RAISING AMBITIONS FOR OFF-GRID COOLING APPLIANCES

APRIL 2021

ACKNOWLEDGEMENT

This report was developed by a team at Sustainable Energy for All (SEforALL) composed of Clotilde Rossi di Schio, Brian Dean, Alvin Jose, Ben Hartley, Andrea Stojanov, Stephen Kent, Therese Gadi, Meriam Otarra and Jenny Nasser. It includes major contributions from a team at CLASP composed of Colin Taylor, Riley Macdonald, Elisa Lai, Ana Maria Carreño and Ruth Kimani.

SEforALL would like to thank the following people and organizations, without whose input the report would not have been possible: Daron Bedrosyan, Leo Blyth, Martina Bosi and Bonsuk Koo (World Bank), F. Andrew Dowdy (Engineers Without Borders USA), Iain Campbell (Rocky Mountain Institute).

SEforALL acknowledges with gratitude the financial assistance provided by the Children's Investment Fund Foundation (CIFF) that made this report possible and the Cooling for All funding provided by the Kigali Cooling Efficiency Program (K-CEP) and the Swiss Agency for Development Cooperation. We also acknowledge the funding provided by the Austrian Development Agency, the Ministry of Foreign Affairs of Denmark, the Ministry for Foreign Affairs of Iceland, the IKEA Foundation and the Rockefeller Foundation for their core support to our work. For a full list of our supporters, please visit our website at **www.SEforALL.org**.

Cover photo by Gavi, The Vaccine Alliance
Inside photos by the Asian Development Bank

ABSTRACT

This Sustainable Energy for All (SEforALL) knowledge brief reviews best available cooling technologies and their capacity to be supported at different levels of the Multi-Tier Framework (MTF) for Measuring Energy Access. The goal of this assessment is to better understand the potential off-grid use of these cooling technologies and to develop a methodology to identify the best available cooling technology for a variety of situations with challenging access to electricity, such as in off-grid or weak grid settings. The knowledge brief includes a survey of current efficiency levels across a range of off-grid cooling appliances and identifies best practices for adoption and promotion of efficient off-grid cooling appliances. It shares recommendations for development and financing programmes to help them identify high-quality, efficient off-grid cooling appliances and lays the groundwork for deeper technical work related to off-grid appliance standards.

RECOMMENDATIONS

In areas where affordable cooling solutions are now available and with the right market interventions, communities are positioned to leapfrog to more efficient technologies that are more suitable to off-grid settings. The following recommendations, aimed at multilateral development banks, bilateral donors, climate funds, project developers and governments, can support new opportunites to deliver access to sustainable cooling for all in off-grid settings at different stages of energy access.

ENCOURAGE AND INCENTIVIZE THE USE OF THE MOST EFFICIENT, BEST AVAILABLE OFF-GRID COOLING APPLIANCES to accelerate the delivery of access to sustainable cooling and support energy access efforts. This should be through utilizing quality criteria to identify the best available appliances. Programmes should also allow rolling eligibility to ensure new best available appliances qualify, that no technologies or companies are locked out, and that there is sufficient flexibility for the off-grid appliance market to grow and for technologies to advance.

SUPPORT THE USE OF PASSIVE AND CLIMATE-FRIENDLY COOLING SOLUTIONS: Encourage integrated solutions that include passive and nature-based solutions to reduce the need for appliances. Support the transition to efficient off-grid cooling appliances that use climate-friendly refrigerants.

SUPPORT INFORMATION SHARING FOR DECISION-MAKING:
Support the creation and sharing of consistent and user-friendly product labelling and manuals with the information necessary for consumers to make the best purchasing and operation decisions, including on affordability, reliability and usability. Development programmes should systematically leverage the resources, tools and product information sheets at their disposal to ensure a consistent level of information for off-grid cooling solutions. Use #ThisIsCool to share information on sustainable cooling solutions. Target youth, as a driver of change, and inform young entrepreneurs to enable them to grow markets for off-grid cooling solutions and foster more competitive economies.

DESIGN PROGRAMMES TO MEET THE NEEDS OF VULNERABLE POPULATIONS:
Design programmes that use modern approaches to enable sustainable solutions for vulnerable populations. This includes pay as you go (PAYGO) models, bulk procurement, and non-traditional incentives that support sustainable development and local jobs. Take into account the last-mile delivery constraints of each appliance, including ease of transport, installation requirements and maintenance considerations.

ADOPT AND IMPLEMENT STANDARDS:
Work with other programmes to utilize existing standards and incorporate them into a programme's eligibility requirements to increase the uptake of high-quality products and protect consumers.

SUPPORT TESTING INFRASTRUCTURE TO ENABLE ACCURATE MEASUREMENT AND COMPARISON:
Set policies that require the use of third-party, independent testing facilities and verification processes for manufacturers. Testing policies should balance technical robustness with the cost of participating and allow sufficient time and budget for testing.

INCLUDE MEASUREMENT AND EVALUATION IN PROGRAMME DESIGN:
Ensure that products operate as intended and that proper maintenance practices are in place to maintain optimal working conditions of the equipment to reduce risk for programme implementers and consumers. This is especially important for larger, more expensive products like refrigerators.

CONDUCT DEEPER TECHNICAL WORK FOR OFF-GRID APPLIANCES:
Understand the impact of cooling in addition to other basic energy services in determining energy access needs in relation to the Multi-Tier Framework (MTF) for Measuring Energy Access.

1 INTRODUCTION

As global temperatures rise due to climate change, access to sustainable cooling solutions[1] is a growing concern for governments, development institutions and climate funds. Demand for cooling, and the energy it consumes, is growing across low- to middle-income countries that experience high temperatures, and sustainable cooling is increasingly recognized in these areas as an energy service that is critical to realizing Sustainable Development Goal (SDG) 7. For those living in off-grid settings who may lack access to reliable electricity or basic service altogether, affordable and efficient cooling solutions are only now coming within reach for some. In recent years governments, multilateral development banks, bilateral donors and climate funds have assessed available options to increase access to cooling, yet standards for off-grid cooling appliances have not yet emerged as a central focus. This poses a challenge as standards set the quality and performance characteristics needed to develop policies and programmes to increase access to cooling solutions.

To support these institutions in developing strategies to deliver access to cooling in off-grid settings, this knowledge brief reviews cooling technologies and their capacity to be supported at different energy capacity levels of off-grid energy systems defined in the Multi-Tier Framework (MTF) for Measuring Energy Access. The goal is to support project developers and implementers in identifying efficient and climate-friendly off-grid cooling solutions suitable for various levels of energy access, and to support the development of more targeted financing and incentive programmes. Sustainable Energy for All (SEforALL) will work with partners implementing cooling investment programmes to integrate the recommendations of this brief as best practice. These recommendations also lay the groundwork for deeper technical work related to off-grid appliance evaluation efforts and standards definition.

1.1 Access to cooling and the risks for people without access to electricity and cooling

According to SEforALL's *Chilling Prospects* report series, over 1 billion people across 54 high-impact countries[2] remain at high risk from a lack of access to cooling. This includes 318 million people living in poor, rural settings, who are among the over 780 million people globally who have no access to electricity. These people are likely to live off-grid, and while they may have access to passive cooling solutions, access to sustainable energy is crucial to gain access to other sustainable cooling solutions, such as an efficient refrigerator to keep nutritious food safe, a fan to deliver comfort necessary for quality sleep, or air-conditioning to protect a family during a heatwave.

Energy access must go beyond the electricity necessary to power a lightbulb; it should include sufficient power for a cooling appliance and reach a service level of electricity that is reliable at periods of peak demand when temperatures are often at their highest. Globally, those without access to "reasonably reliable" electricity necessary for these purposes could be as high as 3.5 billion people (Ayaburi et al. 2020).

[1] Cooling solutions include service solutions, financial solutions, policy solutions and technology solutions, which can be both passive and active. In this brief, cooling solutions considered are fans, refrigeration and air-conditioning appliances.
[2] Countries identified in SEforALL's *Chilling Prospects* series as facing the biggest risks, measured by extreme heat, food losses, and damaged or destroyed vaccines and medicines.

Access to sustainable energy is crucial to gain access to other sustainable cooling solutions, such as an efficient refrigerator to keep nutritious food safe, a fan to deliver comfort necessary for quality sleep, or air-conditioning to protect a family during a heatwave.

Distributed off-grid renewable energy systems, including solar home systems (SHSs) and mini-grids, are widely viewed as fundamental tools for closing energy access gaps in poor rural settings, and are increasingly the most economically viable. Development of energy-efficient, cost-effective and innovative technologies that can be supported in off-grid and mini-grid situations have a critical role to play in expanding access to sustainable cooling. Efficient appliances that can be supported by off-grid systems can drive increased sales of those systems, as has been demonstrated in the case of televisions.

The off-grid appliance market remains nascent and disorganized, suffering from the fact that most appliances currently available in retail markets require too much power to be supported by SHSs (Efficiency for Access 2019). A lack of data makes it challenging to characterize the market and technologies available. The efficiency, quality and affordability of cooling appliances for off-grid settings have been improving and should be considered for programmes that aim to deliver access to energy services in off-grid settings. These technological innovations have often been driven by specialist appliance manufacturers or entrepreneurial private sector companies that understand the demand for off-grid appropriate appliances. Moreover, by understanding the different electricity service levels required to power improved cooling appliances, energy access project implementers can establish a nominal efficiency baseline for these appliances and track project progress over time.

1.2 Overview of Multi-Tier Framework for Measuring Energy Access

The MTF is a framework developed by the World Bank Group to go beyond binary measurements of having or not having an electricity connection to a system of measurement that acknowledges the spectrum of service levels experienced by households. It uses a tiered approach to measure a household's access to energy (supply side). This is also useful when we think about cooling appliances and how they fit into each tier (demand side).

The MTF identifies the key attributes that together determine the "usability" of services. For electricity, this includes: the electricity capacity; hours of electricity service received, in the evening in particular; and the reliability, quality, affordability, legality and safety of service (See Table 1), (World Bank 2015).

TABLE 1
Summary of MTF tiers of energy access

		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
TIER CRITERIA			Task lighting and phone charging	General lighting and phone charging, television, and fan (if needed)	Tier 2 and any medium-power appliances	Tier 3 and any high-power appliances	Tier 4 and very high-power appliances
PEAK CAPACITY	Power capacity ratings (in W or daily wh)		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
			Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	Or services		Lighting of 100 lmhr/day	Electrical lighting, air circulation, television and phone charging are possible			
AVAILABILITY	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs

1.3 Cooling appliances and the Multi-Tier Framework for Measuring Energy Access

In a warming world, access to cooling for those living in poor rural settings prone to heat stress is no longer a luxury, it is an issue of equity. As governments and development financiers work to bring energy and the services it delivers, including cooling, to off-grid communities, the MTF has emerged as the authoritative standard for service levels delivered. However, the MTF does not yet reflect cooling as an essential energy service in a warming world or recognize the technological advances in cooling appliances that have yielded higher efficiency and lower power demand levels.

Creating a meaningful link between the MTF and off-grid cooling appliances can ensure that access to cooling and access to energy investments are mutually reinforced and beneficial. Moreover, a survey of best-in-class products can reveal how energy efficiency has brought cooling services up the energy ladder for lower tiers of energy access. Capturing these efficiency levels also creates a nominal standard for the finance and procurement of cooling appliances when targeted to off-grid settings with variable rates of energy access.

