VeraSol

RAPID PRODUCT ASSESSMENT: A NEW APPROACH TO TESTING PRODUCTIVE USE APPLIANCES

RAPID PRODUCT ASSESSMENT FEBRUARY 2022

AUTHORS

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The report is funded by UKaid, the IKEA Foundation, the Rockefeller Foundation, and the Good Energies Foundation through the Efficiency for Access Coalition. The views expressed do not necessarily reflect the official policies of Government of the United Kingdom or the funders of this project.

PARTNER ORGANIZATIONS

TABLE OF CONTENTS

Background

THE RAPID PRODUCT ASSESSMENT APPROACH IS DESIGNED AS A FLEXIBLE FRAMEWORK THAT CAN BE ADAPTED TO VARIOUS PRODUCTIVE USE APPLIANCES.

WHY RAPID PRODUCT ASSESSMENT FOR PRODUCTIVE USE APPLIANCES

High quality, energy-efficient productive use equipment (PUE) has the potential to accelerate the deployment of distributed renewable energy solutions, unlock mini-grid development and improve utility health in rural and underserved communities in sub-Saharan Africa (SSA). Despite this potential, off-grid solar (OGS) companies, mini-grid developers, utilities, and other appliance retailers struggle to identify and deploy PUE in rural and underserved communities.

VeraSol[1] tests off-grid appropriate appliances and productive use equipment to generate consistent and comparable performance data that fill critical information gaps and inspire market competition. These services make it possible for market actors to identify good-quality products, de-risk investment and purchasing decisions, support healthy market growth, avoid market spoilage, and protect consumers. While product-specific test methods and laboratory testing is the recommended best practice to verify the quality of off-grid solar products, this testing process can be time and resource intensive.

As new types of PUE emerge in the off-grid market, there is a need to develop a more direct and affordable pathway to verify the quality of nascent PUE technologies that have an unclear commercial path and/or may not be sold in large volumes. Given low market penetration and nascency of these technologies, generally test method do not exist for these products. The Rapid Product Assessment is a first step to enable a consistent way of evaluating product quality and performance and generate data to inform product design. This approach would also enable buyers and investors to gauge and compare a product's quality based on a preliminary assessment of performance with reduced time and cost investments.

The Rapid Product Assessment approach is designed as a flexible framework that can be adapted to various PUE, such as egg incubators, solar dryers, agro-processing machines, cold chain coolers, and others. The development of test method for any specific product type is based off closest available test methods, e.g. similar technologies deployed in large-scale commercial markets, with some modifications to simply and make test methods more relevant for emerging markets.

KEY ELEMENTS OF RAPID PRODUCT ASSESSMENT

The Rapid Product Assessment is characterized by the following key elements:

Flexible product sampling: Companies that request testing are responsible for providing and shipping at least one product sample (ideally two samples, with one on standby) to the testing partner. There is no minimum stock quantity required for sampling as PUE technologies are often manufactured in small batches.

A network of local testing facilities: Rapid product testing is conducted by local testing partners operating in environments similar to where the products are likely to be used. The tests are performed in less controlled conditions, for example, testing a product using a solar module under a typical solar day instead of using a solar simulator that provides specific voltage and current input. While some testing conditions are uncontrolled (e.g., ambient temperatures), they are more likely to be representative of how a product would be used by end consumers. By partnering with testing facilities in key off-grid markets, the approach also contributes to building local testing capacity and technical expertise for PUE technologies.

Focused testing on essential parameters: The testing aims to evaluate the most essential aspects of product functionality, performance, safety, and usability. Testing will validate if the product:

- Can operate properly (functionality)
- How easy it is for end-user to install and operate the product (usability)
- Can deliver energy services as claimed by manufacturers (performance)
- Is it safe for end-consumers (safety)

Product data-sharing: The test data will be published on the VeraSol Product Database[2] to enable data transparency and help market actors compare product quality.

PRODUCT TYPES THAT CAN BE TESTED THROUGH RAPID PRODUCT ASSESSMENT

Rapid Product Assessment applies to a wide variety of solar-compatible PUE that are not covered within the VeraSol scope.[3] PUE applications are grouped into five main categories as indicated in Table 1.

TABLE 1: PRODUCT CATEGORIES ELIGIBLE FOR RAPID PRODUCT ASSESSMENT

CATEGORIES	SUB-CATEGORIES	PRODUCT EXAMPLES
Motor-driven equipment	Large motor-driven equipment (motor size range 700-1500 Watts[4] (W))	Commercial mixer/grinder, mills, grain hullers, rice polishers, chaff cutter, milking machines, etc.
	Medium motor-driven equipment (motor size range 300-700W[5])	
	Small motor-drive equipment (motor size range 20-300W[6])	Ropemakers, sewing machines, juicers, clippers, etc.
Agricultural heating & drying	N/A	Food dryers, egg incubators, etc.
Cooling equipment	N/A	Cold storage, ice makers, etc.
ICT	N/A	Modems, computers, tablets, etc.
Power conversion and supply	N/A	Uninterruptible power supply, inverters, rectifiers, etc.

Rapid Product Assessment: Egg Incubator Beta Testing

WHILE EGG INCUBATORS ARE STILL A NASCENT TECHNOLOGY,THEIR ESTIMATED ADDRESSABLE MARKET CAN REACH MORE THAN 1 MILLION UNITS BY 2033.

