Mid-term Review Report of the GEF UN Environment Project "SolarChill Development, Testing, and Technology Transfer Outreach"

Climate Change Mitigation Unit of UN Environment

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Climate Change Mitigation Unit of UN Environment

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SolarChill Development, Testing, and Technology Transfer Outreach Project
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ABOUT THE EVALUATION[1]

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Brief Description: This report is a Mid-Term Review of a UN Environment-GEF project to be implemented between 2016 and 2019. The project's overall goal is to develop, transfer and commercialize a sustainable, environment friendly and grid-independent cooling technology. This is the so called SolarChill technology. The SolarChill project was launched back in 2001, to develop and deliver affordable, technically reliable, ozone layer and climate friendly, solar powered and lead acid battery free refrigeration technology. Two applications will use the SolarChill technology, in vaccine coolers (SolarChill-A) and in light commercial and household coolers (SolarChill-B). The project is currently in the field test phase. A total of 113 SC-A and 45 SC-B will undergo 12 months field test in Colombia, Kenya and Swaziland. In parallel, a technology transfer exercise, to local manufacturers, will take place.

Key words: SolarChill technology, Vaccine cooler, Mid-Term Review, GEF, SKAT, HEAT, UN Environment, WHO, UNICEF, technology transfer, Sustainability, commercial cooler, domestic refrigerator, environment friendly, greenhouse gas, hydrocarbon refrigerant, Mobisol, Remote areas, Power/electricity grid, Colombia, Kenya, eSwatini, Swaziland

Mid-term Review under the Climate Change Mitigation Unit, UN Environment

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List of acronyms and abbreviations

MTR	Mid Term Review
UN Environment	United Nations Environment (Previously called the UNEP)
GEF	Global Environment Facility
UNICEF	United Nation International Children's Emergency Fund
WHO	World Health Organization
MOH	Ministry of Health
MOE	Ministry of Environment
SKAT	Schweizerische Kontaktstelle für Angepasste Technik, meaning Swiss Centre for Appropriate Technology
HEAT	Habitat, Energy Application & Technology
GIZ	Gesellschaft für International Zusammenarbeit (German International Cooperation)
DTI	Danish Technological Institute
CHAK	Christian Health Association of Kenya
SELF	Solar Electric Light Fund
PATH	Program of Appropriate Technology in Health
IEA	International Environmental Agency
GAVI	Vaccine alliance
Global LEAP	Global Lighting and Energy Access Partnership
GHG	Green-House Gas
LPG	Liquified Petroleum Gas
RFQ	Request for Quotation
TCO	Total Cost of Ownership
SDD	Solar Direct Drive
SC-A	SolarChill-A: SolarChill technology for vaccine refrigerators
SC-B	SolarChill-B: SolarChill technology for small commercial and household refrigerators
OEM	Original Equipment Manufacturer

Executive Summary

“A nation’s greatness is measured by how it treats its weakest members.”
-Mahatma Ghandi-

Refrigeration is a key element in the cold-chain for food, medicine and vaccines preservation. Lack of relevant cooling systems results in extensive food, medicine and vaccines spoilage.
In regions of the world without reliable electrical grid (impacting over 1 billion people), preservation of temperature-sensitive vaccines, medicines and food is problematic. In such regions and until recently, fossil fuel operated units are mainly used. These refrigerators are inexpensive but present a number of problems related to operating costs, effectiveness in maintaining appropriate temperatures, fuel supply, flammability, environmental impact through greenhouse gas emissions and emission of toxic fumes that are dangerous to humans in enclosed spaces.

In addition, most of current solar vaccine refrigerators rely on lead acid batteries to store energy. These batteries break down frequently, especially in hot climates. Batteries are also vulnerable to theft and pose an environmental hazard upon disposal. Hence, the SolarChill Direct Drive (no battery, no fuel needed) technology combined with a refrigeration system using an environment friendly natural refrigerant seems to be the most appropriate technical solution for such applications.

The SolarChill project was launched back in 2001, to develop and deliver affordable, technically reliable, ozone layer and climate friendly, solar powered and lead acid battery free refrigeration technology. It uses solar power to run a direct current (DC) hydrocarbon-based refrigerator compressor. Hydrocarbons (isobutane R600a), used as refrigerants, are safe for the ozone layer and for the climate. Energy efficient refrigeration system, freezes an ice bank in the SolarChill cabinet. Solar energy is thus stored in an “ice battery”. An electronic thermostat maintains the units at the required temperatures. The required temperature range for vaccines is between 2 and 8 degrees Centigrade, day and night. The optimum temperature range for perishable food storage is 3 to 5 °C.

In low-sun situations, or with power completely disrupted, the ice bank combined with the thick insulation of the cabinet maintains acceptable temperatures for up to 5 days. The thickness of the insulation varies according to the ambient temperature for which the specific SolarChill units are designed.

This technology is a reliable and sustainable solution to meeting refrigeration needs. It is an environment friendly approach to supporting the delivery of health care and food security to poor populations in difficult access remote areas.

The field test will cover two types of SolarChill applications:
- SolarChill-A (SC-A) vaccine cooler, for temperature-sensitive vaccines and medicines
- SolarChill-B (SC-B) for food preservation for domestic and small commercial applications

The SolarChill consortium/partners include the Danish Technological Institute (DTI); Gesellschaft für International Zusammenarbeit (German International Cooperation, GIZ); Greenpeace International; Programs for Appropriate Technologies in Health (PATH); Habitat, Energy Application & Technology (HEAT); SKAT Foundation; UN Environment; United Nations Children's Fund (UNICEF); World Health Organization (WHO); with consultation by SELF.

The review identifies lessons of operational relevance for future project formulation and implementation (especially for the remainder of this project).

The SolarChill-A and B field tests are to be conducted in Colombia, Kenya and the Kingdom of eSwatini (Swaziland). During the Project Preparation Phase (2012/2013) the field test sites (health centers) for SolarChill-A were selected, by Ministry of Health (MOH) of each country with the purpose of covering a wide range of climatic conditions.

According to the IEA, 2010, the total demand (SC-A and SC-B) is estimated to grow from currently some 30,000 units in all three countries to over 1.5 million units in 2050 (with over 90% of the demand coming from Kenya).

SolarChill-A units to be field tested require having WHO PQS (Performance, Quality, Safety Certification). These performance requirements are to ensure a level of quality for refrigerators that are used to store temperature-sensitive vaccines and medicines. SolarChill-B units to be field tested will first be laboratory tested by the Danish Technological Institute (DTI).

The selected SolarChill-A suppliers include Vestfrost, Godreg & Boice, B-Medical, Haier and Zero Appliances. The Ministry of Health of each country was involved in the selection of the models that are being field tested.

Each SolarChill unit is delivered with solar panels, mounting rails, needed cables and accessories. Data logging systems are shipped separately by DTI and will be mounted by HEAT's country managers at the field test sites.

The intention of the GEF SolarChill Project is to stimulate the global market uptake of the SolarChill direct drive technology, especially in off-grid areas, in both the health and food security applications. The Project also intends to provide transparent field test data, which can be widely referenced and used for outreach activities and technology transfer. Further, these results will be used to provide valuable feedback to SolarChill manufacturers for design improvement.

Clearly, the set objectives are:

1. Procure and install (for field test) a total of 198 SolarChill-A units in three countries (66 in each), namely Colombia, Kenya and eSwatini (Swaziland). Field test to run for 12 months.
2. Laboratory testing of prototypes, procurement, and field testing of a total of 45 SolarChill-B units in the above three countries (15 in each country)
3. Information dissemination (e.g. marketing campaign, increased awareness etc.) and technology transfer

With regard to the above objectives, and from the available field information that have been collected in the three countries, the SolarChill project is currently behind schedule. It is unlikely that most of the project goals will be met within the originally time lines, ending on December 2018.
The minimum expected delay will be anywhere between six and twelve months. The longest delay is expected to be in Kenya. An accelerated installation rate, will significantly limit extra delays in Colombia

and Swaziland. With a reduction of the duration of the field test to 6 months (instead of the current 12 months) the field test objectives could be met in the countries within the December 2019 extended project delivery dead line. Note that from the end of the field test, there is a need for at least two to three months to compile the final data and to draft the final project review.

Key factors influencing the above-mentioned delays varies by country. They are principally linked to logistics (shipping and in-land transport – Kenya and Colombia), missing parts (Colombia and Swaziland), custom clearance and import duties (Kenya and Colombia), technical trainings (Swaziland and Kenya), access to test sites (Swaziland), low installation rate, length of the field test, miscommunication due to language barriers (mainly in Colombia), etc.

The important objective of technology transfer could be met in Swaziland through sufficient financial support and ongoing SolarChill technology development work with a local refrigerator manufacturer, The Fridge Factory (formerly Palfridge). No foreseen technology transfer work neither in Colombia nor in Kenya.

Adjustments to objective one: The current number of deployed SolarChill-A field test units have been reduced from 66 per country to 37 in Colombia, 40 in Swaziland and 36 in Kenya. Another 70 SC-A units planned to be manufactured by The Fridge Company and deployed in the three countries. Unfortunately, as we speak, there is no firm delivery date of these 70 SolarChill-A units.

Request for Quotations (RFQs) have been raised by HEAT. All units have been negotiated and procured by the UNICEF. Ministry of Health (MOH) in Colombia and in Swaziland will finance the import duties, taxes and the cost of warehousing and transportation to the test sites. In Kenya, the government will not handle any of these costs. After the government declined to agree on the custom exemption, it had earlier agreed to its commitment to the project, the project partners decided to alter the choice of brands. Through the change in the choice of models and the transition to a lower unit prices, it was possible to have the same number of units as planned originally (same budget for the units' price plus customs fee).

Below is a summary of the progress and barriers, per country (see also Annex-III), pertaining to the above three objectives, together with comments and requests made by the major local stakeholders.