When published, the MTF provided an indicative list of appliances in different tiers of access; this brief examines how cooling appliances can meet more tiers than previously expected: even lower tier energy access can power more efficient products, which confirms the importance of efficiency in energy access.

TABLE 2

Cooling appliances identified as applicable to MTF tiers of energy access

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
COOLING APPLIANCES IDENTIFIED IN MTF			Fan	Fan Air Cooler	Fan Air Cooler Refrigerator and Freezer	Fan Air Cooler Refrigerator and Freezer Air Conditioner
COOLING APPLIANCES IDENTIFIED IN THIS ASSESSMENT		Table fan Air cooler	Table fan Ceiling fan Pedestal fan Air cooler Refrigerator	Table fan Ceiling fan Pedestal fan Air cooler Refrigerator and Freezer Air conditioner	Table fan Ceiling fan Pedestal fan Air cooler Refrigerator and Freezer Air conditioner	Table fan Ceiling fan Pedestal fan Air cooler Refrigerator and Freezer Air conditioner

1.4 Off-grid cooling solution status

For those living in rural poverty, there are three primary needs that can be supported by enhanced access to sustainable cooling: human comfort and safety; food, nutrition, and agricultural productivity; and health services. To meet these needs, there are a range of different cooling solutions that can be broadly categorized as service solutions, financial solutions, policy solutions and technology solutions, which can be both passive and active (SEforALL 2020). Active technology cooling products captured by the initial survey in the MTF include fans, air coolers, refrigerators, freezers and air conditioners (ACs), which are examined in this brief.

The number and variety of fans, refrigerators and air coolers have steadily increased alongside improvements in affordability and efficiency (Lai et al. 2019). At the same time, ACs are becoming more efficient, though the cost and availability of efficient units typically prevents those with less purchasing power from acquiring them (International Energy Agency (IEA) 2019).

Product sales are projected to grow rapidly; the Efficiency for Access (EforA) 2019 State of the Off-Grid Appliance Market Report projects a doubling of sales for off-grid fans and refrigerators from USD 12.6 billion globally at the end of 2018 to USD 25.3 billion by 2030 (EforA 2019 and 2021). The growth of pay-as-you-go (PAYGO) and Cooling as a Service (CaaS) business models together with the increase in sales of larger SHSs are likely to enable the growth of cooling appliance markets in the coming years. **However, for many appliances, market penetration in off-grid communities remains low and a significant gap between current sales and market potential exists – for example just 4 percent of rural households in Africa own a refrigerator (GOGLA 2021).**

Technology-based cooling solutions for those living off-grid are not limited to those that require energy. Passive solutions, such as the use of vegetation, shading and natural ventilation for buildings, are fundamentally needed for all homes to reduce the need for air-conditioning and can improve thermal comfort and productivity. Roofs painted with reflective coating, or "cool roofs" have been proven to lower indoor air temperatures without requiring energy.

The challenge of off-grid refrigeration affordability is being examined by the teams in the Chill Challenge, an initiative of Engineers Without Borders USA (Engineers Without Borders USA, 2020). The objective is the development of refrigerators and ice makers that are significantly more affordable for off-grid communities than currently available units. These include 150–250 litre (L) refrigerators that can chill 20 L of water per day from 35°C to 3°C, and cost less than USD 12 per month to own and operate, and ice makers that can produce 100–1000 kg of ice per day at a cost of USD 0.03 per kg or less. This initiative is seeking innovative solutions that can operate with off-grid energy and that are suitable for use in remote developing communities.

1.5 Status of off-grid cooling appliance standards

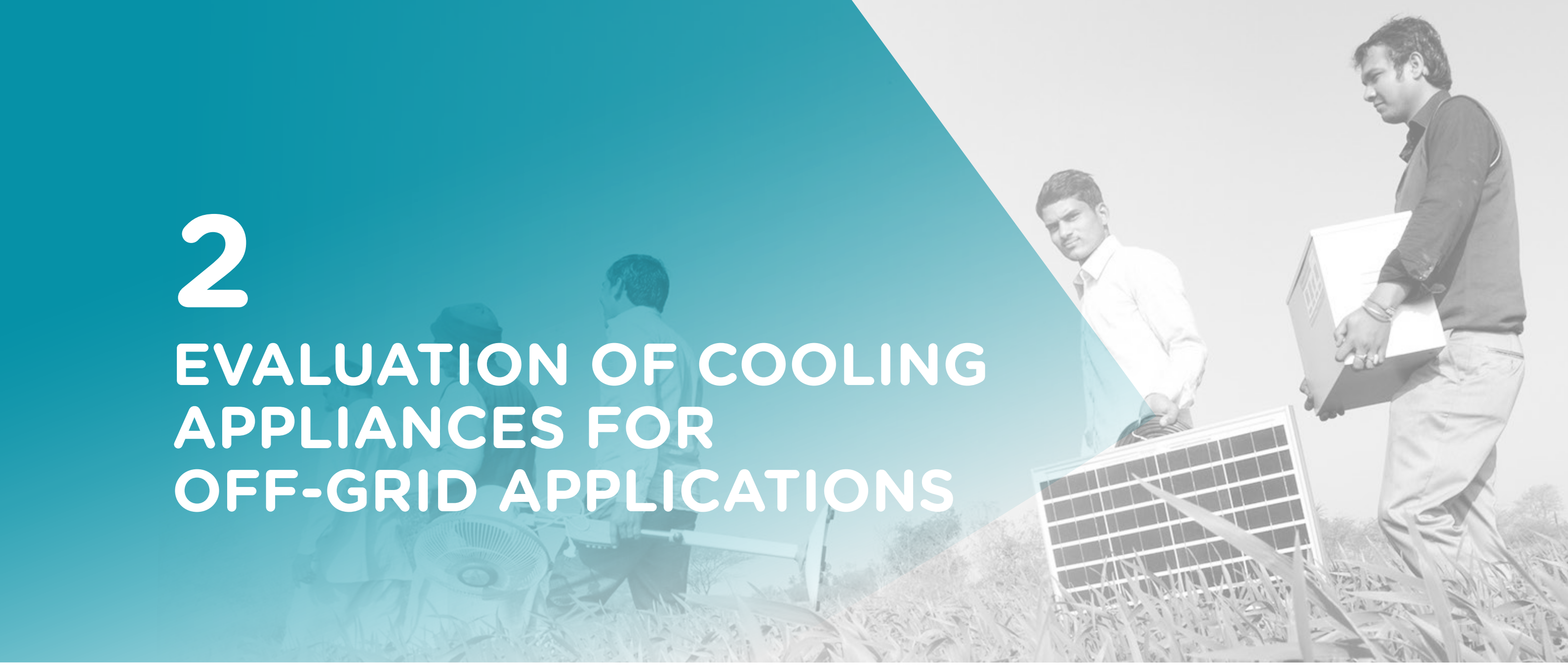
The nascency of the off-grid appliance market means that standards developed specifically for off-grid cooling products are mostly non-existent, except for very specific sectors such as World Health Organization (WHO) standards for off-grid vaccine refrigerators. There is a lack of reliable performance data in the market that makes it difficult for actors to develop market baselines and select high-performing products.

There are two types of appliance standards that can be applicable to off-grid cooling appliances: mandatory minimum energy performance standards (MEPS) and voluntary high energy performance standards (HEPS), which typically include a range of performance and quality specifications.[3] Given the state of the market, it is important to focus on requirements related to quality, safety and consumer protection, while incorporating efficiency into standards.

Recent efforts dedicated to increasing the energy efficiency of cooling appliances to support their use in off-grid settings include five years of Global LEAP Awards and its competitions for efficient fans, refrigerators and cold chain technologies to stimulate markets and improve product performance. VeraSol, together with EforA, piloted a quality assurance framework for standalone off-grid fans that included quality criteria, evaluation of products using the quality criteria, and shared findings to promote quality products. The EforA research and development (R&D) fund has also awarded GBP 2.9 million in funding for innovative and efficient solar-powered cooling appliances.

The Global Cooling Prize is a competition administered by the Rocky Mountain Institute (RMI), using a USD 3 million prize to stimulate the development of a five-times lower climate impact room AC at no more than two-times the cost of current baseline units. While the prize is not targeted specifically to off-grid communities, it is possible that the technologies developed may be efficient enough to be utilized in off-grid settings. Under the prize criteria, the maximum power draw of finalists can be no more than 700 Watts (W). (RMI 2018)

[3] Countries with MEPS do not usually specify that they only apply to on-grid products - for example, MEPS in Brazil apply to all products on and off the grid. Many countries with large off-grid markets have not developed any on-grid MEPS at all. On-grid MEPS may not be as appropriate for the off-grid context, even if they apply according to the regulations.



2 EVALUATION OF COOLING APPLIANCES FOR OFF-GRID APPLICATIONS

This knowledge brief focuses on four cooling technologies: fans, refrigerators and freezers, air coolers, and air conditioners (ACs). Fans and refrigerators are commonly available in the off-grid solar market. In countries with hot and dry climates, such as Pakistan, evaporative air coolers are in increasing demand because they consume comparable amounts of electricity to fans, while delivering comparable cooling to ACs when humidity is low.

This section provides an overview of each technology in the off-grid context and how currently available technology relates to the Multi-Tier Framework (MTF). Cooling technologies analyzed have been allocated in a MTF tier based on the following:

TABLE 3
Criteria to assess tier for each cooling technology analyzed

	MINIMUM DAILY OPERATION[4]	TIER 1	TIER 2	TIER 3	TIER 4
FANS	5 hours	3–49 W peak power 12–199 Wh daily consumption	50–199 W peak power 200–999 Wh daily consumption	200–799 W peak power 1–3.4 kWh daily consumption	800–1999 W peak power 3.4–8.2 kWh daily consumption
REFRIGERATORS/ FREEZERS	24 hours				
AIR COOLERS	5 hours				
AIR CONDITIONERS	3 hours				

Data for fans, refrigerators, freezers, and air coolers were gathered from Verasol Product Database, Okra Solar, CLASP Market Surveys and Mangoo.org, while AC data were gathered from government product information websites in Asia.

2.1 Fans

Fans are electrically powered mechanical devices that deliver cooling by moving hot air out of a space, moving cool air into a space, or moving air within a space to make occupants feel cooler. Fans do not cool the air directly like an AC. Depending on blade size and mounting, fans can be divided into three main types: ceiling fans, pedestal fans and table fans.

Ceiling fans are mounted on the ceiling, and their blades rotate horizontally and have a typical size range of around 1,000 to 1,400 millimetres (mm). Pedestal fans are mounted on a pedestal of fixed or variable height with a blade protected by a fan guard and the blade size ranges from 320 to 650 mm. Table fans (or bracket-mounted fans for walls, surfaces, or ceilings) have a blade protected by a fan guard and the blade size ranges from

[4] Minimum hours defined based on minimum consumer needs.

100 to 380 mm. Fans can be broadly utilized in off-grid settings given their relatively low electricity needs (less than 200 W, typically less than 60 W) and the ability to use them intermittently, as compared to refrigerators that need to operate continuously. The primary metric determining their cooling service delivery is the amount of air they move (air flow), which is a function of the fan blade size and the revolutions per minute.

The efficiency metric for fans is determined by their service value:[5]

ServiceVal(SV) = Airflow (m^3/min)/ Input power (W).