WHY EGG INCUBATORS

Among various types of PUEs, egg incubators were selected as the first product to trial for the Rapid Product Assessment approach, due to increased demand in the market[7] and their potential to significantly increase the productivity of poultry farmers and rural households.

Poultry farming is common for rural households in Africa, especially amongst women and children, as it helps sustain food self-sufficiency. In Cameroon, for example, traditional poultry farming accounts for more than 70% of farming activities. Still, an average of 43% of newly hatched chicks do not survive, causing a significant loss of food sources and money.[8]

Egg incubators offer a solution to this problem by creating the optimal conditions and stable environment for eggs to incubate and hatch, enabling farmers to increase the success rate of hatching chicks.

While egg incubators are still a nascent technology, it is estimated that the addressable market for egg incubators in six Sub-Saharan African markets – Tanzania, Zimbabwe, Zambia, Rwanda, Malawi, and Mozambique – can reach more than 1 million units, totalling a market value of 117 million USD by 2033.[9]

To validate the testing approach and understand the performance of egg incubators, we conducted beta testing. Beta testing is a trial and experimental process that helps validate whether a draft testing procedure is practical and can yield meaningful test results. The beta testing process and results can help inform certain testing decisions, uncover any bugs or issues, and identify areas for improvements before releasing a test procedure to a wider audience.

Box 1. How do egg incubators work?

An egg incubator is a machine that creates the optimal conditions and stable environment for an egg to incubate and hatch. Temperature and humidity are critical factors for successfully hatching eggs.

Over the hatching period, the temperature and humidity levels need to be adjusted based on the development stages of embryos. An egg incubator typically has a temperature and humidity control unit and display (showing the temperature and humidity). Other features, such as a small fan (to improve air circulation), an automatic egg turner, and a hatcher can increase the hatching success rate.

FIGURE 1: AN EGG INCUBATOR TEST SAMPLE

THE BETA TESTING PROCESS

The test sample for beta testing was procured from an agricultural and livestock equipment distributor in Kenya. Kijani Testing – based in Kisumu, Kenya – was selected to be the testing partner through a competitive selection process.

The beta testing took place in two stages. The first stage was a controlled test conducted at Kijani's test lab to monitor energy consumption, temperature, and humidity. The second stage involved collecting end-user feedback and was conducted at an end-user's residence.

Controlled Testing: For controlled testing, the test protocol was designed to mimic the temperature and humidity required for hatching, but with a shortened testing duration of 10 days. A typical hatching cycle is about 21 days.

- *Pre-incubation period (~3 days)*: We followed the product's user manual to set up the egg incubator and visually inspect the machine. We prepared eggs for testing by marking an "x" on one side of the eggs, enabling us to observe the rotation of eggs during the incubation period. After the eggs were marked, we tested how the machine would operate at different levels of capacity by placing varying numbers of eggs in the incubator and checking if the eggs can rotate smoothly.
- *Incubation period (~5 days)*: During this period, the temperature was set constant at 37.5°C and 50% relative humidity (RH), which are optimal conditions for embryos to develop according to the test protocol and existing literature of egg hatching. The eggs required turning, either manually or by using the automatic egg turner, two to three times a day to prevent the developing chick from sticking to the shell. Turning the eggs also ensures that the eggshell surface temperatures are consistent.
- *Lock-down period (~2 days)*: During this period, we maintained the same temperature at 37.5°C but increased the RH to 65%. We laid the eggs horizontally to help the chicks get into a hatching position.

Field Testing: The egg incubator and a solar energy kit were installed at the home of a rural poultry framer in Alendu, Kisumu. Remote monitors were also installed on the egg incubator to track energy consumption, temperature, and humidity in real-time.

TEST PARAMETERS AND EQUIPMENT NEEDS

Generally speaking, a parameter is any characteristic that can help define or classify a particular system. For egg incubators, temperature and humidity are critical factors for successfully hatching eggs. However, there are other parameters that we tested to assess the egg incubator quality.

Table 2 highlights the key parameters measured during controlled testing and the equipment used to record data.

TABLE 2: KEY PARAMETERS MEASURED DURING CONTROLLED TESTING AND THE EQUIPMENT USED TO RECORD DATA

PARAMETERS	METRICS	EQUIPMENT
Product information	User manual and warranty documents	Camera, visual inspection
	Supplier communication, training & contacts	Mobile phones
Product packaging	Type of packaging, quality of packaging, contents inside the package	Camera, visual inspection
Safety	Evaluate external safety deficiencies (e.g., exposed moving parts, sharp edges, deformed metal, etc.)	n/a (visual/quality inspection)
	Electrical protection (e.g., shock hazard, miswiring protection, fail-safe features, etc.)	Multimeter
Functionality	On/off switches, connectors, and ports functionality. The product set up requirements	Depending on what is provided by the supplier. PV panels, solar batteries, charge controller, extension cables, visual inspection.
	PAY-G functionality	Activation token from supplier
Performance **(energy performance)**	Total energy consumption per given time period (Wh)	Voltage and current sensors or power meter. Watch/clock
	Capacity (number of eggs)	n/a (visual/quality inspection)
Performance **(service delivery)**	Temperature maintenance (°C – °C)	Data logger with temperature sensors or handheld thermometer (+/- 0.1F/0.05^{C} accuracy)
	Humidity control (%)	Hygrometer (+/-5% RH accuracy)
Performance **(environmental condition)**	Solar irradiance (W/m^2)	Pyranometer / Solar irradiance meter (+/- 1 W/m^2 accuracy)

RESULTS FROM LABORATORY AND FIELD TESTING

Laboratory tests focus on generating consistent product performance and functionality, while field testing focuses on how the customer interacts with the product. While a product could be very efficient in the laboratory setting, if the customer is unable to set it up or run it correctly, the test results may be inaccurate or even completely negated. Field testing is very useful in determining the usefulness of the user manual and training materials and identifying any design flaws.

