SWITCH TO SOLAR
April 2023

SOLAR GREEN ENERGY CAMBODIA

SOLAR SMART COOLING SYSTEMS IN CAMBODIA

A Case Study for Solar Green Energy (SOGE) Cambodia

SWITCH to Solar

switchasia GRANTS PROGRAMME

Funded by the European Union

CZECH REPUBLIC DEVELOPMENT COOPERATION

sevea (Energy)Lab

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1. Overview

The Kingdom of Cambodia's economy still heavily relies on its agriculture sector, which contributes 22% of the country's GDP and employs one-third of the workforce[1]. Most of the population (61%) lives in rural areas, with 77% of households depending on agriculture, fisheries, and forestry for sustenance. However, Cambodian farmers are vulnerable to climate change, which can result in drastic temperature increases, altered rainfall patterns, and extreme weather occurrences. The United Nations Food and Agriculture Organization (UNFAO) notes that 45% of Cambodians are experiencing moderate or severe food insecurity[2].

The use of solar energy in Cambodia's agriculture sector has immense potential. With the country's growing demand for electricity, farmers are struggling to access affordable and reliable energy sources to power irrigation systems and other farming operations. This has resulted in low crop yields and high operational costs. However, solar energy can be an effective solution for these challenges by providing a readily available and sustainable source of power, particularly given the country's high solar irradiation levels. SWITCH to Solar seeks to capitalize on this opportunity. This includes understanding solar's application in Cambodia's agri-fishery sector, testing existing and new solar technologies, building knowhow's and capacity within aligned financial intermediaries, and providing technical assistance to solar technology providers.

2. Executive Summary

This case study focuses on two solar technology solutions from Solar Green Energy (Cambodia) Co., Ltd. (SOGE), a local company which was established in December 2013. SOGE's business strategy is to design, manufacture, and distribute high-quality solar products and solutions, while also providing the necessary technical support, maintenance services, and sector-specific innovation. Through the SWITCH to Solar Project, two different Solar Smart Cooling Systems (SSCS) designed and installed by SOGE were tested and evaluated within in two different value chains: leafy vegetables and poultry.

The first SSCS demonstration site occurred at an urban farm located in Siem Reap where the farmer grows leafy vegetables using a hydroponics system which is enclosed in a net house. A second demonstration site was installed at a chicken production farm located in Kampong Thom. These two demonstration sites test technologies that generally perform similar functions, including monitoring and modification of internal environmental conditions to maximize production; however, each solution incorporates an entirely different design, electrical, and mechanical components.

This case study seeks to better understand the assumed benefits from the usage of the SSCS technologies; these include:

- **Production Increase:** Solar Smart Cooling Systems create optimal growing conditions for growing leafy vegetables, reducing chick mortality, and increasing hen egg-laying production.
- **Increase in Operational Efficiency:** Automated system can save on farm labour, allowing staff to focus on other priority tasks.

[1] https://www.ifad.org/documents/38714170/41804382/cambodia_case_poultry.pdf
[2] https://www.usaid.gov/cambodia/agriculture-and-food-security

- **Reduction in Operational Expenses:** Solar powered systems offset costs related to other sources of energy such as grid and diesel.
- **Reduction in CO2 emissions:** Switching to solar should offset CO2 emission, which would be expected if operations were powered by grid or diesel.

3. The SWITCH to Solar Project supporting Cambodia's Agri-fisheries

Acknowledging the importance of the agri-fishery sector in Cambodia, the SWITCH to Solar project was conceptualized by People in Need along with EnergyLab[3] and Sevea[4], and funded by the European Union through the SWITCH-Asia Programme[5], and the Czech Republic Development Agency (CzDA)[6]. The project is implemented across the Tonle Sap Region of Cambodia to support micro, small, and medium-sized enterprises (MSMEs) to adopt solar-based technologies with the purpose of promoting clean energy and foster green employment in the agri-fishery sector. The project also aims to support local farmers by educating them on the benefits of using solar-powered technologies which can make their products more sustainable and of high standard quality.

One of the goals of the project is to establish demonstration sites, which are the practical application of energy-smart, sustainable consumption practices for the agri-fisheries sector. Applications are solicited through an open-window challenge fund. The objectives of the demo-sites are (i) to test and showcase an innovative solar technology in real life conditions (ii) to provide a proof-of-concept (iii) to facilitate scale up, broader adoption, and distribution of the solution.