Fans are one of the most common household appliances in hot and humid climates like South Asia due to their relatively low price. In the global off-grid household appliance market, fans have been ranked as one of the most in-demand appliances for homes since 2014 and rank fifth in appliance demand for 2020. Similarly, in the healthcare appliance market, fans were in high demand for clinic infrastructure before the pandemic and have continued to be in high demand during the pandemic. Demand for fans is expected to grow due to a warming planet and, in part, due to improvements in efficiency and affordability (EforA 2020).

An analysis of Energy for Access (EforA)-tested fans found that between 2018 and 2019, the average efficiency of fans improved by more than 49 percent, possibly due to wider adoption of energy-efficient, brushless direct current (BLDC) motors, which can be up to 39 percent more efficient than typical alternating current (AC) motors. There is also evidence to suggest that the use of efficient fans can result in significant cost savings for consumers. One analysis found that total solar energy system costs for efficient pedestal and table fans were on average 42 percent lower than costs for inefficient fans, and 25 percent lower for ceiling fans (EforA 2021).

Table 4 shows the price ranges for off-grid fans.

TABLE 4
Price distribution of off-grid fans by fan type

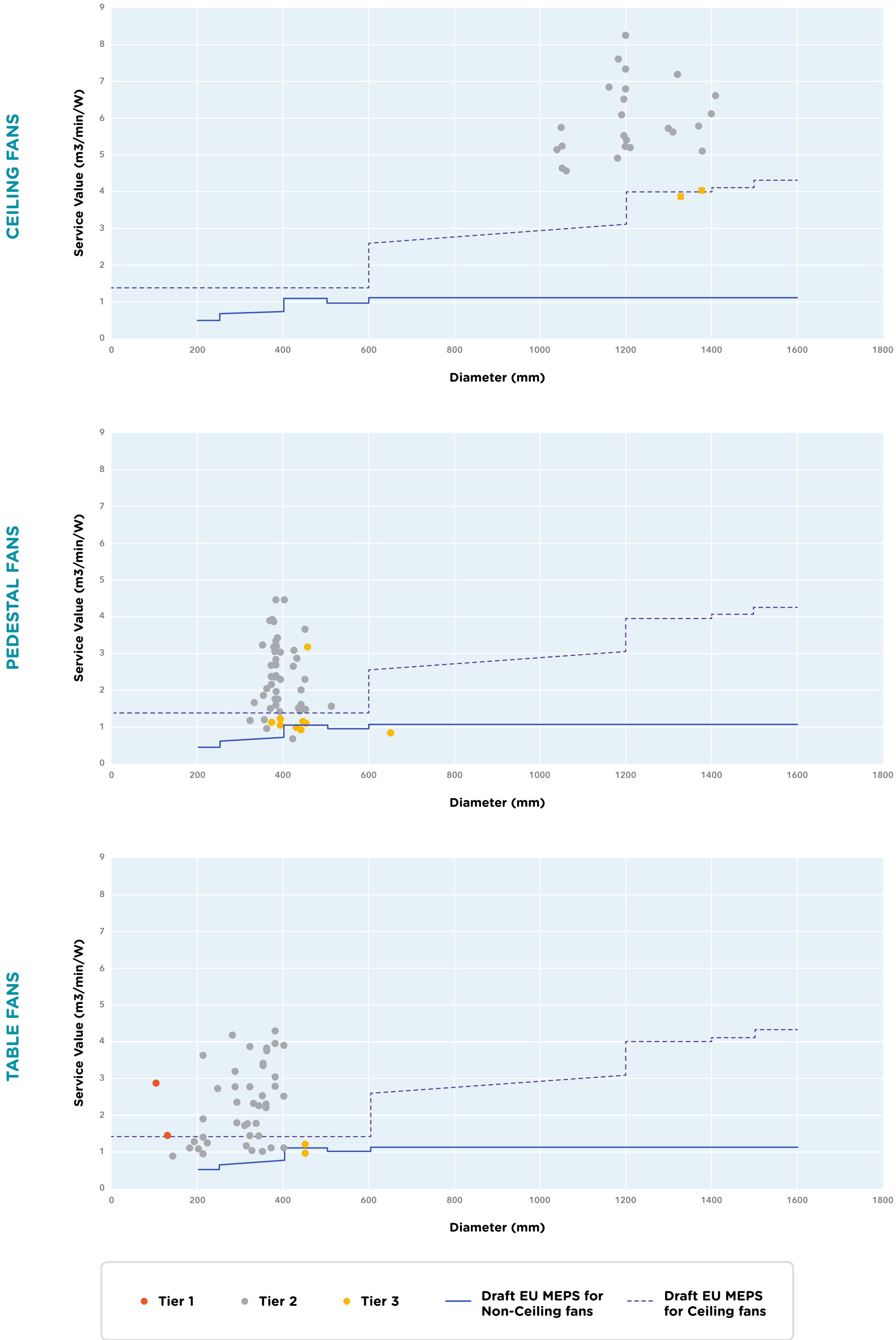
FAN TYPE	MINIMUM PRICE (USD)	25TH PERCENTILE PRICE (USD)	75TH PERCENTILE PRICE (USD)	MAXIMUM PRICE (USD)
CEILING FANS	14	22	76	135
PEDESTAL FANS	7	23	46	126
TABLE FANS	8	13	37	141

With the improved efficiency of fans, it is now possible to use table fans with an MTF Tier 1 level of household energy access, and ceiling and pedestal fans with a Tier 2 level of energy access (Figure 1). Off-grid fans are quite efficient, with some of the 'best available technologies' significantly more efficient than the most stringent technology standards for on-grid fans.[6,7]

[5] The two factors that impact the service value for a fan are the efficiency of the motor and blade design.
[6] Standards utilized here are draft EU MEPS, which are considered to be the world-leading efficiency policy for on-grid fans.
[7] Utilization of on-grid standards for off-grid appliances can be very helpful in identifying the most efficient off-grid appliances. On-grid appliance standards are far from being a perfect substitute for off-grid appliance standards though, as they might miss out specific needs for off-grid use and might require the appliance to reach stringent parameters not relevant in the off-grid context while having a negative impact on affordability.

FIGURE 1

Off-grid efficiency distribution for ceiling fans, pedestal fans and table fans[8]



[8] Fan data analyzed were collected from the Verasol Product Database, CLASP Market Surveys, and Mangoo.org.

2.2 Refrigerators and Freezers

Refrigerators and freezers, or refrigerating appliances, are insulated cabinets with one or more compartments that are controlled at specific temperatures. Refrigerators can increase food security by reducing food waste and extending the shelf life of perishable foods. They can be utilized for business or productive-use applications, enabling improved income generation for small retailers by providing a place to store cold drinks, food, medicine and other perishable items. Refrigerators can reduce the number of trips to the market as well as offer an opportunity for owners to earn additional income (EforA, ENERGIA 2020).

EforA defines refrigerators utilized for off-grid markets as having at least one fresh food compartment that operates between 4 and 12˚C (39.2–53.6˚F) and a volume typically between 16L and 250L, although models up to 500L are available. Refrigerator-freezer combination units (i.e., refrigerator-freezers) have at least one fresh food compartment that operates between 4 and 12˚C (39.2–53.6˚F), at least one frozen food compartment where the storage temperature is -6˚C (21.2˚F) or colder, and a volume typically between 50L and 300L.

Refrigerators and freezers operating on thermal absorption processes, using LPG and kerosene as an energy source, have been used in off-grid locations for many years. However, with the falling cost of solar panels, vapour-compression units driven by electricity currently dominate the market. Off-grid electrically powered refrigerators and freezers include AC-powered units designed for on-grid service (which require an inverter), and DC-powered units that can work directly off solar panels and batteries. Solar direct drive (SDD) refrigerators are designed to be connected to PV panels directly and operate without electric batteries. They contain an integrated phase change material (PCM) or thermal storage alongside insulation that reduces losses and allows operation during the nights or when energy is not available. Currently in the off-grid solar market, vapour-compression units are more common and are typically powered with a solar energy system with electrical batteries. For medical refrigeration, SDD refrigerators or freezers are the only type eligible for certification by the World Health Organization (WHO) for use in off-grid areas (WHO 2020).

A common proxy to understand the performance of a refrigerator is:

Energy consumption per year (kWh/year).[9]

Refrigerators are one of the most challenging appliances to optimize for both energy efficiency and cost-effectiveness and are generally unaffordable for vulnerable consumers and communities (EforA 2021). Even with financing, the down payment for an average-sized refrigerator (150L) can be the equivalent of up to five-times a rural customer's disposable monthly income (EforA 2020).

TABLE 5

Average price of off-grid refrigerators by size

REFRIGERATOR SIZE RANGE	AVERAGE PRICE (USD)	SHARE OF PRODUCTS ANALYZED
10-100L	542	49%
101-200L	980	38%
201-300L	812	13%

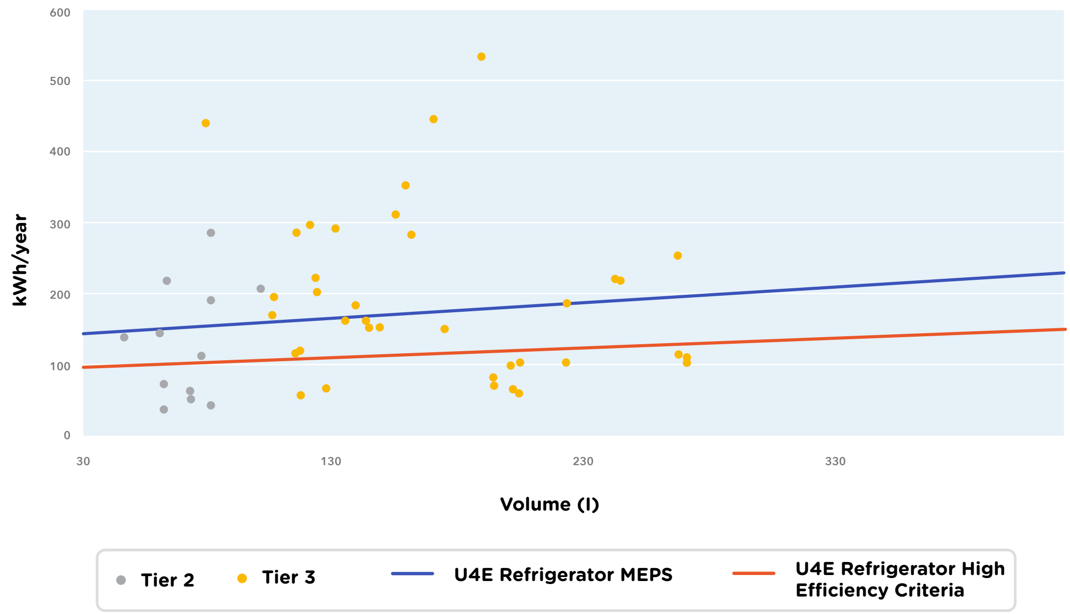
Refrigerators rank high in perceived consumer demand both for households (fourth) and for businesses or productive-use appliances (second and third respectively) and have improved their energy efficiency significantly, by an average of 36 percent, over a two-year period (EforA 2021). Available off-grid refrigerators show a wide range of efficiencies, with some refrigerators consuming five-times the electricity of same size units. In comparison to on-grid appliance standards, data show that best available technologies are significantly more efficient, using less energy per year, than world-leading efficiency policies for on-grid refrigerators[10] (Figure 2).

[9] For the refrigerator-freezer energy consumption analysis, 32˚C reference ambient temperature is utilized.

[10] MEPS and high-efficiency label levels contained in United for Efficiency's (U4E) model regulation for refrigerators.