Box 2. Rated technical specifications of the egg incubator used for beta testing

Capacity: 64 eggs

Power Type: AC/DC

Power Input: 80 W

Voltage Range: 220-240Vac / 12Vdc

Frequency: 50/60HZ

Recommended Solar Panel Capacity: 300Wp

Recommended Battery Capacity: 200 Ah

Features: Automatic Control of turning, ventilation, humidity, temperature, alarms, etc.

For this particularly sample, the incubator is advertised to be able to run on both AC and DC power supplies. Most appliances with these two options typically run on AC power and have a small rectifier connected to the DC input port to convert the DC power to AC. We tested both options over four weeks. The controlled testing was conducted in a laboratory on both DC and AC power modes for two weeks, and field testing was conducted by a user at their household using the DC power mode for another two weeks.

The section below highlights the egg incubator testing parameters and key results from laboratory and field testing.

PRODUCT INFORMATION

What the protocols measure

The focus of the product information evaluation is to evaluate how key information is communicated to users. The testing is done by reviewing user manuals, installation manuals and verbal or virtual training. The evaluation is based on the following parameters.

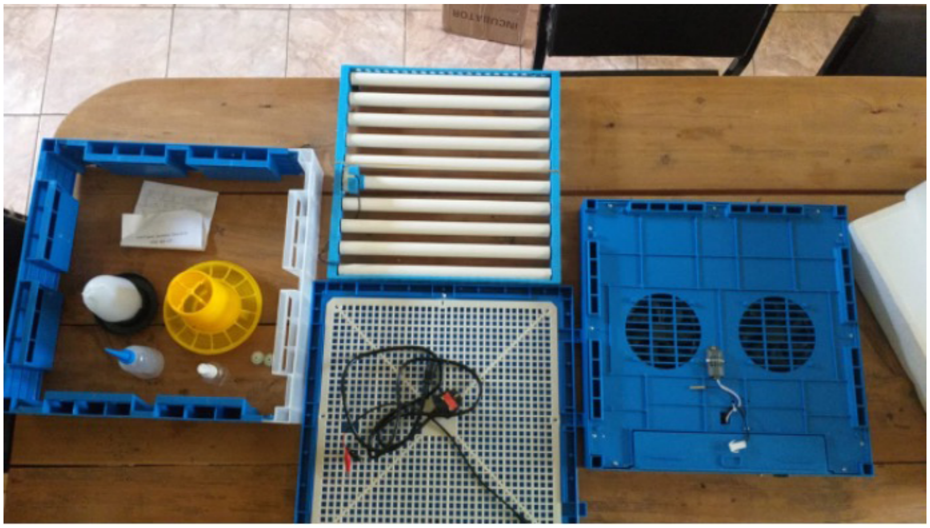
- **Content of the manuals**: Do the consumer-facing materials, such as the user or installation manuals, make it easy for customers to set up the products? They should also include a phone number in case the customer needs technical support.
- **Online training vs physical training**: Depending on the location of the supplier and the end-users, are there options for virtual or in-person training?
- **Required accessories**: Are all the required accessories provided by the supplier in the package or do customers need to acquire them independently? In the case where the supplier offers the option to acquire some accessories independently, what issue might arise from this, or what are the advantages of using this option?

Beta testing results

For the egg incubator we beta tested, the product information was provided via a user manual and phone training conducted by a poultry expert via the distributor. While the phone training was useful and enabled the laboratory to ask questions, some information that was conveyed during the phone training did not match what was included in the user manual. For instance, some instructions provided by the poultry expert differed slightly from what was specified by the manufacturer in the user manual. This highlights the need for product distributors and manufacturers to align the instructions provided to end-users.

The accessories included in the package made it easy for the end-user to set up the egg incubator and rear the chicks. The components included with the egg incubator included feeding troughs, a water bottle (to adjust humidity) and power cables (Figure 2).

FIGURE 2: INCUBATOR AND ACCESSORIES



CAPACITY TEST

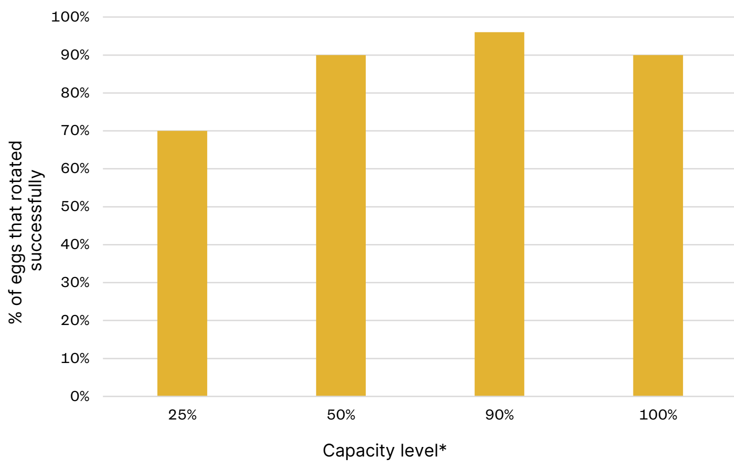
What the protocols measure

Capacity is important because it indicates the maximum yield that the product can deliver. This rating also allows consumers to assess which product would meet their needs based on the desired number of eggs they want to hatch. The capacity test verifies the actual egg capacity of the incubator in comparison with the rated capacity by the manufacturer. It also informs the optimal number of eggs that can be placed in the incubator to allow for all eggs to rotate during the turning process without sustaining any damage. The process involves marking eggs on one side and putting them in the incubator. The egg turning process is then activated either manually or automatically. The egg turning intervals was set at every 4 hours, with each rotation set to be 180^0. After each turning cycle, we examine how many eggs rotate successfully (i.e., achieving a 180^0 turn). The process is repeated for different capacity levels (25%, 50%, 90% and 100% of advertised capacity) to observe the optimal capacity level for egg turning.