Special note: The level of local interest and jurisdiction varies according to applications. Whereas SolarChill-A is for healthcare delivery the primary focal point is with the Ministries of Health (MOH). Correspondingly, since SolarChill-B is for commercial and household applications with a potentially higher market size and environmental impact, the country focal point is with the Ministries of Environment (MOE)

Colombia

- See field test pictures in annex IV
- 37 SC-A units are delivered in-country. All field test sites have been identified and assessed.
- Technical trainings are completed by HEAT's country managers.
- To date (July 2018), 12 units have been installed (by HEAT's country managers), up and running. Installations expected to be completed by end of October 2018. No major field issues reported. The installation rate should ramp-up from four per month to at least 8 units per month
- SolarChill B: No SC-B units have been procured to date. Field test details yet to be determined
- No financial plans are in place yet to help end-users with the initial high price of SC-A and SC-B
- No SolarChill technology transfer work succeeded in Colombia due to lack of interest from local manufacturers. The main reason is the low annual volume foreseen for the off-grid technology
- Ministry of Health (MOH) estimates the future need in SC-A to about 100 units. With a preference for the combined (cooling and freezing) models. The needs in SolarChill-B are unclear with a minimum of 150 units

- Currently, MOH do not have any budget to procure additional SolarChill Direct Drive units
- For the Ministry of Environment (MOE), the SolarChill-B is of higher importance due to its larger potential volume. MOE is requesting financial support from the SolarChill project to conduct a market feasibility study and evaluate the real need for SolarChill-B units
- MOE expressed a clear disappointment regarding the Project's lack of focus and budget for technology transfer work
- MOE does not have funds to financially support the market penetration of SolarChill-B

Kenya

- The 36 SC-A units have been received after significant delays due to import duties issues
- Technical trainings (for installation and maintenance) have been conducted/completed by HEAT and the Kenyan Ministry of Health
- Installations expected to start in August, led by 3 technical teams from CHAK. At least 2 months will be needed for complete installation
- No SolarChill-B units have been procured. Field test details yet to be determined
- No financial plans are in place to help end-users with the initial high price of SC-A and SC-B. That said, Active discussions with PayGo providers (Mobisol, GreenWish) are taking place
- As there is no refrigerator manufacturing business in Kenya, the technology transfer work will not take place
- No governmental financial support

Kingdom of eSwatini (Swaziland)

- See field pictures in annex IV
- The 40 SC-A units have been received. Sites have been selected and assessed. MOH granted access to these sites only in mid-June which delayed the installation by at least one month. Two installations have been completed to date (mid-July 2018). All installations expected to be completed in December 2018
- Technical trainings (for installation and maintenance) have been completed in July by HEAT. Seven technicians from the Ministry of Health (MOH), six from the other involved ministries and health centers technicians attended these trainings
- Ministry of Health (MOH) estimates the future need in SC-A to 382 units, covering ALL remote health center locations. The needs in SC-B are yet undetermined
- No SC-B units have been procured. Field test details yet to be determined
- No financial plans in place yet to help end-users with the initial high price of SC-A and SC-B. Nevertheless, there are encouraging price projection for the SC-B units with the collaborative development work between Palfridge and MobiSol
- SolarChill technology transfer work have been successfully initiated with "The Fridge Factory" (Palfridge), a local manufacturer. A prototype for lab testing at DTI is expected to be ready in late December 2018. Production of the 70 SC-A units for field testing is planned for February 2019

To date (July 2018), very limited field performance data have been collected by DTI from the SolarChill-A units, but the few available ones shows good performance that meets the WHO/PQS temperature requirements.

From my field visit of May 26-31 to Colombia (Bogotá and Monteria region, north-west), to Swaziland on June 10-15 and the meetings I had with local authorities and key stakeholders (MOH, MOE, hospitals, health centers personnel, suppliers etc.), there is **no doubt about the relevance and the importance of this project for the local communities**, especially the SolarChill-A (SC-A) part. For example, in "Pueblo Bujo", a remote health center in Monteria area, the installed SolarChill-A unit is expected to increase the vaccines storage capacity from about a week to more than a month. As this site is equipped with a B-Medical combined model (freezing and cooling capacity), the storage capacity can be even higher with the possibility to use the frozen water (icepacks) to perform home visits for extramural vaccination (e.g. patients with impossible and/or difficult mobility).

Nevertheless, this project suffers important missing element in its construction as well as in its execution. Here are a few insights, which will be further developed in this report:

- The project objectives have been developed and set about ten years ago. Since then, these objectives haven't been re-evaluated taking into consideration the technology advancement, the real local needs, the longer-term goals, etc.
- Lack of field test protocol document and field test success criteria document: When the field test starts? At the installation of the first unit or when all units are installed? What are the criteria for a successful field test?
- Why the field test countries haven't been selected based on real needs e.g. electrification level, which is much lower in some west African countries compared to Colombia and Swaziland
- Suppliers and manufacturers haven't been involved in the field test as major players
- Some current SC-A field test units are at too high purchase price (about 4 times the price objective). One could ask why we are field testing models that might not be commercialized under their current design?
- Some missing elements in the Request for Quotation (RFQ) creating delivery delays and additional fees e.g. procurement via non-local representatives (i.e. in Colombia, the main suppliers' contact persons are sitting in Europe at 7 hours difference and do not speak Spanish!), no clear after sales and servicing contract with local agencies, spare parts provision, etc.
- Lack of a long-term commercialization plan. Currently, the project ends at the completion of the field test, with a deadline set for December 2018, which might be extended till December 2019 if budget permits. What's next? How and who will handle the longer-term commercialization work?
- No plan for the technology transfer work neither in Colombia nor Kenya
- No clear plan on how the units' initial price will be reduced to allow mass adoption, production and commercialization.

Recommendations

- For future projects, there is a need for an "Initial Project Review" exercise, by an external expert, in order to identify weakness and/or gaps in the project structure before the execution and implementation process starts
- Reduce the field test time of SolarChill-A from 12 months to a max of 6 months. And set a clear field test protocol and success criteria.
- Reduce SolarChill-B field test from 12 to 6 months and review its technical requirement for lab test
- Manufacturers should be more involved and take more responsibilities in the field test process: Trainings, installation, monitoring, servicing, etc.
- Do not start the SolarChill-B field test before addressing the high initial price issue
- Take the learnings from the SolarChill-A field test to improve the SolarChill-B field test: review the lab test requirement, improve communication with the procurement team, a better advisory role of the UNICEF procurement team to improve the RFQ content, etc.
- Accelerate the SolarChill-A units' installations to avoid further delays
- Clarify (or re-negotiate if needed) the after-sales service contract including spare parts provision, preferably with the local sales office of the original manufacturers e.g. after the warranty period: to whom, and following which process, should be addressed the service calls? How much a service intervention will cost?
- Work with current manufacturer and possible external partners to reduce the initial cost (especially for SolarChill-B) via technical design review and supply chain optimization
- Support local (by country) surveys to determine the market potential for SolarChill-B. Use this information during the technology transfer exercise
- Put more focus and budget against the technology transfer process

- SolarChill-A combined capacity (cooling and freezing) is the preferred design option for remote health centers in Colombia. But it's not the case in Swaziland. It means, adjust the units design to the local needs
- Going forward (and via the RFQ process), connect with local manufacturers' representatives for any commercial, technical and after sales services. Time difference and the language barriers make effective communication very difficult
- Minimize the number of active stakeholders in order to avoid complex communications and project's delays

Introduction

This Mid Term Review (MTR), is aimed to evaluate the project status (ON/OFF track) to date, identify gaps, what went well, what went wrong and provide relevant recommendations.

The SolarChill project was co-initiated with Greenpeace International through UNEP's Economy Divisions Ozone Action Branch: the unit responsible for phasing out ozone-depleting substances. In addition, the Energy Branch manages a number of projects on energy efficiency in refrigerators. In particular, the project compliments UNEP's POW output (b): "low carbon and clean energy sources and technology alternatives are increasingly adopted, inefficient technologies are phased out, and economic growth, pollution, and greenhouse gas emissions are decoupled by countries based on technical and economic assessments, cooperation, policy advice, legislative support, and catalytic financing mechanisms."

The SolarChill (SC) project started back in 2001. The project's objectives, agreed in 2003, aims to tangibly improve the quality of our environment and human health by delivering affordable, ozone layer and climate friendly, lead battery free, solar powered vaccine cooling and food refrigeration to parts of the world that are without reliable electrical supply. From financial point of view, the initial GEF council approval was given in November 2009. The project covers two applications, SolarChill-A (SC-A) for vaccine refrigerator and SolarChill-B (SC-B) for household and light commercial refrigerator. Each model (SC-A and SC-B) will undergo a 12 months field test in Colombia, Kenya and Swaziland.

Project phases completed to date:

- GEF fund approval and co-financing: 2,983,365 + 8,033,500 = 11,016,865 USD
- SolarChill technology development
- Suppliers and models' selection
- WHO/PQS lab tests and compliance for SolarChill-A
- Selection and assessment of field test sites in Colombia, Kenya and Swaziland
- Procurement, shipment and arrival of the field test units to respective countries
- Customs clearance and administrative work completed in the three countries
- Equipment's placement started in Colombia and Swaziland. Planned to start in August in Kenya

The table 1 below shows the key project's milestones going forward and current best estimate for completion dates. As field delays might occur, these dates might/will be impacted.

Table 1: Project's milestones

Milestone	Deadline
Project Desk Review	26 April – 18 May 2018
Telephone interviews, surveys etc.	2 – 15 May 2018
Inception Report	18 May 2018
Telephone interviews, surveys etc.	21 - 25 May 2018
Mission to Colombia	28 – 31 May 2018
Mission to Swaziland	11 – 14 June 2018
Draft report to Climate Change Mitigation Unit	26 July 2018
Draft report to Executing partners	15 August 2018
Final Report Compilation	05 September 2018
Final Report shared with all respondents	18 September 2018

As the project is about midway from completion, an external consultant (Antoine Azar) was hired to undertake a Mid-Term Review (MTR) of the project. The consultant will lead the MTR design and information analysis. More specifically:

1. Manage the inception phase of the review
2. Coordination of the data collection and analysis phase of the Mid-term Review
3. Coordination of the reporting phase: prepare report summary, write main report, take into account and answer stakeholder’s comments
4. Managing internal and external relations of the review team, with transparent communication on progress and issues

Project areas that will be reviewed in detail:

1. Check/analyze the field test protocol, its duration and its success criteria
2. Check/analyze the field test data collection process, the teams involved, the dissemination of these data and its evaluation
3. Evaluate the equipment’s procurement process
4. Analyze equipment’s cost and its impact on the long-term project’s viability
5. Financial plans: Government incentives, micro financing etc.
6. Outreach plan: Today and after the field test
7. Marketing plan beyond the field test, i.e. After a successful field test, what is next?
8. After the field test: How SC-A will be linked to SC-B? And most importantly, what is the current plan to make SC-B affordable for the remote areas populations!
9. Evaluate the project strength, weakness and risks and their impact on the project success

Ultimate result of service and intended audience: The consultant will deliver a concise Mid-Term Review Report for the project "SolarChill Development, Testing, and Technology Transfer Outreach". It should describe the project’s progress against the set objectives, whether it’s on-track, key risks and proposed corrective actions, lessons learned and recommendations. This report is the property of the UN Environment and it’ll be shared with the consortium parties, the MOH/MOE of the three field test countries and any other party/group that the UN Environment consider relevant.

Evaluation Methods

Three countries will be covered under this mid-term evaluation report, namely Colombia, Kenya and the Kingdom of eSwatini (Swaziland). The evaluation process will be based on 1) site visits and face-to-face meetings and interviews of key players in Colombia and eSwatini, and 2) Skype calls and interviews. The idea of these meetings and interviews is to capture stakeholders' point of views on this project, their potential concerns, things that went well and opportunities for improvement.

Data and information were initially collected from HEAT's country managers and double checked and confirmed with the local stakeholders such as the Ministries of Health, Of Environment, Of Commerce and Trade. Also, with other partners such as WHO, UNICEF, GIZ and Greenpeace. Interviews with local end-users (in the health centres) in Colombia helped me a lot to understand the importance of this project for local communities and how such project could improve their current health service system.

The field test technical data will be collected via GPRS/GSM systems that equip every field test unit. Performance data will be collected by two centres, one at the data logger provider and one at DTI. In Colombia, the HEAT country managers do have access to this data and will be warned in case of any anomalies.

Unfortunately, the field visits' timing of this mid-term review won't allow deeper and more detailed analysis of performance data as limited number of SC-A units have been installed by the issuance date of this report (no SC-B units installed at the time of this report).

The Project

1. Context: Health Care & Environmental

According to the World Health Organization (WHO), "Atlas of African Health Statistics – 2017", *the percentage of children who receive up to three doses of pentavalent vaccine (penta3: Diphtheria, Pertussis, Tetanus, Hepatitis B and Hib) in the African Region is low and has remained almost stagnant during the period 2010 - 2016. WHO estimates show that, in 2016, only 74% of children under one year old received the penta3. This is far below the 90% global target for immunization set by the Global Vaccine Action Plan. Progress with routine polio immunization has been rather slow. After increasing fairly rapidly from 55% in 2000 to 74% in 2010, coverage of polio immunization (Polio3) declined to 72% in 2011 and has remained fairly stagnant since then.*

In remote regions around the globe, health care and well-being are an everyday challenge. These are regions, with difficult access and are of lower socio-economic level compared to the main cities. In Colombia for example, livestock is the only income for families living in remote areas around the region of Monteria. Water supply is mainly from the surrounding small rivers, of lower quality and with minimalist sanitary installations, and these regions are often controlled by paramilitary groups.