FIGURE 2

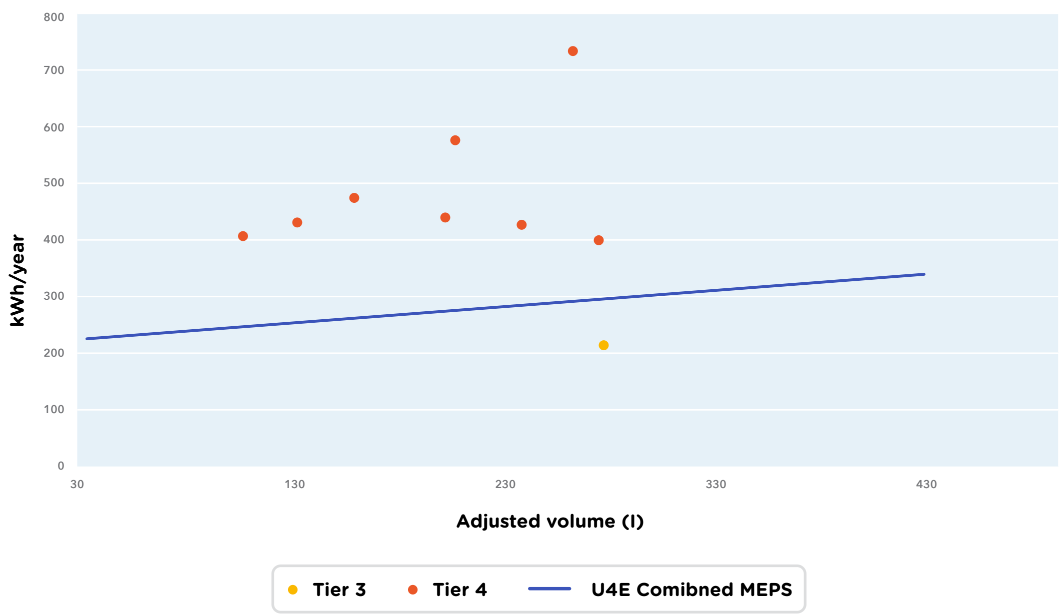
Efficiency distribution of off-grid refrigerators[11]



Refrigerator-freezers can require up to five-times more energy per day to operate than a refrigerator alone and those analyzed typically consume 1 kWh per day or more at an ambient temperature of 32˚C (EforA 2021). Only a limited number of refrigerator-freezers available for the off-grid market can cool to -6˚C,[12] thus limiting the options available. Most products evaluated for the off-grid market are relatively inefficient, using more energy per year than those for the on-grid market (Figure 3). (United for Efficiency 2019). As shown in Figure 3, only one off-grid refrigerator-freezer appliance clearly distinguishes itself as a best available technology, but it costs USD 2,286, more than double the price of any other refrigerator-freezer.

FIGURE 3

Efficiency distribution of off-grid refrigerator-freezers[13]



[11] Data were collected from the Verasol Product Database, Okra Solar, CLASP Market Surveys and Mangoo.org

[12] Minimum definition of a freezer compartment under IEC 62553:2015.

[13] Data were collected from the Verasol Product Database, Okra Solar, CLASP Market Surveys and Mangoo.org

2.3 Air Coolers

Air coolers (evaporative air coolers or swamp coolers) are devices that use water evaporation to cool the air. They are particularly useful in areas of low humidity but are less effective in humid climates. Air coolers can be as rudimentary as fans applied with water-saturated pads or can be more complex systems that include a water feeding system. The air coolers considered for off-grid applications include as key components a fan, a thick pad and a water reservoir.

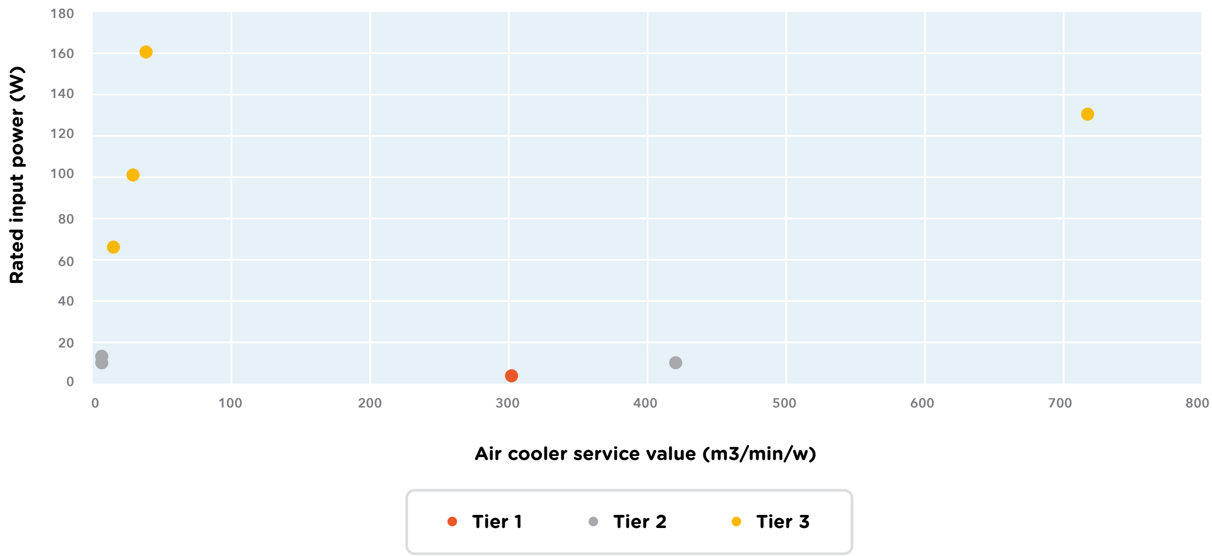
The fan portion of the air cooler is the main energy-consuming component, determining the air cooler's efficiency as:

ServiceValue (SV) = Air flow (m^3/min) / Input pow(W).

While air coolers can be particularly suitable for providing cooling in areas of low humidity, they require more frequent maintenance than fans, mostly in the water system. They also require a consistent water supply, which might be challenging in remote areas with scarce water availability.

Data on air coolers in the off-grid market remain unreliable and inconsistent, thus insufficient for conducting in-depth analysis, but as a fan is the main energy-consuming component of air coolers, key results of fans were used to determine the potential efficiency of air coolers and MTF tier compatibility.

FIGURE 4
Efficiency distribution of off-grid air coolers[14]



The lowest power capacity rating of an air cooler observed is 2 W with units that are suitable for MTF Tier 1 or 2 homes. For air coolers suitable for Tier 3 homes, the rated input power starts at 65 W. Figure 4 shows that the service received does not align with the rated input power and units have very different energy-efficiency levels.

[14] Data were collected from online retailers; no independently tested data were available and no on-grid air cooler efficiency policies were found to use as benchmarks.

2.4 Air Conditioners (ACs)

ACs are cooling devices that typically use a vapour compression cycle of a refrigerant (heat transfer medium) to provide space cooling to a specific temperature. There are varying sizes and system configurations for ACs, but in an off-grid context the type of systems adopted include unitary ACs that are window mountable, and split systems with separate indoor and outdoor units. The key components are evaporators, compressors, heat exchangers, expansion valves and refrigerants.

While more accurate energy performance measures of ACs are derived through indicators such as the seasonal energy efficiency ratio (SEER) or the cooling seasonal performance factor (CSPF), a common metric used for the energy efficiency of ACs is:

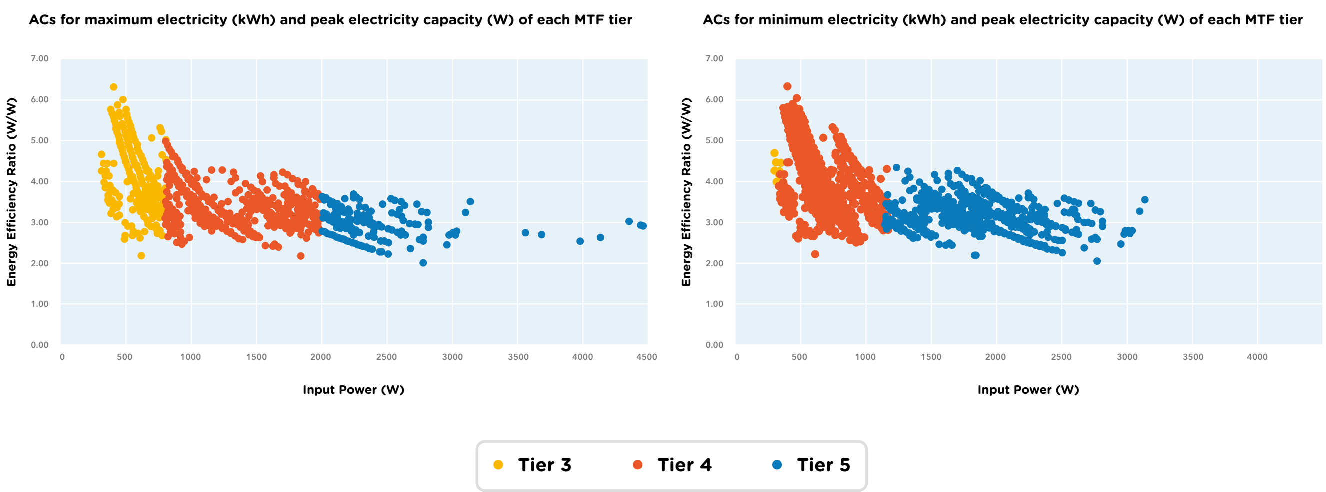
Energy Efficiency Ratio (EER) =
Cooling Capacity (W)/ Power Consumption (W).

ACs are considered high-load home appliances that are typically used by households with Tier 5 electricity supply, and thus have seen only negligible uptake by rural households or businesses with electricity sources unable to meet their power needs at affordable prices. In some developing countries, ACs are no longer considered a luxury product because lower capital cost and lower power capacity units are now available. These ACs with improved design, better control units and local service chains are enabling more ownership of ACs for households with Tier 4 electricity access. Appliance data also show that the use of ACs by households with Tier 3 electricity supply is now more possible depending on the purchasing power of the end user.

However, the more affordable ACs from a capital cost perspective that are compatible with Tier 4 and Tier 3 electricity supply tend to be less energy efficient, which impacts operational affordability for the end user, as well as their ability to access cooling when needed. This market segment would profit from energy-efficiency improvement considering the sizeable market growth expected, especially in developing countries. The series of figures below illustrates the performance of select ACs[15] that are commercially available in the Asia Pacific region within the MTF energy access criteria.

Figure 5 examines the relationship of efficiency and input power for available ACs and their applicability within the MTF tiers. The figures show that in a full Tier 3 energy access home (left), there are many high-efficiency ACs that can be used, while if the minimum Tier 3 energy access criteria are applied (right), there are considerably fewer ACs applicable for Tier 3 homes.

FIGURE 5
Air conditioner input power (W) and energy efficiency (W/W).