Beta testing results

The tested egg incubator was advertised to have a capacity of 64 eggs. The testing results indicated that when the incubator was at full capacity, the eggs were very tightly packed, which resulted in 10% of eggs not being able to rotate fully as shown in Figure 4. In addition, the eggs rubbed against each other during the egg turning process, which could potentially lead to breaking. Further testing showed that too few eggs in the incubator (25% capacity) would cause eggs to roll around during the turning process, which could also increase the risk of breaking or not rotating properly. We found that the optimal egg capacity was between 70% to 90% of the advertised value for this incubator.

FIGURE 3: PERCENTAGE OF EGGS THAT TURNED AT VARIOUS CAPACITY LEVELS



*100% capacity is determined based on the maximum number off eggs that can fit inside the incubator based on manufacturer's advertised value.

HUMIDITY

What the test protocols measure

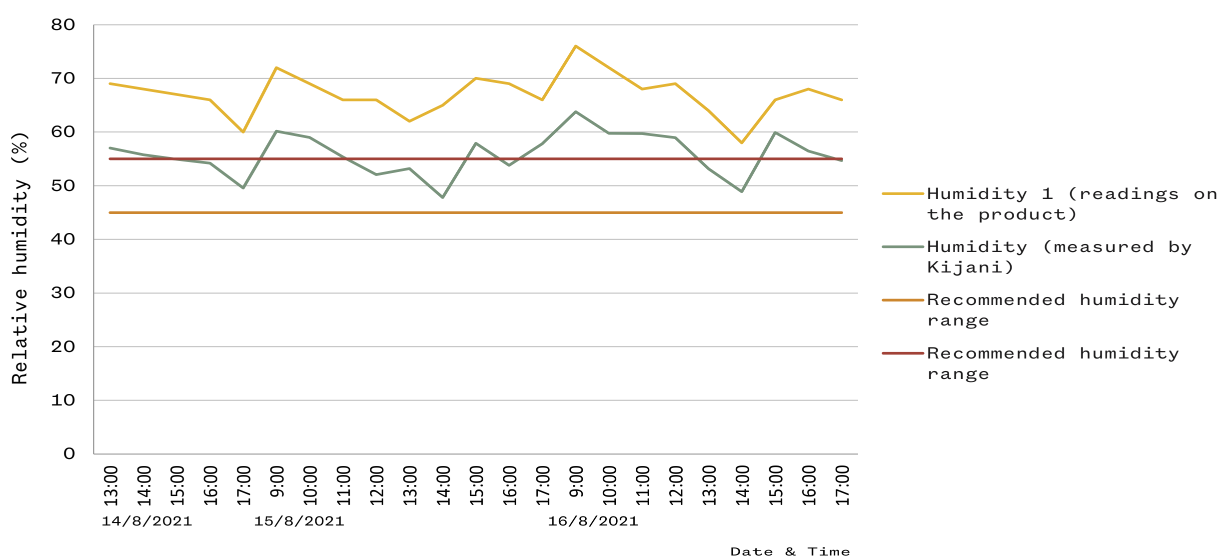
There are two recommended humidity settings specified in the test protocol based on the humidity level needed for different embryo development stages. As shown in Table 3, during the incubation period, days 1-17, the recommended humidity is 45% to 50%. During the lockdown period, days 18-23, the recommended humidity is 65% to 70%. The increased humidity before hatching keeps the membrane of the eggs moist and soft so that chicks can break out of the shell. In other words, if the humidity is not properly controlled and monitored, it could increase the fatality of chicks even if the embryos are fully formed because they would not be able to break out of their shell.

TABLE 3: HUMIDITY AND TEMPERATURE SPECIFICATIONS FOR INCUBATION AND LOCKDOWN PERIODS

	DAY 1-17 (INCUBATION PERIOD)	DAY 18-21 (LOCK-DOWN PERIOD)
Egg turning	2-3 times/day	No turning (lay eggs horizontally for hatching position)
Optimal Temperature (°F/°C)	99.5°F (37.5°C)	
Acceptable Temperature Range (°F/°C)	99-100°F (37.2-37.8°C) (with forced air incubator) 100-101°F (37.8-38.3°C) (with still air incubator)	
Relative Humidity (RH%)	45-50%	65%-70%
Additional notes	Keep water channels in the incubator full to facilitate proper humidity	Increase ventilation as embryos grow bigger, especially from days 18-21.