Electrical grids, in such locations, are either not existent at all or very unreliable due to prolonged blackouts, especially in winter/rain seasons, or due to severe voltage fluctuations which harms or destroy electrical equipment. A recent off-grid PV market analysis, ran by Global LEAP*, estimates that the annual market for off-grid fans, televisions, and refrigerators could grow from an estimated USD524M in 2015 to USD4.7B in 2020, an 800% increase, and for refrigerators alone it would be USD1.081B. A detailed analysis can be found here: http://globalleap.org/resources/

Vaccines and temperature sensitive medicines need a stand-alone and reliable cooling systems running independently from the grid. The WHO/PQS approved direct drive SolarChill-A technology, using hydrocarbon as refrigerant, is today the most appropriate, sustainable and environment friendly solution for such applications.

The aim of the SolarChill consortium is, 1) to bring this technology to a break through, reaching a much higher market penetration. 2) to transfer and further commercialize the SolarChill-A. 3) to begin the development, laboratory and field testing, transfer and commercialization of SolarChill-B. And 3) to bring down technology cost, increase local manufacturing capacities, and stimulate consumer demand so the product can compete on price and performance with fossil fuel and battery driven refrigerators.

Nevertheless, and as the SolarChill Direct Drive technology already exists and is commercially available, one could logically ask why are we field testing this technology?
Here the main reasons:

- Field end-users feedback highlighting a number of SDD units' failure in the past:
  - During the international aid following the Haiti's Earthquake, a number of WHO certified units failed to perform (interview carried out by HEAT with the responsible WHO officer for SolarChill appliances, Dennis Maire, now retired)
  - The NGO "Médecins Sans Frontières" reported failures of solar technology for vaccine fridges, hence it cannot be used by MSF
- Lack of reliable field test results to confirm, beyond any doubt, the reliability and field performance of the SolarChill Direct Drive technology

The upcoming field test data (first ever collected on such technology) will be of great help to demonstrate the quality and the technical performance of the SolarChill technology. These data shall also be used to leverage market penetration and encourage potential manufacturers to invest and develop.

The environmental benefits of this project are related to the elimination of:
- Direct greenhouse gas emissions from burning fossil fuel to run the absorption cooling technology
- Direct greenhouse gas emissions from the routine transport of fuel
- The use of potent greenhouse gas HFC refrigerants
- The negative environmental impact of lead acid batteries and its electronic charge regulators when disposed

2. Stakeholders and implementation structure

The Evaluation Office of UN Environment identifies stakeholders broadly as all those who are affected by, or who could affect (positively or negatively) the project's results. Key groups should be identified, such as: implementing partners (SKAT, HEAT, DTI, suppliers etc.), government officials, civil society leaders and beneficiaries.

The SolarChill consortium/partners include the Danish Technological Institute (DTI); Gesellschaft für International Zusammenarbeit (German International Cooperation, GIZ); Greenpeace International; Programs for Appropriate Technologies in Health (PATH); Habitat, Energy Application & Technology (HEAT); SKAT Foundation; UN Environment; United Nations Children's Fund (UNICEF); World Health Organization (WHO); with consultation by SELF.
Therefore, the review will identify lessons of operational relevance for future project formulation and implementation (especially for the remainder of this project).

The table 2 below, describe the roles and responsibilities of the key project's stakeholders. Based on the interviews I ran with each one of them, and the meetings I had with the Ministry of Health (MOH) and Ministry of Environment (MOE) in Colombia and Swaziland, it seems to be a clear alignment on the importance of this project and a high level of interest, from all stakeholders, to successfully meet the project's objectives. There is a real belief that the SolarChill technology is the most adequate sustainable solution for such specific applications: (a) Health temperature-sensitive products in regions with very limited and/or unreliable electrical grid; (b) food preservation in regions that lack refrigeration due to the absence of reliable electrical grid.

The representatives of the Colombian Ministry of Environment (MOE), highlighted the bigger importance, from environmental point of view, of the SolarChill-B project due to its wider application and bigger market volume. Hence, their insistence for more focus and funds towards the technology transfer aspect, especially with local manufacturers. This same MOE team, insisted on the importance of running a local market study to evaluate the potential needs for SC-B units. Such information could and will be of great help in the discussions with local manufacturers encouraging them to develop and invest in the production of SolarChill HFC/ODS-free technologies.

Table 2: Stakeholders, roles and responsibilities

Stakeholders	Contact Person and Role	Responsibilities
UN Environment	-Geordie Colville / Senior Program Officer -Cicilia Magare / Program Management Assistant -Leena Darlington / Fund Management Officer	Project implementation and management in collaboration with SKAT. Annual project implementation reporting and half year progress reporting.

		Fund management of the GEF grant, via expenditure reports and the annual financial audit report
SKAT (Schweizerische Kontaktstelle für Angepasste Technik, meaning Swiss Centre for Appropriate Technology)	Sanjay Gupta / Project Manager	Setting up all sub-contracts, coordinate with all the consortium partners, facilitate procurement of equipment and monitor the project beside regularly reporting to UNEP on the progress of the project. It monitors the performance of all the sub-contractors and see that they comply with the set indicators and fulfil the objectives of the project in a timely manner.
HEAT and Country Managers (Habitat, Energy Application & Technology)	-Dietram Oppelt / HEAT -Simon Mischel / HEAT Int. Project Manager -Ramona Nosbers / HEAT int. Project Manager -Elisabeth Ngodza / Country Manager, Swaziland -Peter Chawira / Technical Manager, Swaziland -Rafael Rivera / Country Manager, Colombia -Carlos Ferney / Country Manager, Colombia -Rebekka Oelze / Country Manager, Kenya	Connect all participating partners and countries. Planning and execution covering all aspects of the SolarChill project: site selection and procurement (via UNICEF), in-country logistics and installation of the units, contribute to develop training materials, technology transfer (development of SC-A and SC-B), outreach activities, and active dissemination of the SC technology beyond partnering institutions and countries. For country managers: coordinate all project activities and this includes; training of local technicians, monitoring/reporting, communicating with the advisory committee, organizing and carrying out project meetings and country specific reporting.
DTI (Danish Technological Institute)	Ivan Katic / Senior Specialist, Solar Energy	SC-A: 1-Development of technical specifications and guide for purchase and installation of field monitoring equipment. 2-Collect, collate and report field test monitoring data for SC-A in collaboration with UNICEF and HEAT SC-B: 1-Development of laboratory test protocol for SC-B 2- Development of SC-B design specifications 3- Contribute to design the field test protocol for SC-B in collaboration with HEAT 4- Development of technical specifications and guide for purchase and installation of SC-B field monitoring equipment 5- Collect, collate and report field test monitoring data for SC-B in collaboration with HEAT
UNICEF (UN Intl. Children's Emergency Fund)	Dereje Haile / Procurement Manager Julia Behr / Procurement Manager Claudia Melani / Procurement manager	Based on the RFQ provided by HEAT/SKAT, negotiate with relevant suppliers and procure the goods accordingly
GIZ (Gesellschaft für International Zusammenarbeit)	Nika Greger – Project Manager	Technology transfer: 1-Together with HEAT, Contribute to the development of design guide/TT package for new manufacturers (sizing and design guide SC-B in dialogue with partners) i.e. Palfridge

		2- Contribution, with HEAT, to produce the report on technology transfer 3- Financial support to the project funds 4- Annual progress report to the German Environmental Ministry
WHO (World Health Organization)	Isaac Gobina / Technical Assistant	Only involved in the SC-A project. WHO/PQS pre-qualification of the SC-A units. WHO role on this project is as technical adviser.
Independent Consultant	Terry Hart	Consultant
Greenpeace International	Janos Maté	
SELF (Solar Electric Light Fund)	Steve McCarney / Solar Energy Consultant	Technical consultant (contracted by SKAT). Active contribution in drafting the installation manual
University of Dresden - Germany	Thomas Tannert / Project Manager	Pre-qualification tests before delivering to DTI for WHO/PQS qualification Technology transfer to Swaziland So far, involved with SC-A only
PATH (Program of Appropriate Technology in Health)	Sophie Newland / Program Officer	More active role back in 2003 on the field evaluation of SC field test in Senegal and Indonesia. Currently inform role, participating in conf calls. No active role.
CHAK (Christian Health Association of Kenya)	Rebekka Oelze / Health Quality Management Systems Advisor	Implementation advisor of the SolarChill project in Kenya (responsibilities similar to the country manager)

3. Project financing

The SolarChill project is funded by the GEF (Global Environment Facility) and co-financed by other organizations such as Bilateral Aid Agency, NGOs and national governments. According to the UN Environment GEF's Fund management, the SC project is on track concerning its financial situation. That said, Kenya completely missed its official financial support commitments made at the beginning of the projects. Current Kenyan Ministry Of Health (MOH) refused to fulfil the commitment made by the previous government to support the import duty fees and taxes, and the in-land logistics of the 36 SolarChill-A field test units estimated at USD60.000. Unfortunately, not much can be done on this level. A way to avoid this to happen in the future is to ask for the financial support to be in cash instead of in-kind, but this is often a sensitive negotiation to have with government's officials. Also, for the three countries, this is a relatively small project that warrants little attention from the local authorities.

The two tables below show the GEF funding and the co-financing details.

Table 3: GEF funds

GEF Agency	Type of Trust Fund	Focal Area	Country Name/ Global	(in $) Grant Amount (a)	Agency Fee (b)	Total c=a+b
UNEP	GEF TF	Climate change	Colombia, Kenya, Swaziland	2,712,150	271,215	2,983,365
Total Grant Resources				2,712,150		2,983,365

Table 4: Co-Financing partners and amounts

Sources of Co-Financing	Name of Co-Financier (Source)	Type of Co-Financing	Co-Financing Amount ($)
Bilateral Aid Agency	GIZ	Cash	1,820,000
National Government	Colombia, Kenya, Swaziland MOH	In-kind	675,000
Bilateral Aid Agency	GIZ	In-kind	40,000
Not profit organization	Greenpeace	In-kind	6,000
Not profit organization	Greenpeace	cash	6,500
Not profit organization	PATH	In-kind	56,000
Bilateral Aid Agency	GIZ	Cash	2,600,000
Bilateral Aid Agency	UNEP	In-kind	230,000
Bilateral Aid Agency	GIZ	Cash	650,000
Not profit organization, Bilateral Aid Agency	DTI, UNEP PATH, Greenpeace (Combined exp. Jan 2000 to Nov 2009)	In-kind	1,600,000
Not profit organization, Bilateral Aid Agency	DTI, UNEP PATH, Greenpeace (Combined exp. Nov 2009 to Nov 2011)	In-kind	350,000
Total Co-Financing			8,033,500

Another financial aspect in this project is the needed support for end-users to afford the current high initial price of both SC-A and SC-B. In the coming five to ten years, and with higher production volume and more competition, it is expected that prices will get to a more commercially viable levels. In the meantime, there is an urgent need to build a strong financial scheme to bridge the gap during this “Death Valley” period. This support can take different “and/or” formats such as tax exemption, government support, micro financing, leasing program, etc. Unfortunately, to date none of the above have been set. This is a high risk for the project viability especially for SolarChill-B. The ongoing discussions with financing partners, like MobiSol to combine SC-B refrigerators with PayGo systems, could help resolving this financial issue.