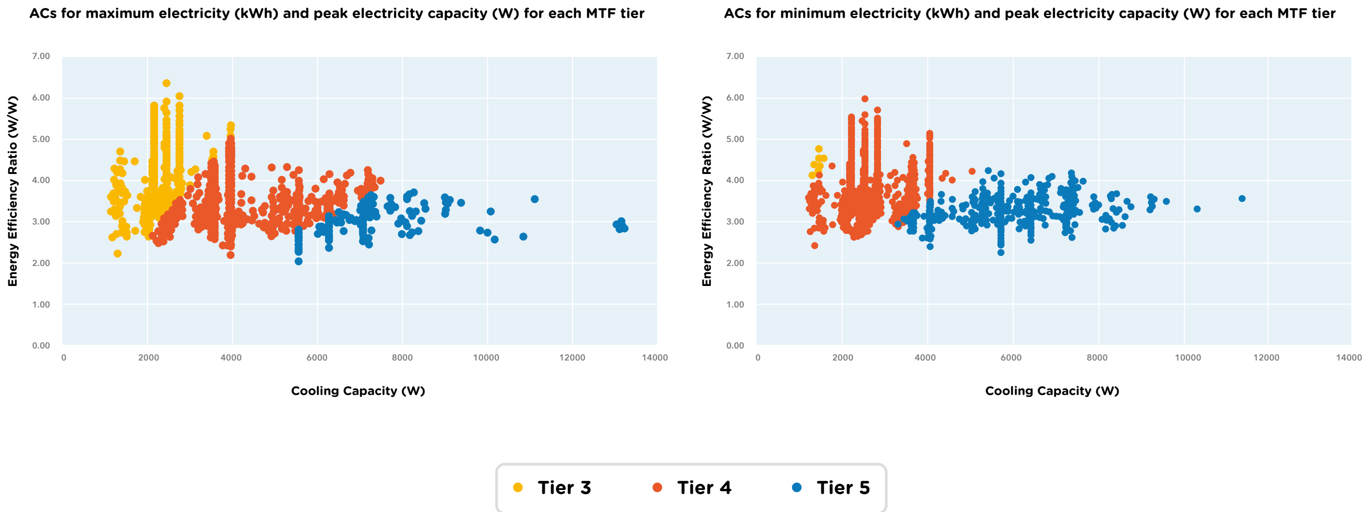


[15] Selected ACs include split ACs and window/wall ACs and do not include portable or spot cooler ACs.

The lowest power capacity rating of ACs observed, 300 W with energy efficiency ranging between 3.1 and 4.7 EER (W/W), is possibly suitable for some MTF Tier 3 homes. For the Tier 4-suitable AC units, those with a rated power capacity between 400 and 600 W have a wide range of efficiency between 2.2 and 6.5 EER (W/W). The trends show that the ACs that are suitable for homes that have the lowest available Tier 3 electricity supply are higher on the energy-efficiency scale, between 3.9 and 4.7 EER.

Figure 6 uses the same AC data and examines the relationship between efficiency and cooling output for available ACs and their applicability within the MTF tiers. The figures show that at a full Tier 3 energy access home (left), the available cooling capacity can supply more than 5000 W of cooling, while if the minimum Tier 3 energy access criteria are applied (right), the available cooling capacity is less than 2000 W. This shows the range of available cooling that can be delivered by current ACs for Tier 3 energy access homes.

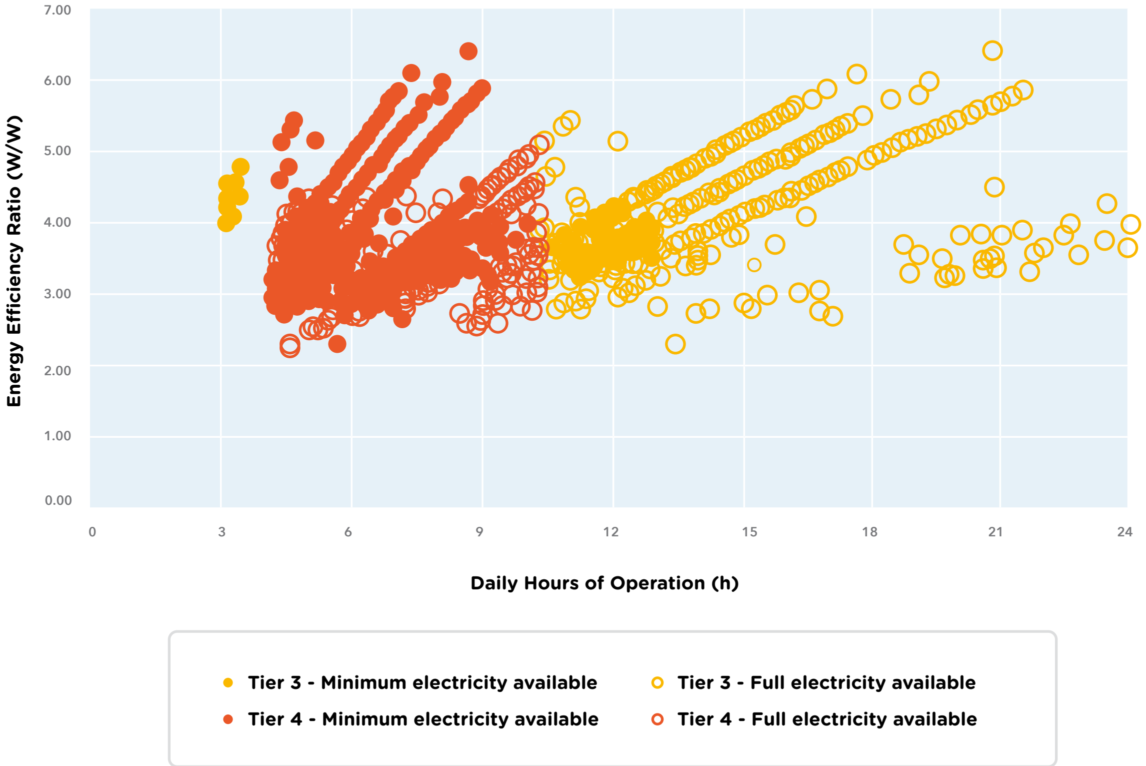
FIGURE 6
Air conditioner cooling capacity (W) and energy efficiency (W/W).



Looking more closely at the ACs to examine the hours of availability shows that ACs that are suitable for Tier 3 electricity access can range from about three hours a day for a home with minimum available electricity (shown with solid dots) to nearly 12 hours a day of AC operation for homes with a high range of Tier 3 electricity availability.

FIGURE 7

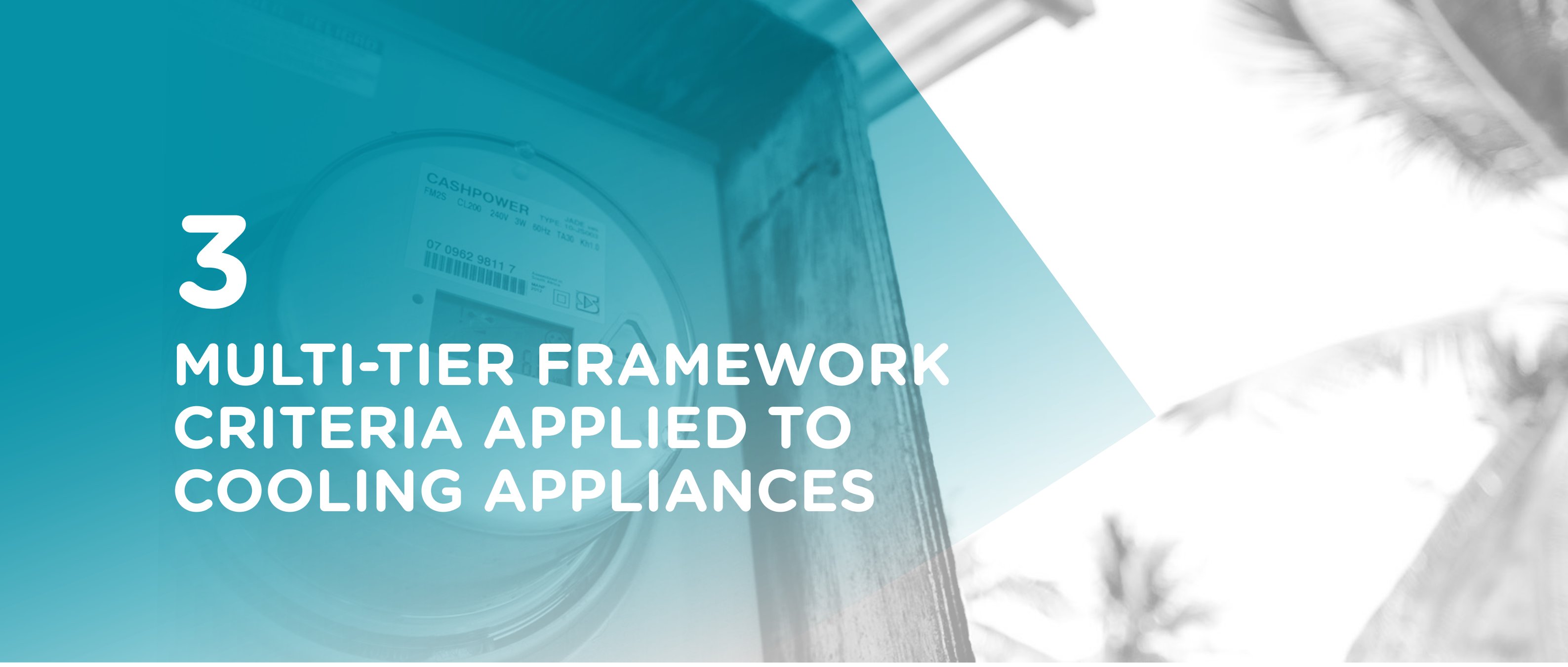
Hours of operation and efficiency for air conditioners based on the minimum and maximum electricity (kWh) for each tier



Off-grid refrigerators, freezers and ACs and the use of hydrofluorocarbon refrigerants

A significant number of refrigerators and ACs continue to use hydrofluorocarbon (HFC) gases as refrigerants, which have high global warming potential (GWP) (EforA 2021). Small split-room ACs often utilize R-410A, a HFC gas with a high GWP of 2100 (IEA United Nations Environment Programme (UNEP) 2020). The 2016 Kigali Amendment establishes a phase-down schedule for HFCs, an effort that has the potential to avoid up to 0.5°C of warming by the end of the century. To promote sustainable cooling for all, programmes should only invest in efficient and climate-friendly technologies.

Photo: Asian Development Bank



3
MULTI-TIER FRAMEWORK CRITERIA APPLIED TO COOLING APPLIANCES

In the absence of quality standards, SEforAll has developed a quality criteria framework designed to help investors, development programmes and other market stakeholders differentiate and compare the quality and performance of individual cooling appliances. By defining these key metrics and establishing a formalized evaluation structure, investors and development programmes can identify the best products on the market and encourage companies to enhance their products' quality and performance, thus increasing programme impacts and transforming the off-grid cooling market.

The quality criteria draw on several principles in the World Bank's Multi-Tier Framework (MTF), which is designed to measure access on a household level and adapt it to enable evaluation of individual cooling products. Each product is evaluated based on its "compatibility" with specific MTF energy supply tiers and a set of quality criteria (see Annex for detailed description).

Compatibility indicates which tier level of energy systems can power a given appliance, as well as the number of hours that the cooling product can operate within each tier. Compatibility of refrigerators with the MTF was determined based on whether the refrigerator could operate for at least 24 hours given the minimum daily energy in each MTF tier. Fans and air coolers were considered compatible with a tier if they could operate for at least five hours given the minimum daily energy of the MTF tier, and air conditioners (ACs) for at least three hours. While these are not officially accepted values, they were used to better understand the feasibility of using these services.