Beta testing results
Some incubators come with a manual setting to change the humidity, and some are equipped with sensors to increase or decrease humidity automatically. With the incubator used for beta testing, a user can input the desired humidity level using a display panel. The display also showed the actual humidity over the desired humidity. If the humidity went below or above the desired humidity by ±5%, an alarm would go off, signalling the user to manually add water (to increase humidity) or to open a hatch at the top of the incubator (to decrease humidity). Because the adjustment to humidity levels had to be conducted manually by a user, in both lab and field testing, the humidity was quite erratic and needed constant monitoring. During the 3 days of humidity measurement, 38% of the recordings were 10% over the recommended humidity range, between 45 and 55% (Figure 4).

FIGURE 4: HUMIDITY READINGS AND MEASUREMENTS DURING THE INCUBATING PERIOD



EGG SURFACE & AIR TEMPERATURE

What the protocols measure

In an ideal scenario, the temperature set on the incubator should be the same as all egg surfaces and air within the incubator. However, there is generally some variance between the air and egg surface temperatures. Depending on the placement of the heating mechanism used by the incubator, the eggs closest to the heat source could be slightly warmer than the eggs farthest from the heat source. If the incubator is equipped with a fan, the eggs closest to the fan will generally be slightly cooler than the rest of the eggs. The inconsistency of the temperatures could delay the development of embryos, causing a delay in hatching or unhealthy chicks.

To make this testing replicable in the future, anticipating that filling the incubator with real fertilized eggs is not sustainable in the long run, we tested both ceramic and fertilised eggs during controlled testing. This was to compare the surface temperatures and check if ceramic eggs can be used in place of fertilised eggs during Rapid Product Assessment. The focus of this aspect of the test is to deliver repeatable and consistent data on the product's temperature performance instead of hatching rate. Hatching rate - the number of eggs that can hatch successfully, was monitored during field testing.

The temperature as displayed or automatically set in the incubator indicates the air temperature inside the incubator. Checking the egg surface temperature will show how evenly distributed the air temperature is inside the incubator and if the incubator's temperature sensors are accurate.

Beta testing results

For this testing, the eggs were laid out in the incubator as illustrated in Figure 5. The temperatures of the eggs measured in each location are shown in Table 4 below.

FIGURE 5: LAYOUT OF EGGS THAT TEMPERATURE MEASUREMENTS WERE TAKEN FROM

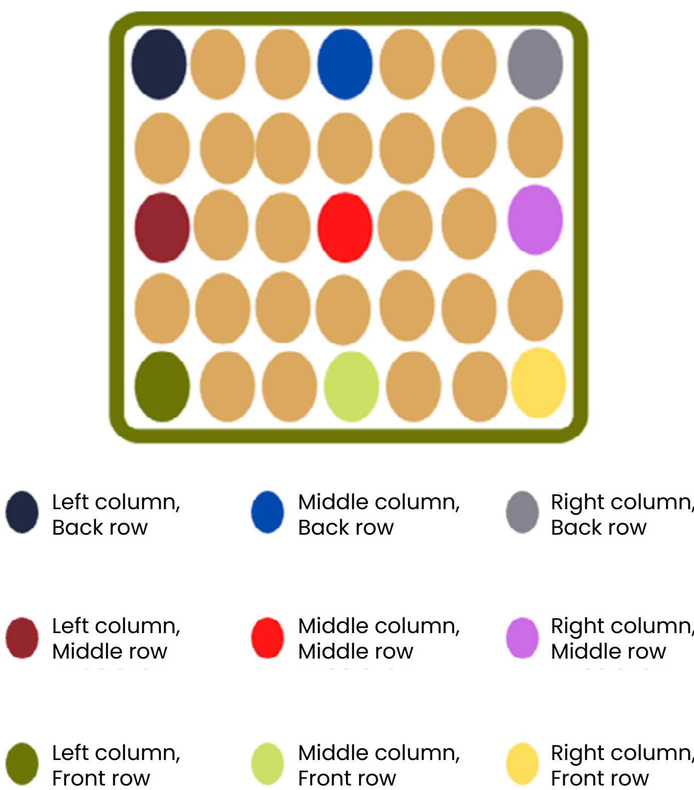


TABLE 4: TEMPERATURE MEASUREMENTS OF EGGS IN VARIOUS LOCATIONS INSIDE THE EGG INCUBATOR

Measurement (°C)	**Left column, Back row**	**Left column, Middle row**	**Left column, Front row**	**Middle column, Back row**	**Middle column, Back row**	**Middle column, Middle row**
Egg Type	Fertilized eggs	Fertilized eggs	Fertilized eggs	Fertilized eggs	Ceramic eggs	Fertilized eggs
1	37	37	36.8	37.4	36.7	37.4
2	37.5	37.3	36.3	36.8	36.6	36
3	37.4	37.5	36.8	37.7	37.7	36.4
4	37.5	37.5	37	37.1	36.9	36
5	35.4	36.6	35.5	37.9	38	36.9
6	37.1	37.3	37.2	37.9	38	36.9
Average	37.0	37.2	36.6	37.5	37.3	36.6
Max-Min	2.1	0.9	1.7	1.1	1.4	1.4

Measurement (°C)	**Middle column, Middle row**	**Middle column, Front row**	**Middle column, Front row**	**Right column, Front row**	**Right column, Middle row**	**Right column, Back row**
Egg Type	Ceramic eggs	Fertilized eggs	Ceramic eggs	Ceramic eggs	Ceramic eggs	Ceramic eggs
1	36.5	36.7	36.4	36.8	36.9	36.9
2	36.1	36.3	35.8	35	36.7	36.5
3	36.9	37.1	36.7	36.6	37.4	37.4
4	35.9	36.2	36	36	37	37.2
5	36.8	36.7	36.6	36.4	36.3	35.1
6	36	36.7	36.6	36	37.4	37.4
Average	36.4	36.6	36.4	36.1	37	36.8
Max-Min	1	0.9	0.9	1.8	1.1	2.3

Based on the test results, we noted that:

- The difference between the ceramic and fertilised egg surface temperatures is minimal, within +/-0.25°C. This leads us to believe that ceramic eggs can be used in place of the fertilised eggs for controlled testing.
- Temperatures of both the ceramic and fertilised eggs in the back row were generally higher, with as high as 37.9 °C and 38°C for fertilised and ceramic eggs respectively.
- The eggs at the front part of the incubator had lower temperatures, with the lowest measurement being 35.5°C.