GIZ, suggested to connect with GAVI (vaccine alliance) to join forces on the SolarChill technology. Understand who are GAVI’s suppliers, what are the average prices of their equipment, investigate possible joint development effort and/or technology transfer to other partners. An approach that could be a win-win solution.

On the technology transfer work, GIZ confirmed that Palfridge have received part of GIZ fund and the next fund transfer is under preparation. These funds are dedicated to help with their production lines to produce the SolarChill units. In addition, technical support is provided.

Evaluation Findings

The attached Annex-II, lists the project results framework and related progress to date, including deviations and delays.

As this is a Mid-term Review (MTR), **the report will put attention on the field test process, identifying implementation challenges and risks to achieving the expected objectives, actions for cost/price optimization, and what corrective actions are required and planned.** The MTR will assess project performance to date in terms of relevance, effectiveness, efficiency and long-term viability, and determine whether the project is on-track for achieving its intended outcomes within the agreed time lines. It'll also highlight the point of view of key internal and external stakeholders, the support they provided and their concerns if any.

1. <u>Original plan</u>

The field test will run in three countries, Colombia, Kenya and Swaziland for a proposed duration of 12 months. A total (for the three countries) of 198 SC-A units and a total of 45 SC-B units will be placed for the field test. Within these three countries, the test sites have been selected in a way to cover a wide range of climatic conditions. The countries' respective Ministry of Health / Ministry of Environment (MOH/MOE) have selected the health centers, to place and test the SolarChill-A units. The UNICEF has approved the SolarChill-A suppliers (Vestfrost, Godreg & Boice, B-medical, Haier and Zero Appliances) as well as the models to be tested. All SC-A models are WHO Performance Quality and Safety (PQS) approved. Tests have been performed by/at DTI in Denmark, ensuring a level of performance and quality for refrigerators that are used to store temperature-sensitive vaccines and medicines. Each SC-A unit is delivered with its solar panels, mounting rails and needed cables. Data logging systems are shipped separately by DTI and will be mounted, on site, by the country managers.
A similar process will be followed for the SolarChill-B units, but with a less stringent set of technical performance requirements designed by DTI.

A cost reduction work was also planned to bring the SC-A and SC-B price to a reasonable level (see table 9 below) within the project duration. This work is "assumed" to continue beyond this project time lines to further reduce the technology price and reach a competitive pricing in comparison to current fuel and battery driven technologies. Unfortunately, there is no written/confirmed plan for this longer-term work.

The other important part of the project plan is the outreach activities and the technology transfer work with a specific focus on helping and supporting local manufacturers to invest and develop the SolarChill technology. This work is expected to include cost/price reduction exercise moving towards more commercially affordable product. The economy of scale will only kick in with the increased manufacturing of both SolarChill-A and B units around the world, especially in developing countries.

2. <u>Progress to date</u>

This section analyses the current situation and progress to date covering both SC-A and SC-B, including price analysis and the environmental impact of introducing SolarChill technology in replacement of existing fuel and/or lead battery driven technologies.

2.1 <u>Deviation from the original plan</u>

In Colombia, 37 SC-A units will be field tested, 36 in Kenya and 40 in eSwatini (Swaziland), for a total of 113 units instead of the 200 originally planned. About 70 units are planned to be provided by Palfridge (but yet no firm delivery timelines yet). Apart from the time delays, no other deviations have been noticed to date.

2.2 Progress with SolarChill-A

All sites, in the three countries, have been identified by the respective MOH and assessed by HEAT's country managers and their technical teams. All units have been received in their respective countries. Field installation started in Colombia and Swaziland and planned to start in Kenya towards mid-August 2018. DTI has assembled the last HOBO type data loggers and send them to destinations in Kenya and Swaziland. In both cases, and in Colombia, there were some procedure issues regarding customs exemption that were more complicated than foreseen. Similar custom issues were faced with the Nexleaf data loggers. For such matters, and following my meetings with the main parties, this custom clearance work should have been handed over to professional shipping agents to avoid delays.

N.B. One Nexleaf data logger was installed by HEAT in Cameroon as dissemination activity. DTI has included it in the test and data collection process.

2.3 Progress with SolarChill-B

Current lab test requirement, set by DTI, for SC-B are mainly according to the IEC standards for house-hold refrigerators and few are based on lab tests performed by DTI on various SolarChill models. In the conversation I had with DTI, I pinpointed some details in the SolarChill-B specification and test methods, which seem a bit unclear in the current version:

a. The word pull-down test could be misunderstood, actually the test is a warm reload test of a limited amount of fresh goods (4.5% of the internal net volume). Potential manufacturers should have a clear understanding of the requirements, so it is suggested to update the relevant documents and refer to applicable standards or in other ways justify each deviation
b. The precise setting of the average temperature during the reload test is not so important, as long as the fluctuations stay within the range. This should be better explained so that manufacturers do not misinterpret this target as a requirement
c. DTI will have a look at the lab tests performed so far, and see if/how the warm reload test can be relaxed on this background
d. Revised requirements will be published by mid-August 2018

After laboratory testing of two brands (Vestfrost and Leff), DTI has set them up for real test (still ongoing) with PV panels at DTI. The aim is to check the long-term performance of the Leff brand refrigerator. A third appliance (from Defy) is still under test but, according to DTI, and from the current lab test results, it won't qualify for the project. Recently, the Palfridge company in Swaziland has expressed interest to deliver some units for Swaziland, so this option is currently under consideration. Swaziland has already identified sites for SolarChill-B installations. In Kenya there are 15 sites available for SC-B and the Colombian MOH has raised interest in receiving SC-B units.

2.4 Progress with the technology transfer work

As mentioned earlier, the technology transfer effort is exclusively focused on the work led by HEAT with The Fridge Factory (Palfridge) in eSwatini. A lot of delays have been accumulated and the current time lines sounds somehow optimistic. From the meetings and calls I had with Palfridge and HEAT teams, here below are key progress areas.

- Status of the prototype building:

The prototypes are going to be built at Palfridge as soon as the ECU (electronic control units) are available from the manufacturer. With a delivery lead time of 10 weeks, the assembly is expected to take place in November 2018. In the meantime, there has been an agreement to work (in parallel) on a cooling-only design. Which is easier to build and will better fit the needs in eSwatini.

- Prototype testing by/at DTI:
  These prototypes will be ready for testing, most probably by end of 2018, as they will have to be tested at Palfridge first.
- Production of the 100 units as agreed between GIZ and Palfridge (out of which, 70 units would be dedicated for the SolarChill project) is expected to start in February 2019 at the earliest.
- Expected unit price of the field test fridges:
  The price of the two compartments version (cooling and freezing) is expected at around USD2,500. The exact and final unit price will be confirmed with Palfridge as soon as all parts are collected.
- Projected price per unit at mass production:
  The unit price at mass production would not change much as the annual volumes are still very low. That said, the one compartment solution, with its single cycle system (only one compressor and a much easier electronic control), could reach a final price at around USD1000.

3. Price analysis

SolarChill Direct Drive (SDD) refrigerators have higher upfront cost, a main market penetration barrier that must be addressed. Compared to the other alternatives, mainly kerosene refrigerators or refrigerators with batteries, SDD technology has its main advantage in the low annual Total Cost of Ownership (TCO). In a recent publication, WHO and UNICEF estimate the annualized TCO at or below USD700 compared to USD800 and more for kerosene refrigerators or LPG powered refrigerators (WHO & UNICEF, 2017).

Table 5 below will help to better understand the price challenge of the current SC-A field test units

Table 5: Delivered SolarChill-A unit price per supplier (USD)

Colombia	Model Number	Price per unit (USD)	Number of units
Godrej	GVR50DC SDD	3395	6
B Medical	TCW40SDD	5282	17
Vestfrost	VLS024SDD	2585	14
eSwatini			
Haier	HTCD-90	3950	5
Zero Appliance	ZLF30DC	2920	15
Vestfrost	VLS024SDD	2670	15
B Medical	TCW40SDD	5762	5
Kenya			
Vestfrost	VLS024SDD	2670	20
Zero Appliance	ZLF30DC	2920	16

4. Price analysis of SolarChill-A

Currently, SC-A suffers a high purchase price ranging fromUSD2,585 (Vestfrost/Denmark) up to USD5,762 (B-medical/Luxemburg), depending on the manufacturer and the model's design. These purchase prices are more than double of the target price within the project duration and up to four times the projected figures within the coming 5 to 10 years (see table 6 below). During this mid-term project evaluation work, I didn't see any price reduction activities (neither on the technical nor on the supply chain levels) undertaken with the current SC-A suppliers. Hence, and apart from the work with Palfridge, it's unlikely to see significant price reduction within the project's time lines. Nevertheless, an encouraging technology transfer work have been initiated by HEAT with Palfridge in Swaziland, but yet no pricing figures are available as we speak (July 2018). Note that Palfridge is not a current WHO approved supplier of the SolarChill technology.

Why these high prices?

On one hand, and from the commercial point of view, the SolarChill Direct Drive is a niche technology with a very low annual produced volume and a limited number of suppliers, hence a low level of competition.

On the other hand, there is a high level of technical requirement (especially for SC-A) in order to pass the quality, reliability and temperature performance requirement:

- It's a solar direct driven technology, which means a limited number of hours per day where the electrical power is available (sunny period)
- It's a Direct Driven technology. No batteries to store energy during the day and re-use it during the sun off hours
- Due to the above, the design and the built of these units have to be of higher quality to achieve the needed requirement:
  - Thicker insulation to reduce thermal losses
  - Control and monitoring system to insure compliance with the temperature range especially for vaccines and medicines applications
  - Units are equipped with GSM data transmission loggers
  - Some models (e.g. B-medical units) have a combined, freezing and cooling, system. This is often operated with two separated refrigeration circuits
  - Compressors and fans are of the DC type, more expensive than the regular AC type
  - Solar panels account for about 50% of the unit price. High quality panels still at high price, nonetheless these prices are coming down year-on-year. Conservative WHO requirements, for SC-A units, result in oversized panels for sunny locations, thus expensive systems: The nominal power of the solar panels is high to ensure that solar direct drive (SDD) appliances can keep vaccines at acceptable temperatures continuously, the installed photovoltaic array often produces excess power that is not used by the primary cooling load and this excess power generally goes unutilized.

5. Price analysis of SolarChill-B

SC-B is also powered by a Direct Drive SolarChill technology. Nevertheless, it is expected to be at a lower price point compared to SC-A. The reasons for the price difference are mainly on the technical side:

- commercial and domestic applications require less stringent temperature requirement. Hence less expensive design
- It's a cooling unit, no freezing requirement, which allows the use of only one refrigeration system
- Less strict technical requirements for solar panels

From my conversation with DTI: Negotiations with Leff (potential SolarChill equipment manufacturer from China) are currently taking place regarding production of a cost-effective pilot series for Kenya, and this looks promising. Vestfrost has also promised to deliver their SC-B model (even with short notice), but no specific order has been placed yet as test sites haven't been fully selected in the three countries.

Colombian MOE want to include local manufacturers in the project, but since they (local manufacturers) were not interested when first asked, it is very unlikely they can deliver a pilot series within the project´s time frame.

Current plans call for SC-B field test units to be supplied by Vestfrost and Leff. Palfridge could deliver as well if their development work is achieved within the coming two to three months at the latest.