TABLE 6
Criteria to assess tier for each cooling technology analyzed

	MINIMUM DAILY OPERATION[16]	TIER 1	TIER 2	TIER 3	TIER 4
FANS	5 hours	3–49 W peak power 12–199 Wh daily consumption	50–199 W peak power 200–999 Wh daily consumption	200–799 W peak power 1–3.4 kWh daily consumption	800–1999 W peak power 3.4–8.2 kWh daily consumption
REFRIGERATORS/ FREEZERS	24 hours				
AIR COOLERS	5 hours				
AIR CONDITIONERS	3 hours				

[16] Minimum hours defined based on minimum consumer needs.

In addition to the tier compatibility criteria and the energy-efficiency measure, a set of quality criteria were developed to help determine product quality, such as service delivery and safety, and affordability for fans, refrigerator-freezers and air coolers. ACs were not included in this evaluation because they are considered a newer technology for the off-grid setting and are still relatively uncommon in off-grid areas. An A to D scale was used to rate the product for each measurement indicator. The ratings help users differentiate between products that fail (D), products that pass (C or B), and the best available products (A). International standards for each product category were used as well as existing lab-tested data to develop the requirements for each rating, seeking to create an even distribution across rating levels, ensuring that higher-rated products truly represent best available technologies that compare favourably with their on-grid counterparts.

Based on the analysis, off-grid fans and air coolers could be linked to a minimum Tier 1, refrigerators to a minimum Tier 2, and refrigerator-freezers and air conditioners to a minimum Tier 3. The tier level previously determined for fans' applicability was Tier 2. Currently available and low-energy consumption technologies for the off-grid market, such as fans and air coolers, could possibly be utilized with a solar energy system smaller than 50 W or 200 Wh, as defined in MTF Tier 1.

Compatibility of refrigerators with the MTF was determined according to whether the refrigerator could operate for at least 24 hours given the minimum daily energy in each MTF tier. Based on the analysis of refrigerators and refrigerator-freezer units for off-grid utilization, most of the appliances evaluated can be utilized in Tier 3. This is an improvement from Tier 4, which was previously considered as the minimum tier for refrigerators and freezers.

TABLE 7

Off-grid cooling appliances applied to MTF energy access tiers

		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
TIER CRITERIA			Task lighting and phone charging	Task lighting, phone charging, television and fan	Tier 2 and any medium-power appliance	Tier 3 and any high-power appliance	Tier 4 and very high-power appliance
PEAK CAPACITY	Power capacity ratings (in W or daily wh)		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
			Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 W
AVAILABILITY	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
FANS							
REFRIGERATORS							
REFRIGERATOR-FREEZERS							
AIR COOLERS							
ACS							

TABLE 8

MTF criteria applied to fans and attributes that programmes can choose as voluntary or mandatory based on their needs

	MEASUREMENT INDICATORS	INDICATOR DESCRIPTION	RATING A	RATING B	RATING C	NOT RECOMMENDED
MTF COMPATIBILITY	Tier compatibility	Product is compatible with which energy supply tier as defined in the World Bank's MTF[17]	Tier 1 and above			
	Daily hours of operation (hours)	Hours product can operate with the minimum daily energy for a given MTF tier	Min of 5 hours			
EFFICIENCY	Efficiency Index [(m³/min/W)/(EU MEPS Level)]	Ratio of air delivery relative to energy consumption, compared to EU MEPS	X > 2	1.5 < X ≤ 2	1 < X ≤ 1.5	X ≤ 1
SERVICE DELIVERY	Ceiling fans air delivery (m³/min)	Amount of air flow provided by fan at maximum speed	X > 200	150 < X ≤ 200	100 < X ≤ 150	X ≤ 100
	Table & pedestal fans air delivery (m³/min)		X > 30	20 < X ≤ 30	10 < X ≤ 20	X ≤ 10
SAFETY	Physical ingress protection	Rates the effectiveness of the sealing of electrical enclosures and fan blade guard against intrusion from foreign objects (e.g., fingers, tools, dirt)	Meets IP40	Meets IP30	Meets IP20	No protection
DURABILITY	Damage to the motor after drop test	Are there any dangerous failures to the motor after the drop test? (For table and pedestal fans only)	No			Yes
CONSUMER PROTECTION	Performance reporting[18]	Power consumption at max speed (W)	Reported			Not Reported
		Air delivery (m3/min)	Reported			Not Reported
	Truth-in-advertising	Rated power consumption is within a defined percentage of lab-tested values	X ≤ 5% below or above the tested value	5% < X ≤ 10% below or above the tested value	10% < X ≤ 20% below or above the tested value	X > 20% below or above the tested value
		Rated air delivery is within a defined percentage of lab-tested values	X ≤ 5% below or above the tested value	5% < X ≤ 10% below or above the tested value	10% < X ≤ 20% below or above the tested value	X > 20% below or above the tested value
	User manual evaluation	User manual included (yes/no)	Yes			No
		Includes instructions on product installation, use, and maintenance	Includes information on installation use and disposal	Includes information on installation and use	Includes information on installation	Not included
	Warranty (months)	Warranty duration	24+ months	12 months	6 months	No warranty
		Level of after-sales service provided	Product replacement	Virtual/in-person technician support	Spare parts available	Not provided
AFFORDABILITY	Fan cost (USD)	Fan cost [USD], based on a minimum order quantity of X	e.g., $45 (minimum order quantity (MOQ): 500)			

[17] Compatibility is determined based on whether the fan can operate for at least five hours given the minimum daily energy in each MTF tier and changes depending on fan capacity and electricity consumption.
[18] The metrics are included on consumer-facing information, such as product packaging, user manual, product nameplate, etc.

TABLE 9

MTF criteria applied to refrigerators and attributes that programmes can choose as voluntary or mandatory based on their needs

	MEASUREMENT INDICATORS	INDICATOR DESCRIPTION	RATING A	RATING B	RATING C	NOT RECOMMENDED
MTF COMPATIBILITY	Tier compatibility	Product is compatible with which energy supply tier as defined in the World Bank's MTF[19]	Tier 3 and above			
	Daily hours of operation (hours)	Hours product can operate with the minimum daily energy for a given MTF tier	Min 24			
EFFICIENCY	Efficiency - Energy Efficiency Index (EEI)[20]	Energy consumption relative to United for Efficiency recommended MEPS	X < 0.67	0.67 ≤ X <1	1 ≤ X ≤ 2	X > 2
SERVICE DELIVERY	Fresh food compartment temperature (°C)	Minimum temperature of fresh food compartment	X ≤ 4°C (for food storage)	4°C ≤ X ≤ 12°C (for beverage storage)		X > 12°C
	Freezer compartment temperature (°C)	Minimum freezer compartment temperature measured	-18°C ≤ X < -12°C	-12°C ≤ X < -6°C	-6°C ≤ X ≤ 0°C	X > 0°C
	Autonomy (hours)	Time that the product's compartment stayed within an 8-degree temperature rise (from 4°C to 12°C or 8°C to 16°C), with no external power supply	X ≥ 2 hours	1 hour ≤ X < 2 hours		X < 1 hour
	Pull-down time (hours)	Time required to lower the temperature of a refrigerator compartment from ambient temperature (32°C) to 4°C or 8°C	< 8 hours to reach 4°C	< 8 hours to reach 8°C		> 8 hours to reach 8°C
SAFETY	Safety evaluation	Product meets IEC 60335-1 (general requirements) and IEC 60335-2-24 (particular requirements for refrigerating appliances, ice-cream appliances and ice makers)[21]	Yes			No
ENVIRONMENTAL	Foam blowing agent	Does foam blowing agent comply with Montreal Protocol requirements?	Yes			No
	Refrigerants	Does the product use natural refrigerants?	Yes			No
	Presence of harmful chemicals	Are any of the following chemicals present in product: lead (except in batteries), mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated biphenyl ethers (PBDE)?	No			Yes
CONSUMER PROTECTION	Performance reporting[22]	Daily energy consumption (kWh/24h)	Reported and specifies conditions at which product was tested	Reported		Not Reported
		Voltage (V)	Reported			Not Reported
	User manual evaluation	User manual included (yes/no)	Yes			Not Reported
		Includes instructions on product installation, use, and maintenance	Includes information on installation, use, and disposal	Includes information on installation & use	Includes information on installation	Not included
	Warranty (months)	Warranty duration	36+ months	24 months	12 months	No warranty
		Level of after-sales service provided	Product replacement	Virtual/in-person technician support	Spare parts available	Not provided
Affordability	Refrigerator cost (USD)	Refrigerator cost [USD], based on a minimum order quantity of X	e.g., $500 (minimum order quantity (MOQ): 500)			

[19] Compatibility is determined based on whether the refrigerator can operate for at least 24 hours given the minimum daily energy in each MTF tier and changes depending on refrigerator capacity and electricity consumption.
[20] Product Annual kWh/ United for Efficiency MEPS Annual kWh.
[21] Manufacturers may provide a test certificate and/or test report showing that their product has been tested against the appropriate safety standards (IEC 60335-1 & 60335-2-24).
[22] The metrics are included on consumer-facing information, such as product packaging, user manual, product nameplate, etc.

TABLE 10

MTF criteria applied to air coolers and attributes that programmes can choose as voluntary or mandatory based on their needs

	MEASUREMENT INDICATORS	INDICATOR DESCRIPTION	RATING A	RATING B	RATING C	NOT RECOMMENDED
MTF COMPATIBILITY	Tier compatibility	Product is compatible with which energy supply tier as defined in the World Bank's MTF[23]	Tier 1 and above			
	Daily hours of operation (hours)	Hours product can operate with the minimum daily energy for a given MTF tier	Min of 5 hours			
EFFICIENCY	Efficiency Index [(m³/min/W)/(EU MEPS Level)]	Ratio of air delivery relative to energy consumption, compared to EU MEPS	$X > 2$	$1.5 < X \leq 2$	$1 < X \leq 1.5$	$X \leq 1$
SERVICE DELIVERY	Air delivery (m³/min)	Amount of air flow provided by fan at maximum speed	$X > 30$	$20 < X \leq 30$	$10 < X \leq 20$	$X \leq 10$
SAFETY	Physical ingress protection	Rates the effectiveness of the sealing of electrical enclosures and fan blade guard against intrusion from foreign objects (e.g., fingers, tools, dirt)	Meets IP40	Meets IP30	Meets IP20	No protection
	Water ingress protection	Rates the effectiveness of the sealing of electrical enclosures against water	Meets IP01			No protection
CONSUMER PROTECTION	Performance reporting[24]	Power consumption at max speed (W)	Reported			Not reported
		Air delivery (m3/min)	Reported			Not reported
	Truth-in-advertising	Rated power consumption is within a defined percentage of lab-tested values	X ≤ 5% below or above the tested value	5% < X ≤ 10% below or above the tested value	10% < X ≤ 20% below or above the tested value	X > 20% below or above the tested value
		Rated air delivery is within a defined percentage of lab-tested values	X ≤ 5% below or above the tested value	5% < X ≤ 10% below or above the tested value	10% < X ≤ 20% below or above the tested value	X > 20% below or above the tested value
	User manual evaluation	User manual included (yes/no)	Yes	Yes	Yes	Not included
		Includes instructions on product installation, use, and maintenance	Includes information on installation use and disposal	Includes information on installation and use	Includes information on installation	Not included
	Warranty (months)	Warranty duration	24+ months	12 months	6 months	No warranty
		Level of after-sales service provided	Product replacement	Virtual/in-person technician support	Spare parts available	Not provided
AFFORDABILITY	Air cooler cost (USD)	Air cooler cost [USD], based on a minimum order quantity of X	e.g., $100 (minimum order quantity (MOQ): 500)			

[23] Compatibility is determined based on whether the air cooler can operate for at least five hours given the minimum daily energy in each MTF tier and changes depending on air cooler capacity and electricity consumption.

