TARAWA WATER SUPPLY SOLAR DISTILLATION PROJECT – COMMUNITY WATER SECURITY

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ABSTRACT

Many Pacific Island Countries face water security challenges, and this is expected to worsen due to the impact of a changing climate. In response to this challenge, the Tarawa Water Supply Solar Distillation Project explored the viability of solar distillation units as a source of potable water in Kiribati. It involved installing 50 solar stills at six household and community locations in Tarawa, and assessing their technical, social, financial and environmental performance.

The solar stills performed largely as expected, generating water in a relatively low-cost manner with minimal specialist input (relative to what might be required for the management of a reverse osmosis unit as an alternative). However, monitoring data shows that there were several instances of contamination (indicated by the presence of E. coli), and outages due to damage or maintenance tasks failing to be undertaken. It is believed that this is due to the households and communities managing the systems taking some time to come to understand what is required to make them work effectively and safely.

The solar stills may enable communities in Kiribati to achieve more resilience to the effects of drought when used in conjunction with complementary technologies (e.g. rainwater harvesting). As they require less technical input and less energy than alternatives such as reverse osmosis or desalination units, they have a relative advantage in communities with less access to specialist knowledge. In Kiribati, this means that they may be more cost effective when installed in the outer islands.

Following the installation of the solar stills, and a period of observation and monitoring, the following key conclusions were made:

- Reasonable and achievable maintenance plans and delegations are crucial to the successful operation of the technology. Whilst water quality is improved when the systems are operated well, contamination of the distillate is still possible and the system must be managed accordingly.
- The systems were generally received positively by the communities and households in which they were trialed.

While this is a Kiribati based pilot, the technology is universally applicable in areas struggling to supply fundamental potable water needs, and is an insight into the culture of household and community-maintained water supplies.

This project was conducted by Kiribati Ministry of Infrastructure and Sustainable Energy and Engineers Without Borders New Zealand, with volunteer support from Volunteer Services Abroad and funding from the New Zealand Ministry for Foreign Affairs and Trade.

KEYWORDS

Solar distillation, water security, community

PRESENTER PROFILE

India is a Water Resources Engineer in Wellington NZ and has been the EWBNZ programme manager for the TWSSD project since 2019, from scoping through to completion.

1. INTRODUCTION

The New Zealand Ministry of Foreign Affairs and Trade (MFAT) engaged Engineers Without Borders New Zealand (EWBNZ) to provide technical support for a Pilot Tarawa Solar Distillation Water Supply Project. The aim of this project was to deploy solar distillation technology in Kiribati to demonstrate the suitability of this technology as a sustainable alternative potable supply for households and remote communities in the Pacific.

The key project partner in Kiribati was the Ministry of Infrastructure and Sustainable Energy (MISE) Water and Sanitation Engineering Unit (WSEU), who are responsible for "*ensuring that the people of Kiribati have sufficient access to reliable, safe water supplies and safe sanitation facilities and practices*". MISE staff worked with EWBNZ to procure the solar stills, oversee their installation and monitor their performance.

This project had the technical outcomes of piloting the technology as well as the social outcomes of developing procurement capacity and experience within MISE. This report will focus on the outcomes of the pilot regarding social, economic and technical opportunities and learnings; however it should be noted that in any partnership, that capacity development and equal partnership is necessary for long-term success of any project.

2. BACKGROUND

In Kiribati, water sources are predominantly groundwater from brackish groundwater lenses, rainwater collection, and desalinated sea water from reverse osmosis plants (SPC, 2007).

Kiribati is a geographically isolated nation, with almost 120,000 people spread across 33 islands over 3.5 million km^2 (Kiribati National Statistics Office, 2020).

Over half of the population is located in South Tarawa which has its water supply serviced by the Public Utilities Board (PUB) (Public Utilities Board, 2019) and a six-year project is under way to deliver desalinated water to properties across the atoll (Nasih, 2019). While these highly populated regions have water supplied to communities to some degree, communities outside of the major centres are frequently required to source water independently. It is these communities that require more options for sufficient and sustainable water supplies and were the ultimate users in mind for the project.

The effects of climate change and an increasing population are putting more pressure on water supplies, and alternative methodologies for sourcing affordable and clean drinking water are sought. As some of the more remote islands in Kiribati do not have highly trained technical staff available to maintain complicated equipment, a key requirement of these technologies is that they are easy to operate and maintain.

This trial utilized the desalination Carocell units manufactured by FCubed based in Melbourne, Australia. As a modular unit that does not require electricity unless a solar pump is specified, the Carocell units are functional and can be easily understood, operated and maintained, by technical specialists and community members alike.

The technology focuses on the concept of boiling contaminated water and collecting condensation, which is a familiar concept to anyone accustomed with food preparation and boiling water. This technology was recommended for research by the project facilitator, MFAT, as a means of desalinating water without the high running costs of standard desalination units, as it requires comparatively little maintenance and is solar powered. This technology has been successfully deployed in many other nations with similar climates and water security challenges (FCubed, 2017) but has not been tested on a large scale in Kiribati with consideration for local context.

3. TRIAL PROCEDURE

TRIAL INITIATION

Prior to the trial commencing, the project had a lengthy scoping stage in order to establish agreements between project partners and agree on desired outcomes. This scoping stage explored project drivers, technology selection, and the value of partnerships and capacity development (Eiloart, 2019). The trial itself was then jointly managed by MISE and EWBNZ, commencing with the scoping, procurement and installation of the trial units. MISE then conducted the monitoring phase with EWBNZ remote support. The monitoring was concluded in December 2020, and the results discussed with all stakeholders in March 2021.