In parallel, a joint development effort has been initiated between Palfridge and MobiSol to design and commercialize and affordable Direct Drive SolarChill units for SC-B applications (commercial and household). Work is in progress and initial indications, according to HEAT, shows a price point getting closer to the set target of USD400. In my opinion, this price target is a challenging goal to be met.

6. Technology transfer

There seems to be two misinterpretation issues with the technology transfer definition and approach:

a. This project started before "having" a demonstrated performing and reliable SolarChill technology. In other words, the technology transfer work should start after the field test results, not before
b. In order to have the legal rights to "transfer" a technology, one must own that technology. In this project, the only technology owners are the manufacturers themselves. Logically, they won't share their know-how with the competition. I think what is taking place here is simply a technology development, not transfer. (General transfer of the basic design ideas, which are or have been generated by the SolarChill consortium)

7. Environmental impact

Recently, HEAT conducted a study (Emission Study SolarChill – 2018) for the evaluation of carbon emission savings when replacing the fossil fuel refrigerators by the use of SolarChill appliances. Potentially, the three project countries will have around 5,800 SC-A vaccine refrigerators by 2020, this number is expected to grow to over 17,000 in 2050 (table 6). The growth is projected to be the result of a strongly growing population and an improved penetration of health facilities and the increased uptake of SolarChill technology.

The resulting emission reduction impact of SC-A will be an annual emission reduction growing from approximately 1,800 tCO_2 in 2020 to around 9,200 tCO_2 in 2050.

Table 6: Estimated number of vaccine refrigerators per million inhabitants (Source: HEAT Analysis)

Total vaccine refrigerators (per million)	2020	2030	2040	2050
Colombia	312	428	540	651
Kenya	5,406	8,217	11,810	16,296
eSwatini	109	151	184	214
Total	**5,827**	**8,795**	**12,534**	**17,161**

Similarly, with the uptake and market penetration of SolarChill-B refrigerators, 80-100% of the conventional fossil fuel powered refrigerators can be replaced with resulting emission reductions from 0.6 $MtCO_2$ in 2020 to 5.2 $MtCO_2$ by 2050 (table 7). Complete details can be found in HEAT 2018 study.

Table 7: Emissions reduction potential of SC-B in tCO2 (Source: HEAT Analysis)

Type B emission reductions rough GEF Project	2020	2030	2040	2050
Colombia	34,017	88,285	142,830	215,061
Kenya	584,103	1,698,253	2,905,368	4,953,684
eSwatini	12,435	31,334	45,186	66,033
Total	**630,555**	**1,817,871**	**3,093,383**	**5,234,777**

Project Structure – Risks, Weaknesses and Strengths

HEAT, as country planning and execution partner, has appointed country managers (one in Kenya, one in Swaziland and two in Colombia) to manage these field tests, including receiving of units, installation, commissioning and monitoring. In addition, HEAT has provided technical trainings, and related material, to local technicians. These trainings cover servicing and installation. Country managers will be the main contact/liaison between the field and the project's stakeholders e.g. DTI, UNICEF, UN Environment, SKAT, countries' officials etc. HEAT is also managing and maintaining the SolarChill website, a key element of the outreach activity. The country managers will be in charge of resolving any field issues. In Colombia and Swaziland, import duty fees and transportation (from arrival port to test site) costs will be handled by the respective countries' MOHs. In Kenya the pre-selected SC-A models have been changed to a lower priced one to cover the import duty fees that the Kenyan government did not cover.

The procurement work was managed by the **UNICEF**'s central procurement office based in Copenhagen, Denmark. As a procurement expert, the UNICEF has an important advisory role to make sure that the customer is not missing key elements in his Request for Quotation (RFQ). The UNICEF received the request for the equipment (SolarChill-A) procurement from HEAT. According to the UNICEF's procurement process, the "customer" (HEAT/SKAT in this case) shall provide an RFQ that include all details of the goods to be purchased, such as:

- Number of units
- Any design options to be added
- Specific language for the technical documentation and spec sheets
- Technical and installation trainings if needed
- Complete addresses of goods delivery
- Any mandatory country specific certification
- Extended warranty terms if needed
- Specific servicing and spare parts provision including contracts with local representatives of the said supplier
- Etc.

From my field visits and meetings with key local stakeholders, some of the above details were missing (or wrongly submitted) in the original RFQ e.g. specific SC-A certification for Colombia, causing extra warehousing fees and delivery delays. Absence of an after-sales service contract (especially beyond the warranty period). Missing spare parts provision agreement. These details where missed in the RFQ but at the same time the UNICEF procurement team did not fulfil its advisory role in pointing out such important gaps in the RFQ document.

For future projects, the UNICEF's procurement team strongly recommend the following:

- Initial meeting between the project team and the UNICEF's procurement office to go through the details of the procurement process and avoid misunderstandings, delays and extra fees
- Need for a custom clearing agent for each country
- Preferably one contact person between the project team and the UNICEF's procurement team

Use the above learnings to improve the procurement process of SolarChill-B units. Note that the UNICEF will not be the procurement agent for SC-B, as these units are for commercial and domestic use.

The Danish Technological Institute (**DTI**) is in charge of 1) setting technical guidelines, 2) lab testing of SC-A and SC-B, and 3) gathering and evaluation of field test data.

For performance monitoring, DTI has selected three suppliers (Nexleaf, B-Medical and Hobo) for the data acquisition systems that will equip each SolarChill-A unit. These systems have been tested at DTI in Denmark, and in Colombia with positive results. Nevertheless, some remote areas do not have proper GSM network coverage, hence data transmission will be an issue. In Colombia, country managers will work with data logger suppliers and with DTI to find a proper solution for such sites e.g. data transmission once per week by moving the data logger to a network covered area (or move the equipment to other clinic). In Kenya, locations out of network coverage will not be equipped with data logging systems. Performance data will be manually collected and regularly sent to the country managers.

Key parameters will be monitored by the Hobo loggers (External/internal temperatures, relative humidity, door openings etc.) following a pre-set protocol. Parameters reading will take place every five minutes, and every one-hour (depending on the data plan in the country, this amount can be reduced to once per day to reduce cost) the collected data will be sent, via a GSM system, to a central server at DTI. All data will also (as a back-up) be available, for one year, at the data-logger suppliers' server with access granted to DTI. Nexleaf and B-Medical data will be downloaded from their respective web sites. In Colombia, country managers will also have access to the data collection system. A user-friendly interview and questionnaire will supplement the measurement for non-technical feedback.

Concerning the SolarChill-B, DTI has already performed lab tests on 3 units from 3 different suppliers. Two of them passed the performance requirement. The two selected suppliers are expected to supply the SC-B units for a field test in the three recipient countries.

Based on the field test results, feedback will be provided to all suppliers in order to improve the product performance, redesign it (as needed) for cost reduction and market it for greater reach especially in off grid regions. Concerning this specific activity, **WHO** suggests sharing the field test data, not only with manufacturers, but also with potential end-users, universities, NGOs, engineering and development partners, etc.

1. Quality of Project Design

Based on the meetings and calls I had with the project's stakeholders, I noted a clear alignment on the extreme importance of this project, from both health care and environmental point of views. I also noticed a high-level of commitment from key stakeholders to successfully achieve the set objectives.

1.1 Project strengths

a. SolarChill Direct Drive (SDD) technology have a confirmed and strong advantages when compared to existing Kerosene or LPG or battery driven technologies. Amongst these strength:
    - Reliable and continuous, local energy supply without the continuous need for supplying fossil fuels
    - Clean and pollution-free energy supply
    - Reduced electronic waste amounts (no battery)
    - Lower maintenance costs
    - Lower operating costs
    - Lower carbon source energy supply
    - Elimination of potent greenhouse gas refrigerants (HFCs)

b. Government support and cooperation in Colombia and Swaziland: Tax exemption, warehousing, transportation, etc.

c. Great appreciation from the end-users: Fit for purpose project

d. Quality training materials and technical trainings sessions led by HEAT

e. Quality project management team and country managers (HEAT): Relevant technical trainings, quality installation of the field test units, follow-ups with local stakeholders, etc.
f. Important technical and evaluation work done by DTI in order to make sure that the delivered units are of required quality and compliant with relevant standards.
g. Technology transfer to The Fridge Factory (Palfridge) in Swaziland: From my meetings with Palfridge and with HEAT, seems the price projection for a SC-B design could be close to the targeted price point of USD400. Still to be confirmed.
h. Performance data collection and its evaluation by DTI will provide solid evidence to other potential end-users on the SolarChill technology's reliability

On the other hand, there are gaps and weaknesses in the project design that should be highlighted and taken as "lessons learned" for future project.

1.2 Project weaknesses

a. Lack of initial project review that could have pointed out structural and/or execution gaps
b. Project is spread on a too long period of time between the initial start and the execution. Pre-set objectives haven't been neither reviewed nor updated in-view of the technological advancement that occurred during these years. The GEF approval process should be more flexible in order to allow objectives' adjustment for such long project
c. Suppliers and manufacturers haven't been involved in the field test as major players. Hence, responsibilities will be difficult to determine in case of field failure
d. On what base the field test countries have been selected? Lowest electrification countries e.g. in the west African region, haven't been chosen, why?
e. Current high initial price of SC-A and lack of a clear plan on how it'll be reduced to allow mass adoption. This price barrier will be even more impactful on the SC-B units as it impacts remote population with lower economic level
f. High number of stakeholders involved in the decision-making process leading to a number of delays that could have been avoided
g. Procurement process: Did not take into consideration neither the time difference between supplier and end-user nor the potential language barrier. Lack of after sales service and spare parts provision for the field test units
h. Lack of a long-term commercialization plan. Currently, the project ends at the completion of the field test, with a deadline set for December 2018, which might be extended till December 2019 if budget permits. What's next? How and who will handle the larger commercialization work, which, I think, is the heart and key goal of this project. Who will handle service calls especially after the warranty period? How much a service call will cost?
i. No technology transfer work is possible in Colombia (no interest from local manufacturers due to low annual volume of the SDD technology) and Kenya (no local manufacturers)

2. Key risks and proposed mitigation measures

This project face two types of risks:

a. Known risks that are embedded in the project since day one such as the high technology cost, the technology performance in "real world", etc.
b. Unknown risks that occur during the project's progress such as countries cooperation, equipment's delivery delays, financial issues, technician training, installation and technical issues, etc.

Table 8 below shows the main risks that might or will impact either the project's objectives or its time lines against the originally set goals and timing. If not timely addressed, the high risks factors could jeopardize the long-term viability of the project. Hence, there is a need, for all stakeholders, to re-think the "What" and the "How" to achieve the pre-set goals especially for the SC-B part.