[24] The metrics are included on consumer-facing information, such as product packaging, user manual, product nameplate, etc.

4

BEST PRACTICES AND LESSONS LEARNED FOR FINANCING PROGRAMMES

Given the nascency of the off-grid appliance market, financing programmes are an essential tool to help grow and strengthen the market. This type of solution can catalyze commercial activities through procurement or investment and help companies pilot and deploy new technologies or business models. Financing solutions can take on a variety of forms such as loans, grants, subsidies, or incentives, and be delivered through a variety of channels including financial institutions, venture capital firms, governments and development finance institutions.

In recent years, the off-grid sector has embraced results-based financing (RBF) as an innovative market development strategy to catalyze the uptake of sustainable solutions and overcome market barriers that hinder adoption of new technologies. RBF is a mechanism whereby a donor or agency disburses funds to a recipient contingent upon achieving a pre-agreed set of results and can target either actors from the supply side (e.g., appliance manufacturers and distributors) or the demand side (e.g., consumers). The three key principles underlying the RBF approach are:

1. **Payment is tied to achieved results**
2. **Recipients have the flexibility to choose how to achieve the results**
3. **Trigger for fund disbursement is independent verification of results.**

To understand the benefits, challenges and opportunities related to the value of quality criteria, financing programmes, development programmes and industrial manufacturers were surveyed.[25] Overall, the groups agreed that incorporating product quality criteria in financing programme design is an essential best practice for improving the overall state of the off-grid appliance market. Additionally, stakeholders shared that careful consideration must be given on how to integrate quality criteria into a programme to ensure effective use of limited funding. The following sections summarize the benefits, challenges and opportunities of incorporating product quality criteria into a programme's design, and recommendations on key considerations when designing a successful programme.

[25] The entities surveyed include: Amped Innovation, BGFA, Devidayal, Energy 4 Impact, Global Ice Tec AG, Greenlight Planet, IFC/WBG, Independent consultant, M-KOPA, Okra, Tamoor Fans, SNV, Super Star, (Bangladesh Fan). The survey included both gathering answers to questionnaires and conducting interviews.

BENEFITS

DEVELOPMENT PROGRAMME PERSPECTIVE

Donor-driven development programmes are typically supported by public funds and thus are tied to a government's development or energy access objectives. It is imperative to ensure that funding is used to maximize a programme's impact and that funders receive a high return in investment.

The development sector is aware of the essential role product quality plays driving growth in off- and weak grid markets. Promoting access to quality products increases consumer confidence, leading to increased and accelerated sales, enhanced affordability and expanded reach. One development programme representative noted that: "[quality criteria] help build credibility and confidence in this still very nascent sector across the various stages and stakeholders, including governments, private sector, regulators, donors and consumers." Quality criteria also promote consumer protection. One interviewee noted that: "when introducing people to new products to the off-grid market, it makes sense to have certain quality parameters, especially considering the high costs to consumers. If refrigerators are low quality, it will cause market spoilage."

INDUSTRY PERSPECTIVE

Manufacturers of high-efficiency, sustainable solutions are facing increasingly unfair competition because of the proliferation of cheaper, low-quality products in unregulated markets. Incorporating product quality criteria in financing programme specifications can protect programme investments with quality products and allows manufacturers to differentiate high-quality products.

Interviewees noted that quality considerations are especially important for products with longer lifetimes and higher costs, such as refrigerators. To improve their affordability, products are coupled with consumer financing such as pay-as-you-go (PAYGO) and more recently, Cooling as a Service (CaaS). PAYGO models require significant capital investment but can mitigate the risk of payment defaults by providing consumers with quality products that deliver more cooling services in the appliance lifetime. A Bangladesh fan manufacturer noted that their participation in the Global LEAP RBF programme encouraged them to increase investment in design, supply chain quality control and manufacturing to become "the number one trusted brand for fans in Bangladesh."

CHALLENGES

Discussions with stakeholders uncovered several challenges to integrating product quality criteria into financing programmes.

LACK OF STANDARDIZED QUALITY CRITERIA FOR OFF-GRID COOLING PRODUCTS

While standards for refrigerators, fans and evaporative air coolers are well defined through international bodies such as the International Electrotechnical Commission (IEC), these standards do not comprehensively evaluate cooling products intended for off-grid use. Alignment on quality and performance parameters will lower the barrier for manufacturers to participate in financing programmes. In some cases, companies chose not to participate in financing programmes because they viewed the quality criteria as poorly designed, not appropriate for their products, or too costly. As such, designing a quality criteria framework that is accepted by industry is key to facilitating the adoption of the framework at scale.

COST AND CAPACITY CONSIDERATIONS FOR MANUFACTURERS' PARTICIPATION

Product testing can be expensive and resource-intensive for manufacturers. Testing expenses include setting aside product samples, warehouse sampling, in-house verifications, shipping to third-party test labs, and test fees. Small companies that have limited funding may not be able to pay the testing fees required for extensive quality verification. The lack of local testing facilities for off-grid appliances can make testing even more time-consuming and expensive, which can create a dynamic where the majority of programme participants are large companies.

Many off-grid product manufacturers are faced with competing priorities beyond controlling and maintaining product quality, such as seeking financial investors, solving complex supply chain challenges, and vetting downstream partners and suppliers. Therefore, setting stringent and unrealistic product quality criteria to qualify for financing programmes may not yield the expected results. Manufacturers may opt to not participate when they compare the resource input needed to meet the criteria against their other business needs and resources. This may result in a negative secondary effect where companies that are ineligible to participate in programmes are discouraged from improving product quality.

OPPORTUNITIES

LEVERAGE INTERNATIONALLY RECOGNIZED TEST METHODS AND QUALITY CRITERIA

Financing programmes can scale up the use of off-grid cooling appliances. Incorporating test methods and quality criteria within programmes can ensure the delivery of high-quality products, consumer protection and accelerated market growth. For programme designers without technical expertise, it can be burdensome to set custom quality requirements and easier to align programme requirements with existing frameworks to ensure the effectiveness of the programme. In cases where test methods and quality frameworks do not exist for a given product, programme implementers should consult manufacturers and other technology experts for a basis to define product quality considerations that reflect the needs and maturity of the market.

Existing frameworks include VeraSol for solar energy kits, the Global LEAP Awards for off-grid TVs, fans, refrigerators, solar water pumps, and electric pressure cookers, SEforALL's forthcoming quality criteria for off-grid cooling appliances, and international standards (i.e., IEC). Consistency of test methods and quality criteria enable manufacturers to reduce costs by allowing them to design their products to meet one set of requirements.

UNDERSTAND THE LOCAL CONTEXT WHEN DESIGNING A PROGRAMME

Setting unrealistic or uninformed product quality criteria can prevent participation from companies that may benefit from such programmes. For example, requiring off-grid refrigerators to meet World Health Organization (WHO) standards for a programme whose goal is to scale the off-grid refrigerator market for household or productive use may not satisfy the end user's needs. Understanding the market characteristics and stakeholder context before designing a financing programme is key to avoiding these pitfalls. Consultations and dialogue can provide valuable information, and ensure inclusive, impactful and meaningful financing mechanisms and programme specifications are designed and implemented.

USE AN INDEPENDENT, THIRD-PARTY TESTING AND VERIFICATION PROCESS

Third-party, independent testing and verification may add costs, but the benefits outweigh the costs for both programmes and companies. The benefits include:

1. Consistent comparison of product quality data and/or performance
2. Strong reputation and competitive advantage for a product, service, or company
3. Improved reliability of products and evaluation results.

Incentivizing manufacturers to participate in third-party testing can help develop the off-grid cooling appliance market and provides a common platform where products from a range of different stakeholders are tested and verified in the same place, with the same equipment and under similar environmental conditions. It also ensures centralized, aligned and timely reporting to increase the efficiency of programmes, while providing neutral and unbiased data of the state of the off-grid appliance market. When programmes design the third-party testing and verification process, they should consider balancing the technical rigour and cost. For example, SNV Kenya partners with local testing facilities to keep the cost of testing and verification affordable. Efficiency for Access (EforA) is also piloting a new approach to allow for different testing and evaluation processes based on a product's relative market maturity level, the feasibility of conducting lab or field testing, and relative costs.

USE A CONSISTENT AND HARMONIZED APPROACH TO LOWER THE BARRIER FOR PARTICIPATION

Financing mechanisms and their requirements for product eligibility can vary depending on donors, implementers, technologies and the region of implementation. These variations in requirements can hinder companies' participation due to the high cost and time investment needed to meet each programme's unique specification requirements. Therefore, when possible, programmes

Photo: Asian Development Bank

targeting similar products in the same region should align quality requirements, verification, and the testing and administrative processes.

While a harmonized approach may lower the barrier for companies' participation, a transparent and flexible framework would allow for customization based on programme needs and priorities. In this case, the alignment between programmes can still be achieved by leveraging the same underlying technical specifications and using the same resources and tools to gather consistent information.

BUILD FLEXIBILITY INTO PROGRAMME DESIGN TO ALLOW FOR TECHNOLOGY ADVANCEMENTS

Many financing programmes are designed with a three- to five-year implementation timeframe yet the off-grid market is growing fast. It is important to ensure that quality criteria do not inhibit newer types of products and technologies from participating in such programmes.

Rolling eligibility, a competitive process that allows a financing programme to accept and evaluate products for inclusion into an eligibility list, continuously allows newer technology to be accepted. For example, the 2019–2020 Global LEAP results-based financing (RBF) programme allowed inclusion of solar water pump and refrigerator products evaluated after the completion of the 2019 Global LEAP Awards competitions. This approach enables flexibility for the manufacturers to continue to perform research and development (R&D) and for newer products to be included in the programme. This allows for market advancements and for programmes to expand their scope as the market evolves.

MONITORING & EVALUATION IS KEY TO ENSURING PRODUCTS PERFORM AS EXPECTED

Although lab testing is needed to provide comparable product performance and quality data, it does not necessarily account for how a product will perform when deployed with end users or in the long term. For example, harsh environmental conditions in many off-grid regions may lead some products to experience early failure that was not identified during lab testing. Similarly, manufacturers may not be providing the level of after-sales support or honouring the warranty that they had claimed during the evaluation process. Monitoring and evaluation (M&E) can therefore play an essential role in reducing risks for financing programmes and go one step further than the quality criteria to ensure that products still meet the criteria and deliver the same level of service to end users. M&E can be in the form of physical visits, mobile surveys or phone calls to gather feedback on experiences with the product.