The recommended temperature for incubating is 37.5°C. While the average egg temperature measured in each location did not deviate significantly from the recommended temperature, there were several cold spots measured around 35°C, which is the minimum temperature required for embryo development. The hatching results during beta testing showed that some of the embryos were not fully formed because of the temperature and humidity inconsistency. Eggs in both cool and hot zones hatched and some from both zones did not. We noted that the eggs in the cold zones that did not successfully hatch were not fully formed and the ones in the hot zones that did not successfully hatch were fully formed but died in the shell.

POWER & ENERGY CONSUMPTION MEASUREMENT

What the protocols measure

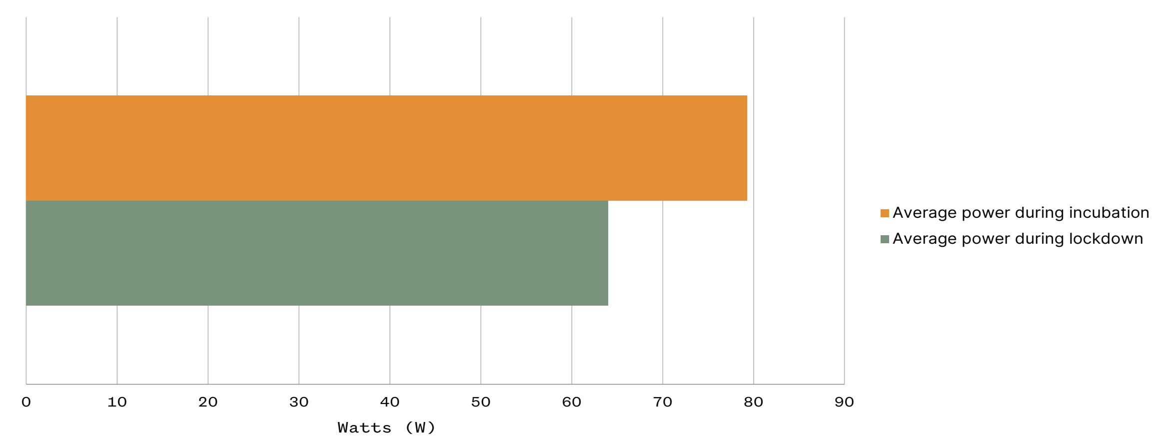
The power and energy consumption tests measure the maximum power and daily energy consumption of the egg incubator to verify how accurate the manufacturer-rated power and energy consumption is. This figure is useful to estimate the size of the solar energy system needed or the potential energy cost for end-users connected to the grid.

Beta testing results

During the incubation phase using a typical solar day, the average power consumption was 628Wh per day (over 8 hours). During the incubating phase, the automatic egg roller is active and so power consumption spikes can be observed when the motor and fan kick on. The maximum power measured during this phase was 100W.

Power consumption during lockdown days is generally lower since the egg roller function is turned off. During the lockdown period, the average power was 64 Watts (W) and daily energy consumption was 542.4 Watt hours (Wh) over 8 hours, which is 13% lower when compared to the incubation phase (Figure 6).

FIGURE 6: AVERAGE POWER CONSUMPTION DURING INCUBATION VS DURING LOCKDOWN



There was also a slight variance in energy consumption between AC and DC modes during the incubation phase. When running on AC power, the egg incubator's average power consumption was 70W compared to 85W in DC mode. This is likely due to power conversion losses from the inbuilt rectifier converting DC to AC power.

SOLAR IRRADIANCE & BATTERY CHARGING

What the protocols measure

This test verifies if the battery supplied is suitably sized to power the product when the weather is overcast or there is no sun. Some incubators will stop providing the optimal conditions for eggs to hatch when not powered for more than an hour. Therefore, it's important that the batteries can power the incubator through the night and in low solar irradiance (rainy or cloudy) conditions.

Beta testing results

The battery was fully charged before the test. The incubator was then powered by the battery alone to observe how long it takes to fully discharge the battery. This incubator had a 200 Amp hour (Ah) lead-acid battery, which took a little over 25 hours to drain (Table 5). This means the solar system can adequately support the operation of the egg incubator over one day of low sunlight. If the battery had drained in less than 12 hours, it would mean the battery is undersized and might not be able to power the incubator throughout the night.

On a typical sunny day, the average charging current was 13.1 Amps (A), which is more than double the current drawn by the incubator. This means the battery sizing is suitable for the current draw of the egg incubator. Figure 8 below shows currents during solar charging at various solar irradiance conditions.

