (Gold Standard, n.d.–c). The Gold Standard´s official vision is "*Climate security and sustainable development for all*" (Gold Standard, n.d.–d). Its mission is "*to catalyse more ambitious climate action to achieve the Global Goals through robust standards and verified impacts*" (Gold Standard, n.d.–d). Different project types, like community biogas plants, clean cooking, safe water access etc. can be assessed and verified with specialized methodologies. As a result, credible claims for the projects impact are issued by the GS. The carbon credits produced contribute towards SDG 13 Climate Action (Gold Standard, n.d.–a). In 2020, GS issued 34 million carbon credits. This number increased by 28% over the year before. In total, already 151 million carbon credits have been generated to date (Gold Standard, n.d.–b). To put this numbers into perspective, the total annual CO_2 emissions of Austria are about 100 million tons (Ritchie et al., 2020).

The validation process of every GS project involves a number of steps. Fig. 9 below shows these steps for a safe drinking water project, where emission reductions are reached by energy efficient cooking stoves. The project activities shown are similar to the case study project in Soroti assessed within this thesis and therefore the corresponding methodology (see 5.3.1) was used. The only difference between the schematic description in the figure and the real activities in Soroti is that the main firewood saving is achieved by SODIS and not by efficient stoves.

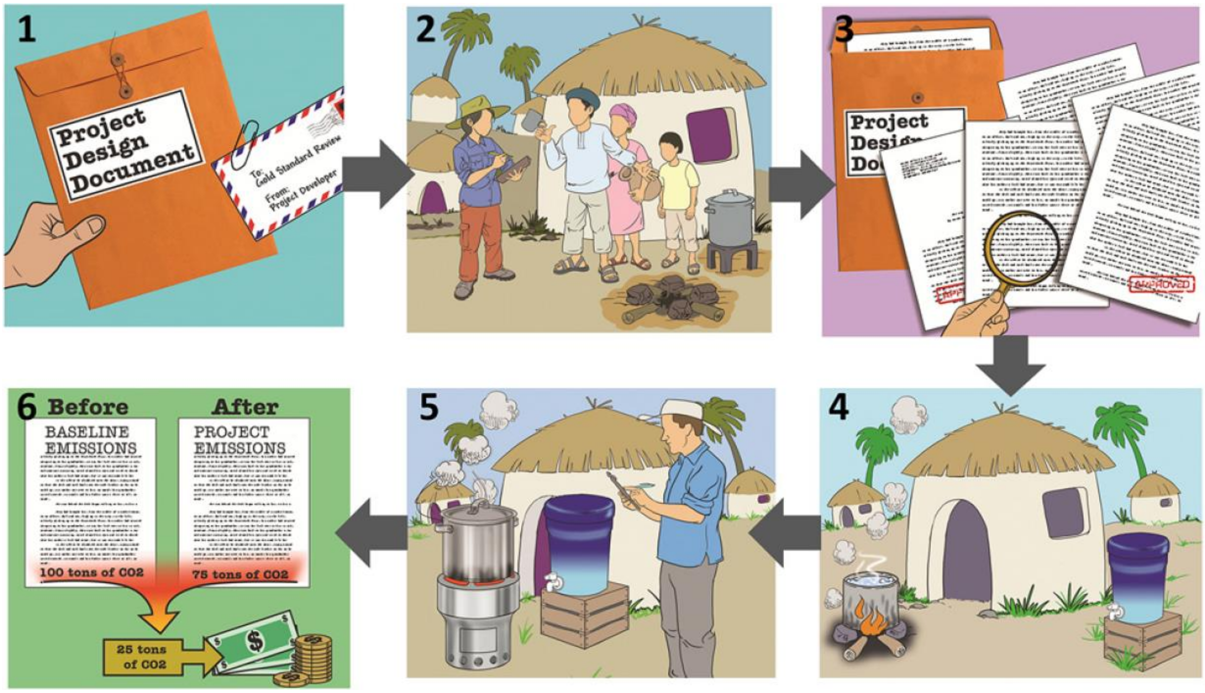

Fig. 9: Steps of a project in Gold Standard (Summers et al., 2015, p. 5 see Fig.1)

The GS validation process involves the following steps:

1) The project developer completes the project design document template and sends it to GS for reviewing. This document includes all relevant characteristics of the baseline HWT techniques in the project area and the planned activities.

2) If the project meets all formal GS requirements, a third party checks the project proposal by interviewing relevant stakeholders and confirms the reported possible emission reductions which were calculated in the baseline.

3) After positive confirmation, the project developer can start the planned activities for CO_2 reduction in the project area and is able to install the project technology.

4) Continuous project surveys by a third party on site deliver data regarding the behavioral change caused by the activities and the usage rate of the project technology throughout the project duration.

5) With this data project emissions are calculated.

6) The remaining project emissions are subtracted from the baseline emissions. The difference is the base for the carbon credits issued by GS. Before this step, no carbon credits are sold and the project developer as to pay all costs incurred. The verified credits representing the monetized climate impacts can later be purchased in the carbon markets (Summers et al., 2015).

The GS ensures the necessary ecologic and social safeguards and community engagement processes for the local people´s needs. It claims that its impact goes beyond just the climate outcome by also enabling transformational benefits for people and nature by supporting sustainable development globally (Gold Standard, 2019b). The different GS methodologies are updated on a regular basis. They give instructions on how to calculate baseline and project emissions, which parameters to use, which default values to apply, survey requirements and much more.

One critical aspect of the GS methodology for calculating the baseline emissions is the concept of 'suppressed demand'. One can think of it as a rule to include theoretical emissions in the baseline scenario, which in practice have never been or will never be emitted. For a drinking water project, Summers et al. (2015, 12) describe it like this:

> *"The idea is that current boiling practice is limited by availability and/or affordability of fuel, and if fuel were available, people would boil their water. So providing an alternative to boiling can be counted as carbon credits even when people are not currently boiling. In other words the credits are issued for emissions avoided rather than emissions reduced."*

Suppressed demand is used as a policy tool. It gives underprivileged HHs that maybe even can´t afford any firewood and therefore actually don´t cause emission the chance to also be benefited by project activities financed by the carbon market. Otherwise such HHs would just not be interesting for project developers, because they are not emitting enough CO_2 in the baseline to be reduced throughout the project (Summers et al., 2015). This perverse exclusion effect would be counterproductive for sustainable development.

Nevertheless the shortcomings of the theoretical 'suppressed demand' option leading to overestimated hypothetical emission reductions has been criticized by observers and scientists. Hodge and Clasen (2014) state that the carbon credit financing of safe drinking water projects shouldn´t be justified by its CO_2 reductions. However, from a human health and sustainable development perspective 'suppressed demand' is very valuable. If it did not exist, project developers would exclusively target HHs were water is already made safe by boiling, leaving out HHs who suffer water-borne diseases as they can´t boil their water properly (Hodge & Clasen, 2014). In personal interviews WASH experts and carbon credit experts were confronted with the ambivalence of 'suppressed demand'. They shared the opinion that from a moral and ethical point of view its positive impacts on health and sustainable development outweigh its shortcomings in CO_2 accuracy. One WASH expert describes the issue like this:

> "*There's … skepticism and frustration that we need to employ this fiction of suppressed demand in order to make carbon credits work for water [projects]. I think people resent that because it is based on … this fiction essentially that people are boiling a whole lot of water using non-renewable wood resources which we know they're not doing so. … I see all of this as a vehicle for doing the right thing that is based on assumptions that are not realistic*" (Summers et al., 2015, 13).

Another carbon crediting expert mentioned the risk of dirty development in the absence of the concept (Summers et al., 2015, 13):

> "*If you think about it in a more simple context outside of water … you don't want to encourage the behavior of countries that are on a development pathway where it's cheaper to go dirty first and then they see even more incentive because they can go from a high baseline of pollution and claim carbon credits.*"

Despite all arguments, in the end the duty of safe water carbon projects is to provide safe drinking water for underprivileged people (Summers et al., 2015). The interest of the emission causing western countries for financing such projects at the moment seems to be higher when carbon credits can be claimed in return than just simply supporting the poor with developmental aid.

3.3.6. The BOKU CO_2 offsetting program

The BOKU CO_2 offsetting program is active in the Austrian voluntary carbon market. It has been hosted by the BOKU since 2011 and offers carbon credits generated by climate mitigation projects that were developed together with scientists from BOKU University and external partners. It includes biogas, afforestation, forest protection, composting and drinking water projects in Uganda, Ethiopia, Nepal, Costa Rica and Colombia, with CO_2 reductions on microscale level. With a total volume of 150,000 carbon credits aimed to be reached within the next years, it is more than a thousand times smaller in volume in comparison to the GS. Nevertheless it aims for ensuring highest possible quality, based on the GS methodologies which are adapted for every of its projects. The uniqueness is that BOKU claims to be the first and only university developing their own climate mitigation projects and generating carbon credits. These are bought by companies, BOKU faculties and private people to offset their CO_2 emissions. The scientifically monitored projects also have a strong focus on the SDGs and on social benefits on local communities. An external scientific advisory board consisting of important stakeholders of the Austrian CO_2 scene assures the program's quality (BOKU, n.d.). One of their projects called 'Clean Air and Safe

Drinking Water for Soroti' is in the center of this thesis. In the next chapter this project is described in more detail.

4. “Clean Air and Safe Drinking Water for Soroti”: Project background & previous findings

The project ‘Clean Air and Safe Drinking Water for Soroti’ is one of the projects integrated in the BOKU CO_2 offsetting program. Its aim is to provide safe drinking water for 2000 Ugandan HHs and at the same time reduce GHG emissions. Many different project activities around WASH improvements are bringing additional benefits to the people. The project is situated in rural Uganda. The following subchapters give details to the project area, the project history and previous findings from a baseline study.

4.1. Project Area

Uganda is a very fertile country due to its extensive water bodies and nutrient-rich soils. The climate is tropical. Two main dry seasons between from Dec-Feb and June-Aug and two rainy seasons from Mar-May and Sept-Nov determine the water and agriculture cycles. Detailed geographical information can be found in the study by Wornig (2021).

The project area lies in the sub county of Gweri in the district Soroti. The area has been chosen for the project, because of its potential to improve the living conditions of many underprivileged families. About 265,000 people in Soroti live in rural areas. According to the Uganda Water Supply Atlas, 85% of the people the rural areas have access to safe drinking water. In Gweri this number is even lower at only 78% (Uganda Ministry of Water and Environment, 2022). Both the national and the district values are higher than the Sub-Saharan average of 68% (United Nations, 2015, p. 58). The main water sources in Gweri are deep boreholes. As they deliver groundwater, pre-treatment is not as neccesary as if surface water would be used for SODIS. However, people pre-treat the water trough cloth filters, if it is turbid. In total 123 deep boreholes are spread among the sub-county. Furthermore shallow wells (n=31), rainwater harvesting tanks (n=14), protected springs (n=9) and one tap stand act as additional water supply. There is no piped water supply system in Gweri (Uganda Ministry of Water and Environment, 2022).

4.2. Project History

The project kick-off for ‘Clean Air and Safe Drinking Water for Soroti’ happened in February 2019. Since then, the project has been implemented by three main partners: The social enterprise

‘Helioz’, who found the WADI device and provides safe drinking water for people in many countries of the global south, the local partner ‘Water School Uganda’ (WSU), who are experts in WASH interventions in Uganda, and the University of Life Sciences Vienna (BOKU) – Institute of Sanitary Engineering and Water Pollution Control, which ensures the scientific backing. Helioz consciously decided on the monitoring by BOKU and not by any expensive official carbon credit standard like GS because the cost for certification would have been too high, less money could go directly to activities in the local communities and they had previously collaborated with BOKU on a project in Bangladesh. The whole project is financed by carbon credits via the BOKU CO_2 offsetting program. The project aims for providing safe drinking to at least 12,000 people daily by practicing SODIS with WADI. At the same time, emission reductions of 20,000 t CO_2 e will be achieved by burning less firewood for water disinfection of at least 40,000 liters of water/day. Therefore the main aim is to shift water disinfection practices from boiling water with firewood to practicing SODIS with WADI (Helioz & BOKU, 2018).

Today, four years after the start of the project, many milestones have been achieved:

- Selection of the participating HHs
- Free of cost distribution of 2000 WADI devices for 2000 selected HHs in Gweri
- Training of the SODIS method with WADI by WSU
- Regular field visits
- Baseline study (conducted 2019) within the master thesis of Wornig (2021)
- Annual reports by Helioz
- Behavioral change in the disinfection process
- Impacts on various SDGs through different additional project activities
- Actual CO_2 emission reductions

Fig. 10 shows a WADI in use during the project survey in 2021. The device is placed in the sun alongside the bottles. A family presents their daily WADI routine in Fig. 11.

To assess the achievement of the main project objectives and the projects impacts of various SDGs, the recent project survey delivers the underlying data. The calculated results are compared to the previous baseline findings described in the next chapter 4.3.

Fig. 10: WADI device in use at the field visit in 2021 (Source: WSU, 2021)

Fig. 11: Family practicing SODIS with the WADI method (Source: WSU, 2021)

Next to the activities around water disinfection, a variety of other project activities is constantly carried out. The local partners of WSU are experts in bringing holistic health and life improvements to the poorest people of Uganda. So in addition to the WADIs and the bottles, also hand washing facilities ('tipi taps') including soap, improved latrines, drying racks, waste management facilities and reusable pads for menstrual hygiene were given to the people according to their individual needs. In the third year of the project over 4700 WASH facilities, including latrines, tipi taps, bathing shelters and drying racks have been constructed together with the beneficiaries in their HHs (Helioz, 2021, p. 37; Helioz & BOKU, 2021, p. 3). The HHs received proper training in how to use and maintain them. Boreholes have been repaired, efficient cook stoves ('Lorena stoves') have been constructed, separate housing for the HHs animals have been built and health groups among the communities have been educated. Wornig (2021) describes these interventions in more detail. In 2022 two ferrocement tanks with a volume of 10,000 liters have been built for Telamot and Omugenya primary school for water storage. Also constant measures for COVID-19 preventions are carried out in the project villages (Helioz & BOKU, 2022). These interventions result in mannigfold positive impacts to the wellbeing of the project beneficiaries. Further details and their contribution to the SDGs are discussed in Chapter 6.1.3.

4.3. Baseline Study Findings

A 'baseline study' quantitatively describes the current status of a particular situation within a specific population (Anyaegbunam et al., 2004). Different variables of interest are examining the what?, who?, where?, why? and how? of the drinking water situations in Soroti. The baseline study was conducted in 2019 and embedded into a master's thesis by the Medical University Vienna and its Center of Public Health. The author is Anabell Wornig, and she was responsible for the baseline results which are summarized in this sub chapter. Her thesis acts as the main reference on which this thesis is built up upon.

Wornig (2021) found that the main method of water disinfection in the project area was boiling the water with firewood. This is in line with the precondition for the choice of the project area to reach potential CO_2 reductions. The WHO observations of global disinfection preferences for sub-Saharan Africa also confirm boiling as the common method (WHO, 2016b). Only 51% of the HHs really treated their water before drinking, the rest consumed the unsafe water without treatment. The main wood collectors were adult females with 87%. They walk an average distance of 1.5km to nearby woods for collecting their firewood and they need about 2.5 hours for this chore.

The following Table 3 gives an overview of the most important variables for the potential CO_2 reduction and the results of the baseline calculation (details on the calculation in chapter 5.3).

Table 3: CO_2 total emission reduction due to baseline study (Wornig, 2021, p. 82 Table 12)

Fraction of households using firewood (for water treatment)	**51%**
CO_2-reduction per WADI/per year	**1.49 t CO_2 e**
Emissions from firewood burning for baseline scenario / year	3.60 t CO_2 e
Emissions from firewood burning for project scenario / year	0.50 t CO_2 e
Number of WADIs distributed in the area	**2000**
Assumed usage rate for technologies in project scenario	95%
total emission reduction potential	1.49 * 2000 = **2978 t CO_2 e**

The value for the assumed usage rate with 95% was taken from earlier WADI usage experiences from Bangladesh (Schmitz & Reisinger, 2018). A CO_2 reduction of 1.49t CO_2 e/WADI/year was found leading to a total emission reduction potential of 2978 t CO_2 e. Throughout the project duration of five years, it was calculated that the project could contribute to at least 14,890 t of CO_2 reduction. These are the essential numbers to which the project survey results are going to be compared to through the pre- and post-analysis.

5. Material and Methods – empirical Case Study

This chapter explains the different methods and materials used and how they are interwoven into each other. To answer the research questions and reach the objectives of the thesis, a mixed method approach of empirical data collection and analysis was chosen.

The research approach is an empirical case study investigating the ongoing project: 'Clean Air and Safe Drinking Water for Soroti'. The data have been mainly collected through a survey, covering different households of project beneficiaries in the project area. The derived quantitative data from this 'project survey' was complemented by in-depth interviews adding qualitative data to the research. The findings were used for further calculations.

The results of the 'project study' have been compared to the results of the 'baseline study' of Wornig (2021) (see chapter 4.3), which she conducted within the same project, but before the project activities started in 2019. Through this pre and post evaluation of local data the project impacts can be measured and described.

In detail explanations of the different methods of the case study are following in the upcoming sub-chapters. Firstly, the quantitative data part and the qualitative data part are explained separately, subsequently the carbon emission reduction calculation tool and the SDG impacts assessment table is shown. The chapter concludes with a consideration of the validity and limitations of the study.

5.1. Quantitative Data: Project Study

The following paragraphs are describing how the quantitative data have been collected and evaluated.

5.1.1. Data collection

5.1.1.1. Aim of the 'project study'

As part of this thesis, new data have been collected directly from the project area in Uganda. The aim was to get comparable recent data through the so called 'project study' which acts as a follow-up study in the project. In a second step the analyzed data should be compared to the results of the 'baseline study' and changes should be described.

Both the, baseline and project studies use HH surveys as main way to collect local data. A 'baseline study' describes the status quo in a target population before applying a project technology or start any project activities. A 'project study' however describes the situation where the project participants have already adopted the project technologies which lead to emission reductions in the project area (Gold Standard, 2017). As the GS methodology is applied, in person interviews with a robust sample of >100 HH are required. Face-to-face interviews are the most suitable choice due to the remoteness, extreme poverty levels and missing infrastructure of the project region.

5.1.1.2. Selection of the participating HHs

The project study builds upon the structure and scope of the baseline study, the key difference being that the project study explores developments since the baseline, especially the behavioral change in disinfecting water. A mixture of cluster sampling and random sampling was used to select the HHs to be interviewed. In a first step the total sample of 2000 project HHs was clustered by two main criteria:

1. Location: HHs which are spread across many different villages within the parish of Gweri (=project area) are chosen to avoid selective local biases and get a broad geographical variation. This is to avoid a similarity of answers, which are only given in a specific part of the parish, due to very local reasons (e.g. the water source used).
2. Participation in baseline study: 245 HHs have already taken part in the baseline survey. It was preferred to interview a crucial number of those again in the project study to ensure a high comparability. These HHs are already familiar with the survey structure and the interview process. This criterion will make the results more reliable.