4. About the Company

Solar Green Energy (Cambodia) Co., LTD. (SOGE) was legally registered with the Ministry of Commerce in December 2013. It was initially founded in 2008 as an association known as the Renewable Energy Development Association (REDA). The goal of the company is to increase the use of green energy in Cambodia by providing high quality and standard products and services. In 2013, the REDA team decided to expand their market as an official private sector firm to reach the full market potential in the renewable energy sector, and further develop the capacities of their team. Hence, they decide to close REDA and start Solar Green Energy Cambodia (SOGE). SOGE sells a variety of products, such as solar on- and off-grid solutions, solar water pumps, solar hybrid systems, and solar back-up systems. With the country experiencing a steady economic growth of roughly 7% annually, electricity demand has been increasing by a factor of 10% per year. SOGE aims to unleash the full potential of the solar energy sector to benefit rural populations through a reduction in electrification costs and price of electricity usage.

In addition to being a leader in Cambodia's burgeoning renewable energy sector, SOGE is also a women-owned enterprise. Furthermore, the company has committed itself to working across the agri-fishery sector, and with small holder farmers to improve their bottom line. During an interview with Ms. CHIN Ol, SOGE Project Manager, she stated *"I am proud to be part of SOGE, we are one of the first*

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[3] www.energylab.asia
[4] www.seveaconsulting.com
[5] https://www.switch-asia.eu/
[6] http://www.czechaid.cz/en/

green companies to specifically focus on the agri-fishery sector. We believe that solar energy technologies can bring substantial benefits to farmers because they can reduce operational costs and increase efficiency. Additionally, solar energy can assist the Kingdom of Cambodia to reduce CO2 emissions and help fight against climate change." She also added how appreciative SOGE is to the SWITCH to Solar project, *"thanks to SWITCH to SOLAR project, we had the occasion to implement and test two new solar solutions in order to increase the variety of products for our potential customers. Innovation and creativity are the keys to our success*."

5. Demonstration Site 1: Solar Smart Cooling System

The SWITCH to Solar demonstration site includes the expansion of SOGE's Solar Smart Cooling System into the nursery. The first case study focuses on Mr. Sam Sary's farm. He installed the first hydroponic net house at the back of his property in 2020 to grow leafy vegetables. In Mid-2021, he expanded by adding two more hydroponic net houses – one for leafy vegetable production and one to serve as a nursery. This addition also coincided with the installation of SOGE's Solar Smart Cooling System in the two net houses.

5.1 Farmer Profile

Mr. Sam Sary produces vegetables using a hydroponic system. His farm and household are located at Aranh Village, Siem Reap Commune, and leafy vegetables production is his main business income.

Mr. Sam Sary mostly grows leafy vegetables such as lettuce, curly cabbage, bok choy and Chinese kale. Seeds are bought in the local market. The production starts from seeding the plants in sponges within the nursery. When seedlings are big enough, they are placed in the hydroponic channels for further growth until harvest. Historically, Mr. Sam Sary's main customers have been restaurants and hotels in Siem Reap. However, with the almost complete shutdown of Siem Reap's tourism economy due to COVID, Mr. Sam Sary is now selling to the local market and neighbors.

Location	13.3124587, 103.8485653
Coordinates	Siem Reap Commune, Siem Reap District, Siem Reap Province
Contact	Mr. Sam Sary
Phone	+855 77 922 997
Value chains	Vegetable
Plot size	100 x 13 m (home plot)
Net house size	13 x 13m (GH #1), 20 x 13 m (GH #2), 2 x 16 m (nursery)
Work force	3 people (Mr. Sam Sary's family including himself)

Table 1: Characteristics of Mr. Sam Sary's farm.

Figure 1: Layout of the farm.