Table 8: Key risks and mitigation measures

Risk factors	**Risk description**	**Risk rating**	**Mitigation measures**
High up-front SolarChill technology cost	Today, the purchase price of SC-A models are at up to 4 times the price of existing fuel and battery supported technologies. Despite the lower life cost of SDD, this high up-front price is and will remain the main commercialization barrier especially for the SC-B units where majority of end-users are in remote areas with a lower economic level.	High	a- Work with suppliers on a Bill Of Material (BOM) Tear Down Analysis (TDA) to optimize and reduce current costs b- Investigate possible government financial support and/or micro-financing or leasing approach to support the market penetration especially for remote and lower economic level populations c- Encourage and support local suppliers and facilitate connections with potential partners e.g. Palfridge-MobiSol, Leff
Lack of long-term commercialization plan (beyond the field test)	The current project plan seems to be limited to the field test and its results. There is no clear commercial and financial strategy for after the field test. What will happen after December 2019? e.g. Who will take over the market penetration and commercialization work?	High	As soon as relevant field test data is available (i.e. 2 to 3 months into the field test), set and start an outreach activity with potential suppliers and end-users, development partners, NGOs, universities, etc. With the field data and the future market potential for SC-A and SC-B, accelerate the technology transfer work to increase competition and reduce technology cost. The steering committee team to agree on a hand-over and a progress follow-up approach beyond December 2019.
Unclear field test protocol and success criteria	Lack of a clear field test protocol and success criteria. How to determine if the field test was successful or not?	Moderate	Draft and distribute to the field: A field test protocol, success criteria, reporting process, issues resolution and servicing plan, spare parts list and its management, etc.
No firm/realistic time lines for the delivery of the 70 SC-A units from Palfridge	Current production time line is set to start in February 2019 (after a successful lab tests at DTI that are planned for December 2018). From the available information, there is a risk of missing this date.	Moderate	Accelerate the technical cooperation between Palfridge/HEAT/Mobisol to meet asap the PQS requirement. And provide needed budget.

Lack of after sales service agreement and spare parts provision agreement (especially beyond the warranty period)	Field test issues will occur. As the test sites are remote, servicing and maintenance will take longer time if no agreed process with the suppliers is set especially after the warranty period Availability of spare parts in a central warehouse (or multiple warehouses) is crucial for servicing within reasonable timing	Moderate	Re-negotiating an already signed agreement will always put the requester in a weaker position and might come with an extra financial burden. Nevertheless, SDD is a new technology under field test in remote regions, timely servicing is important to collect maximum data within the field test time lines. a- Set a service level agreement with all suppliers covering the warranty period and up to five years following the warranty period b- The service agreement to include the availability, at relevant locations, of key spare parts, such as compressors, fans, controls, refrigerant etc. c- Similar agreement to be set with the data loggers suppliers
Technical hazard and lack of experience with HC refrigerants	Hydrocarbons are flammable and require specific safety procedures particularly during maintenance and servicing.	Low	Only trained and suppliers' approved technicians shall service the units when opening the refrigeration system is required i.e. interventions requiring vacuum and refrigerant re-charge.
Field test delays	Delays caused by: Swaziland: Delayed delivery of the field test units. Missing solar panels. Completion of the technical training. Access to the field test sites Colombia: Delayed delivery of field test units. Custom clearance issues. Missing parts. Low installation rate Kenya: Delayed delivery of the field test units and data loggers. Delayed installations. Delayed trainings. Custom and import duty/taxes issues.	Low	Most of those issues have been addressed by now. Continue active cooperation with local authorities to resolve any pending issues. Accelerate equipment's installation especially in Kenya.

2.1 Watch-outs

a. During sites selection and assessment, give priority to sites with GSM/GPRS network coverage
b. Before shipment to the field test sites: Make sure that all units are delivered with proper documentation, no missing parts and with the proper solar panels as per the WHO/PQS certification
c. Mounting of the temperature sensors and their cables must be done in way that it does not interfere with the refrigerator users
d. Solid and weather resistant mounting and placement of the solar panels
e. Do not overload the fridges to avoid extra electrical consumption
f. Close monitoring of possible condensation inside the cabinets (especially with the vertical models) that might damage vaccines and/or medicines

2.2 Recommendations for urgent/immediate actions

a. Set field test success criteria: How and what will determine the pass/No-pass of the field test? And what will happen if No-pass?
   - An approach that can be adopted is, for example, to determine the number of acceptable major failures by model during the total period of the field test
   - Determine what is considered as "major failure" and what is not. Generally speaking, major failures are such as the unit cannot maintain the required temperature range, compressor or electronic controller failure, refrigerant leak, capillary tube clogged, start capacitor failure. Non-major failures are such as fan failure, disconnected wire, broken gasket, broken solar panel, blown fuse, etc.
   - Minor failures fall under the normal servicing and maintenance process
   - In case of major failures, the manufacturer must take back the failed unit(s), investigate the route cause and determine whether the failure is an isolated case or whether there is symptomatic cause. If the later, the manufacturer must run a re-design exercise, re-approve the new design and a new field test must take place

b. Reduce the field test duration for both SC-A (to 6 months) and SC-B (to 6 months) and increase the installation rate

c. DTI to revise and re-issue the SC-B technical requirement for equipment certification

d. Accelerate and prioritize the SolarChill-B technology transfer work with Palfridge

e. For SolarChill-B, initiate/accelerate the work on price reduction before starting the field test e.g. with Palfridge in Swaziland and Leff in China

f. For SolarChill-B, re-evaluate the RFQ and make sure it includes all relevant technical and financial items such as service agreement with local suppliers' representative (including the after-warranty period), spare parts provision, etc.

g. All current and future shipping activities to be handed to a local custom clearing agent

h. For the SolarChill-B field test, make sure suppliers are actively involved in the field test organization and settings

2.3 Recommendations for the next 2 to 4 months

a. Re-determine a clear framework for the technology transfer work

b. Set a long-term plan for after the field test including a hand-over process as the project will end by December 2019

c. As budget permit, undertake a market survey to evaluate the potential demand on SolarChill technology. Use this information in the technology transfer process.

Final Conclusions

"*The United Nations Development Assistance Framework (UNDAFs), in all three countries, list the improvement of health services as a goal. This project will support the objectives in all three countries by distributing and testing solar vaccine refrigerators for use and testing in remote health clinics.*"

Three main areas are evaluated in this mid-term evaluation report:

a. The upcoming SC-A and SC-B field tests
b. The technology transfer to local manufacturers
c. The outreach, commercialization and market penetration of SC-A and SC-B

1. <u>Field Test of the SolarChill-A units</u>

From the current available information, and despite the faced delays, it seems that the SolarChill-A field test is conditionally on-track, in the three countries. In order to meet the extended December 2019 dead line, some key actions and decisions needs to be taken:

a. Reduce the SC-A field test time from 12 to 6 months. Apart from the future Palfridge units, all other models are commercially available, and mass produced. Hence, this is not a field test of a newly developed technology. Despite the 4-seasons weather condition argument, I still believe that 6 months are enough, knowing that data collection can continue beyond the 6 months field test
b. Accelerate the installation of the field test units in all of the three countries
c. Increase cooperation with Palfridge to timely deliver their 70 SC-A field test units
d. Set clear field test success criteria based on the units' performance (see paragraph 2 in the previous section)
e. Re-negotiate appropriate after-sales service contracts with the units' OEMs, e.g. who the local technician should call in case of failure after the warranty period? How much this service will cost?

2. <u>Field Test of the SolarChill-B units</u>

Two models from two different manufacturers (Vestfrost and Leff) passed the performance lab tests at DTI. Procurement process has not been launched yet. No final decision on the suppliers' list for the 45 SC-B units to be bought. Presently, this part of the project seems to run with significant delays and could be described as off-track. Here are a list of proposed actions/decisions that can bring the SC-B field test to be completed within the project time lines:

a. Capture and use all of the learnings (Procurement, dealing with customs, logistics, technical, etc.) gained from the SC-A filed test
b. Heavily involve the manufacturers of SC-B units in the field test (unlike what happened with the SC-A field test)
c. Set clear field test success criteria based on the units' performance (see paragraph 2 in the previous section)
d. Reduce the field test duration from 12 months to 6 months
e. As we speak, make sure all test locations are selected and assessed
f. Where possible, procurement contract to be set with local suppliers or their local representatives
g. Organize a timely installation of the field test units

Note that undertaking a <u>major equipment's redesign</u> work for cost reduction (whether it's for SC-A and/or SC-B) could imply the need for a second field test.

3. Technology transfer

Technology transfer work, with The Fridge Factory (Palfridge) in Swaziland, have been initiated by HEAT. Prototypes are planned to be built by/at Palfridge and lab tested at DTI (for performance compliance) in December 2018. Once approved, the production of 100 SC-A units is expected to start in February 2019. A field test will be planned accordingly to demonstrate field performance and reliability. From the progress to date, the above time lines seem somehow optimistic.

On the other hand, technology transfer work is not planned neither in Colombia nor in Kenya (as Kenya does not have a refrigerator manufacturing sector, it is not expected that SolarChill can be produced in the country in the near future).

The work with Palfridge could be used as best practice to undertake similar technology transfer initiatives in other relevant countries and/or regions.

4. Outreach

A very good work has been done on the outreach piece via the development of a SolarChill web site, available in English and in Spanish. The site is managed and maintained by HEAT and Greenpeace International and is expected to keep going even after the end of this project in December 2019. HEAT also runs the SolarChill website on Facebook and twitter. It's a great tool to disseminate information on the technology progress, best practices, technical info, etc. A presence on other social media e.g. LinkedIn could also help. On-track.

Outreach activity has also involved : (a) Publication of article about SolarChill in the November 15, 2017 edition of OzoneAction newsletter prior to the 2017 Meeting of the Parties to the Montreal Protocol: (b) Participation in a SolarChill Seminar in Cameroon in May, 2017, organized by SolaAfrica for interested industry and government representatives; (c) communication with other agencies, such as Mobisol, Greenwish Partners, and CLASP that are interested in delivering efficient solar refrigeration to sub-Sahara Africa and other off-grid African regions.

5. Commercialization and market penetration

The situation looks, unfortunately, more complicated concerning the longer-term commercialization and market penetration objectives. Despite the appropriate SolarChill technical solution and lower life cost, the current initial purchase price and the lack of a long-term financial plans, are and will remain a major barrier. This price barrier will be even more impactful with the SC-B units as it impacts a remote population with lower economic level, compared to SC-A where the main end-users are NGOs, health centers and Ministries Of Health with existing financial resources. Approaching the SC-B's end-users with the argument of "lower life cost" won't help a faster market penetration. With the information we have today, the high price issue of SC-A is unlikely to be adjusted and resolved before the project ends in late 2019.

Today, the SC-A units are at up to 5 times the projected price (table 9). Reducing such price gap will need a deep technical and supply chain work (e.g. a detailed evaluation of the Bill of Material and the supply sources) together with a strong and active competition development. On the top of that, the lack of concrete financial plans helping end-users to overcome the high purchase price, could lead this project to a dead-end especially for the SolarChill-B market. These two points must be addressed as soon as possible in order to meet the project's objectives.

As SolarChill-B units needs to comply with less stricter temperature performance requirement and their designs are technically simpler than SolarChill-A units, it can be expected that SC-B type with one compressor and without freezing function can be developed, marketed and sold at lower price compared to SC-A. The work that HEAT is undertaking with Palfridge and the cooperation between MobiSol and Palfridge are key to achieve a commercially viable SC-B solution.

Table 9: Projected SC-A cost reduction potential (Ref. Project Document)

	First batch costs	Target price within project period	Target price after 5 to 10 years
Cabinet	304	199	105
Insulation	304	228	91
Refrigeration unit	932	700	257
CE testing, manual etc.	142	74	24
Solar Panel equipment	270	216	130
Others	230	124	98
Total hardware	**1,951**	**1,541**	**704**
Sales Price	**2,341**	**1,850**	**845**

In conclusion, the SolarChill project is definitely relevant from both health care and environmental sides. Under certain conditions the SC-A and SC-B field tests could be achieved on time. High initial price is a major issue and must be addressed especially for SC-B units. The outreach activity is on-track. Technology transfer work in Swaziland could be met within the extended project's timelines (December 2019).