This kind of geographical or attributional frames is typical for cluster sampling (see Anyaegbunam et al., 2004). In a second step, within these clusters the HH have been selected by simple random sampling, meaning that each HH has an equal chance to be chosen and selection is independent of any further attributes. This helps to avoid conscious or unconscious biases of the researcher or field team (Anyaegbunam et al., 2004). The field team split up to visit the different villages simultaneously. The final selection for interviewing the HHs was made directly on site with the help of beneficiaries lists, depending on if people where home and available. They have not been contacted in beforehand. Because of the COVID-19 related travel restrictions, the researcher couldn´t choose and visit the HHs himself so all the HHs have been chosen by the field team of the local partner WSU.

About 230 HH were interviewed. In the end a sample of 223 complete and valid project survey questionnaires (>11% of total 2000 HHs taking part in the project) could be returned to the researcher. With this sample size of the collected data, the study even goes beyond the minimal requirements of 100HH (Gold Standard, 2017) and exceeds also the FAO´s minimal recommendations of 50 (Anyaegbunam et al., 2004). Therefore enough validity is ensured to describe the important values researched through this study.

5.1.1.3. Privacy and ethical considerations

In-person interviews in private HHs of mostly underprivileged people are an intimate matter requiring tact. More so, if participants shall share information and private data regarding their life situation, income, health issues and fulfillment of basic needs. Therefore, a sensitive approach is needed and ethical standards have to be ensured, particularly if the research team is not familiar with the local practices or cultural background. For all contemporary research, the protection of the human subject is an ethical mandate (Tsan & Nguyen, 2019). Therefore, also this study aims for a good protection of all participants. To ensure anonymity, no original names and other personal data are going to be published.

All of the project partners (WSU, Helioz and BOKU) have discussed the ethical considerations of the survey and agreed on the chosen content. Furthermore, all HHs which have been interviewed were given information about the research purpose and the data handling. They have only been interviewed if they voluntarily agreed. In section one (1. Beneficiary identification) of the questionnaire every participant of the study has given her/his informed consent (Question 1.3. "HH has freely given information and wants to take part in this survey?"). It was agreed that before, during and after the interview participant's needs, time resources and personal property would be respected. If the participant wanted to quit the interview or refuse answering single questions, this was respected. All participants were treated in a respectful way and they were thanked for engaging in the survey by offering their time voluntarily.

5.1.1.4. Survey design

The survey was prepared by the researcher through adopting and refining the baseline survey of Wornig (2021). The survey questionnaire mainly consists of structured interview questions with pre-coded answers. Simple Yes/No-Questions, as well as numeric questions and questions with multiple pre-defined answer categories are used. It was prepared in English language.

The interview should feel like an open dialogue as the interviewer read out one question after the other, without mentioning the possible answers. A translator translated it into the local language, listened to the answer of the interviewee and reported it back to the interviewer. As Uganda is a multilingual country with more than 41 native languages (Ssentanda & Nakayiza, 2017), the translation was crucial, even for the Ugandan field team, as they originate from a different region. The interviewer further ticked the pre-formulated answer which was closest to what the respondent said or wrote down the given answer (eg. if numeric variables like liters, kilogram or age) himself.

The main content of the questionnaire is about the WASH-situation. A special focus is the change in the drinking water disinfection method and the application of the project technology WADI to practice SODIS. The goal was to collect data to get a broad overview of the current situation and the developments that have been taken place since the start of the project. Visiting the participating HHs was essential to make on-site observations regarding the progress of project activities. Furthermore, trust gets build up on both sides, when the project beneficiaries meet the project team.

The questionnaire (see Appendix A) consists of 8 sections with a total of 72 questions:

Table 4: Questionnaire structure

Section Name	Volume
1. Beneficiary identification	11 questions
2. Household Water and Water Treatment	9 questions
3. WADI specific water treatment	9 questions
4. WADI specific water treatment continued	8 questions
5. Energy source - Firewood	9 questions
6. Health	10 questions
7. Household sanitation and hygiene	8 questions
8. COVID-19	8 questions

Sections 1, 2, 5, 6, and 7 were also part of the baseline, but the questions in these sections have been slightly updated and extended. The sections 3, 4, and 8 are new additions for the project survey.

5.1.1.5. Online training of field team

The local partner WSU provided feedback on the questionnaire, and after that feedback was incorporated, the field team was trained. The field team consisted of about ten people from the local partner WSU and local community workers who are engaged in the project. The researcher and the field team came together in an online video meeting to go through the final questionnaire and get some practice. Every single section and all its questions and pre-coded answers were explained. Furthermore, a document called 'Soroti Project Scenario Survey - Description for Enumerators' (see Appendix A) was prepared for the field team. It explained the questionnaire and its structure in detail and gave recommendations on how the interview should be held.

5.1.1.6. Field Visit:

About a week after the online training, the field visits started. The field team from WSU traveled from the capital Kampala in a 6 hours' drive to the project area Soroti, which is in the northeast of Uganda. The field visit took place 10-14 May 2021. The team, mainly employees of the local partner WSU, split up to simultaneously conduct the beneficiary interviews. The aim was to gather data from 200-250 HHs, depending on availability of beneficiaries in 10 different villages in Soroti district.

Fig. 12: Field team in Soroti (Source: WSU,2021)

As the researcher couldn’t be on site by himself, a communication and supervision strategy was agreed on in beforehand. The field team should make daily updates (via mail or phone call) from the field, and communicate observations, challenges, and successes. Also photos were taken by the team and sent to the researcher, to share impressions of the local progress. The researcher was available to the field team during the whole field visit, in case any questions or problems came up.

Day 1:

On the first day of the visit, the questionnaires were pre-tested in 34 HHs. Pre-testing the data collection tool was essential to find out if the developed questionnaires are working well or if further adaptions need to be made. In order to improve data quality, some little adjustments were made to single questions. No bigger changes in the questionnaire design were necessary.

Day 2-5:

Between 40 and 45 HHs were visited each day of the field visit. After returning from the field in the evenings, the filled questionnaires were collected, sorted and scanned in the team office in Gweri. The team emailed the scanned PFD questionnaires to the researcher in Austria on day 2 and day 3. Due to the big amount of data and a lack of stable internet connection, a lot of time was required for this. The researcher looked through the returned questionnaires and did a first analysis. As no noticeable problems or questions arose, the team could continue their data collection for the remaining days. In the following figures (Fig. 13 - Fig. 16) one can get an impression of the field visit.

By the end of the field visit, a sample of 223 HHs had been interviewed and their complete questionnaires were emailed to the researcher. In most cases, the interview lasted around 20-30 minutes. These 223 questionnaires were the base for further analysis of the data.

Fig. 13: Family being interviewed in Soroti (Source: WSU, 2021)

Fig. 14: Couple showing the interviewer their WADI water (Source: WSU, 2021)

Fig. 15: Kids observing the interview situation (Source: WSU, 2021)

Fig. 16: Curious children in front of a typical regional house (Source: WSU, 2021)

5.1.1.7. Limitations

A key limitation of the study is that a field visit is just a single point in time insight into the current project situation. The data was collected in May 2021, during rainy season and after more than a year of hard lockdowns. During that time, project activities like regular trainings or HH visits have been limited. These factors might result in a WADI usage rate below average.

Another limitation is that a full life cycle analysis of the WADI device would be needed, to subtract the emissions caused by the production and transport of a single WADI from the reduced emissions per WADI. According to information supplied by Helioz, the emissions caused per WADI are negligible in comparison to the emission reductions it enables. Detailed research on this is required.

Also precise quantitative predictions into future project development cannot be included in this study. It only gives an insight in the impacts of the first three years of activities by describing the current state in 2021. As this provides our best estimate of the current situation, it is extrapolated to the following years 2022 and 2023 of project activities. This was reasonable as the pandemic seemed continued in 2022 and a conservative approach is preferred. Possible improvements or changes to the worse which differ significantly from the average extrapolation calculated in this thesis must be re-evaluated in further project studies.

5.1.2. Data evaluation

For further analysis, the data management program 'SPSS Statistics 26' was used. Every question from the questionnaire was coded. To make use of the data, 130 different variables were created. Most of them being ordinal variables (answer options are ranked), some being nominal variables (options without ranking) and only a few being scale variables (described by a numerical value). Some examples of variables in the three different categories are listed below:

- Ordinal: HH has given consent, education level, common method for water treatment, condition of WADI, usage rate of WADI, additional boiling of water, latrine assets, handwashing practices, HH waste treatment, basic needs in times of COVID, …
- Nominal: Village name, profession, storage type, reason for boiling water, location of fireplace, stove type, main way of defecation, health improvements, …
- Scale: HH size, age, annual income, total savings, total amount of water used every day, amount of water disinfected with SODIS, amount of water boiled in addition to SODIS, amount of firewood needed for boiling water, wood cost, wood distance, …

All the data was entered by the researcher Max Reisinger in the months after the field visit. As soon as all the data has been entered, further analysis was made within SPSS mainly using the function 'Frequencies' and 'Descriptives'. Both are simple descriptive statistic functions calculating averages, counting entries, calculating percentages and delivering solid results.

5.2. Qualitative Data: Focus Group and Interviews

After the quantitative data was gathered in the project survey in May 2021, some additional qualitative research was conducted in November 2021, with the aim of getting an even deeper understanding of the project impacts. The researcher developed a semi-structured qualitative research questionnaire and personally conducted an online focus group and two in depth online interviews with different local stakeholders connected to the project. Details are described in the upcoming paragraphs.

5.2.1. Data collection

5.2.1.1. Aim of the focus group and interviews

The main reason to conduct further qualitative research was to gather additional information and getting deeper insights on the project. As the researcher couldn´t travel to Uganda himself for the field visit, talking with local people online was a way to partially compensate for this. Another goal was to double check the quantitative data which had already been collected and include qualitative findings in the further calculation of CO_2 emission reductions.

An online focus group with project beneficiaries from selected HHs enabled the researcher to talk to WADI users personally. A focus group is a typical qualitative research method mainly used in social science to study people's behavior. It can be also described as a group interview or group discussion. It allows that several people are interviewed systemically and at the same time (Babbie, 2008).

Two in-depth qualitative interviews were also conducted, using a specially developed semi-structured interview guide. The first interview included two health officials and their observations about the project impact and challenges. The second interview collected valuable information from a field team member and translator, who visited a lot of HHs during the field visit in May 2021.

Semi-structured interviews (SSIs) typically include a mixture of open-ended and closed-ended questions with follow-up why or how question and probes. They help to navigate the dialogue around certain topics on the agenda, by not cutting the momentum and natural direction of the interview but also not losing focus by letting the conversation happen without any moderation. Within the methods of qualitative social science research, SSIs are positioned in between close-ended structured surveys and open-ended unstructured conversations (Adams, 2015). Because of these qualities, the SSIs enriched the research.

5.2.1.2. Focus Group

In preparation for the focus group meeting, an interview guide called 'Moderators Guide Tool' (Appendix C) was developed. It uses SSI questions covering the following topics:

- Introduction: This first section is to get to know each other: welcoming participants, clarify the research objective, introducing name and role, current situation in village

- WADI project - look back: This section is about the changes that the project and the SODIS method has caused in people’s lives, the impact, the benefits and challenges of it, and any special moments they can recall regarding the project activities.
- WADI project - technical: This section is about the personal water treatment practices, treatment criteria, changes in firewood usage and availability of plastic bottles of the people
- Ending: Outlook to the future and wishes for the project are shared.

In the design of the interview guide, the recommendations of Adams (2015), regarding the length, order of the topics, translation requirements, awareness about social desirability of the answers, and the adjustability of the guide, have been integrated. The local partners organized the location and invitation of the chosen participants.

The focus group meeting was held on 18 November 2021. The local partners of WSU traveled to the project area again and organized the meeting (location, invitation and transport of chosen participants, refreshments, etc.). It took place in Telamot village. 14 people (including children) attended the meeting, 8 people were actively taking part in the group interview. Out of these 8 people, 6 persons are project beneficiaries, and 2 persons are engaged in the ‘Village Health Team’ (VHT). In Fig. 17 and Fig. 18 one can get an impression of the focus group setup.

Fig. 17: Focus group participants (Source: WSU, 2021)

Fig. 18: Impressions from the focus group interviews (Source: WSU, 2021)

As it had to be set up as an online focus group, the researcher was moderating the interview via video call. A notebook was placed on a table in front of the participants, who were sitting outdoors beneath a mango tree at the community area of the village. Their chairs were positioned in two rows so that everybody could see the researcher on the screen and the other way around. Every time people were asked a question, the respondents stood up and moved to sit in front of the screen next to the translator and gave their response. Technical assistants took pictures and notes and hosted the meeting locally.

The internet connection was very unstable and crashed a few times due to the remoteness of the area. This technical problem led to interruptions in the understanding. Even though the interview was recorded for further evaluation, the notes that were taken during the focus group were more helpful. In total the focus group meeting lasted for nearly two hours and was successfully rounded up. The atmosphere felt very amiable and rewarding for both sides.

5.2.1.3. Interviews

A further two online interviews were conducted to capture the viewpoints of other stakeholders.

1.Interview:

On 17 November, an administrative district health officer and a local health inspector were interviewed. They have been working in the area for more than 8 years, far before the project started. With their expertise and experiences from their daily work in similar communities, the health insights on a meta level were valuable for the thesis. The interview was hosted by WSU and took place in an office in Soroti. It lasted for about one hour. The notes taken were summarized and used as the basis for further analysis.

2.Interview:

After the focus group on the 18 November (see 5.2.1.2) the researcher interviewed the coordinator of the local field team, who also acted as the translator during the field visit, to hear his views on the project. As he coordinates the field workers, visiting the households on a regular basis, his experiences and perceptions are very valuable for the impact assessment. The interview lasted about an hour. Notes were taken and key points summarized during the online call.

5.2.2. Data evaluation

Due to the technical problems, a classic transcription of the interviews was not possible. Instead the simplified written summaries (see Appendix E) which were made during the interviews were used. In addition, essential and not damaged parts of the audio recordings could be used for quotes (personal communication). Essential findings are described in the three categories: project impact, challenges and individual stories (see 0). Personal quotes by different stakeholders are also included as direct quotations in this chapter.

5.3. Calculation of the CO_2 Emission reduction for WADI

5.3.1. Gold Standard methodology as a foundation

To quantify the measurable climate relevant impact, the Gold Standard (see 3.3.5) was chosen as it is one of the biggest and most established international standards on the voluntary carbon market. Further criteria for choosing the GS have been:

- SDG focus / Co-benefits: GS wants to achieve progress on all SDGs and ensure benefits on neighborhood communities through their projects. It also acts as a Standard for the Sustainable Development Goals (Carbon Offset Guide, n.d.–a)

- Micro scale: GS allows evaluation of micro-scale projects (<10,000 t annual CO_2 credits) (Carbon Offset Guide, n.d.–a; Gold Standard, 2019a, p. 3),.
- Voluntary carbon market: GS only operates in the voluntary carbon market, not on the compliance market (Carbon Offset Guide, n.d.–a). The resulting field of application suits to the voluntary offsetting program of BOKU.
- Developing countries: most of the projects are in developing, low- or middle-income countries resulting in specialized monitoring methods for these local conditions (Carbon Offset Guide, n.d.–a)
- Previous experiences: Both BOKU and Helioz have satisfying previous experiences with applying the methodology to similar SODIS projects in Ethiopia and Bangladesh.
- Practicability: GS constantly develops and publishes new assessment documents and offers a lot of scientific background materials
- Comparability: The results of the total emission reduction were to be compared to the baseline study (see chapter 4.3), where the same GS methodology (Version 2.0) was used, so it was important to stay with the same tool

The combination of these criteria suits very well to the project set-up of 'Clean Air and Safe Drinking Water for Soroti' as it is placed at the voluntary market, is at micro scale level and has a strong SDG focus.

The total emission reductions were calculated by using the GS methodology called 'Technologies and Practices to Displace Decentralized Thermal Energy Consumption - Version 2.0'. This methodology is designed for projects that introduce technologies or practices that reduce CO_2 emissions from thermal energy consumption of households (Gold Standard, 2015). The slightly updated document of GS Methodology Version 3.1 (Gold Standard, 2017), which has no changes in the relevant formulas and therefore secures comparability to the baseline, was also used. This methodology has been further developed and slightly adapted to make it applicable to assessing the emission reductions resulting from people using the WADI device for practicing SODIS. This adapted version was first developed by Centre for Global Change and Sustainability at BOKU and further adapted by the researcher himself. Adaptions were necessary because there has been no specific GS methodology for SODIS with WADI projects at the time of the research.

These adaptions led to an evaluation method which is very similar to the original GS methodology, but it has to be clearly stated that this evaluation method is a development of the University of Life Sciences Vienna and not an official GS scheme.

5.3.2. Adapted CO_2 emission reduction methodology

The GS methodology ‘Technologies and Practices to Displace Decentralized Thermal Energy Consumption` - Version 3.1, Annex 3’ contains a description of how to apply the calculations in safe drinking water supply projects. Only people who boiled water or consumed unsafe water without treatment are qualified for crediting (Gold Standard, 2017), which is the case in Soroti as described in Chapter 4.

Fig. 19 below shows the general emission reduction calculation method:

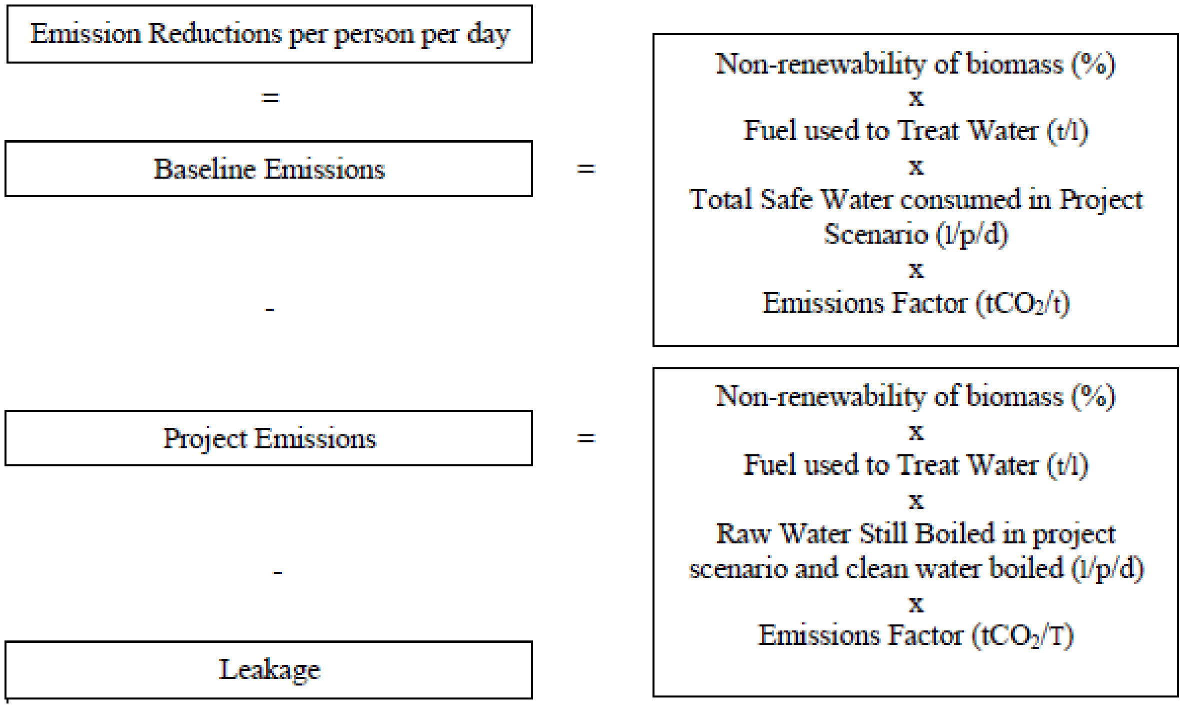

Fig. 19: Simplified calculation of emission reductions per person per day (Gold Standard, 2015, p. 36)

In general, the emission reduction is calculated by taking the baseline emissions and subtracting the project emissions and the leakage effects. The baseline here assumes that people are boiling their water with non-renewable firewood (the main source of energy in all HHs) which Wornig (2021) found in her baseline study. Selected single variables from the figure above are further described in the formulas (see Gold Standard, 2017, pp. 45–47) below (explanation of all the terms is provided in Tables 5-7):

Fuel (firewood) used to treat water for the baseline scenario is calculated as shown below:

Fuel (firewood) consumption baseline scenario
$B_{firewood,b,y} = (1 - X_{boil}) * (1 - C_j) * N_{p,y} * W_{firewood,b,y} * (Q_{p,y} + Q_{p,rawboil,y})$

Resulting baseline emissions from firewood burning in the baseline scenario:

Baseline CO_2 emissions
$BE_{firewood,b,y} = B_{firewood,b,y} * f_{NRB} * EF_{firewood,CO2} * NCV_{firewood}$

Fuel (firewood) used to treat water for the project scenario is calculated as shown below:

Fuel (firewood) consumption project scenario
$B_{firewood,p,y} = (1 - C_j) * N_{p,y} * W_{firewood,b,y} * (Q_{p,rawboil,y} + Q_{p,cleanboil,y})$

Resulting project emissions from firewood burning in the project scenario:

Project CO_2 emissions
$PE_{firewood,p,y} = B_{firewood,p,y} * f_{NRB} * EF_{firewood,CO2} * NCV_{firewood}$

The overall emission reduction calculation is

CO_2 savings per WADI
$ER_y = (\sum BE_{firewood,b,y} - \sum PE_{firewood,p,y}) * F_{firewood} * U_{p,y} * TWQ_y - \sum LE_{p,y}$

A description of all the parameters used for the calculation is given in the tables below. Table 5 shows the fixed parameters, which have been taken from scientific literature, national statistics or the GS methodology.