5.2 The Solar Smart Cooling Systems (SSCS)

Solar Smart Cooling Systems (SSCS) comprises of several components including:

Net houses:

- Net houses are metal structures erected over an agricultural area and covered with a fine-mesh net. Net houses allow for limited climate control and an enclosed environment that protects against insects.
- One mist machine per net house is connected to water sprays and a water tank. When active, they create a cooling mist throughout the entire net house. The sprayers are installed high enough to avoid water accumulation on the plants.
- Powerful industrial ventilation fans are installed between the net houses from the outside.
- Passive roof ventilators provide additional renewal and circulation of the air inside the net house

Figure 2: Misting machines in operation inside a net house

The mist machine and the ventilation fans are automated to switch on periodically as follows:

	Mist machine	Ventilation fans
Running window	9am to 4pm	10am to 3pm
Pattern	15 min every hour	30 min every hour

Table 2: Operations of Mr. Sam Sary's SSCS.

Nursery:

- Powerful industrial ventilation fans are installed between the net house from the outside.
- One mist machine is connected to the water sprayers which are activated when internal temperatures are too high.

- Temperature sensors are located at the top of the nursery's roof.

Figure 3: Cooling system in the nursery – exhaust fan and the switchboard with breakers.

In the net houses, pressure pumps supply water to sprinklers (total number of spray heads is 105: 1st net house – 35 sprinklers and 2nd 70 sprinklers) located at the ceiling of the net houses, which are connected to the mist machines of 8kW nominal power. The exhaust fans are running on a daily basis to maintain the optimal conditions in each net house. An automated system equipped with a timer manages the optimal temperature. The entire system, which also includes the hydroponic pumps that circulate water through HDPE pipes, is powered by a PV solar system with battery backup.

A similar solution is applied at the nursery. A net house where seeded plants are placed to reach a certain age (size) before being placed in the hydroponic system located in the main net houses. Seedlings are placed on water beds instead of the hydroponic channels found in the main net houses. One exhaust fan is installed in the nursery house and equipped with temperature sensors – when temperatures rise above a predetermined threshold, the switch control turns on the ventilation fan to cool the microclimate within the net house until the conditions are back to the optimal level. It is also powered by the PV solar.

The total PV installed is 6.5 kWp (250W panels x 26) with battery capacity of 24 kWh and it serves two net houses and the nursery.

5.3 Expected Benefits

Ensuring the quality and quantity of leafy vegetable production all year round is the main goal for Mr. Sam Sary. To achieve that, Mr. Sam Sary decided to implement hydroponic system coupled with a Solar Smart Cooling System to grow leafy vegetables in a controlled environment.

Main expected benefits of the technology include:

- **Production Increase:** Solar Smart Cooling Systems should create optimal growing conditions for leafy vegetables.
- **Increase in Operational Efficiency:** Automated system should allow staff (in this case Mr. Sam Sary and his family) to have additional time to devote to other tasks.
- **Reduction in Operational Expenses:** Solar powered system should offset costs related to other sources of energy such as grid and diesel.

- **Reduction in CO^2 emissions:** Switching to solar should offset CO^2 emission, which would be expected if operations were powered by grid or diesel.
- **Increase Safety and Quality:** Producing under a fully controlled environment (temperature, humidity, hygiene) will contribute to the improvement of the products' quality and consumer safety.
- **Price Increase:** If successful, this solution could be an opportunity for the farmer to access premium markets.

5.4 Hydroponic Practices (Before SSCS)

It needs to be noted that the SSCS was already in place (installed in mid-2021) prior to the SWITCH programme; however, the data from one net house without solar technology (installed in 2020) will allow the project to understand the farming profile, expenditures, and incomes as well as challenges faced by the farmer when using a hydroponic system without SSCS.

Mr. Sam Sary installed the first hydroponic net house at the back of his property in 2020 to grow leafy vegetables. In mid-2021, he further invested by adding two more net houses, one for hydroponics, and the other as a nursery. Additionally, at this time, a SSCS was installed (supplied by SOGE) for the main two net houses.

Figure 4: Leafy vegetables growing in Mr. Sam Sary's hydroponics system.

5.5 Growing Method

Mr. Sam Sary currently has 13 hydroponic beds, 6 in the first net house and 7 in the second one, and a water table in the nursery. Beds and number of pipes vary, for example in the second net house there are 2 beds of 15 pipes and 5 beds of 16 pipes, where in the first net house the total number of pipes is 60 and beds have different setups. Each pipe has approximately 60 holes for leafy vegetable growth. The full operating capacity of both net houses is approximately 500 kilograms.