As per Kiribati Government protocols, a Working Committee (Tarawa Solar Distillation Pilot Working Committee, TSDPWC) was established through a targeted invitation process in order to maintain effective stakeholder engagement and project momentum. This committee consisted of members representing the following parties:

- Kiribati Ministry of Environment, Lands and Agricultural Development (MELAD),
- Kiribati Ministry of Health and Medical Services (MHMS),
- The Pacific Community (SPC)
- Kiribati Ministry of Finance and Economic Development (MFED)
- Kiribati Ministry of Infrastructure and Sustainable Energy (MISE)
- New Zealand Ministry of Foreign Affairs and Trade (MFAT)
- Engineers Without Borders New Zealand (EWBNZ)

These members engaged consistently through to the end of the trial with regular meetings to discuss progress and provide feedback on project decisions.

SCOPING AND SITE SELECTION

Amongst the first of the committee roles was the development and review of the trial sites selection, which the MISE project team then facilitated for the resulting criteria and process. The outcome of this step was to identify appropriate sites to trial the solar distillation technology that would provide insightful data into the usability of the technology for an independent community but within close proximity to Tarawa and it's centres to ensure that there were reliable alternative water sources for the participating communities. The agreed steps to determine a trial site were as follows:

1. **Village selection** – through WSEU and stakeholder consultation, villages that did not have access to PUB water supplies were chosen. These villages still remained within Tarawa and were selected due to their close proximity, minimising the use of transportation and resources of the trial. Councils and Mayors were engaged in person for this stage (Teinainano Urban Council and Eutan Tarawa Council).
2. **Community selection** – through village councillor consultation, communities within these villages were chosen based on predetermined criteria, such as engagement interest, population vulnerability, and existing access to fresh water sources. In-person meetings with the villages were conducted to select the communities where a councillor had not previously advised the chosen community, therefore all decisions were made internally within the villages with MISE providing decision criteria to support the process.
3. **Site selection** – through community chair consultation, individual sites for the trial installations were determined based on predetermined criteria such as community engagement willingness, existing feed water source availability and availability of space.

From this process, two community and four household sites were chosen for the trial. Despite the focus on site selection engagement and agreements, pitfalls are acknowledged as significant delays later occurred at the Buota Community site due to land ownership disputes. All sites were engaged in a Memorandum of Understanding (MOU) with MISE to establish the responsibilities of the parties involved prior to the trial technology installation and operation.

INSTALLATION

Both supply and installation of the panels was undertaken by Green Living, a local supplier, and consisted of four household installations (two-panel design), and two community installations (15-panel design). Green Living's team attended February 2020 site visits with MISE prior to installation to scope and plan the installations. Installation began in early March after rain delays, however the site set out and post installations were able to start while the weather settled. The Buota installation was delayed due to land ownership disputes, and the Banraeaba installation was relocated part way through construction closer to the shoreline.

These six sites were located as follows (refer Figure 1):

- Banraeaba East (Household, also referred to as Ambo)
- Eita West (Household, also referred to as Tobario)
- Temaiku East (Community, also referred to as the Korokota Church community)
- Bonriki East (Household)
- Buota (one Community, and one Household that is geographically isolated from the community)