REFERENCES

Ayaburi et al. "Measuring "Reasonably Reliable" Access to Electricity Services." The Electricity Journal, Vol. 33, Issue 7. September 2020, https://www.sciencedirect.com/science/article/abs/pii/S1040619020301202

Bhatia, Mikul, Nicolina Angelou, Elisa Portale et al. "Beyond Connections: Redefining Energy Access," World Bank Group, July 2015, https://openknowledge.worldbank.org/bitstream/handle/10986/24368/Beyond0connect0d000technical0report.pdf

Efficiency for Access (EforA), Off-grid appliance market survey, 2019, https://efficiencyforaccess.org/publications/2019-state-of-the-off-grid-appliance-market-report

Efficiency for Access (EforA), The State of the Off-Grid Appliance Market, 2019, https://storage.googleapis.com/e4a-website-assets/Clasp-SOGAM-Report-final.pdf

Efficiency for Access (EforA), 2021 Appliance Data Trend, January 2021, https://efficiencyforaccess.org/publications/2021-appliance-data-trends

Efficiency for Access (EforA), Phasing down HFCs in off- and weak grid refrigeration: an opportunity to reduce greenhouse gas emissions, February 2021, https://efficiencyforaccess.org/publications/phasing-down-hfcs-in-off-and-weak-grid-refrigeration-an-opportunity-to-reduce-greenhouse-gas-emissions

Efficiency for Access (EforA) and ENERGIA, The Role of Appliances in Achieving Gender Equality and Energy Access for All, April 2020, https://efficiencyforaccess.org/publications/the-role-of-appliances-in-achieving-gender-equality-and-energy-access-for-all

Engineers Without Borders USA, Chill Challenge, 2020, https://www.ewb-usa.org/chill-challenge/

GOGLA, Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data, 2019, GOGLA, https://www.gogla.org/sites/default/files/resource_docs/global_off_grid_solar_market_report_h1_2020.pdf

International Energy Agency (IEA), "The Future of Cooling," May 2018, https://www.iea.org/reports/the-future-of-cooling

International Energy Agency (IEA), United Nations Environment Programme (UNEP), Cooling Emissions and Policy Synthesis Report: Benefits of cooling efficiency and the Kigali Amendment, 2020, https://wedocs.unep.org/handle/20.500.11822/33094

Lai, Elisa, Stewart Muir and Yasemin Erboy Ruff, "Off-grid appliance performance testing: results and trends for early-stage market development," Energy Efficiency, Volume 13, 22 May 2019, https://storage.googleapis.com/clasp-siteattachments/Off-Grid-Appliance-Performance-Testing_Results-and-Trends.pdf

Rocky Mountain Institute (RMI), Global Cooling Prize Criteria, 2018, https://globalcoolingprize.org/prize-details/criteria/

Sustainable Energy for All (SEforALL), "Chilling Prospects: Tracking Access to Cooling for All, 2020", July 2020, https://www.seforall.org/chilling-prospects-2020/sustainable-cooling-solutions

United for Efficiency (U4E), Model Regulation Guidelines for refrigerating appliances U4E, 2019, https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficient-and-climate-friendly-refrigerating-appliances/

World Health Organization (WHO), Performance quality safety (PQS) catalogue, 20 April 2020, https://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/

ANNEXES

EXPLANATION OF RATINGS CRITERIA FOR OFF-GRID COOLING APPLIANCES

An A to D scale was used to rate the product for each measurement indicator. The ratings help users differentiate between products that fail (D), products that pass (C or B), and the best available products (A). International standards for each product category were used as well as existing lab-tested data to develop the requirements for each rating, seeking to create an even distribution across rating levels, ensuring that higher-rated products truly represent best available technologies that compare favourably with their on-grid counterparts.

EXPLANATIONS OF THE SPECIFIC RATINGS CRITERIA FOR REFRIGERATORS:

EFFICIENCY: These ratings are based on the UN Environment Programme's (UNEP) United for Efficiency Model Regulation for Refrigerators. The "A" rating corresponds to the Model Regulation's recommendation for high efficiency labelling, while the "B" rating corresponds to products that meet the Model Regulation's minimum energy efficiency performance standard (MEPS) recommendation but not the high efficiency labelling requirements. The "C" rating corresponds to products that fail to meet the Model Regulation's minimum efficiency requirements but use less than twice the maximum energy consumption under the Model Regulation, which is roughly equivalent to the MEPS for domestic refrigerators (both on- and off-grid) in Brazil and China.

TABLE A1
Refrigerator efficiency rating distribution

PRODUCT TYPE	A	B	C	D
REFRIGERATORS	32%	16%	42%	10%
REFRIGERATORS/ FREEZERS	0%	3%	18%	79%

SERVICE DELIVERY:
Fresh food compartment temperature: These ratings are based on potential use cases. The "A" rating corresponds to products that reach an internal temperature of at least 4°C, which is typically the minimum quality requirement for on-grid refrigerators. The "B" rating corresponds to products that reach an internal temperature between 4°C and 12°C, which is a common storage temperature of off-grid refrigerators and is suitable for cooling beverages. Products that failed to reach an internal temperature of 12°C were rated "D".

Freezer compartment temperature: These ratings are based on the freezer compartment star ratings for freezer temperatures found in the IEC 62552:2015 test method for refrigerators. "A" rated products are those with a freezer compartment that reaches an internal temperature of -12°C or below, corresponding to the minimum definition for two- and three-star freezer compartments. "B" rated products are those that reach an internal temperature of -6°C or below, corresponding to the definition for a one-star freezer compartment. "C" rated products are those that reach an internal temperature of 0°C or below, while those unable to reach temperatures below freezing are rated "D" as they cannot be considered freezers at all.

Autonomy: These ratings are based on the range of autonomies in off-grid refrigerators and refrigerator-freezers data. Of all tested refrigeration products, 15 percent took more than two hours for the internal temperature to increase by 8°C, corresponding to an "A" rating, 28 percent took one to two hours, corresponding to a "B" rating, and 56 percent took less than an hour, corresponding to a "D" rating.

Pull-down time: These ratings are based on the internal temperature that a product can reach in eight hours, which roughly corresponds to the typical hours of sunlight available to power these products in a single day. "A" rated products can reach an internal temperature of 4°C in eight hours, meaning they are able to store fresh food based on a single day's sunlight. "B" rated products can reach an internal temperature of 8°C in eight hours, while "D" rated products cannot reach 8°C in eight hours.

CONSUMER PROTECTION:

Performance reporting: These ratings are based on the reporting of the necessary data to evaluate a product's energy performance. Products reporting the daily energy consumption and the test conditions used for determining that consumption receive an "A" rating, as this allows for clear comparisons of product energy performance. Products reporting only the daily energy consumption receive a "B" rating. Those that do not report any consumption information receive a "D" rating.

User manual: These ratings are based on the information contained in the user manual, which can prove valuable for consumers to be able to install, use and dispose of their products properly, with installation being most critical. If the user manual includes information on installation, use and disposal, the product receives an "A" rating, while only including information on installation and use receives a "B" rating, and only including information on installation receives a "C" rating. If the product does not include a user manual, it is rated "D".

Warranty: These ratings are based on the warranty duration as well as the level of service provided. Longer warranties and better service guarantee that the consumer will be able to use the product for longer and receive the expected benefits from their investment. Warranties 36 months or over receive an "A" rating; warranties 24 months or over receive a "B" rating; and warranties 12 months or over receive a "C" rating. Relatedly, providing a full replacement of the product receives an "A" rating, as product failure in this situation implies little cost to the consumer, while virtual or in-person technician support receives a "B" rating, and providing spare parts receives a "C" rating. Products without warranties or without after-sales service receive "D" ratings.

TABLE A2

Fan efficiency rating distribution

PRODUCT TYPE	A	B	C	D
CEILING FANS	15%	42%	39%	4%
TABLE AND PEDESTAL FANS	69%	13%	15%	4%

EXPLANATIONS OF THE SPECIFIC RATINGS CRITERIA FOR FANS AND EVAPORATIVE AIR COOLERS:

EFFICIENCY: These ratings are based on the MEPS for fans in the EU, which are viewed as a benchmark for fan performance in several other countries. These criteria are also applied to the fans in evaporative air coolers. Products that are twice as efficient as the European MEPS level are rated "A" class; those that are at least 50 percent more efficient than the European MEPS are "B" class; those that meet the European MEPS are "C" class; and those that fail the European MEPS are "D" class.

TABLE A3

Fan service delivery rating distribution

PRODUCT TYPE	A	B	C	D
CEILING FANS	19%	42%	38%	0%
TABLE AND PEDESTAL FANS	59%	25%	10%	5%

SERVICE DELIVERY: These ratings are based on the range of airflow delivery observed in the data. For ceiling fans, airflow of over 200 m3/min is rated "A"; over 150 m3/min is rated "B"; over 100 m3/min is rated "C"; and under 100 m3/min is rated "D". For table and pedestal fans, airflow of over 30 m3/min is rated "A"; over 20 m3/min is rated "B"; over 10 m3/min is rated "C"; and under 10 m3/min is rated "D". Due to the similarity in fan size and design in evaporative air coolers and table and pedestal fans, the same ratings are applied to air coolers.

SAFETY:

Physical ingress protection: These ratings are based on the IEC 60529 standard for ingress protection. "A" rated products meet IP40, meaning they protect against ingress of anything larger than 1mm. "B" rated products meet IP30, meaning they protect against ingress of anything larger than 2.5 mm. "C" rated products meet IP20, meaning they protect against ingress of anything larger than 12.5 mm, while "D" rated products do not meet any standard level for ingress protection.

CONSUMER PROTECTION:

Truth-in-advertising: These ratings are based on the accuracy of the reported power consumption and air delivery as compared with the lab-tested values. "A" rated products report power consumption and air delivery within 5 percent of the lab-tested values, which is a greater level of accuracy than what is typically required for on-grid products. "B" rated products report power consumption and air delivery that deviates more than 5 percent, but less than or equal to 10 percent, which is a typical requirement for on-grid products. "C" rated products report power consumption and air delivery that deviates more than 10 percent, but less than or equal to 20 percent from the lab-tested values. "D" rated products report power consumption that deviates more than 20 percent from the lab-tested values.

User manual: These ratings are based on the information contained in the user manual, which can prove valuable for consumers to be able to install, use and dispose of their products properly, with installation being most critical. If the user manual includes information on installation, use and disposal, the product receives an "A" rating, while only including information on installation and use receives a "B" rating, and only including information on installation receives a "C" rating. If the product does not include a user manual, it is rated "D".

Warranty: These ratings are based on the warranty duration as well as the level of service provided. Longer warranties and better service guarantee that the consumer will be able to use the product for longer and receive the expected benefits from their investment. Warranties over 36 months receive an "A" rating; warranties over 24 months receive a "B" rating; and warranties over 12 months receive a "C" rating. Relatedly, providing a full replacement of the product receives an "A" rating, as product failure in this situation implies little cost to the consumer, while virtual or in-person technician support receives a "B" rating, and providing spare parts receives a "C" rating. Products without warranties or without after-sales service receive "D" ratings.

COPYRIGHT AND DISCLAIMER

Vienna (Headquarters)
Andromeda Tower, 15th Floor
Donau City Strasse 6
1220, Vienna, Austria
Telephone: +43 676 846 727 200

Washington, DC
1750 Pennsylvania Ave. NW
Washington, DC 20006 USA
Telephone: +1 202 390 0078

New York
420 5th Ave
New York, NY 10018 USA
Website: www.SEforALL.org

DISCLAIMER

This publication is a study prepared by GreenMax Capital Advisors (GreenMax) and commissioned by Sustainable Energy for All (SEforALL). The information contained in this report is based on stakeholder interviews, which took place between August 2020 and January 2021. All reasonable precautions have been taken by the authors of the report to verify this information; however, they do not guarantee its accuracy or completeness, as it may be subject to change without notice. This publication has been prepared as a general guidance and the findings and recommendations do not necessarily reflect the views of SEforALL.

SUSTAINABLE ENERGY FOR ALL

clasp