The net houses are of high quality: they appear quite sturdy, the roof is higher than usual net houses, and the walls are reinforced with bricks and concrete. The main activity is to produce leafy vegetables using the hydroponic system and distribute harvested products to hotels, restaurants, and local sellers in the nearby market. Hydroponic systems are recognized as a Good Agricultural Practice because they do not use pesticides. The main leafy vegetables varieties produced are bok choy, curly cabbage, Chinese kale and lettuce.

Each growing bed is equipped with several large water tanks which hold the water and fertilizer mixture. The water is circulated from the tanks through the pipes 24 hours per day by 20 to 40 W aquarium-type electric pumps.

A + B fertilizers are purchased in bulk from the local market. They come in the form of white and brown powders that must be diluted with water. During the production cycle, Mr. Sam Sary tests the water quality in the grow beds and adds water or fertilizer as needed to achieve the desired ratio. At the end of each cycle, the system must be dismantled and cleaned thoroughly to avoid algae build-up, this typically takes one week.

5.6 Seedling Nursery

In May 2021, Mr. Sam Sary acquired a 16 x 2m net house to be used as a nursery. This allows seedlings to grow within a controlled environment.

The nursery is equipped with a series of tables of decreasing height that can be flooded with a few centimeters of water.

Figure 4: Leafy vegetables growing in Mr. Sam Sary's hydroponics system.

Figure 5: Beds in the nursery.

Figure 6: Seedlings in the main net house.

Figure 7: Steps of leafy vegetable growth in the hydroponic system.

The entire cycle of growing vegetables takes around 28 - 35 days, depending on vegetable variety, and includes germination, nursery, and actual growth of the leafy vegetables.

5.7 Commercial practices

Mr. Sam Sary started his business in 2020. They do not yet have an accurate breakdown of their costs and profitability. However, they estimate that their expenses for electricity, fertilizer, and inputs represent roughly 25% of their revenue.

Since inception, Mr. Sam Sary's main customers have been hotels and restaurants, who offer competitive prices for Mr. Sam Sary's leafy vegetables. This is a result of (i) high product quality due to hydroponics and net house production (ii) ease and flexibility of harvesting, and (iii) capacity to produce even at low-vegetable season months (April, July, August).

	Lettuce	Curly cabbage / Pok choy	Chinese kale
Price (all year)	1.5 $/kg		
Price (April)	2 $/kg		
Price (July – August)	2.5 $/kg		
Production	40 – 50 kg /bed /cycle	50 – 60 kg /bed /cycle	100 – 200 kg /bed /cycle
Water usage	~900 L /bed /cycle		
Fertilizer A + B	2.8 L /bed /cycle	~4 L /bed /cycle	~5 L /bed /cycle

Table 3: Main characteristics of the crops grown at the hydroponic farm.

The operation of the production cycles allows the farmer to work in batches, and thus to have a continuous production, many tasks are parallelized and cycles partly overlap. This means that "per cycle" or "per grow bed" crop-budget reasoning does not properly reflect how the farmer operates and cannot cover the full complexity of the hydroponic system. However, the ability to overlap production cycles allows the farmer a more consistent and steady cash flow and to more consistently meet customer demands.

Based on this data, a first estimate of the 28 day-cycle budget of the facility without using SSCS can be made as follows:

Revenue			
Vegetable	Units [kg]	Units price [$/kg]	Total per month
Lettuce	45	$1.50	$68.00
Bok Choy / Curly cabbage	55	$1.50	$83.00
Chinese Kale	168	$1.50	$252.00
Total Revenue			$403.00
Expenses			
Seeding			$9.00
Fertilizer			$14.00

Sponges			$18.00
Electricity			$130.00
Total Expenses			$171.00
Net Income			$232.00

Table 4: 28-day cycle budget before SSCS installation.

5.8 Energy consumption

The interview conducted with Mr. Sam Sary before installing SSCS revealed that monthly average spending on the electricity associated with pumps for hydroponics net houses, not including the nursery, was approximately $130 USD. The electricity tariff is 730 riel/ kWh (0.18 USD).

Figure 7: Water tanks containing the water and fertilizer mixture.