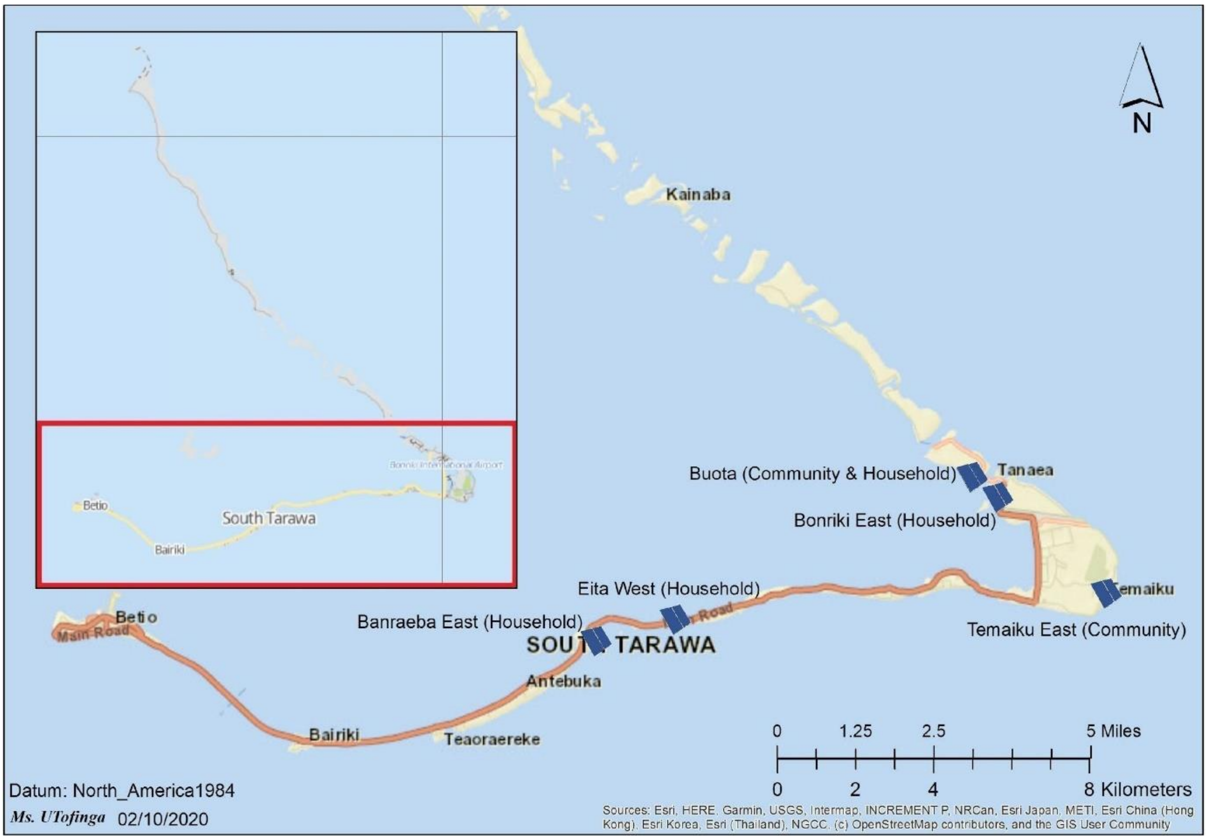

Figure 1. TWSSD trial site map

OPERATION AND MAINTENANCE

Generally, the solar distillation units function well when the operating conditions are as per the manufacturers' recommendations, but when they are operated outside of this range the quality and quantity of the water produced diminishes. The solar distillation units for this trial performed as expected.

WSEU staff made several observations in their monitoring visits regarding recommended site maintenance, such as the need to add fencing and prevent shading from overhanging branches. Each of these are addressable with further support to the communities and households using the units.

At the first monthly site visit in April 2020, the Bonriki and Eita household installations indicated that the two-panel design was insufficient for their water demand, as the Kiribati communal lifestyle resulted in households sharing their water with neighbours.

Common issues in the trial, which are reflected in other Kiribati installations in Green Living's experience, is the failure of the filters and/or pumps. Basic maintenance tasks are designed to address these risks, with the recommendation of cleaning out the filter once a month. Green Living staff would usually be called out after a monthly site visit by MISE, as it was common for the site managers to wait for the monthly visit to report issues in water production. Ideally, any issues would be remediated immediately, to continue operation as well as reduce the risk of permanent damage to the system.

To prepare for installation, there were some site recommendations which were not met in this trial until after installation was complete. These recommendations were addressed during the operation phase of the trial, with examples including a raised platform for tanks, security fencing to protect from children and animals, and clearing of overhanging trees blocking sunlight. Without these interventions, the units did not perform as efficiently as they could have resulting in reductions in solar potential, components such as tank taps being damaged, and feed lines stopping or contaminating the supply.

MANAGERS WORKSHOP

On 20 November 2020, representatives from MELAD, MHMS, MFAT, MISE, (collectively, the 'Working Committee') and managers from each of the trial sites met to discuss the project. This meeting enabled the group to raise issues, and importantly, share lessons learnt with each other.

Notes taken at this meeting were used to inform the Discussion section of this report.

4. DISCUSSION

COST EFFECTIVENESS

Green Living's standard panel farm package at time of purchase was $5000 AUD for five panels, a 500 L tank, solar pump and associated pipes and fittings for the installation. The installation cost is an additional $280 AUD, and an annual maintenance plan is $350 AUD. Each additional call-out from Green Living is $35 AUD. There is value in larger installations due to the base cost of the tank, solar pump and structure being spread out over a larger number of panels.

The lifetime of the panel is broken down in a durability matrix provided by FCubed, based on the lifespan of each component and its ability to be replaced. These life spans assume the units are maintained as recommended by the manufacturers. The component with the smallest lifespan is the internal fabric, at approximately 5 years. The longest lifespan is that of the structure itself, which with good maintenance can last 20 years. However, the internal backing tray has the shortest lifespan of the non-replaceable components, which is 10 years. Therefore, for the purpose of this report and the calculation of cost effectiveness, the panel's lifespan is considered to be 10 years (for consideration of life spans, the durability matrix provided by FCubed is outlined in Appendix A.)

For the purpose of a Whole of Life cost, it is assumed that there would be four callouts a year, and $100 AUD worth of replacement parts would be required over the life of the panel.

This breakdown is presented in Table 1, with a present value of $1,851 AUD (for a single panel in a group of five) over the course of its lifetime. An internal rate of return of 6% has been used to determine the present value of the system.

Table 1. Whole of Life Cost breakdown per panel

Item	Unit	Unit Cost (AUD)	Total cost (NZD)
Supply (per panel)	LS	$1,000	
Installation (per panel)	LS	$280	
Total up-front cost	LS	$1,280	$1,379
Annual maintenance fee	annual	$350	
Service call-out fee (assume 4/year)	annual	$140	
Replacement parts	annual	$10	
Total Annual Cost	annual	$500	$535
Total Cost over lifetime		$6,280	$6,720
Present Value (10 years, 6% IRR)		$4,960	$5,307

Table 2. Whole of Life Cost breakdown per 5 panels

Item	Unit	Unit Cost (AUD)	Total cost (NZD)
Supply (5 panels)	LS	$5,000	
Installation (per panel)	LS	$280	
Total up-front cost	LS	$5,280	$5,650
Annual maintenance fee	annual	$350	
Service call-out fee (assume 4/year)	annual	$140	
Replacement parts	annual	$50	
Total Annual Cost	annual	$540	$578
Total Cost		$10,680	$11,428