The table 10 below shows a summary of the project's objectives and the likelihood of being met.

Table 10: Objectives and likelihood to be met

Project objectives	Likelihood to be met on time
a- The demonstration, via a field test in Colombia, Swaziland, and Kenya, of the SolarChill-A vaccine refrigerator technology	a- High under certain conditions
b- Palfridge to deliver 70 SC-A units for field test	b- Moderate risk of not meeting this goal
c- Collection and interpretation of relevant, reference-able technical data to demonstrate reliable and viable technical and commercial performance achieving user acceptability	c- High
d- Dissemination of information about the technology on a country and regional level to industry leaders and policy makers	d- High
e- Outreach: web-based information sharing in relevant languages	e- High
f- Support to individual manufacturers (particularly in the targeting countries) in their efforts to market Solar Chill units (A and B) and decrease the cost of the units through technical support on design, R&D and production know how	f- Likely to be met in Swaziland within the project's extended time lines
g- Support to transfer the technology know how gained with SC-A refrigerators to SC-B refrigerators with a potentially much larger market and deployment scope. And brokerage activities to increase the market penetration	g- Likely to be met in Swaziland within the project's extended time lines

Recommendations

1. For future projects, there is a need for an “Initial Project Review” exercise in order to identify gaps in the project structure before the execution process starts
2. Set a clear field test protocol and a success criteria documents based on the units’ performance
3. Reduce the field test time of SC-A and SC-B from 12 months to 6 months
4. Original manufacturers should be more involved and take more responsibilities in the field test process: Trainings, installation, monitoring, servicing, etc.
5. All shipping matters to be handed and managed by a professional shipping agent
6. Do not start the SC-B field test before planning on how to address the high purchase price issue if any
7. Take the learnings from the SC-A to improve the SC-B field test: Review the lab test requirement (ongoing), improve communication with the procurement team, HEAT shall improve the RFQ structure and content, and the units’ installation speed, closer follow-up with Palfridge for a timely development and production of the field test units, etc.
8. The UNICEF procurement team shall be more proactive in their advisory role to fill the RFQ gaps
9. Accelerate the SC-A units’ installations to avoid further delays
10. Set or re-negotiate an after-sales service contract including spare parts provision, preferably with the local sales office of the original manufacturers
11. Work with current manufacturer to reduce initial cost (especially for SC-B) via technical design review and supply chain optimization
12. Support local (by country) surveys to determine the market potential for SC-B. Use this information during the technology transfer exercise
13. Put more focus and budget against the technology transfer process. Connect with local manufacturer and share relevant technical and market information to encourage them to invest and develop the SolarChill technology. In Kenya the best alternative is to identify potential local distributors and/or search for manufacturers in neighboring countries. In Colombia the best potential is with appliance manufacturers that have already converted to working with hydrocarbon refrigerants and HFC/ODS-free insulation, or plan to do so in the near future
14. Continue/accelerate the cooperation with Palfridge in Swaziland to: a) deliver the 70 SC-A field test units, b) create competition, and c) reduce the current price points of the SDD technology
15. SC-A combined capacity (cooling and freezing) seems to be the preferred design option for remote health centers in Colombia. But it’s not the case in Swaziland. It means, adjust the units design to the local market needs
16. For effective communication, connect with local manufacturers’ representatives for any commercial, technical and after sales services. It’ll reduce delays, eliminate time difference and language barriers
17. Minimize the number of active stakeholders in order to avoid complex communication and project’s delays i.e. the manufacturer, one local entity (i.e. the MOH) and one implementing technical partner (i.e. HEAT).

Annex I. Project evaluation by country

Country	What went well	Opportunities for improvement	Proposed actions for improvement
Colombia	-All SC-A units are in-country -Test sites selected and assessed -Government support and cooperation: Tax exemption, warehousing, transportation etc. -Great appreciation from end-users -Project management (HEAT): technical trainings, installations quality, follow-ups etc.	-High initial cost. Cost must have been investigated before the start of the field test -Miscommunication with customs leading to about 2 months delay in equipment's custom clearance and reception -Missing components with the received field test units: Additional delays -Too slow installation process (4 units per month), expected to be completed in December 2018 -Despite the clear indications in the location selection process, many field test locations have weak or NO GSM network coverage. As a result, performance data won't be able to be collected remotely. A solution needs to be found with the data logger suppliers -Lack of clear after sales service agreement and spare parts provision agreement with suppliers -Improve cooperation and communication between the key stakeholders -No clear field test protocol nor a success criteria list	-Develop local suppliers with technical support as of the initial design process with a clear outlook on the price/volume progress. Run market survey if needed -Tear Down Analysis of the current BOM and related supply chain in order to understand the cost versus price of the SC-A units. Similar work to be undertaken on the SC-B units -Commercial deals to be discussed and agreed with either local suppliers or local OEMs' representatives. This will help in avoiding language barrier (native speakers) and eliminate the communication issue from time difference (i.e. Colombia – Denmark) -Accelerate field installations - For locations with weak GSM coverage, work with the OEMs to find an appropriate technical solution -Key stakeholders to agree on field test success criteria
Swaziland	-All SC-A units are in-country -Test sites selected and assessed -Government support and cooperation: Tax exemption, warehousing, transportation etc. -Great appreciation from end-users -Technology transfer work initiated with The Fridge Factory -Technical training completed	-High initial cost -Lack of after sales service agreement and spare parts provision agreement with suppliers -Improve cooperation and communication between the key stakeholders -Too much players involved in the project execution, creating extra delays	-Continue the technology transfer work with Palfridge -Tear Down Analysis of the current BOM and related supply chain in order to understand the cost versus price of the SC-A units. Similar work to be undertaken on the SC-B units -Commercial deals to be discussed and agreed with either local suppliers or their local representatives -Accelerate field installations -For locations with weak GSM coverage, work with the OEMs to find an appropriate technical solution -Key stakeholders to agree on field test success criteria
Kenya	-All SC-A units are in-country -Test sites selected and assessed -Technical training completed	-High initial cost -No support from the government's MOH/MOE: No financial nor logistic support -Lack of after sales service agreement and spare parts provision agreement with suppliers -Improve cooperation and communication between the key stakeholders	-Develop local suppliers with technical support as of the initial design process with a clear outlook on the price/volume progress. Run market survey if needed -Tear Down Analysis of the current BOM and related supply chain -Accelerate field installations - For locations with weak GSM coverage, work with the OEMs to find an appropriate technical solution -Key stakeholders to agree on field test success criteria

Annex II. Project's Results Framework – Progress, Deviations and Delays

Description	Indicators	Source of verification	Assumptions	Progress to date – July 2018
Promote, demonstrate, and deploy low-carbon technologies.	Greenhouse gas (GHG) emissions reduction potential.	GHG emissions reduction estimates.	This project will project, not measure, GHG emissions reductions.	SC technology have been developed. Multiple suppliers passed the WHO/PQS qualification. Field test started and to be performed till end 2019 in Colombia, Kenya and Swaziland (Kingdom of eSwatini). Project is delayed
Reduce carbon emissions through off-grid efficiency gains.	Addition or substitution of SolarChill units for fuel-driven units.	SolarChill consortium.	Off-grid efficiencies gains using solar instead of fossil fuel powered.	The project still in the field test stage.
Increased availability and use of WHO PQS prequalified SolarChill refrigerators.	Number of WHO PQS prequalified SC-A refrigerators and available brands.	WHO PQS.	Increased availability of WHO PQS SolarChill A refrigerators will increase accessibility and introduction of SolarChill. Increasing introduction of off-grid efficiency products will lead to reduction in carbon emissions.	WHO/PQS qualified suppliers and models for SC-A still limited to 4 suppliers today. Around 113 SC-A units are available in the 3 field test countries and will be deployed in the coming few months A successful field test of the SC-A units and an appropriate outreach and dissemination of the field test results is expected to increase the end-user's confidence in this technology and to accelerate its market penetration
Increased availability and use of SC-B food refrigerators (for domestic and small-scale businesses)	Number of marketed SC-B refrigerators and available brands.	SolarChill consortium.	Increased availability of qualified SolarChill B refrigerators will increase accessibility and introduction of SolarChill. Increasing introduction of off-grid efficiency products will lead to reduction in carbon emissions.	SC-B project is in the lab test phase. Around 45 units are expected to be field tested in 2018/2019 in Colombia, Kenya and eSwatini Two suppliers passed the performance tests at DTI. These suppliers will provide the field test units Discussions with Leff (China) is ongoing to build a commercially affordable design SC-B project is delayed.
Increased awareness of benefits of SolarChill technology from an environmental and health perspective.	Number of individuals recognizing the benefits of SolarChill.	Number of views of SolarChill website. Questionnaire tracking	Recognition of benefits of SolarChill technology will promote the use of SolarChill and reduce GHG emissions. Annual Interviews will be carried out with all relevant stakeholders (ministries, health facilities, domestic manufacturers, distributors) with the same questionnaire. The interviews and questionnaire will be designed to appropriately monitor the progress of the project with regards to its objectives and also measuring the awareness.	From my field visit to Colombia and eSwatini (Swaziland), I noticed the extreme importance from health-care point of view, of the SolarChill-A units for local authorities and for the remote communities. For example, in "Pueblo Bujo", a remote health center in Monteria area, Colombia: I interviewed the site nurse and she explained that the installed SolarChill-A unit (B-medical) is expected to increase the vaccines storage capacity from about a week to more than a month. And, that the combined freezing/cooling capacity, will further increase the storage capacity with the possibility to use the frozen water/glycol pouches to perform home visits for patient with impossible and/or difficult mobility

Brokerage and linkage activities between manufacturers and whole sellers in the countries and financing organizations (micro-financing)	Appropriate linking parties identified, and contacts established; One partnership established;	Engagement from financing organization confirmed;	Existing financing (micro-financing) organization in at least one of the three target countries exists and shows interest to get engaged;	No relevant progress in this area of the project
Deployment and testing of SolarChill units according to project components with resulting GHG emission reductions.	Number of units of SC-A and SC-B installed and being tested.	Monitoring of the local partners	Every unit installed avoids installation of a kerosene unit (GHG abatement) allows avoidance of corresponding additional fuel combustions. Therefore, every unit installed results in corresponding GHG abatement.	Field test units (113 SC-A and 45 SC-B) yet to be completely installed in the 3 countries. Complete installation is expected no earlier than December 2018
Accurate site selection for testing & evaluating SC-A	Site compliance to SC-A requirements	SolarChill consortium technical experts	Solar equipment site selection protocols have been validated by industry experts	Appropriate field test sites have been selected by the MOHs of respective countries. And these sites have been assessed, for the installation work, by HEAT's country managers
SolarChill installation and monitoring protocol and training program for local technicians.	Training protocols available.	SolarChill consortium technical experts.	MOH will contribute to the appropriateness of the training protocols and format for training.	Installation and monitoring protocol have been produced in collaboration between DTI, SELF and HEAT. Technicians' training was completed, by HEAT's country managers, in Colombia, Kenya and eSwatini
Accurate site selection for testing and evaluating SolarChill B.	Site compliance to SC-B requirements.	SolarChill consortium technical experts.	Solar equipment site selection protocols have been validated by industry experts.	Site selection protocol is validated. Field test sites have been selected and assessed in eSwatini. Yet to be done in Kenya and Colombia. No expected issue on this exercise
Consolidate SolarChill external Communication.	Communication and marketing materials available and accessible.	SolarChill consortium.	Obtaining buy-in of external communication messages will strengthen the overall SolarChill category.	In progress. A more intensive communication and outreach would be beneficial once the field test data starts to build-up.
Engage in technology transfer discussions.	Number of companies engaged in discussion about technology transfer.	SolarChill consortium, Ministry of Industry (MOI) and Ministry of Environment (MOE).	Given the timeframe and investment required for conversion of a manufacturing line, it is anticipated that companies interested in technology transfer will not be able to fully adopt the technology within the scope of this project.	Technology transfer work already in place (by HEAT) in Swaziland with Palfridge, a local manufacturer. No progress in either Colombia nor Kenya (as Kenya does not have a refrigerator manufacturing sector, it is not expected that SolarChill can be produced in the country in the near future). This piece of work is behind schedule.