Table 5: List of fixed parameters

Fixed parameters	
1. $F_{firewood}$	Fraction of households using firewood as their main source of energy
2. TWQ_y	Treated water quality, percentage of safe water provided by project technology
3. X_{boil}	Proportion of users of the project technology that would have used other non-GHG emitting technologies (like chlorine) in the absence of the project technology. This parameter is only applied for premises that are under suppressed demand situation. (value derived from baseline)

4. C_j	Proportion of users of the project technology that in the baseline were already consuming safe water without boiling it (estimated value)
5. $W_{firewood,b,y}$	Quantity of fuel (in kilograms) required to treat 1 liter of water using technologies j representative of baseline scenario b in year y as per Baseline Water Boiling Test = BWBT. (value from BWBT study from Uganda)
6. $fNRB_{,y}$	Fraction of woody biomass saved by the project activity in year y that can be established as non-renewable biomass (default value for Uganda)
7. $NCV_{firewood}$	Net calorific value of the non-renewable woody biomass that is substituted (value from IPCC 2006 Vol 2 Chap 1 Table 1.2)
8. $EF_{firewood,CO_2}$	Emission factor for the substitution of non-renewable woody biomass by similar consumers (value from IPCC 2006 Vol 2, Chap 1, Table 1.4)
9. $Q_{p,y}$ + $Q_{p,rawboil,y}$	Quantity of safe water in liters consumed in the project scenario p and supplied by project technology per person per day in year y plus Quantity of raw water boiled in the project scenario p per person per day. Default value of 4 L/person/day applied (as specified in methodology)
10. $\sum LE_{p,y}$	Leakage from project scenario p in year y (tCO_2e/year)

The following Table 6 shows all parameters that are specific to the project area and the actions of the project beneficiaries and therefore have been monitored during the project study:

Table 6: List of monitored parameters

Monitored parameters	
1. $U_{p,y}$	Cumulative usage rate for technologies in project scenario p during year y, based on cumulative installation rate and drop off rate
2. $N_{p,y}$	Number of person.days consuming water supplied by project scenario p through year y (Based on 365 days * 1 household filter *8.12 person per household)
3. $Q_{p,rawboil,y}$	Quantity of raw water boiled in the project scenario p per person per day in year y
4. $Q_{p,cleanboil,y}$	Quantity of safe water boiled in the project scenario p per person per day in year y

The parameters in Table 7 emerged from further calculations of the fixed and monitored parameters.

Table 7: List of the calculated parameters

Calculated parameters	
1. $B_{firewood,b,y}$	Quantity of fuel consumed in baseline scenario b during the year y in kilograms
2. $B_{firewood,p,y}$	Quantity of fuel consumed in project scenario p during the year y in kilograms
3. $BE_{firewood,b,y}$	Emissions from firewood burning for baseline scenario b during year y in tCO_2e
4. $PE_{firewood,p,y}$	Emissions from firewood burning for project scenario p during year y in tCO_2e
5. ER_y	Emission reductions during the year y in tCO_2e

All of the calculations were made in an Excel-file. The baseline values of Wornig (2021) were updated. Then the project values were subtracted from the baseline values to calculate the actual emission reduction. Two different scenarios have been calculated, one being very conservative the other being optimistic and using the most advantageous interpretations of the data allowed by the GS methodology (see 6.1.2). These scenarios show the possible rage within the real emission reductions are occurring. The average between both scenarios was decided to give the most accurate results which were decided to be the total overall project emission reductions.
In addition to the baseline study also a special 'Firewood Monitoring Sample' consisting of 24 HHs conducted during the baseline visit in June 2019, also before the project activities started, has been evaluated for double checking the results magnitude. It was focusing on the weighting of the daily firewood demand for disinfection. It offers a second way for the calculation of the project´s emission reduction potential by taking the proportional weight of carbon stored in firewood and the molar mass of CO_2, which is created by burning it, into account (see 6.1.2).

5.4. SDG Impact Assessment

During the baseline study in 2019, a number of other variables have been monitored in addition to the emission reduction parameters in order to assess the projects impacts on the SDGs. Wornig (2021) gave a detailed description of different benefits of the project activities on health, financial situation, socio-economic level, equality, education and many more. She matched them with the most suitable SDGs in her Chapter 6.2. The current project study values are compared relatively to these baseline values to see how the SDG impact has changed over the last 3 years. This should reveal the size and nature of the impacts the project activities have had on the wellbeing of the people in Soroti.

The baseline study aimed to break the SDGs down from international level to project and HH level. Wornig (2021) analyzed which SDGs and sub targets are influenced by the project activities. She highlighted the selected SDGs within the wedding cake model (Stockholm Resilience Center, 2016) and described the expected impacts of the project on every relevant SDG.

Now after three years of project activities, the data of the current project study are compared to the baseline situation before the project, using the same collection and structure of the SDGs. The official SDG website from the UN (United Nations - Department of Economic and Social Affairs, n.D.) has been used to source the SDG icons, the wording for the names and the sub targets. The results (mostly relative changes) are listed in the SDG impact table in Chapter 6.1.3. They are further clustered and described in the SDG categories of the Biosphere Level, the Social Level and the Interdisciplinary Level.

6. Results, Interpretation and Discussion

To answer the research question and its two sub-questions, several steps are needed. In a first step the underlying data of the project study are presented. This includes the demographics of the sampled HHs and the variables gathered for further calculation. In a second step the results of the project´s total CO_2 emission reduction are explained (research question 1). Finally the project´s impact on all the relevant SDGs are described (research question 2). This part is mentioning the project benefits and co-benefits which are having an impact on people's lives in Soroti. The qualitative findings round up this chapter.

6.1. Quantitative Findings

6.1.1. Demographics of project study and essential parameters

The data base for the project survey are 223 completed and scanned questionnaires from the field visit, which have been analyzed. 223 households were visited and interviewed in 10 different villages in the project area: Akuya A, Akuya B, Alere, Amodomia, Amusia 1, Amusia 2, Omugenya, Orapada, Telamot *and* Tukum. About two thirds of the interview partners are female (n=151), one third is male (n=72) and all of them have given their consent to take part in the study. This gender disparity can be explained, by two facts:

- Women in general are at home during daytime, when the interviewers visited the HHs, doing HH chores.
- Besides that, all the wood collection for disinfecting and provision of drinking water is typically done by women (>93%), as typical for sub-Saharan culture (WHO, 2016a). Therefore, manly women have been given the WADIs at the start of the project and that is why these women are the main interviewees.

Nearly 60% of the HHs had taken part in the baseline survey at the start of the project 3 years earlier. The age of respondents was between 19 and 100 years, with an average at 42 years. Most of the people (>90%) are farmers as their main occupation. The predominant education level is primary school level (2/3 of people). Only some have visited a secondary or even tertiary school, some don´t have any education at all. The average annual income of a standard HH is 460,000 UGX which at the moment is equivalent to 120€ per HH per year. That low income is clear evidence for the very limited economic opportunities of the project beneficiaries. According to the SDG indicator 1.1, this is classified as extreme poverty condition (United Nations - Department of Economic and Social Affairs, n.D.). The main sources for getting drinking water are nearby boreholes for 98.7% of the HHs, in both dry and rainy season.

The following essential values have been derived. Table 8 below gives an overview, details are explained afterwards. The critical values are the WADI usage rate (Up,y), the Water consumption (Qp,y + Qp,rawboil,y) and the value for Firewood (Ffirewood). These have the most impact on the final emission reduction results. In comparison to the baseline study, a significantly lower usage rate was found (which is reducing the overall emission reductions), a higher amount of water needed per person was chosen on (which is increasing the overall emission reductions) and partly the concept of suppressed demand was integrated in the value of firewood being the main source of energy, which was perviously used also for boiling the drinking water for desinfection (which is increasing the overall emission reductions).

Table 8: Overview of the essential parameters

Parameter		Baseline Study value	Project Study value
Up,y	Cumulative usage rate for technologies in project scenario p during year y	95 %	**58%**
HH size	Number of people living in a household and using the WADI water.	7.84	8.12
Np,y	Number of days multiplied with persons consuming water supplied by project scenario p through year y (Based on 365 days * 1 household filter *8,12 person per household)	2862	2964
Qp,y + Qp,rawboil,y	Quantity of safe water in litres consumed in the project scenario p and supplied by project technology per person per day in year y plus Quantity of raw water boiled in the project scenario p per person per day.	2.423 l	**4 l**
Qp,rawboil,y	Quantity of raw water boiled/needed in the project scenario p per person per day in year y	-	**0.2 l**
Qp,cleanboil, y	Quantity of safe water boiled in the project scenario p per person per day in year y	-	**0 l**
Ffirewood	Fraction of households using firewood as their main source of energy	51 %	**51%/100 %**
fNRB	Fraction of non-renewable biomass	82%	**82%**
∑LEp,y	Leakage from project scenario p in year y (tCO_2e/year)	-	**0**

Usage rate (Up,y):

The usage rate is a parameter which is based on the installation rate and the drop-off rate of the project technology (Gold Standard, 2017). As there are no further details on the parameter from the GS methodology, the usage rate for this project is defined as the percentage of people who are currently using the project technology at least once a week on a regular basis. This leaves a certain bandwidth of actual WADI usage but excludes WADI owners who don´t practice SODIS anymore, who lost their bottles or whos WADI device got broken. The definition also levels out variations in WADI usage in rainy and dry season, because also in rainy season WADI can be used at least once a week. Some people use the WADI every day, as they just prepare water for the daily water demand. Others use the WADI every 2-3 days and disinfect water in advance for the next days as they have jars or bottles for storage available. In both cases the total drinking water demand is covered. Others may use it just one a week due to low time resources or other reasons. In this case the full demand is not covered but at least a regular WADI usage is practiced. All the people who responded that the current usage rate is lower than once a week, are treated as non-users and reduce the total usage rate.

Each of the 2000 participating HHs received one WADI device. How much people would really use them and how much they would change their water disinfection habits could only be estimated in the baseline study. Experiences from a similar project by BOKU and Helioz in Bangladesh (Helioz, n.d.–a) made an assumption of 95% reasonable. However the project study found that the current accumulated usage rate was much lower, at about **58%**, as 42% don´t use the WADI at all anymore as shown in Table 9 below.

Table 9: WADI usage rate in 2021

Usage rate of WADI in 2021		
	Number of HH	Percent
0 days/week	94	42,15%
1-2 days/week	41	18,39%
3-4 days/week	73	32,74%
5-6 days/week	10	4,48%
Every day	5	2,24%
Total	223	100,00%

The table shows that most of the current WADI users use it 3-4 days a week. Differences in general water availability, storage possibilities, available time and water demand are the reasons for altering usage frequencies.

The people were also asked about their previous WADI usage in 2019-2020, the first two years of project activities. This usage rate was found to be higher at about 89%. Only 11% didn´t use the WADI at that time. It has been a conscious decision to not take a weighted or average value between the two different usage rates to keep further calculations as close to the current situation as possible. This keeps the overall results conservative and avoids the risk of overestimation of the CO_2 reduction.

The decline to the current usage rate in 2021 indicates a high drop off rate. People mainly stopped using the project technology because of two reasons:

- Lack of bottles: the bottles for disinfection of water, which they were given within the project activities, got lost, scratched or broken
- WADI device lost/broken: people reported that their device is damaged, got lost by the kids, has a technical problem, etc.

Only very occasionally HHs reported that the reason was a change in water demand, a decrease of awareness or a lack of trust in the method. Another factor that influenced the drop off rate is the limited supply with materials, trainings and regular meetings due to the pandemic.

It seems to be very challenging for these HHs to get new PET bottles. The roots of this problem can only be assumed. During the lockdown a limited availability of bottles and limited possibility to leave the house to get new ones from town may have been a factor. For further project improvement it is essential to supply all the HHs with new bottles and WADI devices if needed. Only when the HHs are supplied with the WADIs, the bottles and regular trainings will an increase in the usage rate be possible.

Another source has been looked at to interpret the found usage rate of 58%: The annual impact report of the project developers for year 3 of the project (September 2020 August 2021) also gives information about the usage practices before the 'project study'. The data have been derived by 2 different HH surveys conducted by WSU. These were including smaller sample sizes of 103 and 120 HHs. Helioz and BOKU (2021, p. 5) found a daily WADI usage range by 58% of HHs (rainy season) to 94% of HHs (dry season). 5.2 % of the interviewed HHs stated to prefer another desinfection method, 2.6% don´t have to treat their water at all and 6.5% stated to not have enough bottles. The lack of bottles doubled within the following 6 months, indicating the declining usage rate. Overall these findings were not taken into account for modifying the derived value for the usage rate of 58% of the 'project study'. This was decided on by the researcher, because the studies lack on detail on the methods, on how the values were assesed and they say nothing about the drop off rate (number of HHs not using the WADI at all anymore). Furthermore objectivity and independence of personal interests, could not be fully ruled out. Therefore, it was not used for describing the parameter of 'usage rate' according to the GS methodology at all.

Household size:

The average HH size found in the project study is 8.12 persons. This value is slightly higher than the value of 7.84 found in the baseline survey (Wornig, 2021, p. 79). That growth can be explained by the fact that in general more people were living in the HHs during the Covid-19 pandemic. About 17% reported that 1-3 additional people were part of the HH, only about 4% reported that 1-3 people less were part of the HH. For the rest of the HHs, the HH size stayed the same. Therefore it is reasonable to assume that during COVID (2020-2022) the HH size went up. To allow comparison between the studies, the household size in the baseline value was adjusted to 8.12.

Often several generations are living together in one HH. This is typical for the very rural, and underdeveloped areas like the project area of Gweri, resulting in higher numbers than the average HH size of the whole District Soroti. In the National Population and Housing Census in 2014 this district value was 4.5 persons (Wornig, 2021).

Water consumption (Qp,y + Qp,rawboil,y)

For the quantity of safe water consumed the default value of 4 liters/person/day from the GS methodology is used. This 4 liters expresses the minimum quantity of water per day every single person should be having access to, as this is a basic human right. (GS 2017, p.48). *'The human right to water is indispensable for leading a life in human dignity',* the UN already stated 20 years ago (UN - Committee on Economic, Social and Cultural Rights, 2003, p. 1).

The real drinking water demand of the project beneficiaries lies below the default value. The human dignity precondition is therefore not satisfied at all in the project area according to the GS methodology. The majority of the WADI users disinfects 6-18 liters per HH per day. This gives a mean value of ~12 liters per HH or ~ 1.5 liters per person. As this value lies far beyond the 4 liters, and during the pandemic an even stronger focus on clean water and good hygene was needed, it is reasonable to apply the default of 4 liters for further calculations.

The baseline study found a drinking water demand of 2.42 l/person/day (Wornig, 2021, p. 79). Even though Wornig didn´t make use of the GS default, it is now updated through the project study. This makes a considerable change in final results.

Raw water boiled (Qp,rawboil,y):

This parameter describes how much water is still boiled for disinfection in the project scenario, even though the people have been equipped with the WADI. Only 37 HHs still have to boil ~11 liters in average. This makes an amount of ~1,8 l/person/day in this HHs. Split up among all HHs this gives an average of ~0.2 l/person/day of additionally boiled water. This number is important for the calculation as for this burning of firewood for boiling the water is still causing emissions.

Clean water boiled (Qp,cleanboil,y):

None of the HHs responded to additionally boil already disinfected and clean WADI water. Therefore the value is 0. This is a good indication that there is no misunderstanding in the disinfection method and no mistrust in the technology among the users.

Firewood (Ffirewood):

This parameter plays an essential role as it describes the fraction of HHs using firewood as their main source of energy. On the traditional three stone fire firewood is used to prepare food, to heat up water for personal hygiene and also to boil water for drinking. No liquid petroleum gas nor other fuels were found in the project survey, so just firewood and its net calorific value (NFC) and emission factor is taken into account. Anyway the baseline survey showed that only 51% of the project beneficiaries were really disinfecting their water by boiling on a regular basis (Wornig, 2021). One can assume that the rest (49%) haven´t had the resources (time, money, knowledge, etc.) to do so and consumed unsafe water. According to the methodology this is a so called 'suppressed demand' situation.

Suppressed demand exists when the people are "*deprived of a reasonable level of human development*" and can be used to refer to shortages of safe water (Gold Standard, 2017, p. 41). In the case of this project, HHs are deprived of the access to safe water because of poverty-related issues. If they get the opportunity to reach satisfactory levels of service through the project activities, the baseline can be adjusted: The adjustment is assuming that all these people (49%) would have used firewood as well, if they had the resources to practice the disinfection properly. It can be applied for safe water shortages (see Gold Standard, 2017, pp. 48–49).

This suppressed demand status was made use of only in Scenario 1 of the project study. In the baseline Wornig (2021) didn't make use of it. This results in a significant difference of +49% for this parameter describing the fraction of HHs using firewood to disinfect their drinking water. In Scenario 2 the calculation was held more conservative without using the suppressed demand option and staying with the baseline findings of only 51% of the total HHs really boiling their water. The resulting emission reductions are much lower than when including suppressed demand logic. Within this range of the two scenarios the total real emission reductions are happening. The average between both scenarios was calculated to stick to the GS method including the human right of water but also stay conservative in the calculation of real and not potential emission reductions. This conservativeness leads to lower overall CO_2 emission reductions than if it would have been certified by strictly following only the GS methodology.