Present Value (10 years, 6% IRR)		$9,254	$9,902

It was assumed that installation and maintenance costs for a single panel are the same as for a 5-panel set, therefore the cost per panel is lower for larger installations. We have also based these estimates on

Based on these estimates, over the course of its 10-year life span (82,490 L), a single panel output would cost $0.02 AUD/L, or $22 AUD/ m^3. An equivalent water source such as a 1.5 L bottled water has a cost of $2.50 ($1.67 AUD/L). PUB provide metered water supply connections in South Tarawa at staggered rates. The applicable rate for comparison is $2.00 AUD per 1000 Litres for the first 2500 Litres, 0.2 cents per litre (Public Utilities Board, 2019).

AFFORDABILITY

The baseline study undertaken of the participants involved in this trial indicated a mean household monthly income of $759 AUD (n=21) and a mean household size of 6 (with a standard deviation of 2.8). This equates to $126 AUD/person/month of income.

The baseline study also indicated households are using a mean of 36L/day (n=22) for cleaning and cooking, and with households averaging 6 people each, this roughly equates to 6L/person/day (This amount is less than the minimum 15L/person/day household water recommended by the Sphere Humanitarian Standards but greater than the 3.2L/person/day minimum drinking water recommended by the U.S. National Academies of Sciences, Engineering, and Medicine, as described in Section 6.3.1.)

If we consider the cost of water from the FCubed panels to be $0.02 AUD/L, this equates to $0.72/household/day or $22 AUD/household/month, which is about 3% of average monthly household income.

However, the upfront cost of this system means that it is unlikely to be affordable for private households without financing options.

WATER QUALITY

A key component of the monitoring stage was monthly water quality testing to understand the practical expectations of community maintained and operated water supplies in Kiribati. If operated as designed then water quality of the output from the panel should be potable, however in practice there are many opportunities for contamination. FCubed provided water quality test results prior to the pilot commencing from installations in other countries that indicated favourable treatment result. However, as a Kiribati Government related project supplying water for potable needs, MHMS required their own standard tests of the panels. Also, as the pilot focussed on community maintained and operated installations and to identify training needs, it was anticipated that water quality would be lower in this study.

Water quality sampling was undertaken by MISE and MHMS during monthly monitoring visits to each trial site. These results varied significantly across the length of the monitoring period and between sites. The sampling methodology was adjusted as the monitoring phase progressed, potentially contributing to these result variations.

The parameters of focus are discussed in the following sections, and data is included in Appendix B.

ESCHERICHIA COLI

Of particular concern are the instances where Escherichia coli (E. coli) has been detected in the distillate. Due to the available data, at this stage the cause of positive E. coli readings is unknown. Possible sources include bird faeces or other sources of contaminants on the outside of the panel being washed into the storage tank during the next rain. In some circumstances the intake water was clear of E. coli and the output water tested positive for the bacteria. As discussed previously, the sampling methodology changed between samples, including sampling points varying between tests at each site. Depending on the specific set up at each site, an output water could have rainwater and distilled water combined or separated, which are not distinguished in data and would shed light on possible causes for this contamination.

For any further trials it would be recommended that further water quality monitoring be undertaken, if possible, with the distillate and collected rainwater tested separately, and with commentary provided on the cleanliness of the outside of the panels. This should be in addition to an assessment of the practices undertaken by the system users; if it is found that activities are being undertaken that may be contributing to the risk of contamination, this should be addressed with further training.

TURBIDITY

Turbidity is a value indicative of the effectiveness of treatment and quality of source water. Most potable water treatment systems require a turbidity limit of 1 NTU to ensure the treatment process works effectively to remove or deactivate harmful pathogens. In solar distillation, source water with low turbidity will enhance the treatment process and increase the longevity of water supply components, especially the pre-filtration and pumps. Clear source water means the filters are less likely to clog and the risk of protozoa breaching the filtration barrier is reduced. Turbidity in output water also indicates whether the treatment process is operating as designed. If the system is working as designed and without cross-contamination, solar distilled water should reduce turbidity of input water substantially.

The monitoring results for this trial show several instances where distilled/collected water has a higher turbidity than 1 NTU. This turbidity is likely due to the intrusion of material from other sources (e.g. dust on the panels, organic matter in the tank), however, it means that it is not reasonable to call the water free of contamination.

It is recommended that further sampling be undertaken, in particular assessing the distillate and runoff from the panels separately.

CHEMICALS

Nitrate, ammonia, fluoride, free chlorine and total chlorine were tested for at each sampling point as per MHMS standard procedure. The guideline values of these chemicals which are used in analysis are in Table 3 as per WHO guidelines (World Health Organisation, 2017), and where values were not of health significance then an aesthetic value is used for analysis.

Table 3. Chemical guideline values

Item	Value	Unit	Comments
Nitrate	50	m/L	Guideline Value
Ammonia	1.5	mg/L	Aesthetic value
Fluoride	1.5	mg/L	Guideline Value
Chlorine	5	mg/L as Cl_2	Guideline Value

A detailed analysis of the interactions between these chemicals and possible products of reactions were not conducted in this study.