Based on the information provided by farmer and PV system size, it is estimated that the equivalent power usage is:

- Two net houses with pumps for hydroponics: **722 kWh/month**
- Two net houses with pumps for hydroponics, cooling system and nursery: **846** kWh/month (based on the solar size)

5.9 Impact of Commercial SSCS

To understand the SSCS's commercial impact on Mr. Sam Sary's business, Sevea collected data related to monthly production and related expenses. It was decided to collect data across both the dry and wet seasons, given the fluctuation in weather and the corresponding impact on the SSCS's performance. Four months of data was collected, including February and March (dry season), and August-September (wet season). The data collection mirrored the baseline data collected for the hydroponic method to ensure a proper comparison could be accomplished.

The hydroponic system must be in operation constantly during the production cycle. And since leafy vegetable production is staggered, the system is in operation almost entirely throughout the year. The continuous operation of the hydroponics and SSCS result in a high rate of energy consumption. The weekly estimated electrical requirements provided by Mr. Sam Sary are between 230 to 250 Kw/h, this includes household appliances (security camera, fans, fridge, TV). For the purposes of this analysis

Sevea, separated out the household appliance energy consumption based on information provided by Mr. Sam Sary.

Period	Monthly Net Income [USD]
February 2022	$293.56
March 2022	$326.69
August 2022	$399.50
September 2022	$485.38

Table 5: Net monthly income for study period

The tables below represent the breakdown of commercial practices for February, March, August and September.

February 2022

Revenues			
Vegetable	Units [kg]	Units price [$/kg]	Total [USD]
Lettuce	35	$0.875	$30.63
Bok Choy	0	$0.00	$0.00
Curly Cabbage	378	$0.875	$331.19
Chinese Kale	61	$0.75	$45.75
Total Revenue			$407.56
Expenses			
Seeding	13	$1.00	$13.00
Fertilizer	7(set)	$13.00	$91.00
Sponge			$10.00
Electricity			$0.00
Labour			$0.00
Total Expenses			$114.00
Net Income			$293.56

Table 6: February profit and loss statement

March 2022

Revenues			
Vegetable	Units [kg]	Units price [$/kg]	Total [USD]
Lettuce	154	$1.13	$173.25
Bok Choy	0	$0.00	$0.00
Curly Cabbage	288.5	$0.88	$252.44
Chinese Kale	0	$0.00	$0.00
Total Revenue			$425.69
Expenses			
Seeding	11	$1.00	$11.00
Fertilizer	6(set)	$13.00	$78.00
Sponge			$10.00

Electricity			$0.00
Labour			$0.00
Total Expenses			$99.00
Net Income			$326.69

Table 7: March profit and loss statement.

August 2022

Revenues			
Vegetable	Units [kg]	Units price [$/kg]	Total [USD]
Lettuce	0	$0.00	$0.00
Pok Choy	0	$0.00	$0.00
Curly cabbage	444	$1.13	$499.50
Chinese Kale	0	$0.00	$0.00
Total Revenue			$499.50
Expenses			
Seeding	20	1	$20.00
Fertilizer	5(set)	13	$65.00
Sponge			$15.00
Electricity			$0.00
Labour			$0.00
Total Expenses			$100.00
Net Income			$399.50

Table 8: August profit and loss statement.

September 2022

Revenues			
Vegetable	Units [kg]	Units price [$/kg]	Total [USD]
Lettuce	0	$0.00	$0.00
Pok Choy	0	$0.00	$0.00
Curly cabbage	523	$1.13	$588.38
Chinese Kale	0	$0.00	$0.00
Total Revenue			$588.38
Expenses			
Seeding	10	$1.00	$10.00
Fertilizer	6	$13.00	$78.00
Sponge		$15.00	$15.00
Electricity			$0.00
Labour			$0.00
Total Expenses			$103.00
Net Income			$485.38

Table 9: September profit and loss statement.

Based on the data collected over a four-month period it is clear that the SSCS enables Mr. Sam Sary to increase his leafy vegetable productivity. Furthermore, the data indicated a positive trend line which illustrates Mr. Sam Sary's ability to optimize the system as he acquires experience and familiarity with the system and its operation.