We also evaluated the battery performance during low solar irradiance conditions (<400W/m^2). During low light conditions, the charging current was 4.7A, while the current drawn by the incubator was an average of 6.5A (Table 5). This indicates that the battery is being drained faster than charging and the 200Ah battery will be fully drained after 98 hours. If the incubator is used in an environment where the irradiance is lower than 400W/m^2, the battery is expected to last an average of 4 days. If the end-user is living in a mostly cloudy climate and would like to get more working days, they would need to add solar panels and batteries to the set-up.

FIGURE 7: SOLAR CHARGING CURRENT VS SOLAR IRRADIANCE

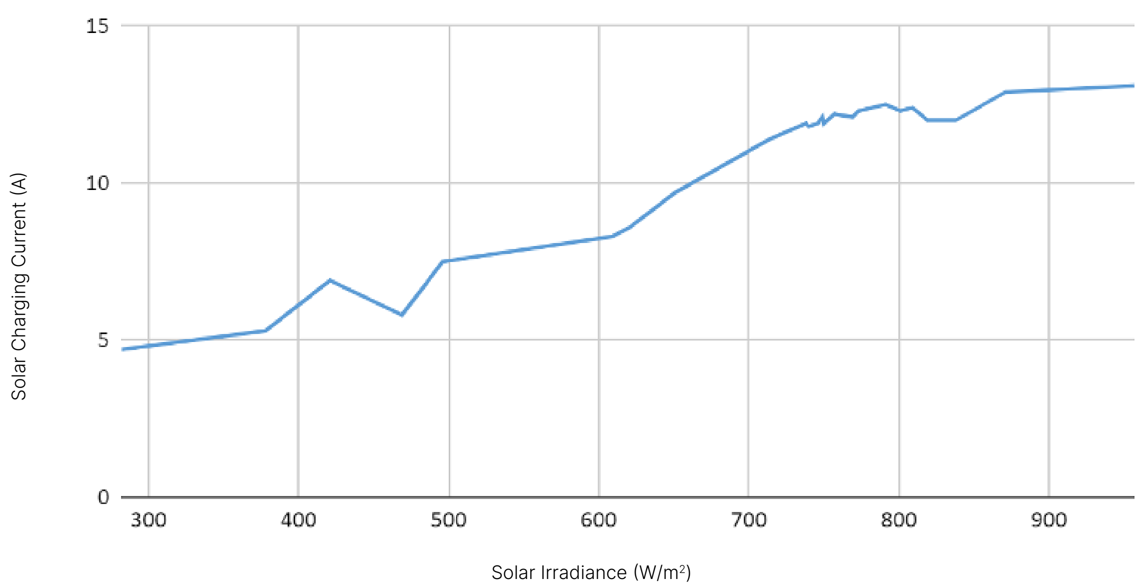


TABLE 5: BATTERY CHARGING TEST RESULTS

Battery depth of discharge (DoD)	80%
Battery capacity (amp hour)	200Ah
Average current of load in 1 hour (amp)	6.32A
Amount of time taken to drain the battery from a full charge (hours)	25.28 hours
Average charging current in low light conditions (amp)	4.7A
Charging current deficit (amp)	-1.62A (4.7A-6.32A)
Amount of time taken to drain the battery in low light conditions (hours)	98.76 hours

Lessons Learned & Next Steps

LESSONS LEARNED

Adequate user manuals and training will be key to increasing the customer base. Given many of the off-grid consumers are first-time users of PUE products, providing sufficient instructions on installation, setup, and use of the product is key to ensuring end-users successful adoption of these new PUE technologies. Poorly designed or written manuals can lead to frustrating experiences where there are poor installations and even injury to the end-user.

Training materials are also often delivered through the user manual. For egg incubators, distributors typically offer virtual training online or through a phone call to help users set up the product. Some distributors even provide guidance on other aspects for egg health and chick-rearing, such as vaccination, nutrition, chicken food, etc.

While designing the user manual and training materials, it is useful to think about the target audience. End users might benefit from simple manuals with descriptive pictures, while supplier technicians might prefer more technical manuals detailing the product's working principles.

Automatic features effectively reduce the risk of user errors and increase successful hatching rates. There are manual, semi-automatic and fully automatic egg incubators, depending on how many of the operations are designed to be done manually by a user. A manual egg incubator may require a user to set the temperature/humidity parameters manually and a user to rotate the eggs or operate a mechanical egg roller. A fully automatic incubator will regulate the temperature/humidity with no need for user intervention and be fitted with an automatic egg turner.

The incubator model used for beta testing was fitted with alarms and LED signals that sound off or change colour once a parameter is outside the acceptable range. While the desired temperature and humidity can be set using a digital panel, a user must manually open and close the incubator to adjust the humidity and temperature, meaning someone needs to be on standby to monitor the egg incubator and make manual adjustments regularly. During field testing, the end-user noted that the operation of this incubator model is tedious.

Given that both temperature and humidity are the most critical aspects to successful hatching, requiring users to adjust these elements manually could lead to user mistakes and inconsistencies in temperature/humidity, thus reducing the hatching rate. The advantages and disadvantages of different egg incubator features are outlined in Table 6 below.