Free chlorine refers to the residual chlorine available in a water supply after treatment to react with any additional contamination that occurs between the treatment plant and consumers. It is used as an additional barrier to harmful contamination. Most disinfected drinking water have target FAC concentrations of 0.2-1 mg/L. Chlorides can occur in drinking water via natural sources, sewage, industrial contaminants and saline intrusion. Chlorine present in groundwater at concentrations similar to that of municipal water supplies however is unusual, and the highest reading in a source sample during the monitoring period was 1.26 mg/L in the source well of Bonriki. However, as the water in the distillation system is not dosed with chlorine, the free chlorine detected in the source wells is most likely entering as water leaking from the municipal supply. Free chlorine values decreased over the course of the monitoring period, indicating a change in environment, however there is potential for sample error improving.

The 1.5 mg/L limit for ammonia is based on the point at which it becomes unpleasant to consume. The WHO consider ammonia in drinking-water to not be of immediate health relevance, and therefore have not proposed a health-based maximum value. The 1.5 mg/L value was exceeded once at Eita West in August 2020, with all other values falling far below the threshold. The cause of this outlier is unknown, and is therefore of some concern, as it may indicate potential problems with the system at that point in time.

All recorded data indicates values below the thresholds for fluoride and nitrates.

QUANTITY

INSTALLATION TYPES

There were two trial sizes in this project in order to assess the benefits and costs of each, referred to as ‘household’ and ‘community’ sites, which are shown in Figures 2 and 3.

Figure 2. Two-panel household carocell installation

Figure 3. 15-panel household carocell installation

During project scoping, it was determined that the average Tarawa household would likely be able to have their drinking water 'needs' met by two panels. However, during monitoring visits, it became apparent that while it was designated as a household supply, the culture of the community meant that the water was frequently shared with neighbours (referred to as 'household clusters' in this project). Requests by users to extend the household installations to five panels was granted in order to meet the water demands of the household cluster users. This early feedback indicated that the single household installation was unlikely to be adequate on a larger scale, due to the consensus by all users that a 'household' system really be treated as a 'community' system.

MINIMUM QUANTITIES

The Sphere Standards cites a 15 L/person/day minimum (Sphere Standards, 2018), however this is intended as a guide for short term emergency solutions for disasters. The standard should be considered as a guide, and does not replace the need for decisions made which consider the context of the emergency. The standard is intended to include water for all uses such as washing dishes and washing children.

For the amount of drinking water necessary to live healthily, the general recommendation from the U.S. National Academies of Sciences, Engineering, and Medicine is about 2.7L/day for women and 3.7L/day for men, or 3.2L/p/day on average. This amount includes water obtained from food or beverages such as tea, but does not necessarily account for the greater fluid intake required for individuals living in hot climates.

SYSTEM OUTPUTS

FCubed provided capacity calculations based on data collected in Tabiteuea, south of Tarawa. With an assumed solar irradiation of 6.80 kWh/m^2.day and an annual rainfall of 810 mm, there is an anticipated average daily output from a single panel of 22.5 L, with 17.9 L from distillation and 4.7 L from rain harvesting. The design of a two-panel household sized system is expected to therefore output an average of 45 L/day, and a 15-panel community unit output 338 L/day. These calculations are based on a 55% efficiency of solar distillation, and the 3 m^2 surface area of the panel.

Unfortunately, as flow meters were not included in the system set up, and water was collected at the same point from both rainfall and solar distillation, it was not possible to verify FCubed's calculations with observed flows. It is recommended that automated flow meters are included in any further trials to enable both verify FCubed's calculations and provide an early indication of when the system is not working.

PERSONS PER PANEL

Drinking water only

If the system is required to produce a minimum quantity of drinking water of 3.2 L/p/day, and a factor of safety of two is used (as the system relies on some rainfall and the consequences of underestimating are severe), then each panel should be able to service approximately 3.5 people.

All potable water needs

The target output volume increases substantially if the water is also to be used for things other than drinking (e.g. cooking and washing), where a value of 15 L/p/day should be used at a minimum. As the consequences of a lower-than-predicted output are still significant but less life threatening, using a factor of safety of 1.5 determines there should be one panel installed per person.

Future trials and installations will require agreement of all users on the desired level of service of the systems, and clear communication on expectations and uses of the systems. If it is to be just for the supply of drinking water, then one panel per 3.5 people is recommended. If the system is to provide potable water for all uses, then one panel per person is recommended.

PHYSICAL SET UP

FCubed and Green Living have recommended construction and site designs that extend beyond the panels themselves in order to optimize their output and longevity. These were considered at the sites during the installation and monitoring phases, and the value in these recommendations discussed in the following sections.

FENCING

It became apparent that to reduce the risk of damage to the system, the sites needed to be fenced. All sites except for Temaiku experienced issues partially caused by a lack of protective fencing. Issues included unintentional damage by children, dogs and free-roaming animals (e.g. pigs), with at risk components being outlet taps and feed lines. Any component failure creates a potential pathway for contamination, and so by protecting the system, potential damage and also potential contamination from unsanitary interaction with potable components is reduced. By December 2020, Eita had a temporary fence in place, and Banraeaba had well established fencing in place. Other sites had recommendations to implement fencing as soon as practicable.

In future installations it is recommended that fencing (or a commitment to putting in fences) be a prerequisite to installation, and the cost of such fencing is included in any installation quotations.