Fraction of non-renewable biomass (fNRB):

For this value, the official CDM default for the fraction of non-renewable biomass is used. CDM offers country-specific data for many states. Uganda has a value of 82% (United Nations Framework Convention on Climate Change, 2022). That means 82% of the Ugandan biomass (manly being forests) are not managed in a way that they can renew. Even though it hast not been updated since 2017, it is the most recent value found for Uganda.

The reason for this high rate is that people in Uganda are highly dependent on biomass for their energy production. Over 80% of people in rural Uganda cook their food and boil their water with firewood manly. With 2.6% annually Uganda has one of the highest deforestation rates worldwide (World Bank, 2019), which also indicates unsustainable forest management. Limited access to more firewood saving practices and technologies are a high risk for further deforestation and land depletion.

Leakage ($\sum LE_{p,y}$):

The leakage estimation tries to capture GHG emitting behaviors and/or consumption patterns of beneficiaries arising as a cause of the project activities. An example would be if the HHs burnt the saved firewood for heating instead or buy fossil fuel powered motorbikes with the money they saved through the project. As no such leakage effects were observed or reported, the risk is assessed as not significant for the overall project impacts. Therefore 0% is the best estimate taken for this parameter.

6.1.2. Total CO_2 emission reduction

For the total CO_2 emission reduction, three different scenarios were assessed – 'Scenario 1' which includes suppressed demand, 'Scenario 2' which excludes suppressed demand, and scenario 3, which is the average of Scenario 1 and Scenario 2. In a complex project like this with so many different parameters to assess, it is important to show the possible range of the potential results. Just one result would not be scientifically tenable in that case.

The results in Table 10, Table 11 and Table 12 below can be confirmed and used for further project development. In 'Scenario 3' (Average Scenario), the overall total CO_2 emission reduction per WADI per year is 2.12 t CO_2 e. That gives an annual reduction of about 4240 t CO_2 e and a total project reduction of 21,200 t CO_2 e over a project duration of 5 years.

Table 10: Scenario 1 (including suppressed demand)

Scenario 1	
Fraction of households using firewood (for disinfection of drinking water) before WADI – including supressed demand	100%
CO_2 reduction per WADI per year	2.81 t CO_2 e
Number of WADIs distributed in the area	2000
Total emission reductions of the project per year	2.81*2000 = 5622 t CO_2 e

Scenario 1 can be interpreted as the most advantageous scenario including the full possibilities of supressed demand logic. The resulting fraction of HHs which have been using firewood in the baseline scenario therefore can be taken as 100% even though in the actual baseline survey showed a far lower value of just 51%. This Scenario 1 can be interpreted as a theoretic maximum limit of emission reductions possible, now and for future project activities, compensating for all underlying conservative assumptions and limitations of the data.

Table 11: Scenario 2 (excluding supressed demand)

Scenario 2	
Fraction of households using firewood (for disinfection of drinking water) before WADI – excluding supressed demand	51%
CO_2 reduction per WADI/per year	1.43 t CO_2 e
Number of WADIs distributed in the area	2000
Total emission reductions of the project per year	1.43*2000 = 2867 t CO_2 e

Scenario 2 can be interpreted as the most conservative scenario including no suppressed demand logic at all. Just the 51% of HHs found to really boil their water with firewood in the baseline are taken into account for emission reductions even though the methodology would allow for also including suppressed demand HHs. This Scenario 2 shall be interpreted as the theoretical minimum limit of emission reductions reached in the project so far.

Table 12: Scenario 3: Average Scenario

Scenario 3: Average Scenario	
CO_2 reduction per WADI/per year	**2.12 t CO_2e**
Emissions from firewood burning for baseline scenario / year	5.2 t CO_2 e
Emissions from firewood burning for project scenario / year	0.29 t CO_2 e
Total emission reductions of the project per year	2.12*2000 = **4240 t CO_2 e**
Total emission reductions of the project for the whole project duration of 5 years (2019-2024)	4240*5= **21,200 t CO_2 e**

Scenario 3 is the average scenario and interpreted as the best estimate to represent the actual project situation. It shall be interpreted as the most realistic scenario in between the theoretic minimum and maximum range of possible emission reductions. The researcher has consciously decided on choosing that average scenario as the one, delivering the total CO_2 reduction results of the project. Scenario 3 is a trade-off: It only includes 50% of the suppressed demand emission reductions, which is still controversial on the emission aspect but extremely necessary and valuable for the people in Soroti under sustainable development and human wellbeing aspects. Choosing for this middle course is not fully in line with the quality criterion of avoiding overestimation (see 3.3.2) of Broekhoff et al. (2019), as with the other 50% of suppressed demand emission reductions still included, there is a significant part of emissions potentially being overestimated. On the other hand, Scenario 3 is not sticking to the GS methodologies, which actually would advise to include suppressed demand to all underprivileged HHs to 100% and therefore enabling their inclusion in the project, ensuring to be benefited as well in regard to safe water and human wellbeing. The results lie in between the very conservative approach and the potentially too limply approach. Nevertheless these results of 2.12 t of CO_2 emission reduction per WADI are rather conservative and in line with the validated methodologies used.

Earlier experiences from a similar project in Bangladesh (Helioz, 2021, p. 31) found a value of 1.90 t/WADI/year (Schmitz & Reisinger, 2018, p. 19) which has been increased by project improvements to also 2.12 t/WADI/ year (Reisinger, 2020, p. 11). Helioz, the company who developed the device and is using it in many different projects in India, Kenya, Sudan, Bangladesh, Uganda and Ethiopia, conducts impact studies and constant monitoring, which has found CO_2 savings of 2 t/WADI/year as an average (Helioz, n.d.–a). Therefore the calculated mean value of 2.12t CO_2 emission reduction gives a reasonable realistic result which lies close to the results of other WADI projects.

Another approach to calculate the emission reductions was taken to interpret and double-check the result of 2.12 t CO_2. This time the amount of firewood needed for disinfecting the daily water demand is the base of calculation, rather than the water demand per person. In 2019 during the baseline visit a 'Firewood Monitoring Sample' found a mean drinking water demand of ~24l/HH/day. The firewood needed to disinfect it was weighted in every HH. The mean value found was 3.3 kg/HH/day. The amount of carbon in dry firewood is about 50% on average (Lamlom & Savidge, 2003), leading to about 1.65 kg of carbon per HH. To calculate the corresponding carbon dioxide weight one needs to take the ratio of the molar masses. From C to CO_2 it is a factor of 3.67 (Knohl, 2012). So the carbon emissions from burning the 3.3 kg daily are about 6.1 kg CO_2 per day and 2.2 t CO_2 per year for every HH. This simplified result is close to the found 2.12 t CO_2 calculated according to GS. Therefore it is legitimating the magnitude of the emission reduction potential under the assumption that the WADI can substitute for the whole firewood demand needed previously for water disinfection.

6.1.3. Other SDG impacts

This section aims to demonstrate the broad impacts of the project on various SDGs. In the following Fig. 20, the SDGs are arranged in the Wedding Cake Model by the Stockholm Resilience Center (2016). It offers an alternative to the official linear structure of the 17 SDGs by adding dependencies between the different goal levels and therefore overcoming the sectoral approach. These dependencies are inspired by the '3 nested dependencies model' of sustainability: ecological, social and economic sustainability. Thereby the biosphere level enables the society level, which in turn enables the economy level. The stable and resilient biosphere therefore is the base for all SDGs (Stockholm Resilience Center, 2016). Wornig (2021) added a color code to the

Wedding Cake Model. The colors highlight the 9 SDGs on which the project has the most impact on.

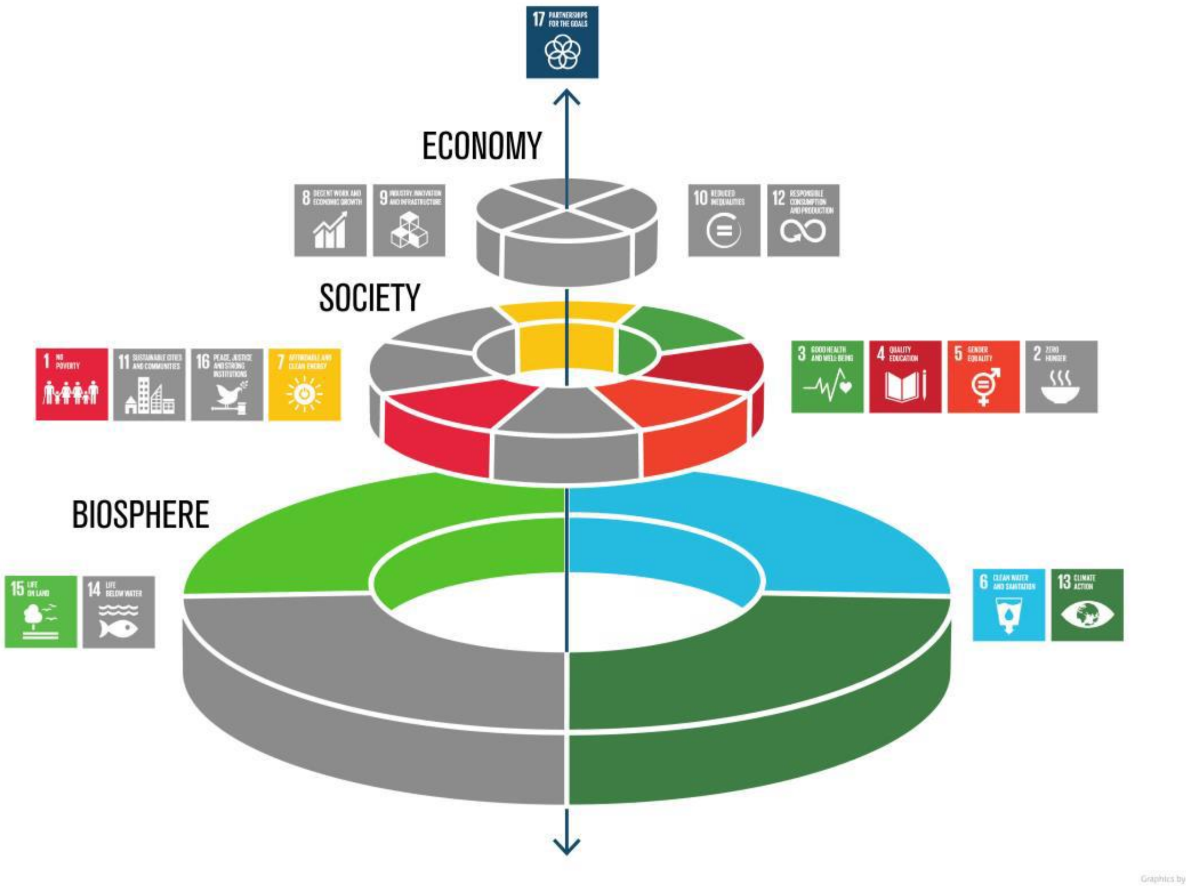

Fig. 20: Project impact shown in amended SDG wedding cake (Wornig, 2021, p. 84 see Fig.21)

By improving the water and hygiene situation of the people in Soroti and at the same time reducing CO_2 emissions, the core project activities have its most impact on SDG 6 (water and sanitation) and SDG 13 (climate action). Both SDGs are assigned to the biosphere level, which is the fundamental one, according to Stockholm Resilience Center (2016). This legitimates the importance of project goals and activities.

An overview of the project´s impacts on all other SDGs targeted in the baseline is given in the following Table 13. The next section of this chapter explains the impacts in detail, drawing on the responses to the project survey of 223 HHs and the additional qualitative interviews. The layout and content is based on the SDG table of the baseline findings from Wornig (2021, pp. 85–87) to make the results comparable. The Wedding Cake Model is used as a structure. The SDGs and its targets mentioned in this chapter are directly cited from the official UN SDG website (United Nations - Department of Economic and Social Affairs, n.D.).

Table 13: Project impacts on the SDGs

Biosphere Level	
6 CLEAN WATER AND SANITATION	• *Target 6.1: Safe and affordable drinking water for all* • *Target 6.2: End open defecation and provide access to sanitation and hygiene*
Impact • 16,200 project beneficiaries are getting access to at least 38,000 l water per day • 16,200 project beneficiaries are getting access to improved hygiene • Open defecation got reduced from 26% to 8% • Soap access was improved from 36% to 50%	
13 CLIMATE ACTION	• *Target 13.2.2: Indicator: Total CO_2/Year*
Impact • Calculated emissions reduction per Wadi/HH/ year: 2.12 t CO_2 • Annual emissions reduction of whole project covered by 2000 Wadis: 4240 t CO_2 • Total emission reduction of the project (5 years project duration): 21,200 t CO_2	
15 LIFE ON LAND	• *Target 15.2: End deforestation and restore degraded forests*
Impact • Firewood reduction per year: ~ 3000 t • Total firewood reduction of the project (5 years project duration): ~ 15,000 t	

<table>
<tr><th colspan="2">Society Level</th></tr>
<tr><td>1 NO POVERTY</td><td>• Target 1: End poverty in all its forms everywhere
• Target 1.4: Access to basic services (overlap with SDG 6)</td></tr>
<tr><td colspan="2">Impact:
• Lowering the average cost for medical treatment to 11€/treatment (-2€/treatment)
• Time savings for firewood collection: up to 2.5h/day
• More time and better health condition for income generating activities</td></tr>
<tr><td>3 GOOD HEALTH AND WELL-BEING</td><td>• Target 3.3: By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases
• Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination</td></tr>
<tr><td colspan="2">Impact:
• Overall sickness per/HH per month reduced by more than half (from 72% to 32%)
• Reduction of diseases: diarrhoea (-11%), typhoid (-2%), cough (-26%), malaria (-17%)</td></tr>
<tr><td>4 QUALITY EDUCATION</td><td>• Target: 4.1: By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes</td></tr>
<tr><td colspan="2">Impact:
• Time savings for children enable more school attendance possibilities
• Health improvements enable more school attendance possibilities</td></tr>
<tr><td>5 GENDER EQUALITY</td><td>• Target 5.B: Promote empowerment of woman through technology</td></tr>
</table>

Impact: • 2000 WADIs were given to women to help them providing safe drinking water → female empowerment and project ownership • Time savings for women and girls up to 2.5h/day → new possibilities	
7 AFFORDABLE AND CLEAN ENERGY	• *Target 7.1.2: Proportion of population with primary reliance on clean fuels and technology* • *Target 7.3: By 2030, double the global rate of improvement in energy efficiency*
Impact: • Improved cook stoves (Lorena Stoves) were built in many HH (11%) • Less firewood is needed for improved cook stove –> increase in energy efficiency	
Economy Level	
Interdisciplinary Level (connecting all 3 levels)	
17 PARTNERSHIPS FOR THE GOALS	• *Target 17.3: Mobilize additional financial resources for developing countries from multiple sources* • *Target 17.7: Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed*
Impact: • Financing of the project through CO_2 credits on the voluntary carbon market • Broad international partnership contributes to the SDGs an many levels	

6.1.3.1. Biosphere Level

SDG 6: Clean Water and Sanitation:

- *Target 6.1 Safe and affordable drinking water for all*

In the baseline study, 51% of HHs reported the need to treat the water before drinking, and that they boiled it as their standard way of disinfection. It can be assumed, that the rest of the beneficiaries, has just consumed unsafe water without treatment. A lack of time or money for getting firewood for boiling it and lack of awareness about water-borne diseases were the observed reasons (Wornig, 2021). Throughout the project activities and the application of SODIS about 16,200 people got access to at least 38,000 litres of safe water daily. Due to slightly higher HH sizes (8.12 people/HH), 200 people more than originally assumed are benefited.

- *Target 6.2 End open defecation and provide access to sanitation and hygiene*

In the baseline study, 28% of all HH still practiced open defecation as their main way of defecation. The project activities of WSU Uganda included building latrines, which reduced this percentage by a third. Three years after the baseline study, only about 8% of the HHs still practice open defecation. Most of the people (66%) reported they were now using a private HH latrine. 25% reported using a shared latrine. Some of these latrines (17%) were improved latrines with insect cover, to avoid the spread of diseases. About 2/3 of all latrines are placed more than 10m away from the water source. This avoids contamination of the water source by pathogens. Furthermore the access to soap was a challenge for 64% of the HHs in the baseline study. WSU constantly build new handwashing facilities for the HHs. Nowadays only 50% report problems getting soap, meaning the other half of the HHs have sufficient access to soap.

<u>SDG 13: Climate Action:</u>

- *Target 13.2.2 Total CO_2/Year*

The baseline study made an initial estimation of the CO_2 reduction potential of the project. This calculation was based on some assumptions, as it was not clear how successfully the new water disinfection practices would be adopted. A total of 1.49 t CO_2 per WADI/year was calculated and suppressed demand was not taken into account. This has given the total savings potential of 2978 t CO_2 per year through all the 2000 WADIs (Wornig, 2021, p. 82).

The results of the project study including the latest monitored data are considerably higher: it is estimated that 2.12 t of CO_2 are saved/WADI/year, giving annual project savings of 4240t CO_2**.** Over the total project duration of 5 years, this amounts to 21,200 t of CO_2 reduction**.** This saving is the mean value within the possible range of two different scenario results: 'Scenario 1' gives a best case result of 2.81 t/WADI/HH/year and 'Scenario 2' gives a more conservative result of 1.43 t/WADI/year. The mean value of 2.12t CO_2 emission reduction gives a reasonably realistic result which lies close to the results of other WADI projects.

<u>SDG 15: Life on Land:</u>

- *Target 15.2: End deforestation and restore degraded forests*

The rate of deforestation is reduced through the project activities, which in a country with frightening rates of deforestation of 2.6%/year is of high importance and even noticeable on HH level. People who use the WADI need less firewood or even no firewood at all to disinfect their drinking water. How much firewood is still needed is influenced by various factors like: usage rate, weather conditions, seasonal variations, functioning of the WADI device, trust in the WADI device, time for firewood collection, money for firewood collection and type of stove, and the individual diet to just name the most important ones. It would be too complex for this study to assess the precise firewood reduction and the corresponding deforestation reduction.

Nevertheless a rough estimation can be made, based on the baseline firewood consumption. The baseline study found that the HHs use 7kg firewood per day for water disinfection (Wornig, 2021, p. 90). So if all water could be disinfected with SODIS, that would give a potential reduction of 14,000 kg for all 2000 HHs. As the WADI usage rate is not 100% but only ~58% as found in the project study, this makes ~ 8100 kg firewood reduction per day. Extrapolated to a year, this is ~ 3000 t and throughout the project duration, this amounts to ~15.000 t of firewood which are neither burnt nor chopped down.

6.1.3.2. Society Level

During the research period, the global COVID-19 pandemic also hit Uganda and therefore the HHs in the project area in many aspects. As the world´s societies and economies have changed drastically due to this emergency, it is nearly impossible to directly compare and justify the monitored changes. A special COVID-19 section was integrated in the survey which tries to at least get a rough feeling of the pandemics impact on people's lives.

<u>SDG 1: End poverty in all its forms everywhere:</u>

- *Target 1.1: By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day*

The average annual reported income of a project HH is 460,000 UGX which at the moment is equivalent to 120€ or US$ 120 per HH per year. That gives 0.33 $ USD per day per HH. Assuming that just the adult male is earning this income, which generally is the case, the HH lies far beyond the extreme poverty definition of 1.25 $ USD / day. So all kind of costs are substantial for these HHs. In the baseline study (Wornig, 2021 see Annex), found an average income of 130€ per HH per month. This would mean a drastic drop in HH income between 2019 and 2021. It is unclear if the pandemic caused that huge decrease or if there was a misunderstanding in the survey. Either way the project beneficiaries have few financial possibilities.