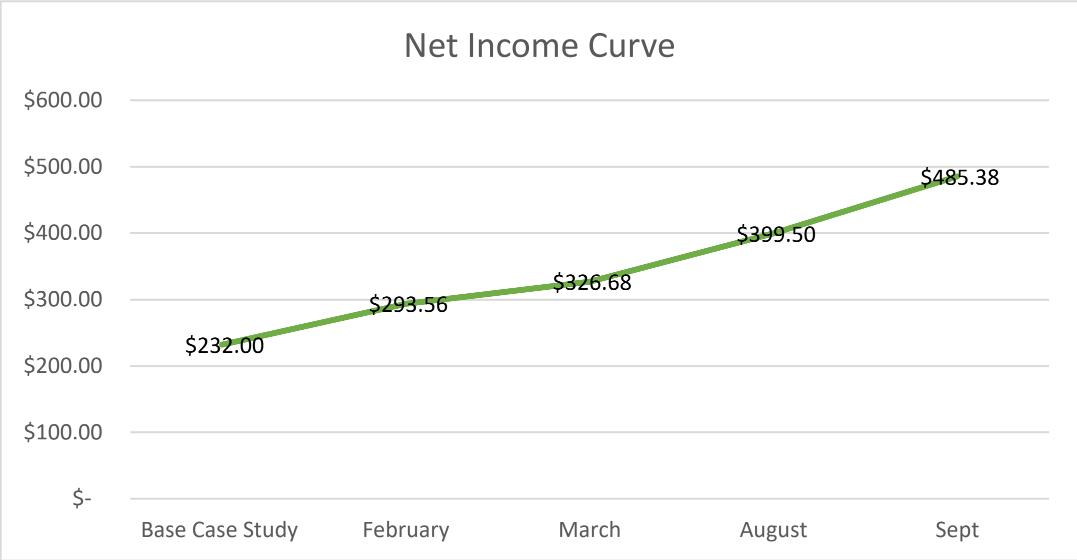

Figure 8: Changes in net income before SWITCH and during data collection.

The bar chart shows the average selling prices of the leafy vegetables Mr. Sam Sary sells before and after the installation of the SSCS. There was a dramatic decrease in prices of leafy vegetables as a result of COVID and its impact in the tourism focused economy of Siem Reap.

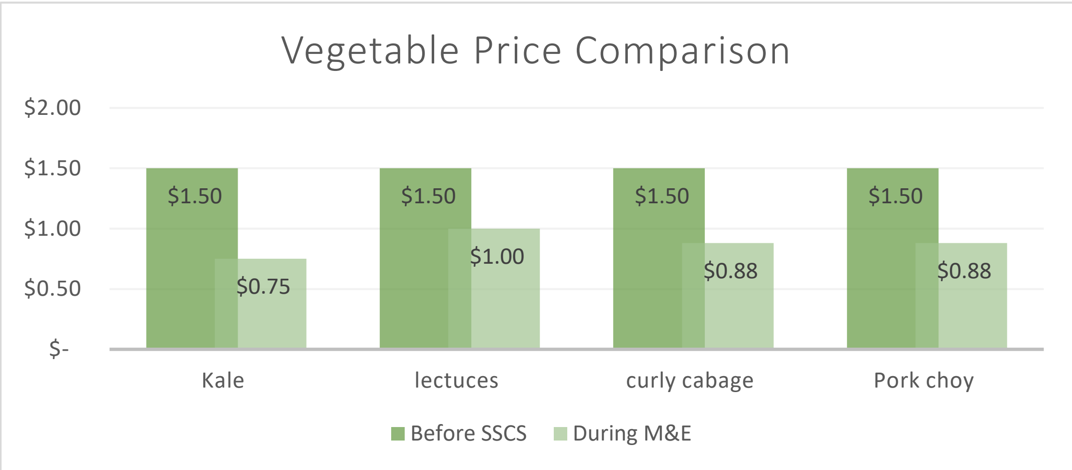

Figure 9: Changes in average vegetable price before SWITCH and during data collection.

5.10 Return on Investment

Based on the data collected over a four-month period a simple return on investment (ROI) calculation was performed. The results show that the ROI for Mr. Sam Sary is approximately 7 years.

- Solar technology and installation price = $12,000 USD
- Mr. Sam Sary invested a total of $12,000 USD for the solar smart cooling system with battery backup to power three net houses. Two net houses are used for leafy vegetable production

and one net house is used for the nursery. Investment was in collaboration between the SWITCH to Solar project and SOGE company

- Assumption: Mr. Sam Sary's monthly production performance and sales earnings continue to remain approximately $376.28 /month in average and vegetable prices will not increase to the value from pre-COVID, then the ROI will be roughly 7 years.