TABLE 6: ADVANTAGE AND DISADVANTAGES OF DIFFERENT EGG INCUBATOR FEATURES

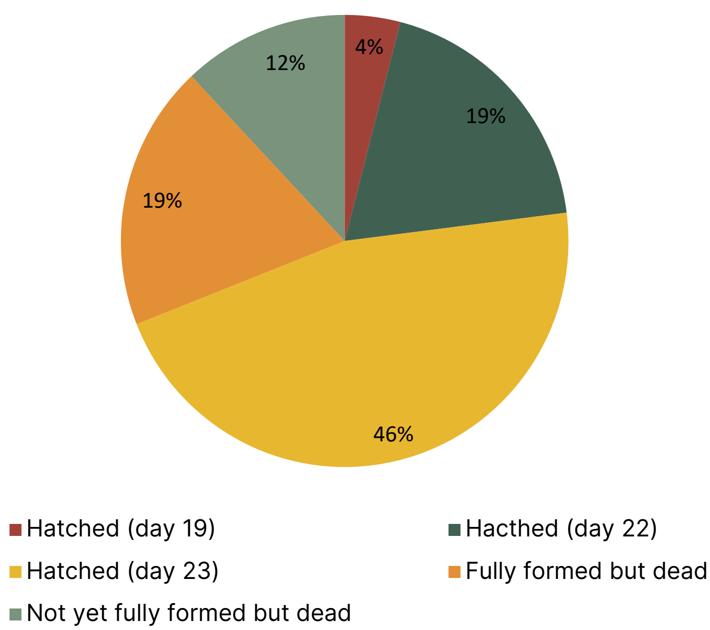
	ADVANTAGES	DISADVANTAGES
Alarm	Good way to notify users if any parameters are outside the recommended range	(For this model) Require actions to be taken by users to correct the issue
LED Signal	Good way to notify a user if any parameters are outside the recommended range	(For this model) Need the user to keep checking visually
Automatic temperature & humidity settings	If it works well, it is hands-off and very convenient to the user	If not properly calibrated, can negatively impact the hatching since the setting will be incorrect
Manual temperature & humidity settings	Allows the user to check and make sure the temp/humidity are within the recommended range	Can be tedious for end-users
Automatic egg turner	Is hands-off and very convenient for the user	Need to enable programming for users to pause egg turning before hatching

Hatching success is largely affected by temperature and humidity, and is likely to vary based on the type of bird. While the egg incubator is advertised to incubate various eggs, such as chicken, duck, pheasant, goose, and guinea fowl, we only tested chicken eggs during beta testing. Compared to the conventional hatching method – one hen would only hatch 12 eggs in 21 days, the incubator could help increase the yield by hatching up to 60 eggs at a time.

We incubated 33 fertilized chicken eggs during the field testing, and 26 of those had formed embryos and seven had partially formed embryos. We gave the seven eggs with partially formed embryos to hens to sit on, and they later hatched successfully. Of the 26 fully formed embryos, 69% hatched successfully, while eight (31%) of fully formed embryos died (Figure 8). On further examination of the eight, we found that the shells were too hard, restricting the chicks from breaking out. This could result from high surface temperatures or low humidity, further emphasizing the importance of proper temperature and humidity levels.

Each bird breed has a different sized egg and thus would require different incubation conditions and duration. Future testing with eggs from different bird breeds can help uncover additional insights on egg incubator's performance and hatching rates for various types of eggs.

FIGURE 8: HATCH RATE



CONCLUSIONS & NEXT STEPS

The purpose of egg incubator beta testing was to validate specific test protocol design decisions as well as pilot the Rapid Product Assessment approach. The beta testing showed that nascent PUE products can be tested in a time-efficient way and still generate rich performance data. The entire beta testing for the egg incubator was conducted within four weeks, with two weeks for controlled laboratory testing and two weeks for field testing. Going forward, the Rapid Product Assessment will primarily focus on controlled laboratory testing, which generates comparable performance data. We will supplement with a field-testing component only when user feedback is needed.

Working with Africa-based testing facilities, such as Kijani Testing, also eliminated some logistical challenges of shipping and transporting the product thus shortening the overall turnaround time from sampling to receiving test results. Through working with local testing facilities in key regions of sub-Saharan Africa, we can enhance the testing capacity in the region and market stakeholders can easily access testing resources, thus fostering a culture of third-party testing.

VeraSol is currently expanding the Rapid Product Assessment framework to other nascent productive use equipment, such as solar milling. Solar mills are an increasingly popular and in-demand technology used by off-grid communities and small-scale farmers to improve grain digestibility for human or animal consumption. Similar to egg incubators, we will develop test protocols, perform beta-testing, and share our learnings from testing.

If you are a program or manufacturer interested in beta-testing new PUE technologies through the Rapid Product Assessment approach, please contact info@verasol.org.

FIGURE 9: HATCHED CHICKS

Endnotes

1. VeraSol is an evolution of Lighting Global Quality Assurance. The program builds upon the strong foundation laid by the World Bank Group for solar energy kits and merges it with comparable product data for off-grid appliances and productive use equipment formerly housed under Equip Data. Learn more: https://www.verasol.org/
2. These egg incubator postings are forthcoming. Learn more: https://data.verasol.org/
3. TVs, fans, refrigerators, solar water pumps, and electric pressure cookers will be tested according to Global LEAP test methods following VeraSol appliance testing requirements.
4. Sizing based on the "The Benefits of Permanent Magnet Motors: Efficiency Opportunities in Off- and Weak-Grid Markets" report.
5. Ibid.
6. Ibid.
7. In Efficiency for Access 2020 Market Survey Report, egg incubators were ranked 13 for impact potential and 16 for perceived consumer demand across 20 different off-grid appliances: https://efficiencyforaccess.org/publications/off-grid-appliance-market-survey-2020.
8. https://www.sciencedirect.com/science/article/pii/S2468227620303550
9. CLASP, Productive use appliances Market Assessment (upcoming)

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