The project study found that the average costs for medical treatment had decreased from ~ 14$ to 11$. This is having at least a little impact on the financial situation. The reduced need for firewood collection has a bigger effect by saving up to 2.5h of firewood collection per day. As this is typically a woman´s chore, it enables them to do other things benefitting the family.

Ending extreme poverty for these families still seems a long way away. The pandemic made poverty even worse. 38% responded to having less income, while 58% said they had no income at all during the pandemic. Only 3% could earn the same income as before. About half of the HHs had to spend all of their savings, one quarter spent some of their savings. Only one quarter of the HHs were able to stay on the same savings level. Furthermore 18% reported that they couldn´t fulfil their basic needs at all, 70% only in a limited way and only 12% managed to have their usual way of fulfilment. SODIS with WADI being a sustainable, time saving and free of cost method, can have a huge impact on their way out of extreme poverty.

SDG 3: Good health and well-being for all:

- *Target 3.3: By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases*
- *Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination*

Waterborne diseases are still a major health treat in Africa. Typhoid fever in particular is one of the most dangerous water-borne diseases in Uganda shown by regular outbreaks. In 2007-2009 in Kasese district more than 8000 people were infected, and in another outbreak in 2015 in Kampala district over 10,000 people got typhoid (Kabwama et al., 2017).

During the project, the reported cases of typhoid decreased from 12.7 % (Wornig, 2021, p. 86) to 10.8%. Other diseases caused by contaminated water like diarrhea decreased from 21.2% to 10%. Less smoke emission was associated with a significant decrease in respiratory infections, especially chronic coughs from 42.5% to 16.4% is observed. A general decrease in the reported amount of sickness is another positive impact of the project. From 72.1 % of HH reporting sickness at least once a month in the baseline study, in the May 2021 survey only 32.1% reported this. So the overall monthly sickness was reduced by more than half.

<u>SDG 4: Quality Education:</u>

- *Target: 4.1: By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes*

The baseline study has shown that children were often obligated to help their parents with household chores like collecting firewood. For up to 17h per week, children, mainly girls (85.7%), had to help their mothers collecting the wood from nearby forests (Wornig, 2021, pp. 89–90). This is often a reason why children don´t attend school. Another one is being ill from water-borne diseases or chronic caught. Both of this reasons are positively impacted by the project activities leading to more time and better health to attend school.

The project study found that 78% of the children of school age attend school, 22% don't. As it is quite common in sub-Saharan Africa for girls and boys between 5 and 14 to help at home, many cultural reasons also affect this situation (WHO, 2016a).

<u>SDG5: Gender Equality:</u>

- *Target 5.B: Promote empowerment of woman through technology*

  The WADI devices were given to women preferably, for two reasons: On the one hand a cultural reason, as the water supply in Uganda typically is a woman´s task. So thematically women are responsible for anything regarding the HH drinking water supply. On the other hand, handing the WADIs to women aims to empower them to manage the new drinking water disinfection method. The time savings of up to 2.5 hours/day through not having to collect firewood or take care of the boiling water, allow the female project beneficiaries to use their time in a different way, for example increasing the family's wellbeing. Therefore women develop ownership over the device, the SODIS method and the whole project. All the knowledge around SODIS helps them to live more relieved lives and gives them more autonomy.

<u>SDG7: Affordable and Clean Energy:</u>

- *Target 7.1.2: Proportion of population with primary reliance on clean fuels and technology*
- *Target 7.3: By 2030, double the global rate of improvement in energy efficiency*

The SODIS method supported by WADI is a clean technology not causing any emissions or health risks in the application. No electricity is needed as it operates with a little solar cell. This makes it very effective for remote areas or underprivileged HHs, without electricity.

As an accompanying measure of the project activities, the typical 3-stone fires were also upgraded in a significant proportion of the HHs. Many families have been taught to build an improved cook stove called 'Lorena stove'. It´s build out of local materials like clay and earth. About 11% of the HHs reported using a Lorena stove, the remaining 89% still depend on the 3-stone fire. Up to half of the firewood can be saved through improved stoves by making the burning process and heat storage more efficient (Uganda Ministry of Energy and Mineral Development, 2008). This again saves time and money and causes less harmful smoke emissions in the hut. In Uganda 63% of all 16,000 child deaths are caused by to respiratory infections that can be directly traced back to indoor air pollution from cooking (WHO, 2015, p. 5). Therefore more improved stoves, in the best case with a chimney, are recommended to be built in future.

The CO_2 reduction potential of improved cook stoves has not been included in the total CO_2 reduction calculation because neither a widespread supply nor a detailed monitoring has happened. Nevertheless it could be another way of achieving firewood and CO_2 savings in the future, and could be included as generating carbon credits as well, if monitoring is set up properly.

6.1.3.3. Interdisciplinary Level (connecting all 3 levels)

<u>SDG 17: Partnerships for the goals:</u>

- *Target 17.3: Mobilize additional financial resources for developing countries from multiple sources*
- *Target 17.7: Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed*

The voluntary carbon market, where the CO_2 savings of the project are sold, provide the main financing. Multiple stakeholders, especially from the European corporate and private sectors, support the project through their CO_2 offset payments.

Different partnerships exist through the project. There is valuable academic knowledge transfer between the BOKU and Makarere University about the accompanying research. Also a close collaboration between the field team in Uganda, the WSU as local experts regarding the WASH improvements on a national level, the Ugandan Ministry of Water and Environment, Helioz as the developer of the WADI and the BOKU as the scientific certifier was essential to guarantee the project operation and project success. Not only was the WADI technology for the SODIS method implemented in the project area, but also all important knowledge transfer, the training of trainers, local capacity building and the inclusion of the beneficiaries needs were made possible. These broad partnerships and workflows contribute to the SDG 17 'Partnerships for the goals'.

6.2. Qualitative Findings

Complementing the findings from the project survey, the focus groups and online interviews also delivered important insights in the impact of the project. The face-to-face connection over zoom enabled people to open up also with intimate topics like menstruation hygiene, disabilities of children and personal fears. One had the feeling that people are free to mention their experiences authentically. A lot of respect, gratefulness and thankfulness was showed and expressed among the project team of WSU and vice versa. The findings are summarized below regarding the project impact, the challenges and individual stories of people from Soroti. Most of them explain and confirm the findings from the quantitative project study, however some differences also came up. The following sub-chapters are bringing attention to the various interconnected SDG impacts reported first hand by local people participating in the project. The underlying information of this chapter is found in Appendix E. Additionally, the researcher used personal communications, which he could remember and reconstruct from the interviews.

6.2.1. Project Impact

Health and wellbeing:

The main impact of the project is the decrease in water-borne diseases as a result of the various facilities installed by the WSU and its field workers that led to a substantial behavioral change in the communities. Not only have the interviewed beneficiaries themselves reported that, but also the regional health officials and the field workers. The various project activities (WADI, improved latrines, hand washing facilities, Lorena stoves, ect.) of WSU around clean water, sanitation and hygene, resulted in nothing less than essential live improvements for the local people. The district health officer said: "*The overall objective of the project interventions was to improve people's lives, and by lives I mean, their health and wellbeing. All of that on household and institutional level […] like in schools, churches, trading centers.*". He continued: "*The biggest benefit [of the* *project] on a macro-level is the social-economic transformation of the lives of people, because a healthy person is a productive person. If you are healthy, you are able to work and produce income, if not, your little income has to be used for [medical] treatment. About 75 % of the diseases in Africa are preventable therefore the [project´s] strategy for preventing diseases goes along with changing the lives of the population." (District Health Officer, personal communication, November 17, 2021)*. The local health inspector also confirmed the decrease of water-borne diseases: "*Apparently we have seen a significant downward trend of this data since the project activities – there is a contribution! (Local Health Inspector, personal communication, November 17, 2021).* Furthermore a beneficiary reported, that she had realized, that since she started practicing SODIS with WADI, the frequency of her children falling sick dropped drastically. "*If you compare data, people who use SODIS have significantly lower sickness!*", a field worker summarized (Local Field Worker, personal communication, November 18, 2021).

So broad consensus was communicated among the positive health impacts and its resulting wellbeing effects. More school attendance, monetary savings, smoke free kitchens, and even an improvement from grass roofed houses to permanent structures were achieved. Also a reduction in domestic violence and a growth in the sense of community among the group members was reported.

> "*Whereas this small interventions like SODIS, water bottles, trainings, improved cook stoves, tree planting and forming community groups and so on, they look simple in terms of macroeconomics, but if you put all of them together prospectively they are making a very very significant contribution in the social economic transformation for the people of Gweri.*" (District Health Officer, personal communication, November 17, 2021).

Many neighboring communities wished for an expansion of the project, to also be benefited by its activities.

<u>Firewood reduction and environment</u>:

The use of energy-efficient cooking stoves is perceived as not only helpful in minimizing respiratory and eye infections for mothers and children, but also as beneficial toward environmental conservation. The local field worker built 45 'Lorena Stoves' (shown in Fig. 21) by himself and trained people from the villages to be able to construct these stoves on their own. Many of the HHs thereby already appreciate a significant fuel wood reduction. The health inspector commented on this success:

> "*We have bundles [of firewood]. You use one bundle to prepare one single meal [with a traditional 3-stone stove], which is too much firewood being spent. At this time [with efficient cook stoves] you can use one bundle to spend about almost a week. That time*

there was a lot of smoke but this time there is limited smoke in the house. So no interference of eyes crying, having running nose, [...], so the women reported that their lives have improved." (Local Health Inspector, personal communication, November 17, 2021).

The fire wood reduction of the new stoves was not included in the total CO_2 reduction calculation as it is not the core of the project activities and precise monitoring was missing, even though it has a huge emission reduction potential.

Fig. 21: Example of a 'Lorena Stove' in a HH in Soroti (WSU, 2021)

Due to the high deforestation rate of the project area, it was emphasized by WSU that every HH should plant about 15 trees every year, to compensate for the trees still being cut down and to restore the local environment.

<u>Hygiene</u>:

One key activity was the awareness building about menstruation hygiene:

> "*Trainings on menstrual hygiene management especially in schools has helped [to] break the silence and demystify menstrual hygiene management. They also taught our girls how to make reusable sanitary towels which has helped reduce stigma and poor self-image*" (Project beneficiary 1, personal communication, November 18, 2021).

Also people can now shower inside the house rather than with a bowl of water in the back of the house. Furthermore open defecation was minimized. As COVID-19 and its health-related awareness came up, handwashing facilities were already in place in the project area.

Usage of WADI:

Most of the community members have taken up the WADI kits. People already own the project, the fieldworker reports: "*It is not our program, it is your program. It is coming to help the community, not actually us*" (Local Field Worker, personal communication, November 18, 2021). According to him, the participating HH can be separated into 3 groups:

1. Users on a daily basis: about 800 HHs are using the WADI on a day to day basis as they usually disinfect the water demand for one day.
2. HHs using it every 2-3 days: around 1100 HH have more bottles available to also store their disinfected water for another 1-2 days. They can even satisfy their demand of the following days with this usage rate.
3. HH having a negative attitude regarding SODIS / WADI: approximately 100 HH don´t use their devices. The reason are manifold. For example, some community leaders are negative about the program and therefore spread the rumor that WADI water causes cancer.

Within the first and second group, immediate thirst makes people still drink some of their daily demand for water from ponds or other unsafe sources. At times when the WADI water is not yet finished or stored somewhere inaccessible for immediate need, this still occurs. One woman reported that given she is a widow, she has too many responsibilities and a lot of work to do on her own, so practicing SODIS would be too time-consuming for her. Furthermore she reported a different taste after disinfection, which she doesn´t like. Therefore she is sticking to her traditional water consumption. Another beneficiary reported that she also observed that the habit of processing drinking water in her home is now entrenched and even when she is away, the children and other members do it. She is thankful for the new knowledge and skills which she has committed to pass on to others so that their lives can be transformed too.

6.2.2. Challenges

One of the biggest challenges is the effect of climate change. Water shortages due to a prolonged dry season caused massive crop failure last year. From June till November 2021, there was no rain at all. Then the rainy season from August-September 2021 just didn´t appear, so when the dry season was just about to start, the ponds, local swamps and rivers had almost no water left. The local field worker described the effects of this threat. He noted that people in water shortages drink contaminated water from rivers and lakes, while in the rainy season, if it occurs, extreme rainfalls are increasingly damaging people's facilities.

> "*Yes it is that serious but we are moving on – moving on just like that*. *[…] November up to March people somehow try to survive, regardless of the water quality." (Local Field Worker, personal communication, November 18, 2021).*

In general, the water availability is very low. One beneficiary reported that up to 360 HH share one borehole. This causes hours of waiting to fetch the water. People who have to walk a long distance, often fall back on contaminated surface water in those situations. So if people don´t have enough water, they won't do any treatment at all. If there were more boreholes, the field worker estimated, then people would be willing to practice SODIS more regularly.

Some beneficiaries reported to have too few bottles, as they have been broken or got lost. Some of them reported cases of stealing of the water bottles and the WADI device. When people leave home leaving the bottles out in the sun, they fear that they might be stolen. Also a fear of poisoning the WADI water by bad community members was expressed by one beneficiary.

For the health officials, it is a challenge to reach the communities, due to missing infrastructure. The villages are expanding quite fast to very remote areas, where it gets hard to supply them. Another challenge during the pandemic was that it has been difficult to gather beneficiaries for further trainings. Schools, which worked as epicenters for knowledge, have been closed for about 2 years in Uganda. These are some of the hindrances of the project.

6.2.3. Individual Stories

Some highlight moments were shared in the interviews. For example, the health inspector was very surprised by the state of the HHs when she visited the project area after project activities were in place:

> "*Actually one time, we moved to one of the HHs, I was impressed. The head of the HH was a very young man and a very young women but their home was so pleasing. Everything*

was so pleasing, the hand washing was in place, there was water, I really felt so impressed and I said: 'Wow, this is meant by being in the community and people taking in what you have told them'. I was so impressed, I was very happy and I moved to the next house. I thought it was only one HH like that, [but] the next home I moved to had the same! I was like 'What is the secret of this community?' See it is like people learned that every home must have these things in place. And there were looking so good. […] I asked them what challenges they still have but they said no, we not have any challenge from that very time our life got transformed. […] I felt so good and I felt so happy for this families." (Local Health Inspector, personal communication, November 17, 2021).

This success may be due to the good set up of the program. The biggest learning for the District Health Officer in that regard was:

"*Start small with the community together and expand extensively so that whatever you achieve becomes sustainable. Allow communities to take decisions in a participatory manner, because in the end of the day they will be owned by the communities. So now the WADI and the bottles are owned by the communities, the ferrocement tanks are owned by the schools [ ], the improved cook stoves are owned by members of the HH.*" (District Health Officer, personal communication, November 17, 2021).

There was also a note on the importance of more efficient cook stoves because it is so much better for the people and the environment. The field worker who personally builds them said:

"*Three-stone fires waste a lot of firewood. Therefore every HH should have a Lorena. It´s not only about cooking but about saving the environment. I love [constructing] it and I do it with passion!*" (Local Field Worker, personal communication, November 18, 2021).

7. Conclusion and Outlook

Given the various global social and environmental challenges we are facing, this case study shows how simple techniques on existential levels like SODIS with WADI can transform people's lives in so many ways. In global dimensions, the project might have just a small impact on climate change mitigation quantitatively with 21,200 t CO_2 reduction, but on a qualitative level it enables the transformation of whole communities through HH empowerment. The identified emission reductions of 2.12 t CO_2 per WADI are in line with findings from similar projects (Helioz, n.d.–b; see Schmitz & Reisinger, 2018).

The project 'Clean Air and Safe Drinking Water for Soroti' is only one example of how carbon credits can have a meaningful impact improving the lives of over 16,000 people. Without a doubt carbon credits are a very controversial concept involving the risk of also being counterproductive to reach our Paris climate goals, the Agenda 2030 or net-zero emissions. Nevertheless carbon credit financing is an increasingly hot topic, which can also be a potential for necessary developments, if set up with the right intentions and monitored rigorously. It can be a valuable interim solution in the near term, until broader climate policies will be established. Until government regulations for CO_2 reductions, which should be compulsory on many levels, are in place "*carbon markets can act as a subsidy that smooths the transition towards a low-carbon future. As an incubator for innovation, they can address a wide array of emission sources and promote new promising technologies. Once we inhabit that future, there will not be room for carbon markets any longer.*" (Streck, 2021, p. 374).

For the people in Soroti, a new area of improved health and reduced need for firewood has begun. With the WADI they have the possibility to benefit not only in health but also in time savings, increased autonomy, strengthened sense of community, more time for family or income generating activities, higher rates of school attendance and a regeneration of surrounding trees and ecosystems, to name just a few. These positive effects of the project activities are recognized by the majority of the local people and the wish for prolonging the project duration and expanding the project area to neighboring villages has been expressed repeatedly.

Most of the findings show that there is a broad feeling of ownership among the project and that the majority of the beneficiaries practices SODIS on a regular basis, even though the total water demand can only be satisfied partly by the WADI as simply to less water is available and immediate need for water is still often satisfied by unsafe water sources. The various facilities and trainings provided by the local partner WSU make a remarkable improvement for the HHs in the communities. Many things on various SDGs have improved since the project started. Nevertheless the big challenge of the COVID-19 pandemic has hindered the project progress within the last two years. As regular trainings and HH visits have not been possible, arising problems couldn´t be tackled straight away and caused a slip in the HHs focus. During this pandemic, it was about bare survival even more in this families which were suffering extreme poverty anyway.

The biggest challenge may be the loss and damage of bottles and also some WADI devices. Despite a new delivery of bottles after the hard lockdown, regular emphasis for the replacement of broken bottles and devices is needed in future to ensure the possibility for constantly doing SODIS for the HHs. It is further recommended to keep up regular trainings, meetings and HH visits to secure broad capacity building. "*Building up capacities is the key!*", notes the District Health Officer (personal communication, November 17, 2021) , when it comes to the sustainability of the project success. Including the people impacted by the project from the very beginning onwards in a participatory manner may be the biggest learning and recommendation for similar projects.

As an outlook for the project duration, the emission reductions could go up again or can even be further increased through ambitious post-pandemic interventions and replacement of bottles. It is recommended that more and more HH get Lorena stoves to further reduce firewood emissions. This could halve the emission from cooking. If monitored properly and included into the total CO_2 reduction calculation, these emissions could also be verified to generate carbon credits in future.

This research showed a way that a project´s impact can be quantified. Through SODIS and its resulting co-benefits a measurable effect on CO_2 reduction and various other SDG impacts could be described. Even though quantifying SDG impacts on local project level is still in its early stages of development, possibilities exist to do so. The use of methodologies and new impact tools like the ones used and mentioned in this thesis would be favorable to see more in future scientific work. This can make the effect of SODIS and also other important project activities more visible and understandable to a broad audience.

Overall the findings are a good example of how interconnected safe water, improved livelihood, environmental protection and climate mitigation can be. To solve global problems like climate change, many local solutions that are sustainable, clean and at the same time increase the livelihood for people are needed.