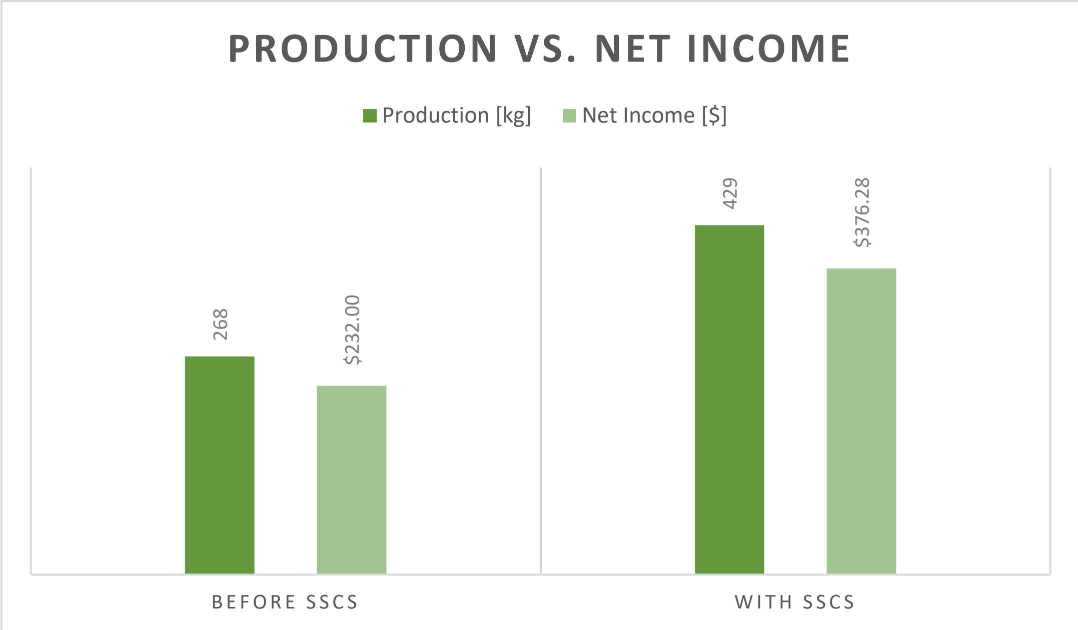

Figure 10: Comparison of production and Net Income before and during the project.

ROI = Cost of investment / additional revenue generated
ROI= $12,000 (SSCS Cost) / $144.28
ROI= 83 months or 6.9 Years

Based on Mr. Sam Sary's business case, an investment in a solar smart cooling system yields an extensive payback period. However, it is important to consider the significant decrease in leafy vegetable prices as a result of COVID's impact on the Siem Reap tourism economy.

Despite an increase in production, approximately 60%, the prices of leafy vegetables in Siem Reap have not recovered since the on-set of COVID. On average, Mr. Sam Sary is losing approximately $.62 per kg of leafy vegetable sold. As a result, the revenue has not significantly increased. Before COVID, Mr. Sam Sary was selling to premium markets in Siem Reap, specifically hotels and restaurants. These customers are almost entirely dependent on Siem Reap's tourism economy, and once this shut down Mr. Sam Sary no longer had access to premium customers. This necessitated a shift to the local market where vegetable prices are significantly less.

5.11 Photovoltaic Solar Performance and CO2 Emissions

Solar technology installed at the demonstration site powers the hydroponics system pumps, SSCS, and a few appliances such as a CCTV camera to ensure the production of leafy vegetables is optimized and secured. The installed PV solar capacity of 6.5 kWp realized by 26 x 250-Watt panels generate around

846 kWh of energy under the Cambodian sun monthly. The excess power is stored in a 10x 12V/200Ah battery to ensure 4hrs a day of power backup for the hydroponic and SSCS systems.

As with all solar technology, during cloudy or rainy days, the PV solar technology will have insufficient irradiation to properly power the SSCS. During these days, temperature is relatively low, and the cooling system is not expected to be necessary, and as a hybrid system, there is always access to electricity from the grid. However, from the start of the data collection period,it has not been noticed that solar power was insufficient and according to Mr. Sary, power supply from the grid was not needed for his net houses and nursery operations.