MOUNTING STRUCTURE

Green Living noted roof mounted installations require additional protective paint to protect the underside of the panels if installed on a galvanised roof due to the roof reflecting UV onto the back of the unit. This was not a part of the trial but is a key consideration for future installations. FCubed have stated that the wind ratings of the system are appropriate for the Kiribati climate, which is rated as a low likelihood of cyclone (GFDRR, 2021) due to the nation's geography. A standalone structure has a much more easily quantified and managed level of resilience to wind when compared to a roof mounted system, which relies on the integrity of the existing building.

The standalone structures also present an opportunity to provide shade, and this has been evidenced by the space underneath them being used by the families and communities for other activities.

TREES

Overhanging trees reduce the amount of sunlight available, and increase the risk of contamination with leaf matter. They also pose a risk if they are to drop any branches or fall onto the structure. It is therefore recommended to have any overhanging trees cleared from the site prior to installation, or to select a site away from trees or any shading structures.

TANK PLATFORMS

To prolong the life of the tanks it is recommended that they are placed on a level, well-compacted platform of gravel or concrete. This reduces the risk of damage to the underside of the tank, enhances structural stability, and decreases the likelihood of contamination from ground particles.

SOURCE WATER

A regular issue encountered by Green Living is the quality of the source water compromising the system. Source water with high suspended solids and turbidity can block the filters faster, and subsequently reduce the lifespan of the pump.

The source water being available in adequate amounts is crucial to reducing the risk of the panels drying out due to water not being pumped through during solar hours. If the system runs dry during solar hours, the filtration fabric in the panels can shrink, which will permanently compromise the efficiency of the system and reduce the capacity of the treatment system and ultimate output volume.

Where past installations have relied on manual filling of a source water tank, Green Living's recommendations are to prioritise a wet well set up, where a well (existing or dug for the system) is linked with a solar pump directly to the system. This reduces the likelihood of the source water running dry due to missed maintenance tasks, and improves the turbidity of the water with natural filtration through the ground to the well, when compared to sea water from the shoreline. A dedicated source of water can also improve the ability to protect the source and reduce likelihood of contamination.

SYSTEM COMPONENTS

Green Living have identified that the most common troubleshooting problem they encounter are blocked filters. This can be mitigated by both ensuring source water is free of macro contaminants and that the individuals responsible for managing the system clean the filter regularly.

It is common for the filters to be forgotten if the maintenance schedule requires them to be checked monthly, so it has been suggested that this is promoted as a weekly task instead, as it is possible the individuals responsible are more likely to remember the task if it is associated with a certain day of the week.

Blocked filters pose a risk as they place a strain on the motor, eventually causing it to burn out. In an attempt to partially mitigate this Green Living are working with FCubed to use brushless motors instead.

INSTALLATION

A key observation made of the installation process is the speed of the installation itself. For a standard installation, it would take Green Living's team on average two days to install the structure and system. A further three days are usually required to also purge the system and have it ready for production. For a community scale potable water treatment system, this is a considerably short timeframe.

This short installation timeframe may make the systems useful in disaster recovery contexts. Additionally, as the systems are relatively easy to install and operate (i.e. without the specialist technical knowledge as would be required for a desalination or reverse osmosis unit) it may be possible to deliver them to communities with zero contact, and assist them to get them running via remote means (and this may prove useful in a pandemic).

All the trial sites were installed as shelter structures, rather than roof mounted. These were easier to install, and have proven to be beneficial to the users as additional shelter. Roof mountings are possible where space is an issue, but add further complications in ensuring that the roof remains watertight, that the roof structure is structurally sound, and that the backs of the panels are painted to prevent UV damage.

MAINTENANCE AND OPERATION

The maintenance program provided by Green Living is a valuable component of the FCubed Carocell units. As a local enterprise they are able to perform regular maintenance tasks, work with individuals to train them in undertaking those tasks, and supply spare parts.

Communities however often do not utilise this arrangement when issues arise, risking irreversible damage to the units. Regular scheduled monitoring visits can pick these issues up, but the risk of permanent damage is less if issues are reported within days of it arising.

The accessibility of the maintenance team for remote communities has also not been tested by this project, and will need to be considered for any projects undertaken outside of Tarawa.

The following maintenance activities were recommended:

Daily - limited to visual inspections of the units including:

1. Check that the solar pump is operating;
2. Inspect the internal fabric is soaked and not drying out; and
3. Check the fittings for any leaks.

Weekly - open and clean the pump filter

These simple inspections can detect any potential damage to the panels and can be used to diagnose any issues using the troubleshooting guide. If there is anything that cannot be easily addressed, it is a simple indication for the need of maintenance support from Green Living.

Monthly - ensuring the panels are clear of debris to guarantee the panel surface is uninterrupted from solar irradiation and for rain harvesting. This is dependent on the surrounding land use of the site. The other task involves ensuring the source water tank does not exceed 150,000 ppm of salt saturation. If fresh water is continually inputted, then this is unlikely to be an issue. If, however, the brine water is recycled through the unit, the salt content will increase, risking damage to the unit.

Aside from maintenance call outs as needed, Green Living are able to conduct monthly or weekly maintenance, and have the spare components required in storage on the occasion a replacement is needed.

MAINTENANCE AND OPERATION TRAINING

Managers were assessed in site visits by MISE for basic tasks such as checking and cleaning filters, checking pump operation, turning the system on and off, and confirming they know how to contact maintenance support (i.e. Green Living). During the Managers Workshop in December 2020, many other operational and maintenance tasks were explained and knowledge shared amongst managers. This has been taken to mean that more training of the managers is required, and over a broader range of issues. It is also recommended that regular meetings between different site managers are organised, to enable information sharing.