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Appendix A: Soroti Project Scenario Survey – Questionnaire

SOROTI PROJECT SCENARIO SURVEY
May 2021 INDIVIDUAL AND HOUSEHOLD QUESTIONNAIRE

Name of Enumerator: ……………………………………………. Name of Supervisor: ………………………………………………………………. Date of Enumeration: …………………………

Number: ……   District: SOROTI   Sub-county: GWERI   Parish: ………………………………   Village: ……………………………………

1. Beneficiary identification

	1.1 Name of respondent and gender 1=Male 2=Female	**1.2 (E)** Number of Household members. Adults/ Children *Please fill in numbers below*	**1.3** HH has freely given information and wants to take part in this survey? 1=yes 2=no	**1.4** Age of respondent in full years (Figures) *Please fill in age below*	**1.5** Educational status of respondent 1=None 2=Primary 3=Secondary/ Vocational 4=Tertiary/ Post-Secondary	**1.6** Do children in this HH older than 5 years attend school? 1=yes 2=no	**1.7** Does anyone in this HH have a physical disability or mental disability? 1= yes 2=no	**1.8** What is your major occupation? 1 =Farming 2= Fishing 3= Business 4= Student 5= Employee 6= Others *(specify below)*	**1.9** How much was your approx. total HH income last year? *Please fill in an amount of UGX*	**1.10** Do you have any HH savings? 1=yes 2=no	**1.11** Was your home part of the baseline survey early 2019 where firewood was weighed? 1=yes 2=no
Answer + Comments	○ 1 ○ 2 Name: __________	No. | Sex: M | F Adults Children (<18 years) Total =	○ 1 ○ 2	_________years	○ 1 ○ 2 ○ 3 ○ 4	○ 1 ○ 2	○ 1 ○ 2	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6: _________	_________ UGX	○ 1 ○ 2	○ 1 ○ 2

2. Household Water and Water Treatment

2.1 (E) What is your main source of water for **drinking** / for **HH use**? *Please fill in the answers below!* 1=Tap Water 2= Borehole 3 = Shallow well 4 = Protected springs 5 = Rain harvesting tank 6= Surface water (river, lake, pond) 7=Do not know 8=Others *(specify)*:	**2.2** What is your main source of water during **dry / rainy** season? 1=Tap Water 2= Borehole 3 = Shallow well 4 = Protected springs 5 = Rain harvesting tank 6= Surface water (river, lake, pond) 7=Do not know 8=Others *(specify)*:	**2.3** Do you have any **problems** with collecting water? 1=yes 2=no	2.3.1 If "YES", what are the problems? **(MA)** *Select as many as apply* 1= Waiting for a long time 2=Long distance 3=Only available some times of the day (trucking, water rationing, poor aquifer) 4=Shortage during dry season 5=Safety concerns 6=Bad taste/smell 7= Turbidity 8=Other *(specify)*	**2.4** What is the **distance** in meters **to** the drinking water **source**? 1 = 0 – 250 meters 2 = 250 – 500 meters 3= 500 – 750 meters 4= 750 – 1000 meters (1 kilometer) 5 = 1000 – 15000 meters (1 – 1,5 kilometers) 6= 1500 – 2000 meters (1,5 – 2 kilometers) 7 = more than 2 kilometers	**2.5** **How long** does it take to fetch water from this source (to and from)? 1= 0 – 10 minutes 2= 11 – 30 minutes 3= 31 – 60 minutes (1 hour) 4= 1 – 2 hours 5= more than 2 hours	**2.6 (E)** How many **liters of clean water** does your household use in total **per day** for drinking, cooking, hygiene, etc.? *Please fill in a number below*	**2.7 (E)** Do you generally **treat** the **water** in any way before drinking it? 1=yes, always 2=no, never 3=some-times, if possible/ necessary	2.7.1 (S) If "YES"/" SOMETIMES", **how** do you usually **treat** your drinking water? **(MA)** 1=Boiling 2=Chemical treatment (Chlorination, Aqua tabs - water purification tablets) 3=Cloth filters 4=Ceramic filters 5=Household sand/coal filters 6=Leave bottles with water in the sun (SODIS) and use WADI device 7=Other *(specify)*
Answer + Comments Drinking: o 1 o 2 o3 o 4 o 5 o 6 o 7 o 8: ________________ HH use: o 1 o 2 o3 o 4 o 5 o 6 o 7 o 8: ________________	Dry season: o 1 o 2 o3 o 4 o 5 o 6 o 7 o 8: ______________ Rainy season: o 1 o 2 o3 o 4 o 5 o 6 o 7 o 8: ______________	○ 1 ○ 2 → ***skip to 2.4***	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8: _________	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7: ___________	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	_________ liters	○ 1 ○ 2 → ***skip to Section 4.*** ○ 3	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 →***if answer 6*** *was among given,* ***continue*** *with* ***Section 3***. *("SODIS/ WADI specific treatment").* ○ 7: __________ → ***otherwise skip to section 4.***

3. SODIS / WADI specific water treatment (<u>only if answer to question 2.7.1. was answer “6”</u>)

	3.1 (E) QUESTION FOR ENUMER-ATOR **If the sun is shining during your visit, is the WADI in use outdoor?** **1= yes** **2= no**	3.2 (E) QUESTION FOR ENUMER-ATOR **What is the condition of the WADI?** *Please request to have a look at the device!* **1 = good** **2 = WADI got lost** **3= noticeable mechanical damages** **4= electronic damages (no face visible)** **5=other:**	**3.3** Can you briefly explain how to do SODIS and use WADI? *Please interpret the knowledge of the interviewee* 1= can´t explain 2=poor 3=sufficient 4=good 5= excellent	3.4 (E) How often **did** you practice SODIS / use WADI **in the years 2020 and 2019** on average? (usage rate) 1=Never 2=1-2 days per week 3=3-4 days per week 4= 5-6 days per week 5=everyday	3.5 (E) How often **do** you practice SODIS/ use WADI **currently in a week** on average? (usage rate) 1=Never 2=1-2 days per week 3=3-4 days per week 4= 5-6 days per week 5=everyday	3.5.1 (E) If this rate of practicing SODIS / use WADI changed from then to now, why? 1=no change in usage rate 2= Water disinfection not necessary anymore 3= WADI device broken/got lost 4= lack of usage knowledge 4= decrease in awareness 5= water demand changed 6= increase in awareness 7= SODIS / WADI became a common routine 8=other:	3.5.2 (E) How much of your drinking water demand can you satisfy with your current usage rate? 1=nothing 2= up to half of total water demand 3=more than half of total water demand 4= the total demand	3.6 (E) If you don´t use SODIS/WADI every day currently, why not? Give a reason and tick your answer(s) **(MA)**: 1=not necessary because I can store finished WADI water up to two days 2=rainy season/clouds 3=no smile on WADI display 4=lack of knowledge 5=lack of bottles 6=no trust in WADI technology 7=lack of water 8=WADI is broken or lost 9=other	3.7 (E) How many Liters of water do you disinfect with SODIS/ WADI per day? *Please fill in a number below*	3.8 (E) Do you boil water after it was treated using SODIS/ WADI? If YES, how many liters of it? *Please fill in a number:* 1=no 2= yes *(specify below in liters/HH/day)*	3.9 (E) How is treated water stored at home? 1=Jerry can 2=Clay pots 3=Water tanks 4=Sauce pans 5=Bottles 6=Buckets 7=other *(specify)*
Answer + Comments	○ 1 ○ 2	○ 1 ○ 2 ○ 3 ○ 4 ○ 5: ____________________________	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8: ________________ ____________	○ 1 ○ 2 ○ 3 ○ 4	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9: ____________	_______ liters	○ 1 ○ 2: _____ Liters per HH/day	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7: __________

4. Water treatment practices continued

	4.1 (E) Do you boil **water for drinking in addition** to the usage of SODIS / WADI? **(MA)** 1=yes 2=no 3= I don't use SODIS / WADI and I don't boil the water before drinking it	4.1.1 (E) If you ticked "YES": **Why** is additional boiling of water necessary? **(MA)** *Tick your answer(s) below:* 1= rainy season/clouds 2=no smile on WADI display – water not ready to drink 3= not enough bottles 4=additional water demand 5= other (*specify below*)	4.1.2 (E) If you ticked "YES", **how many** Liters do you **additionally** boil in a day? *Please fill in a number below*	**4.2 Where** do you **heat up** your water/ **cook** mostly? 1=indoors 2=outdoor	**4.3** Do you heat up water **for other purposes** than drinking in addition to the usage of WADI? 1=yes 2=no	4.3.1 If you ticked "YES", for what other uses do you heat up water? **(MA)** 1= tea/ coffee 2= hygiene 3= bathing 4= Local Beer 5= cooking 6= other (specify below)	4.3.2 (E) If you ticked "YES", how much water do you heat up for other uses in a day? *Please fill in a number below*	4.3.3 If you ticked "YES", how often do you heat up water for other uses /not for drinking in your household? 1=Every day 2= 1-2 days/week 3= 3-4 days/week 4= other *(specify)*
Answer + Comments	○ 1 ○ 2 → ***skip to 4.2*** ○ 3 → **skip to 4.2**	○ 1 ○ 2 ○ 3 ○ 4 ○ 5: ______________	__________ liters	○ 1 ○ 2	○ 1 ○ 2 → ***skip to section 5***	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6: ________ ○	_____________ liters	○ 1 ○ 2 ○ 3 ○ 4: ____________

5. Energy source - Firewood (only if answer to question 5A was answer "1" or 2")

	5.A (E) (S) If you heat up any water for drinking or other purposes, how do you heat it up (energy source)? 1= with firewood 2= with charcoal 3=with electricity 4=with biogas 5= no, I Don't heat up any water 6=other *(specify)*	**5.1 (E)** How much firewood and/or charcoal do you use for **boiling water** for drinking during a day? **(MA)** *Please estimate and put in kg / basins*	**5.2** How much firewood and/or charcoal do you use for **cooking** during a day? *Please estimate and put in kg*	**5.3 (E)** Which type of cook stove do you use mainly in your HH? 1 = 3 stone fire / open fire 2 = simple clay stove 3 = improved cook stove without smoke outlet / chimney (eg. Lorena) 4 = improved cook stove with outlet / chimney (eg. Lorena with chimney) 5 = electric cook stove 6 other *(specify below)*	**5.4** Do you have to pay for your firewood / charcoal? 1=Yes 2=No 3=Some-times	5.4.1 If "YES"/ "sometimes", how much do you pay for firewood / charcoal for a week? *Please fill in UGX/week*	5.4.2 If "NO", who **mainly** collects the firewood? 1= We don´t use any firewood 2= Adult male 3=Adult female 4=Child male 5=Child female 6=A neighbor helps 7=Other:	5.4.3 How much time does the person spend on collecting and carrying firewood during a day? (skip if only "charcoal") *Please fill in hours/day*	**5.5** What is the distance in km to get the whole firewood and carry it home? (skip if only charcoal) *Please fill in Distance in km/day*
Answer + Comments	○ 1 → **continue** with 5.1 ○ 2 → **continue** with 5. ○ 3 → **skip** to section 6 ○ 4 → **skip** to section 6 ○ 5 → **skip** to section 6 ○ 6: ____________ → **skip** to section 6	__________ kg firewood __________ basins of charcoal	__________ kg firewood __________ basins of charcoal	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6: ____________	○ 1 ○ 2 → ***skip to 5.4.2*** ○ 3	____________U GX/week	○ 1 → **skip to section 6.** ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7: _________	________________ _ hours/day	________________ km/day

6. Health

	6.1 In the last 3 month did anyone in this HH fall sick? **(MA)** 1 = yes 2 = no If YES, from … *tick your answer(s)*		6.1.1 If "YES", for how many days was s/he sick? *Please fill in days below*	6.1.2 If "YES", Did they get treatment? 1=yes 2=no	6.1.3 if "YES", where was s/he treated? 1=Health center 2=Home – self care 3=Herbalist 4= None	6.1.4 If "YES", how much money was spent on the treatment 1= *please fill in amount in UGX below* 2= Free treatment	**6.2** On average, how much do you spend on medical treatment/ medicine when someone falls sick once? *(please estimate amount in UGX below)*	**6.3** How often do you or your family members on average fall sick? 1= Weekly 2=Monthly 3=every 2 months 4=Quarterly 5= Every 6months 6=Once a year 7=Never	**6.4** Does drinking non - treated water lead to health problems and diseases in your household? 1=yes 2=no	6.4.1 If "Yes"/"No", why? *Please explain below:*	**6.5** How did the overall health situation in your HH change since the implementation of the WADI project? 1= strong improvement 2= slight improvement 3= no changes 4= slight deterioration 5= strong deterioration
Answer + Comments	○ 1 ○ 2→ ***skip to 6.2***		_________ days	○ 1 ○ 2	○ 1 ○ 2 ○ 3 ○ 4	○ 1: __________ UGX ○ 2	_________ UGX	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7	○ 1 ○ 2	__________ __________ __________ __________ __________ __________ __________	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
	Diarrhoea?										
	Vomiting?										
	Gastro intestinal worms?										
	Respiratory tract infections?										
	Cough?										
	Typhoid Fever?										
	COVID – 19?										
	Fever?										
	Abdominal pain?										
	Malaria?										
	Others *(specify)*										

7. Household sanitation and hygiene

	7.1 Where do you and other adult household members (excluding children under 5) usually go to defecate? **(MA)** *Select as many as apply* 1= Single household latrine 2=Shared household latrine 3=Communal/public latrine 4=Open defecation 5=Plastic bag 6=Bucket toilet 7=At facilities (e.g. school, health clinic) 8= Other *(specify):*	7.1.1 If "LATRINE", which assets does the latrine have? **(MA)** Please list answer(s) 1= just an simple pit latrine 2= insect protection: tight cover OR Satopan 3= ventilation 4 = safe distance of a minimum of 10 meters to water source	7.1.2 If "LATRINE", does the latrine have a handwashing facility with soap/ash? *Select only **one** option* 1 = Yes, with water 2 = Yes, with water and soap/ash 3 = No, take my own soap and water 4 = No, water and soap/ash only sometimes available 5 = No, water and soap/ash never available	**7.2** Hand washing practices: Do you wash hands? 1= yes 2= no	7.2.1 If "YES", when? **(MA)** *Please list answer(s) below* 1=Before eating 2=After eating 3=When hands are dirty 4=After sneezing 5=After visiting the toilet 6=After cleaning children´s pupu? 7=After sleeping 8= Other: *(specify below)*	**7.3** What challenges do you face when getting soap? **(MA)** 1= Soap is not available 2= Need money for other purposes than soap 3= Soap is too expensive 4= I use an alternative (Ash, mud, soil, sand,…) 5= No challenge. Soap is easy to get	**7.4** Do you think if you wash your hands regularly, you will stay healthy? 1= yes 2=no 3=Unsure	**7.5** Where does your household dispose domestic waste? **(MA)** 1=Household pit 2=Garden 3= Designated open area 4=Undesignated open area 5=Bury it 6= Burned 7=Other: *(specify)*
Answer + Comments	○ 1 ○ 2 ○ 3 ○ 4 → ***skip to 7.2*** ○ 5 → ***skip to 7.2*** ○ 6→ ***skip to 7.2*** ○ 7→ ***skip to 7.2*** ○ 8: ________________ → ***skip to 7.2***	○ 1 ○ 2 ○ 3 ○ 4	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 → ***skip to 7.3***	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8: ______________	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7: _________

8. COVID – 19

	8.1 (E).	**8.2**	**8.3.**	**8.4 (E)**	**8.5**	**8.6**	**8.7**	**8.8**
	How did your HH size change during the pandemic in comparison to your usual HH size? 1= 1-2 additional people living in the HH 2= 3 or more additional people living in the HH 3=same HH size 4= 1-2 people less living in the HH 5= 3 or more people less living in the HH	Could your HH generate income in the pandemic? 1= no chance to earn any money 2= less money available 3= same income situation 4= more money available 5= much more income than before	How has the current pandemic influenced your household savings? 1 = had to spend all HH savings 2 = some HH savings were used up 3 = no change 4 = could put more savings aside than before	How did your awareness regarding water safety and sanitation change due to COVID-19? 1= More awareness 2= same awareness 3= Less awareness	How did your awareness regarding the relation between health and safe water change? 1= More awareness 2= same awareness 3= Less awareness	How did your hand washing and hygiene practices change? 1=Less attention 2=Same practices 3=More attention to clean hands and improved hygiene 4=Strong focus on clean hands and safe water and waste water impacts	How much do you think that illness and water consumption are interconnected? 1=no connection 2=some connection 3=very high connection 4= I don´t know	Can/could you fulfill your basic needs (food, water, electricity, community, etc.) during the pandemic? 1=not at all 2= limited 3=same as usual 4= more than usual
Answer + Comments	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4 ○ 5	○ 1 ○ 2 ○ 3 ○ 4	○ 1 ○ 2 ○ 3	○ 1 ○ 2 ○ 3	○ 1 ○ 2 ○ 3 ○ 4	○ 1 ○ 2 ○ 3 ○ 4	○ 1 ○ 2 ○ 3 ○ 4

Appendix B: Soroti Project Scenario Survey - Description for Enumerators

Description for Enumerators

Preparation before the HH visits:

- Please make yourself familiar with the survey and the single questions to avoid misunderstanding: the questionnaire is separated in a **Question line** (upper part on each sheet) and a **"Answer + Comments"** line (lower part). Answers and necessary comments should only be filled in in the "Answer + Comments" line)
- Please look at the Document: ***"Sample Survey SOROTI PROJECT SCENAROI SURVEY"*** and try to understand the answering procedure and the logic behind the document – if you have questions, try to clarify them with your colleagues or the coordinator of the survey at WSU
- Please try to make sure, that the HH are asked and informed about the survey visits in MAY 2021 in beforehand to avoid complications.

At the HH visits:

- Please try to **respect people's homes**, time resources and their **privacy** and **be friendly**
- Make sure, that people are **freely participating** in the survey and take some time to talk to you. Don´t insist on the interview, if somebody is not comfortable or not available at that time. Try to find another appointment (maybe later on the same day).
- Please be **grateful for every single interviewee**, and **thank them** at the start of the interview for their willingness to participate in the survey to help us to further develop the project.
- Please number the Interview (Field **"Number"**) for identification reasons and **tack the sheets** of one survey together
- First collect the **"1. Beneficiary Information Data"**
- Then continue with the rest of the **sections (2. – 8.)**: try to ask questions as **exact as possible** and useful to original wording
- Keep the questions as **open dialog** and **let the interviewees respond in free words. Don´t read out** the possible **answers** (only if absolutely necessary due to misunderstanding). **Tick** the number of the answer(s) **(e.g. " o 2")** **which is/are closest to the given answer options** in the **box "Answer and Comments".**
- All the questions with the add-on: **"(MA)"** = **Multiple Answers** allow multiple answers (**more than one is allowed** if appropriate, **but not necessary**)
- All the **bold** numbered questions (e.g. "**3.1**" are **main questions**, all the **not bold numbered questions** (e.g. "3.1.3") are **follow-up questions** belonging to the main question before. The follow-up questions only need to be asked if a certain answer was given. If this certain answer is not given, just leave the answer box blank and skip to the next main question. (See explanation in the "Answer and Comments" fields (e.g.: "→skip to 3.5") and the filled ***Sample Survey SOROTI PROJECT SCENARO SURVEY***)
- Every time people answer something which is not mentioned in answer options, please specify their answer in your own words as short as possible in the **field** "**Other:"** in the **"Answer + comments"** below at the marked place (e.g.: "**5:** _________") (see the filled ***Sample Survey SOROTI PROJECT SCENAROI SURVEY***)
- Please **write down comments** (e.g. additional useful information, observations, doubts of interviewees understanding, occurring patterns/problems with a specific question, etc.) as well in the "Answer and Comments" box **if applicable**
- Special questions:
  - The questions with a blue background color and the code "(S)" signal the skip to another section of the interview (Q 2.7.1 and 5A), if a specific answer is given
  - The questions with a grey background color and the code **"(E)"** signal that these questions are **essential** questions
- At the end of the interview, **thank your interviewee(s)** for their time and offer them to add any additional/important information, requests or comments
- Offer them to answer open questions they have
- Keep all the sheets of the survey together & dry and continue to next HH
- Enjoy your visit in the project area.