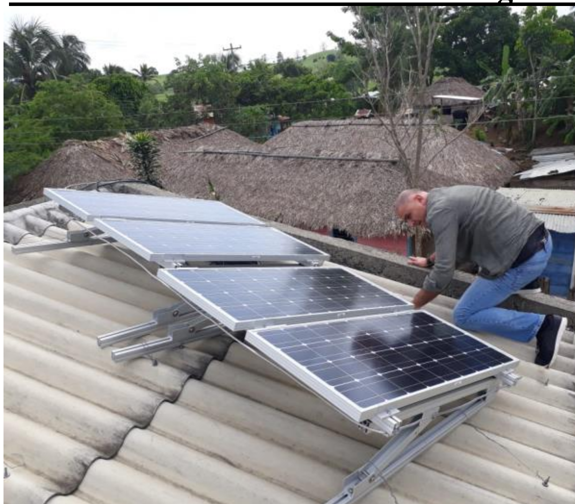
National institutional/sectorial and policy compliance.	Number of national policies in place to mitigate climate change through the introduction of solar refrigeration or other means.	SolarChill consortium, MOI, MOE, MOH.	Adoption of new policies or strengthening of existing policies will help to encourage installation of additional SolarChill units and incent local or regional manufacturers to transition to CFC-free refrigerants and insulation. Note that the policies to be followed are driven by the Montreal Protocol and HC conversions-HPMP strengthening enforcement is an extension of the work is driven by UNEP co-financing. This activity therefore is not part of the project specific outputs or indicators and therefore does not appear in Annex G of the project document.	***Colombia:*** There is currently a well-established legal framework that supports initiatives that contribute to the reduction of ozone-depleting substances. Due to the implementation of these policies, all national manufacturers of domestic refrigerators have changed their manufacturing processes to technologies free of CFC. Today, Colombia does not allow manufacturing or importation of equipment and products that contain or require use of ODS for production or use. In addition, importation of CFC has been prohibited since January 1, 2010. The SolarChill project is in line with the current policies and trends for reduction and elimination of ODS in Colombia. The manufacturers of household refrigerators are using R600a, the ozone staff in the MOE is working in training process and reconversion from R134a to HC. **Kenya:** The National Environment Management Authority (NEMA) is the government agency that is responsible for the management of the environment and environmental policy of Kenya. NEMA is legally obligated to promote the integration of environmental considerations into Kenya's development policies, plans, programs, and projects to ensure proper management and rational utilization of environmental resources for improvement of the quality life in Kenya. **eSwatini (Swaziland):** The Second National Communication identifies the need for fuel-switching technologies to replace the high demand for fossil fuel. Swaziland's Implementation of the 2003 National Energy Policy supports and promotes efficient and environmentally friendly technologies, including solar-powered equipment. Moreover, the country's technology needs assessment that was carried out in 2010 emphasized the need for renewable energy technologies. The assessment identified opportunities for solar-powered technologies in the energy sector and the need for increasing

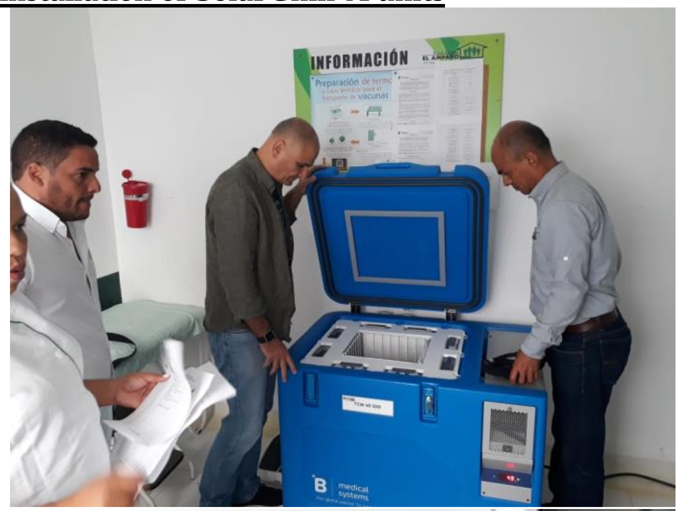
Annex III. Project Analysis: Progress and Barriers by Country

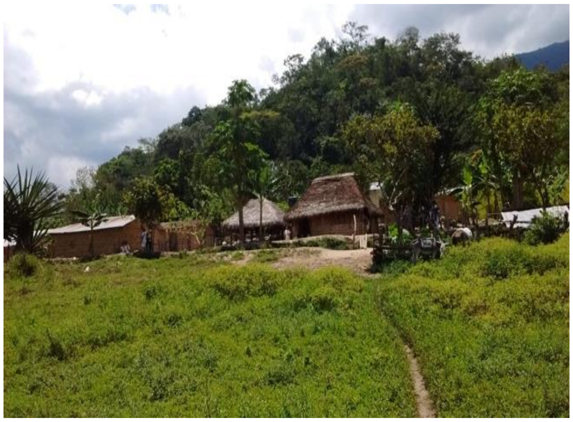
Project Objectives	Expected Outcomes	Expected Outputs	Progress to Date
1. Procure, install 200 SolarChill-A units in three countries (66 per country), namely Colombia Kenya and Swaziland	Procure and install 200 SolarChill-A units in three countries (66 per country)	Demonstration experience and cross-comparison of currently available SolarChill-A products, under field conditions in representative health centers to ensure that safe vaccine storage conditions are met	-**Colombia**: A total of 37 SC-A have been procured by the UNICEFand are currently available at the MOH warehouses. Twelve of them have been installed to date (July 2018). All field test sites have been selected by the MOH and assessed by HEAT's country managers. Current expected installation completion is Nov/Dec 2018. All technicians have been trained -**Kenya**: 36 units available in-country. Trainings have been completed by HEAT. All sites have been selected and assessed. Installations will be conducted by 3 teams from CHAK and expected to take at least 2 months for completion -**eSwatini (Swaziland)**: 40 units available in country. All sites have been selected and assessed. Installations (led by HEAT) will start in August and to be completed in December 2018. Two units installed to date (July 2018). Technical trainings completed by HEAT.
2. Laboratory testing of prototypes, procurement, and field testing of 15 (total of 45) SolarChill-B units in each of the three countries	Development by more than one manufacturer of SolarChill-B and first-hand experience with SolarChill-B in practical applications	-Testing results of SolarChill-B under field conditions in a variety of small institutional and light commercial applications - Brokerage activities to connect financing organizations (micro-financing and venture capitalists) for increased market penetration.	-**DTI**: Three SolarChill-B units (from 3 different suppliers) have been lab tested at DTI. Two of them passed the performance requirement. -Zero field test unit have been procured to date (July 2018) in neither of the 3 countries -Yet no financial plan is in place to help end-users with the initial high prices
3. Information dissemination and technology transfer	Information regarding SolarChill more widely available; increased industry interest in SolarChill A and B production in Latin America and Africa	Marketing campaign, business plans, increased awareness and interest in SolarChill, and updated SolarChill website Preparation of a technology transfer packet	- A user-friendly web site has been created by key stakeholders and publicly available - In Swaziland, a very encouraging initial technology transfer work have been initiated with a local supplier, The Fridge Factory – TFF. Yet (July 2018) no prototype is available for lab testing - No SolarChill technology transfer have been conducted, with local manufacturer, neither in Colombia nor in Kenya. - This activity is behind schedule

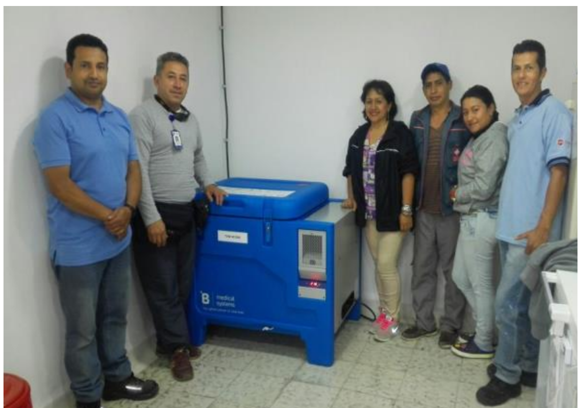
Annex IV. Field photos – Colombia and The Kingdom of eSwatini (Swaziland)

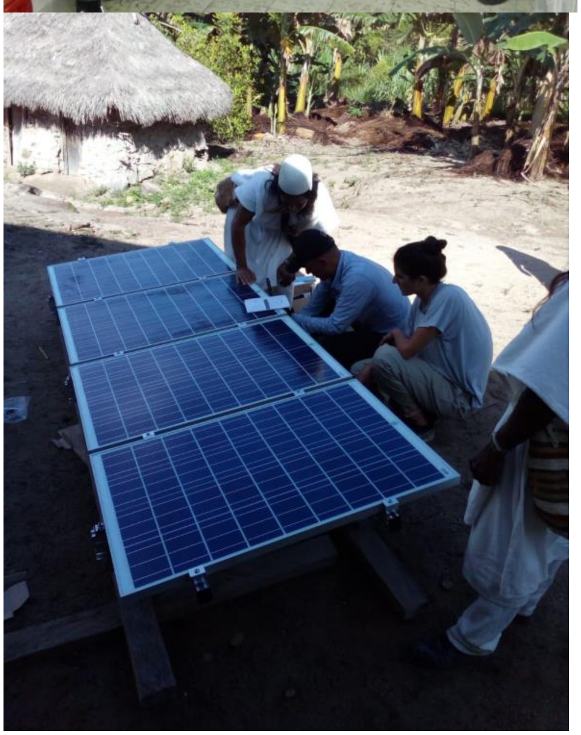
<u>Colombia – Health center – Training and installation of SolarChill-A units</u>

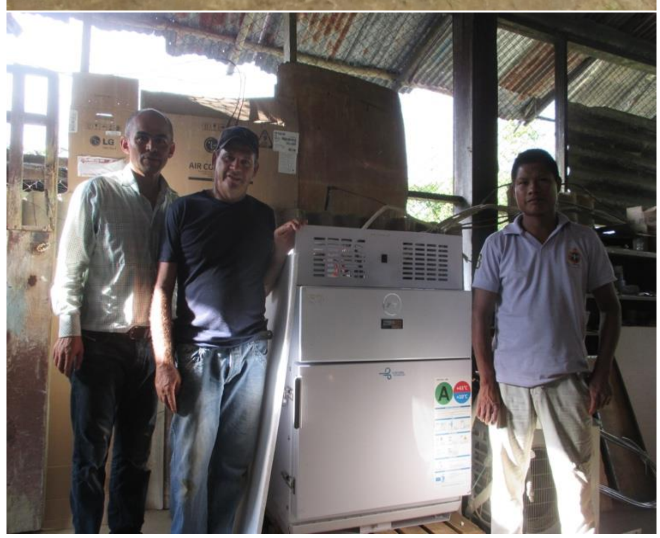












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