Green Living have proposed to increase their site visits to once a week, to decrease the likelihood of damage to the system, as well as making sure key tasks are more likely to be completed.

When working with communities that are outside of South Tarawa, Green Living would recommend the team be in the community for a month. The systems would be installed and running early on in the visit, and there is then the opportunity to train a larger group of people to maintain the systems, experience and work through troubleshooting exercises, and to build working relationships with the community. This is significantly longer than the training undertaken during the installations in this trial. However, this training period is also recommended due to the likely delay in maintenance call outs for outer island communities. Green Living are also working with FCubed to import brushless motors to make the system more durable for the Kiribati climate.

HEALTH

A major outcome of sustainable and safe drinking water is the health implications on communities. Solar distillation is an effective means of removing bacteria and protozoa from water, as well as salinity. However, the monitoring undertaken by MHMS indicates that the distillate is still becoming contaminated with faecal coliforms.

This is of concern, and should be investigated further, with a continued regime of monitoring implemented alongside further training on appropriate disinfection and system management. If possible, the MHMS tests should be undertaken twice at each monitoring point to provide insight into the latent error in the testing methodology.

ENVIRONMENTAL IMPACTS

Environmental impacts were assessed by MELAD Environment and Conservation Division (ECD) as per the Terms of Reference for the Tarawa Solar Distillation Working Committee, "*Consider operational management structures for all activities so they have minimal impact on the environment, cultural and communities/household affairs*". The Environment amendment act and regulations (2017) were used to assess the impact of the units in Kiribati and regulations on their operation and installation through the Environmental Licence application. If an activity reaches a certain impact limit, an Environmental and Social Impact Assessment (ESIA) and appropriate licences are required, alongside monitoring, however it was concluded that this project was too small to have a significant impact on the surrounding environment.

One restriction potentially triggered by the activity was "*Use or extraction of more than 10,000L of water per day from a single source*". Fortunately, the scale of these household and community supplies means that they are far from exceeding these limits, at an approximate daily input of 96L per day. Therefore, an Environmental Licence is not required.

Other potential environment impacts include land clearing, noise generation, and materials use (including aggregate) during construction, and brine disposal during operation. The risk of these impacts are considered negligible at the current pilot scale by MELAD ECD, and this is likely to remain the case with any future installations too.

It was also noted that the use of these units may reduce plastic waste from bottled water. The number of plastic bottles necessary could be further reduced by supplying bottles made from a sustainable material with the units.

5. CONCLUSIONS

This technology pilot was designed to trial low cost and accessible potable water treatment solutions for use in remote communities in the outer islands of Kiribati. The trial focused on the practical application of this technology in a community setting, with valuable feedback collected from partners and water supply managers.

While water quality was improved when going through the system, target values are still not yet achieved. Refining the monitoring systems and operational training would improve these values by managing the water in a manner that reduces the risk of faecal contamination.

Output volumes were not recorded, but through monitoring visits and discussions it was determined that initial designs were insufficient due to the culture of sharing resources with neighbours in Kiribati communities. These systems were upgraded, and it is recommended that water volumes are also monitored.

As with any community scale trial, governance plays a major part in the success of system. This trial highlighted the value of an agreed approach to water supply a management and assigned roles and responsibilities to keep the system running safely and effectively.

The recommendations made across this report are to be applied in any future trials and programmes using this technology in Kiribati, and are recommended for consideration in any other publicly operated water supply systems.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Britannica. (2020). *Kiribati*. Retrieved from Britannica: https://www.britannica.com/place/Kiribati

Eiloart, I. (2019). *Capacity Development and Water Security for Kiribati.* Wellington: Water New Zealand.

FCubed. (2017). *Carocell Solar Water Farms - All In One Solution*. Retrieved from FCubed Solar Water Processors: http://www.fcubed.com.au/aspx/carocell-panels.aspx

GFDRR. (2021). *Kiribati*. Retrieved from Think Hazard: https://thinkhazard.org/en/report/135-kiribati/CY

Kiribati Meteorology Service, Australia Bureau of Meterology, CSIRO. (2013). *Pacific Climate Change Science Program: Current and Future Climate of Kiribati.* Tarawa: Australian Government.

Kiribati National Statistics Office. (2020). *Population*. Retrieved from Kiribati National Statistics Office: https://nso.gov.ki/statistics/population/

Lifestraw. (2021). *Lifestraw Community*. Retrieved from Lifestraw: https://lifestraw.com/products/lifestraw-community

Nasih, F. S.-A. (2019). *South Tarawa Water Supply Project, Kiribati.* Pathumthani, Thailand: Asian Institute of Technology.

Public Utilities Board. (2019). *Public Utilities Board*. Retrieved from Public Utilities Board: http://pub.com.ki/

SPC. (2007). *Kiribati*. Retrieved from Pacific Community: water, Sanitaiton Program Geoscience Division: http://www.pacificwater.org/pages.cfm/country-information/kiribati.html

Sphere Standards. (2018). *The Sphere Handbook.* Sphere Standards.

World Health Organisation. (2017). *Guidelines for Drinking-water Quality.* Geneva: World Health Organisation.