Thank you for your great effort and important work!

Appendix C: Qualitative Interviews: Semi structured Questionnaires

1. Focus group discussion – Project beneficiaries: Moderators guide tool (2nd draft)

Introduction

- Background topic and objectives of this group discussion: scientific research, insights in the local situation, their personal opinion – not about right or wrong
- Ground Rules: 1. Snacks and drinks, mobile phones, recording consent, no wrong answers, my role

Opening Question:

- ***Please tell us your name and briefly introduce yourself to the group by telling us what is your personal connection/your role is in the WADI/Sodis Project in Soroti?***
- Can you describe the current drinking water situation in your village? How do your daily routines/ work around drinking water look like?

WADI Project – look back

Please take a moment to look back on the whole project that started 3 years ago, when you first got the WADI devices.

- *How has the drinking water and health situation changed in your village till today?*
- *How would you describe the overall effect on your life and your wellbeing of the project?*
- ***What are the benefits of the WADI/SODIS system for you?***
  - *Health changes? Sanitary changes – latrines, tipitap? Water quality changes?*
- ***What other benefits did the project bring to your life besides the drinking water aspect?***
  - ***Kids? School? Time or money saved?***
- *What did you like most about the WADI system?*
- ***What are the biggest challenges for you?***
  - *Bottles , Water sources, Storage, technical problems, weather, adapt to new practices, health issues,…?*
- ***Can you remember a special moment, that was of special meaning for you personally, that you would like to share?***
- What feelings come up, when you think about the project

WADI Project – technical

- ***Are you treating your water before drinking it?***
  - ***What are the criteria if you treat or don't treat your water?***
  - *Who of you still uses the WADI as your main way of drinking water purification?*
  - *Why/Why not? Please specify your situation.*
  - *What are the factors why you could / could not maintain your WADI device and the bottles and keep the new drinking water habits?*
- *How well accompanied did you feel by the local field team and WSU?*
- ***Change in firewood usage during the last 3 years with the usage of WADI: Please raise your hand if you would say –same, - more, -less?***
  - *Could you explain to me why … was that case for you?*
  - *How of you could get a more efficient cook stove?*
    - *How sufficient is it for you?*
- *What did you do with the old/broken plastic bottles?*

Future + Closing

- ***What are your wishes and what are your concerns for the future of your drinking water situation?***
- *What are the habits/findings/benefits you want to continue in future?*

2. Focus group discussion – health officials: Moderators guide tool (2nd draft)

Introduction

- Background topic and objectives of this group discussion: scientific research, insights in the local situation, their personal opinion – not about right or wrong
- Ground Rules: 1. Snacks and drinks, mobile phones, recording consent, no wrong answers, my role, reporting back opportunity

Opening Question:

- ***Please tell us your name and briefly introduce yourself to the group by telling us what is your personal connection/your role is in the WADI/Sodis Project in Soroti?***
- What feelings come up, when you think about the project.

WADI Project – look back

Please take a moment to look back on the whole project that started 3 years ago, when the beneficiaries got the WADI devices.

- ***From your point of view, how has the health situation (drinking water related) changed in the project area?***
  - *Diarrhea diseases, Lung diseases, Infections,…*
- *How would you describe the overall effect on health and wellbeing of the project?*
  - *Same, improved, worse?*
  - *What in detail would you say is the reason for this kind of change?*
- ***Where do you personally see the biggest benefits of the WADI/SODIS system?***
  - *Health changes? Sanitary changes? Water quality changes? → each tries to find 3*
- *Who of you, would say, that you in Uganda are harmed by climate change in any way?*
  - *Would you like to share some thoughts to this?*
- ***Where do you see the biggest challenges in using the WADI/Sodis?***
  - *Bottles, Water sources, Storage, plastic issue, adapt to new practices, health issues,…?*

WADI Project – technical

- ***How would you describe the general drinking water situation in Soroti in?***
  - ***What challenges do people face?***
- ***In comparison to other drinking water related projects, how would you rate the SODIS method / WADI device?***
- ***What would you say, in which ways the project is contributing to the sustainable development goals of the UN?***
- *What impressions / feedback / observation about the project in Soroti did you collect since the beginning 3 years ago?*
- ***Can you remember a moment within the project, which was of special meaning for you personally, that you would like to share?***

WADI Project – technical

Future

- ***What are the biggest learnings so far, which you take with you from the project in Soroti?***
- ***How could the situation of the beneficiaries be improved even more?***

Closing

3. Focus group discussion – local team: Moderators guide tool (2nd draft)

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Introduction:

Background topic and objectives of this group discussion: scientific research, insights in the local situation, their personal opinion – not about right or wrong

Ground Rules: 1. Snacks and drinks, mobile phones, recording consent, no wrong answers, my role, reporting back opportunity

Opening Question:

Please tell us your name and briefly introduce yourself to the group by telling us what is your personal connection/your role is in the WADI/Sodis Project in Soroti

Which feelings come up, when you think about the project?

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WADI Project – look back

As the team you have very special role and know a lot about many different households and many elements of the situation over a long time , please take a moment to look back on the whole project that started 3 years ago, when the beneficiaries got the WADI devices.

- ***From your point of view, how has the overall situation changed in the project area?***
  - *Health, drinking water, sanitation, hygiene, wellbeing*
- *How would you describe the overall effect on health and wellbeing of the project?*
  - *Same, improved, worse? What is reason for this change?*
- ***Which unexpected positive or negative impacts / changes did surprise you?***
  - *On forests, biodiversity, women movements, revolutions for village?*
- ***Where do you personally see the biggest benefits of the WADI/SODIS system?***
  - *Health changes? Sanitary changes? Water quality changes?*
- ***Where do you see the biggest challenges in using the WADI/Sodis?***
- ***What was your impression of your work in the field- what were your observations? Any patterns?***
  - *Easy/Difficult to change, motivation of beneficiaries, observations, change in awareness/practices?*
  - *Bottles, Water sources, Storage, plastic issue, adapt to new practices, health issues,…?*
- ***Can you remember a special moment, which was of special meaning for you personally, that you would like to share?***

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WADI Project – technical

- ***From your perception, which percentage of beneficiaries do regularly treat their water in any way before drinking it and how many drink it without treatment?***
  - ***What are the criteria you observed when people treat or don't treat their water?***
  - ***Most of active WADI users don´t fulfill their full drinking water demand with the WADI. What could be the explanations for that?***
  - ***The overall usage rate of WADI seems to have declined. Where do you see the main reasons for that?***
  - *Please describe the importance of the WADI/Sodis aspect compared to the other aspects like tipitaps, latrines, hygiene… in the people's perception?*
- *Have you noticed any patterns in the application of WADI in the households?*
  - *Common questions, observations, developments, side effects?*
- *What are the most important factors why people could / could not maintain their WADI practice and keep the new drinking water habits?*
- ***Which changes in firewood usage for water purification could you observe since the beginning?***
  - *Could you explain to me why … was the case?*

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Future + Closing

- *What are the biggest learnings so far, which you take with you from the project in Soroti?*
- *Is there anything else which has been overseen so far, that should be mentioned? Any blind spot?*
- *How could the situation of the beneficiaries be improved even more?*
  - *Which concrete issues should we address next?*
  - *What do you see that the project would need right now?*

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Appendix D: Parameters for Emission Reduction Calculation

Fuel consumption for the baseline scenario is calculated as shown below:

$$B_{firewood\,b,y} = (1 - X_{boil}) * (1 - C_j) * N_{p,y} * W_{firewood\,b,y} * (Q_{p,y} + Q_{p\,rawboil,y})$$

Parameter	$Bfirewood, b, y$
Data unit	kg
Description	Quantity of fuel consumed in baseline scenario b during the year y
Source of data be used	Calculation according to GS methodology (2015): http://www.goldstandard.org/sites/default/files/revised-tpddtec-methodology_april-2015_final-clean.pdf
Applied value	3631
Purpose of parameter	Calculation of baseline emission BEfirewood,b,y
Any comment	Calculated value

Parameter	X_{boil}
Data unit	%
Description	Proportion of users of the project technology that would have used other non-GHG emitting technologies (like chlorine) in the absence of the project technology. This parameter is only applied for premises that are under suppressed demand situation.
Source of data be used	Baseline study (Wornig, 2021)
Applied value	1,2
Purpose of parameter	Calculation of fuel consumed in baseline scenario Bfirewood,b,y
Any comment	

Parameter	C_j
Data unit	%
Description	Proportion of users of the project technology that in the baseline were already consuming safe water without boiling it
Source of data be used	Project study
Applied value	0
Purpose of parameter	Calculation of fuel consumed in baseline Bfirewood,b,y and project scenario Bfirewood,p,y
Any comment	Water in the project area can be classified as not safe.

Parameter	$N_{p,y}$
Data unit	person.days
Description	Number of person * days consuming water supplied by project scenario p through year y

Source of data be used	Calculation according to GS Methodology (2017): Based on 365 days * 1 household filter * 8,12 person per household (monitored value) HH size monitored and actualized in project survey
Applied value	2964
Purpose of parameter	Calculation of fuel consumed in baseline Bfirewood,b,y and project scenario Bfirewood,p,y
Any comment	Tendency of household size rising due to COVID 19; this value could increase significantly if WADI is used by several households

Parameter	$W_{firewood,b,y}$
Data unit	kg/Liter
Description	Quantity of fuel required to treat 1 litre of water using technologies j representative of baseline scenario b in year y as per Baseline Water Boiling Test =BWBT.
Source of data be used	BWBT was not conducted in the baseline study. Therefore value is derived from another BWBT in Uganda: https://www.researchgate.net/publication/317167869_ (Turinayo et al., 2014 see Fig.2) Performance_characterization_of_improved_wood_cooking_stoves_for_monitoring_househol d_energy_interventions_in_Uganda
Applied value	0,31
Purpose of parameter	Calculation of fuel consumed in baseline Bfirewood,b,y and project scenario Bfirewood,p,y
Any comment	Important value: improved cook stoves could cause significant reduction of this value

Parameter	$Q_{p,y} + Q_{rawboil,y}$
Data unit	Liter
Description	Quantity of safe water in liters consumed in the project scenario p and supplied by project technology per person per day in year y plus Quantity of raw water boiled in the project scenario p per person per day. Default value of 4 L/person/day applied (as specified in GS methodology)
Source of data be used	Calculation according to GS Methodology (2017) Project survey
Applied value	4 (default value)
Purpose of parameter	Calculation of fuel consumed in baseline Bfirewood,b,y and project scenario Bfirewood,p,y
Any comment	GS methodology (2017) Annex3.2: suppressed demand for potable water, WHO Minimum water Quantity needed

Subsequently baseline emissions can be calculated:

$$BE\ firewood, b, y = Bfirewood, b, y * fNRB * EFfirewood, CO2 * NCVfirewood$$

Parameter	$BEfirewood, b, y$
Data unit	tCO_2e
Description	Emissions from firewood burning for baseline scenario b during year y

Source of data be used	Calculation according to GS Methodology (2017)
Applied value	5,20
Purpose of parameter	Calculation of Emission reduction
Any comment	Calculated value

Parameter	$Bfirewood, b, y$
Data unit	kg
Description	Quantity of fuel consumed in baseline scenario b during the year y
Source of data be used	Calculation according to GS Methodology (2017)
Applied value	3631
Purpose of parameter	Calculation of baseline emission BEfirewood,b,y
Any comment	Calculated value

Parameter	f_{NRB}
Data unit	%
Description	Fraction of woody biomass saved by the project activity in year y that can be established as non-renewable biomass (default value for Uganda)
Source of data be used	UNFCCC CDM value: https://cdm.unfccc.int/DNA/fNRB/index.html (United Nations Framework Convention on Climate Change, 2022)
Applied value	82
Purpose of parameter	Calculation of baseline emission BEfirewood,b,y
Any comment	Expired in 2017, but no actualized CDM value online

Parameter	$EF_{b,firewood,CO_2}$
Data unit	tCO_2/TJ
Description	Emission factor for the substitution of non-renewable woody biomass by similar consumers
Source of data be used	IPCC (2006) Vol 2, Chap 1, Table 1.4: (Garg Amit et al., 2006, 1.24 see Tab.1.4) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf
Applied value	112
Purpose of parameter	Calculation of baseline emission BEfirewood,b,y and PEfirewood,p,y
Any comment	

Parameter	$NCVfirewood$

Data unit	TJ/kg
Description	Net calorific value of the non-renewable woody biomass that is substituted
Source of data be used	IPCC (2006) Vol 2, Chap 1, Table 1.2: (Garg Amit et al., 2006, 1.19 see Tab.1.2) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf
Applied value	0,0000156
Purpose of parameter	Calculation of baseline emissions BEfirewood,b,y
Any comment	

Fuel comsumption for the project scenario is calculated as shown below:

$$Bfirewood,p,y = (1 - Cj) * Np,y * Wfirewood,b,y * (Qp,rawboil,y + Qp,cleanboil,y)$$

Parameter	$Bfirewood,p,y$
Data unit	kg
Description	Quantity of fuel consumed in project scenario p during the year y
Source of data be used	Calculation according to GS Methodology (2017)
Applied value	204
Purpose of parameter	Calculation of baseline emissions BEfirewood,b,y
Any comment	Calculated value

Parameter	C_j
Data unit	%
Description	Proportion of users of the project technology that in the baseline were already consuming safe water without boiling it
Source of data be used	Project study
Applied value	0
Purpose of parameter	Calculation of fuel consumed in baseline Bfirewood,b,y and project scenario Bfirewood,p,y
Any comment	Water in the project area can be classified as not safe.

Parameter	$N_{p,y}$
Data unit	person.days
Description	Number of person * days consuming water supplied by project scenario p through year y
Source of data be used	Calculation according to GS Methodology (2017) Based on 365 days * 1 household filter * 8,12 person per household (monitored value) HH size monitored and actualized in project survey

Applied value	2.964
Purpose of parameter	Calculation of fuel consumed in baseline Bfirewood,b,y and project scenario Bfirewood,p,y
Any comment	Tendency of household size rising due to COVID 19; this value could increase significantly if WADI is used by several households

Parameter	$W_{firewood,b,y}$
Data unit	kg/Liter
Description	Quantity of fuel required to treat 1 litre of water using technologies j representative of baseline scenario b in year y as per Baseline Water Boiling Test =BWBT.
Source of data be used	BWBT was not conducted in the baseline study. Therefore value is derived from another BWBT in Uganda: https://www.researchgate.net/publication/317167869 (Turinayo et al., 2014 see Fig.2): Performance characterization of improved wood cooking stoves for monitoring househol d energy interventions in Uganda
Applied value	0,31
Purpose of parameter	Calculation of fuel consumed in baseline Bfirewood,b,y and project scenario Bfirewood,p,y
Any comment	Important value: improved cook stoves could cause significant reduction of this value

Parameter	$Qp, rawboil, y$
Data unit	Liter
Description	Quantity of raw water boiled in the project scenario p per person per day
Source of data be used	Project survey
Applied value	0,22251983
Purpose of parameter	Calculation of fuel consumed in project scenario Bfirewood,p,y
Any comment	37 HH are still doing addboil: 10,89 liters in average --> /223 (total amount) of HH 37 out of 223 HHs are still boiling 10,89 liters water in average in addition to WADI usage. That's divided per HHsize of 8,12 persons is 0,22251983 l / person / day

Parameter	$Q_{p,cleanboil.y}$
Data unit	Liter
Description	Quantity of safe water boiled in the project scenario p per person per day
Source of data be used	Project survey
Applied value	0
Purpose of parameter	Calculation of fuel consumed in project scenario Bfirewood,p,y
Any comment	The parameter specifies the amount of water, which is unnecessarily boiled/Wadi water would still be boiled. This is not occurring due to the survey.

Subsequently project emissions can be calculated:

$$PEfirewood,p,y = Bfirewood,p,y * fNRB * EFfirewood,CO2 * NCVfirewood$$

Parameter	$PE_{p,y}$
Data unit	tCO_2e
Description	Emissions from firewood burning for project scenario b during year y
Source of data be used	Calculation according to GS methodology (2015): http://www.goldstandard.org/sites/default/files/revised-tpddtec-methodology_april-2015_final-clean.pdf
Applied value	0,29
Purpose of parameter	Calculation of emission reduction ERy
Any comment	Calculated value

Parameter	$Bfirewood,p,y$
Data unit	kg
Description	Quantity of fuel consumed in project scenario p during the year y
Source of data be used	Calculation according to GS methodology (2015): http://www.goldstandard.org/sites/default/files/revised-tpddtec-methodology_april-2015_final-clean.pdf
Applied value	204
Purpose of parameter	Calculation of project emission PEfirewood, p, y
Any comment	Calculated value

Parameter	f_{NRB}
Data unit	%
Description	Fraction of woody biomass saved by the project activity in year y that can be established as non-renewable biomass (default value for Uganda)
Source of data be used	UNFCCC CDM value: https://cdm.unfccc.int/DNA/fNRB/index.html
Applied value	82
Purpose of parameter	Calculation of project emission PEfirewood,p,y
Any comment	Expired in 2017, but no actualized CDM value online

Parameter	$EF_{b,firewood,CO_2}$
Data unit	tCO_2/TJ
Description	Emission factor for the substitution of non-renewable woody biomass by similar consumers

Source of data be used	IPCC (2006) Vol 2, Chap 1, Table 1.4 (Garg Amit et al., 2006, 1.24 see Tab.1.4) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf
Applied value	112
Purpose of parameter	Calculation of baseline emission BEfirewood,b,y and project emissions PEfirewood,p,y
Any comment	

Parameter	$NCVfirewood$
Data unit	TJ/kg
Description	Net calorific value of the non-renewable woody biomass that is substituted
Source of data be used	IPCC (2006) Vol 2, Chap 1, Table 1.2: (Garg Amit et al., 2006, 1.19 see Tab.1.2) https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf
Applied value	0,0000156
Purpose of parameter	Calculation of baseline emission BEfirewood,b,y and project emissions PEfirewood,p,y
Any comment	

Appendix E: Summaries of the Qualitative Interviews 1-3

Author: Max Reisinger

Qualitative Interview 1: project beneficiaries (focus group)

Opening Question: Please tell us your name and briefly introduce yourself to the group by telling us what is your personal connection/your role is in the WADI/Sodis Project in Soroti?

Can you describe the current drinking water situation in your village? How do your daily routines/ work around drinking water look like?

- Handwashing, rubbish bins, WADI was accepted very good, less diarrhea, health increasing,
- Since the invention of SODIS, improvements for both adults and children: Water and sanitation, if project would continue – great value
- Very grateful for Water school
- SODIS: used to drink directly,
- Too much work (widow) : Using the traditional methods: water is tasty, that's why she is not using WADI
- Sarah: new latrine SODIS: happy to have Wadis – encourages others to do the same: wish for continuing Water school to do same work. Good knowledge, she is able to pass knowledge to other people

Benefits/challenges:

- When water school entered, it has given us very great benefit,
- Before shower behind house, now within the house
- Drying rack, rubbish pit,
- Something they didn't have knowledge about before
- Challenges: bottles getting lost, easily be stolen
- Concern that people are putting poison to water (not very common but sometimes)
- Annette (55:00) 360 Households sharing one borehole – long waiting hours
- Boys and girls are able to go to school

Women's life:

- Women could save a little money, buy clothes for her children, borrow money for spraying oranges
- Cooking stove: improved

Any special moment:

- Sanitation , people have greatly improved,
- Leaders of the group – stronger community
- Less waterborne diseases (also less children ill)
- Also good for sanitation within Covid 19 pandemic
- Also encourage to go to vaccination
- It was not possible, before not possible to move around and see other homes, first he had to put things right at his ow place and saw the impacts, then he could encourage others
- He is grateful and requests if there as a way of helping disabled children
- 1:26 (white dress): able to get solar system and kids are able to read indoors, before kerosene lamp risk of burn house)
- 1:30: Menstruation hygiene – when after school, they have reusable pads, - different organizations, they forget about the topic – water school included it: girls could go to school

Observations:

Location:

- People are sitting together in the shade of an Orange tree in simple chairs,
- Birds tweet in the trees, it is morning, all are looking interested and curious into the screen
- Children are gathering in the background and are curious what happens on this screen

Body Language:

- Seem to be on eye level and open up also with intimate topics like menstruation hygiene and disabilities of children, fears of getting poisoned,
- A lot of respect, gratefulness and thankfulness are showed and expressed among the project team of WSU

- Had the feeling that people are free to mention their experiences authentically

Frame:

- Translation from English to local Ugandan language and back
- Also some greetings in English/local language from them to me and the other way back
- Bad connection so big delay in answers and questions
- Difficult to really get the meaning of their stories (only to 30%)

Summary by WSU:

Max's recording

- Permission was granted to do the recording
- Introduction giving names, address and role in the project

Question1: Describe the current situation of your village compared with before the project intervention:

Participant 1:

- Since the project came in, WASH facilities have been set up for example Improved pit latrines, better home environment, use of WADIs to process water for drinking.
- Homes are more clean and reduction of water related diseases.
- The project has helped us to monitor homes as VHTs.
- There is increase in handwashing.
- There is decrease in diarrhoea

Participant 2:

- More people use WADIs in the community
- Increased access to drinking water for both children and adults.
- Decrease in disease incidence and severity in the community possibly because there was more monitoring and engagement with beneficiaries.
- Improved sanitation due to effective training of beneficiaries which facilitated their understanding what they need to do and how it benefits them as homes and community.
- Requests that this project can continue and similar ones introduced in the area as they will be of great value to the community.

Participant 3:

- Grateful for the project because there are people in her community who did not want to dig pit latrines. The project helped to transform their attitude and now the latrine coverage has greatly increased as well as their health and economic status.
- Through the project, she joined VSLA and her living and economic conditions have improved greatly for which she is very grateful.
- Regarding SODIS, she does not use the technology because she used to get water from a borehole, put it in a pot and drinks ad lib as need arises.
- Being a widow, she has a lot of work to do, she does not have time to fill bottles, put them in the sun, wait for it to get ready, wait for it to cool and then drink.
- However, she sees other people doing and enjoying it!
- The VHTs who supervise her area have been trying to convince her but because of her many responsibilities, she is not able to use SODIS and WADI.
- When she sees her friends using SODIS and WADIs, she does not know how the water tastes because she has never drunk it!
- She views the process as being tedious and cumbersome.
- At one point she was convinced by her neighbour to taste the processed water and she noticed that it had a different taste from the unprocessed one. Because of this, she prefers to continue with the traditional method of drinking raw water from a pot.
- However, she is grateful for the several other things Water School Uganda has exposed the community to. May be Water School Uganda should do more refresher trainings. Who knows she and others may get won over to start SODIS+WADI method.

Question 2:

How is she experiencing the WADI and SODIS method?

- She used to have a substandard latrine. She is thankful for the training got from Water School Uganda which triggered her to make a good latrine.
- She has realised that since she started practicing SODIS and WADI, the frequency of her children falling sick dropped drastically.

- She has also observed that the habit of processing drinking water in her home is now entrenched even when she is away, the children and other members do it**.**
- The habit of drinking water has grown and visitors know that when you visit her home, you will be offered a cup of water to drink soon after settling down.
- The benefits she has got from this cause her to encourage other community members to practice SODIS and WADI.
- She recommends intensifying joint monitoring by Water School Uganda Field Team with VHTs in order to support sustainability of project outcomes and increasing the spread of the program to everyone in the community.
- She is thankful for the project for the new knowledge and skills which she is committed to pass on to others so that their lives can be transformed too.

Question 3:

Looking back at the whole project since they got the WADI, where do they see the benefits and where do they see challenges and their WASH situation?

Simon

- From the time Water school Uganda came into this village, we have got a lot of benefits. For example, before this project, whenever one wanted to defecate, one would just get a hoe, go to a bush, dig a hole and defecate.
- If you wanted to bathe, you would just go behind a bush with a basin of water and have your bath.
- But when Water School Uganda came to this village, we were encouraged to have WASH facilities using locally available materials and tippy taps for hand washing; drying racks to dry and disinfected utensils using sunshine; rubbish pits for proper disposal of solid waste; processing drinking water using SODIS and WADI.
- All these were new ideas that Water School Uganda helped us pick up and benefit from as a community and individual households.
- Many people have continued practicing SODIS and WADI for water treatment despite challenges associated with bottles getting lost, some people stealing the WADIs machines especially when nobody has stayed at home.
- The biggest challenge is related to some people steal your water from the rack plus the WADI machine when no one is at home.

Max shared his positive experience from Bangladesh on how the communities worked together to protect their WADIs ….

- Being a family man who has children, after disinfecting the water a thirsty child might drink the water before it is ready and gets sick. In such situations it can lead to resistance to SODIS and WADI technique.
- The other challenge is dealing with the fear of being poisoned by unfriendly people within the community. This fear is generally common in Africa but no incident of poisoning has been reported in this project and therefore Water School Uganda should continue with its work since most households really appreciate the project and its outcomes.
- In the dry season you can see a lot of people drinking SODIS water because of the high temperatures.

Host

- Reiterating most of what has been said.
- Access to water – 360 households share one borehole.
- Request that if it is possible for Water School Uganda to provide at least one borehole so that the people can be able to access water for processing more easily and in larger quantities.
- Grateful for the field team for concerted monitoring to ensure the communities improve in all programme standards.
- Recommends skilling aspect to be incorporated in program especially for youths, boys and girls who have dropped out of school.
- WASH programs are good but adding the element of improving livelihoods will not only improve the community but also support upscaling program-reach and sustainability.

Question 4:

What criteria does she use to decide which water to treat or not?

- She treats the water irrespective of where she gets it from. Her family must NOT drink untreated water.

Question 5:

How have the lives of women been affected in the households by the new techniques with a focus on WASH?

- The disease incidence has greatly reduced in the benefitting homes making running the home easier.
- The saving on medical costs has also freed them to be able to save and invest through VSLA groups also introduced by the project.

- As a beneficiary and one who supervises others as a VHT, I have a group that meets in my home every Friday and I have seen the huge leap in Members' investment; improvement in both economic and mental health; reduction in domestic violence; and growth in sense of community among the group members.
- Members are able to carry out a variety of activities and enjoy mutual learning.
- Group members are able to access loans for agrochemicals and tools which has helped to modernise their farming methods for example for citrus plantations, for which they are grateful to Water School Uganda.
- The other thing is Carbon dioxide emission reduction. Through use of energy-efficient cooking stoves which are not only helpful in minimising respiratory and optical ailments for mothers and children but also beneficial toward environmental conservation.
- Personal hygiene in the homes has improved as members breathe clean air; have more peace of mind; and soot does not mess up their clothes as was in the past.

Question 6:

Does she have an energy-efficient cooking stove? Approximately how many homes have energy-efficient cooking stoves in this village?

- Yes, she has an energy-efficient cooking stove. In this village, approximately 20 households have modern cooking stoves.

Next Question is Special:

Some stories from the project experience

1. Sanitation in the benefitting community has greatly improved. This is a great project achievement.
2. We have seen increase in harmonious co-existence in our community.
3. There have been opportunities to share and practice new ideas.
4. Trainings on menstrual hygiene management especially in schools has helped break the silence and demystify menstrual hygiene management. They also taught our girls how to make reusable sanitary towels which has helped reduce stigma and poor self-image.
5. Women are a bigger proportion of the community and through the VSLAs, they have been economically empowered. This has contributed to household developments.
6. Decrease in in incidence of waterborne and water-related diseases.
7. Building the culture of cleanliness contributed to prevention and control of COVID-19 by having handwashing facilities at the entrances of homes, near the latrine, and next to the drying rack where household utensils are cleaned.
8. Recommend introducing skilling aspect so that school-dropouts, youths, and child-mothers can be equipped and empowered.
9. During monitoring visits, Water School Uganda has encouraged people to go for vaccination against COVID-19

Host:

- When Water School Uganda came into this home, everything became better. Being leaders in the community, we were challenged to be exemplary. Through the project, our WASH, economics and image of our home have developed enviably. One of our greatest benefits is that I work together with my wife, and the children emulate us. It is lovely.
- I therefore plead that this program continues and spreads to other communities as well for others to benefit too.

John:

- As a VHT, I have been moved by warm welcomes from satisfied beneficiaries of this project due to the positive impacts in their lives. This was facilitated by my having ensured that all needed WASH facilities were installed in my home and I practiced what I teach the community members.
- I recommend that project mainstreaming to include persons with disabilities.

Host:

- Before Water School Uganda's intervention, we lived in grass thatched houses. Through saving and borrowing, we have been able as a couple to construct our own Corrugated Iron roofed house, have solar lighting which makes reading easier for our children. We used to kerosene lamps which give less light and are very risky.
- On menstrual hygiene management, women and girls used to use rags when menstruating. When Water School Uganda came in, they introduced use of proper sanitary towels and reusable pads. This has transformed community attitudes with respect to menstrual hygiene management for which I am very grateful.

Max:

Thank you to the whole group from Max.

Qualitative Interview 2: health officials

- Improved lives: health and wellbeing in private and institutions (schools)
- 2 health clubs
- Water source and water tank
- Train teachers, and VHT
- Former times numbers of diseases were high
- Diseases down →better livelihood,
- Money savings for permanent structures (stabile house)
- Importance of handwashing
- Communities give bottles
- Trained on saving firewood
- Improved latrines: insect cover
- WADI ownership: all of them used WADI

Biggest benefit (32:00)

- Biggest benefit: transform lives: social – economic transformation:
- People can work and have income
- 75% of despises are preventive
- Covid learnings: explanation of prone CT to more villages
- CO_2 reduction through efficient cook stoves
- Reduction of deforestation: climate change mitigation
- Small changes all together huge benefit!
- Fear adaptation

Rose:

- Now one bundle for a week, before 1 per meal
- In all 2000 have improved cook stoves
- (48:00): so impressed , very happy, what is the secret of this

Martins:

- 2 step latrine: family and visitors (very important in Africa) – supervision
- School primary: 2 tip taps: very clear difference, "I wish water school could help" - very lucky moment (50:00)

Rose:

- Villages grow rapidly - reaching every household, walk very long miles, funding not good,
- People don't take time
- Covid: just one by one trainings
- (57:00) School children: minister come: so happy and pleased, more applause, put handwashing

Biggest learnings: (59:00)

- Martins: start small with the community together and expand extensively
- People own the WADI
- Providing items, rethinks

Learnings Rose (1:04):

- Also grow capacities not just more households
- Also reach health centers, schools
- Not just bring items and leave but stay there and support in building capacities
- Not forget about institutions and health facilities

Introduction

Martins:

- District Health officer: working in low-income communities
- Significant benefits for communities
- Over 8 years with water school

Rose:

- Governmental health inspector: working with people on the ground in GWERI with HH
- Project activities have transformed lives of community especially when they have been given the bottles for treating the water on HH level and sanitation and deforestation reduction

How has the drinking water situation water changed during the project period?

Martins:

- "Overall objective of the project interventions was to improve people's lives, and by lives I mean, their health and wellbeing. All of that on household and institutional level (schools, churches, trading centers)"
- Specific parameters:
    - Providing safe of adequate water to the population at that time when they need it
    - Repairing the boreholes: deep boreholes are the main source of water
    - Construction rainwater harvesting tanks in schools
    - 2 x 1,5 l bottles of water for every child in schools
    - Health clubs were trained on how to manage their water with WADI
    - WADI in schools and selected households
    - Training of teachers and community members (village health teams)
- Outcome of this interventions:
    - "Previously over the last years the water borne diseases were high. Apparently we have seen a significant downward trend of this data since the project activities – there is a contribution!"

Rose:

- Diseases trend is going down
- The livelihood of people have been improved: savings, permanent structure houses, hand washing facilities
- WADI kits: most of the communities have took it up – great achievement
- Fuel was saved, not to over waste and also teaches how to replant trees
- Improved latrines , sato pans fly cover, without smell
- WADI: all of the families that ware given the bottles used WADI, other people in communities which were not covered, asked when are coming bottles to us
- All of them started, and also replaced broken bottles

Biggest benefit of WADI:

- "The biggest benefit on a macro-level is the social-economic transformation of the lives of people, because a healthy person is a productive person. If you are healthy, you are able to work and produce income, if not, your little income has to be used for [medical] treatment. About 75 % of the diseases in Africa are preventable therefore the [projects] strategy for preventing diseases [] goes along with changing the lives of the population. "
- Communities wished that the program would expand to other areas
- Issue of Co2 reduction: improvement of cook stoves, reduced pollution from smog (cancer) , minimal carbon dioxide
- Reduction of deforestation because little wood fuel is now being used. Very few tree are cut down for fuel. So on a macro perspective the project has made contributions to climate change mitigation.
- Water schools interventions is very very significant in transforming societies in low income communities, because they are able to take actions that impact greatly on their health and economic empowerment.
- People moved to permanent constructions so the live conditions automatically change.
- "Whereas this small interventions like SODIS, water bottles, trainings, improved cook stoves, tree planting and forming community groups and so on, they look simple in terms of macroeconomics, but if you put all of them together prospectively they are making a very very significant contribution in the social economic transformation for the people of GWERI"
- Cook stoves
    - Villages were learning from project area on how to build improved cook stoves
    - "We have bundles [of firewood]. You use one bundle to prepare one single meal, which is too much firewood being spent. At this time you can use one bundle to spend about almost a week. That time there was a lot of smoke but this time there is limited smoke in the house. So no interference of eyes crying, having running nose, so the women reported that there live have improved. All of the HH have improved cook stoves."

Special moments in the field:

- "Actually one time, we moved to one of the HHs, I was impressed. The head of the HH was a very young man and a very young women but their home was so pleasing. Everything was so pleasing, the hand washing was in place, there was water, I really felt so impressed and I said: 'Wow, this is meant by being in the community and people taking in what you have told them'. I was so impressed, I was very happy and I moved to the next house. I thought it was only one HH like that, [but] the next home I moved to had the same! I was like "What is the secret of this community?" See it is like people learned that every home must have these things in place. And there were looking so good. […] I asked them what challenges they still have but they said no, we not have any challenge from that very time our life got transformed. […] I felt so good and I felt so happy for this family."

- When Covid came and more handwashing should be in place, these facilities already were there!

Challenges:

- Villages are expanding and splitting. It is difficult to reach all the HH. Infrastructure is missing.
- Covid: you cannot gather people to talk to them. You need to go door to door to inform them. So that causes higher costs.
- Schools were used as learning centers but now they have been closed down for nearly 2 years. So schools were the epicenter of knowledge. So now we have to rethink our interventions on going on.

Biggest Learnings

- Martins: “Start small with the community together and expand extensively so that whatever you achieve becomes sustainable. Allow communities to take decisions in a participatory manner, because in the end of the day they will be owned by the communities. So now the WADI and the bottles are owned by the communities, the ferrocement tanks are owned by the schools [ ], the improved cook stoves are owned by members to the HH. “
- Start small and grow. Now we can expand it to the next communities
- “Build up capacities to ensure a successful output. Waster school did not just bring their items and left again. They trained the people, started health clubs and therefore brought the knowledge**. “**

Qualitative Interview 3: local team (WSU)

3 WADI user categories:

- Daily basis: 2000 maybe 800: bottles are the reason
- Every 2-3 days: more HH ~ 1100 , store it till tomorrow
- Negative attitude: ca. 100 people: community leaders are negative: when community head tells that water in sun→ cancer

Why bottles lost:

- Kids take some to school and lose
- Some use bottles to sell milk
- There has been redistribution
- Bottles cheap in a box in pandemic, so as long as people come to town, they can get them easily
- Man often spend their day in brewery

Why only satisfy water demand up to half:

- Sometimes they drink it from pond because they need it immediately, for example when WADI water is not finished

Health impacts (25:00):

- before intervention: many people sick → seek for medical services
- Nearby village also want the WADI interventions
- “If you compare data, people who use SODIS have significantly lower sickness”
- Commitment:
- Ownership: they owned the program – “it is not our program, it is your program. It is coming to help the community, not actually us” (23:00)
- Tipitap, separate animal houses, handwashing

Menstrual Hygiene: (29:00)

- It is a key activity
- Before girls were ashamed when they had their menstruation and didn´t go to school
- Take them through how to best handle this things – it was missing in the beginning
- Encouraged to take the reusable ones, to sustain themselves

Environmental conservation:

- Most of HH have modern cook stoves: reduce deforestation
- Plant 15 trees per year, for everyone to cut down
- Climate Changes: not sufficient rain, too much sun, difficult to farm
- Dry Season: August to November normally some rain – this year June onwards drought
- April till June normally enough rain
- All crops failed as thy dried up and died off
- Last rain in October – most swamps are dried out

- When water even went down,
- Water shortage from now November to March –. Actually it has already started
- People in water shortages also drink contaminated water from rivers and lakes. “Yes it is that serious but we are moving on – moving on just like that” – November up to March people somehow try to survive, regardless on the water quality (35:15)
- some communities dig a deep well
- People are realizing how trees and water are connected
- Boiling water for heating the bath tub for the husband

Personal stories (50:00):

- Lorena building: every household should have a Lorena, it’s not only about cooking but about saving the environment
- “I love it and I do it with passion” (50:02)
- 3 stone stoves waste a lot of firewood
- 45built by himself , rest is trained to do in villages

Biggest challenges (59:00):

- Weather changes, break down of facilities when there is a lot of rain
- Handouts: many people only come if you have handouts,
- Political affairs: Politicians come to meeting and use meetings as a platform for their campaigning – (56:50)
- Limitations on time
- Boreholes are few – low access to water so lo access to disinfection – many people just don´t have enough water, so they can’t disinfect. If there would be more boreholes, people would be willing to do more SODIS.
- No water testing possible
- If problem with Water – VHT communicate between to Health assisted, health inspector and then to district