APPENDIX A – FCUBED DURABILITY MATRIX

F Cubed – Useful Life Matrix

The durability of the panel depends on number of factors however the components (as outlined below) have been selected to ensure the maximum operating life of the panel but also provide the capability of replacing components to extend the life on a continual basis:

Component	Composition	Lifespan	Replaceable
Outer Frame	Aluminium	20+ years	No
Internal Element (Fabric)	Treated Fabric to absorb solids and control flow	5+ years	Yes
Top Film	Treated Polycarbonate (UV Protected/Cyclone and Hail Tested)	10+ years	Yes
Bottom and Inner Film	Polycarbonate	10 years+	Yes
Internal Backing Tray	Treated Aluminium (Anti-Corrosive)	10 years	No
Water Trough and Outlets	Extruded Plastic	20 years	Yes (except internal trough)
Irrigation Fittings including inlet tubing, inlet pipe and accessories	Plastic	5-20 years	Yes
Leg Supports	Galvanised Steel	20+years	Yes

F Cubed overs a 1 year manufacturer's warranty F Cubed Limited warrants your product to be brand new and free of defect and rust in material and workmanship for a period of Twelve (12) months, starting from the original purchase date.

The warranty covers defects in manufacturing discovered while using the product as recommended by the manufacturer. The warranty does not cover loss theft or deliberate damage, nor is coverage extended to damage caused by misuse including continual exposure to climactic conditions when not in use for extended periods or industrial waste water treatment abuse, unauthorized modification, improper storage conditions, lightning or natural disasters.

APPENDIX B – WATER QUALITY DATA, MELAD ECD

WATER QUALITY MONITORING DATA

Supply	Date	Sample Point	E. Coli	Total Coliform	Turbidity	Temperature	pH	Conductivity	Nitrate	Ammonia	Fluoride	Free Chlorine	Total Chlorine
			per 100 ml	*per 100 ml*	*NTU*	*Celsius*		*ms*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Buota HH	4/05/2020	In Source Well	3	7	4.93	28.9	7.58	9.24	1	0.31	0.93	0.93	0.01
Buota HH	4/05/2020	Out Tap	0	14	0.27	31	8.78	0.25	0.32	0.21	0.28	0.28	0.02
Bonriki	4/05/2020	In Source Well	20	5	4.94	30.1	7.93	12.76	1.54	0.78	1.26	1.26	0
Bonriki	4/05/2020	Out Tap	0	0	0.44	30.9	8.51	0.35	0.56	0.24	0.04	0.04	0
Eita West	4/05/2020	In Source Well	75	1	0.52	19.9	7.61	4.32	1.32	0.02	0.75	0.75	0.02
Eita West	4/05/2020	Out Tap	0	0	0.47	21	8.39	0.14	1.58	0.04	0.02	0.02	0.02
Banraeaba East	4/05/2020	In Source Well	29	0	0.56	28.9	7.58	7.08	1.9	0.01	0.42	0.42	0
Banraeaba East	4/05/2020	Out Tap	0	82	0.12	34.1	7.63	0.17	0.62	0.02	0.02	0.02	0
Buota Com	10/08/2020	Out Panel	7	0	0.43	41.6	6.78	122.1	0.078	0.46	0.09	0.04	0
Buota Com	10/08/2020	Out Tank	1	0	3.27	33.1	7.45	151.1	0.094	0.6	0	0.03	0
Buota HH	10/08/2020	Out Panel	1	3					0.161	0.05	0	0.02	0.02
Buota HH	10/08/2020	Out Tank	0	0	0.87	33.3	7.28	84.42	0.2	0.04	0.1	0.01	0
Bonriki	10/08/2020	Out Panel	2	TNTC	0.68	33.7	7.02	81.16	0.112	0	0	0.05	
Bonriki	10/08/2020	Out Tank	4	28	0.55	41.45	7.47	87.4	0.125	0.01	0	0.03	
Temaiku	10/08/2020	Out Panel	1	26	0.2	37.2	7.39	140.6	0.188	0	0.04	0.02	0
Temaiku	10/08/2020	Out Tank	0	0	0.55	43.7	6.98	27.23	0.125	0.01	0	0.04	0
Banraeaba East	10/08/2020	Out Panel	0	0	0.01	37	6.42	65.54	0.307	0.01	0	0	0.02
Banraeaba East	10/08/2020	Out Tank	4	14	0.66	40.5	6.57	201.9					
Eita West	10/08/2020	Out Panel	2	1	0.09	38.6	7.18	242.5	0.138	2.85	0.15	0.03	0
Eita West	10/08/2020	Out Tank	1	2	0.01	37.1	6.66	2.4					
Buota Com	14/09/2020	In Source Well	0	0	0.81	44.3	7.76	3.9		0.12	0.06	0	0.01
Temaiku	14/09/2020	Out Panel	0	2	1.02	39.6	7.24	2.98		0	0.22	0	0
Temaiku	14/09/2020	Out Tap	0	0	0.07	40.1	8.23	193.7	0.006	0.01	0.01	0	0
Banraeaba East	14/09/2020	Out Panel	0	1	0.19	45	7.01	851.1	0.018	0.02	0.01	0	0
Banraeaba East	14/09/2020	Out Tap	0	1	0.27	42.3	7.9	812.1	0.019	0.03	0.14	0	0.03
Eita West	14/09/2020	Out Panel	0	2	0.35	42.2	8.29	18.29	0.021	0.19	0.03	0.02	0.01
Eita West	14/09/2020	In Source Well	0	15	0.37	47.1	7.54	16.89	0.43	0.48	0.85	0.03	0
Eita West	14/09/2020	Out Tap	0	4	0.15	41.4	8.06	218.5	0.017	0.29	0.15	0.04	0.02