A quite significant reduction of CO^2 is expected for this technology given the constant use of the hydroponic system and the internal cooling needed in the net houses on the hot and sunny days.

Technol-ogy	Consump-tion/production	Forecasted daily usage ratio	Total an-nual power production	Conversion factor of tCO^2 for Cambodia	Annual emission added/saved tCO^2
PV solar	6.5 kWp	100%	10154.3 kWh	0.58 grid	5.89

Table 10: CO^2 emissions and reductions while using SSCS

CO^2 reduction as a result of powering the net houses and nursery with PV solar: **5.89 tCO^2**
TOTAL avoided CO^2 emissions: **5.89 tCO^2/year**

Solar installation also allows Mr. Sam Sary to power some household appliances which further offset monthly electricity expenses.

5.12 Increase in production

Production improvement is a key expected benefit provided by SSCS. In traditional leafy growing practices where farmers grow seedlings in a nursery and then plant directly into open-air soil, total time from nursery to harvest is between 60 to 75 days. For Mr. Sam Sary, when utilizing a hydroponics system in conjunction with a SSCS, the total production time was reduced to between 28 – 35 days. This allows for an increase in the number of production cycles per year. The table below illustrates the leafy vegetable production length using traditional growing practices, and Mr. Sam Sary's current operation.

Vegetable Production Cycle (Nursery to Harvest)				
Types of Vegetables	Traditional Planting Practice		Hydroponic + SSCS	
	Nursery (day)	Planting till harvest (day)	Nursery (Day)	Planting till har-vest (day)
Chinese Kale	15	60	14	21
Lettuce	15	45	14	14

Cabbage (Curly, Bok Choy)	15	45	14	14

Table 11: Comparison of practice in growing vegetables in soil and in hydroponics.

According to the data, the SSCS installed by SOGE significantly improved Mr. Sam Sary's leafy vegetables production. The table below shows the total monthly production from February 2022 until September 2022.

Period	Total Vegetable Production [KG]
February 2022	474.50
March 2022	442.50
August 2022	444.00
September 2022	355.00

Table 12: Quantity of total harvest during the study period.

The total production capacity of Mr. Sam Sary's farming operation is approximately 500 kg. However, it is rare to be at full capacity, vegetables are grown in batches to ensure constant production and income, and to limit cash flow fluctuations.

6. Demonstration site 2: Solar Smart Cooling System Operating within the Poultry Value Chain

The second Solar Smart Cooling System case study focuses on Mr. Chhouden Chhim's chicken production business line. Mr. Chhouden Chhim first started chicken farming in 2018 which included the installation egg-producing a solar egg incubator. The farming concept came into life through participation in an UNDP incubation program. Since 2018, Mr. Chhouden has developed a social enterprise entitled Green Farmer Community (GFC), which aims to achieve production of good quality chickens and chicks, supply chicks to the local farmers within the community, establish market linkage support, provide training support and vaccination provision to the local farmers. GFC has grown to incorporate other value chains including cashews, rice and crickets. Mr. Chhouden is active in promoting GFC's model and good animal husbandry practices to local farmers, community members, and students enrolled at local vocational training programs.

The Solar Smart Cooling System (SSCS) comprises of 10 sprinklers located on the roof of the chick house and hen house (five sprinklers per building) which are activated based on the internal temperature of the houses. Mr. Chhouden can select the temperature at which sprinkler activation occurs, it is generally set at 30 degrees Celsius. A tower located adjacent to the chick and hen houses holds two 1,500 liters water tanks that supply water to the rooftop sprinklers. The water tanks are supplied with water that is pumped from an underground well by a 120W submersible pump powered by a 250W solar panel with battery backup of 2 x 12V-65Ah (1,560 Wh). The submersible pump is also automated and programed to switch on once levels in the water tank reach a certain point. Solar panels (14 x 250W) installed on the roof of the chick house provide power to the egg incubators and charges 8 batteries with a capacity of 19,200 Wh.

Figure 11: Rooftop Sprinkler System

The SSCS should aid in reducing chick mortality and increasing the occurrence of ideal chick raising and hen egg laying conditions. The operational flow of this system consists of groundwater being pumped to elevated water tanks. Through gravity, water from the tanks flows to roof-mounted sprinklers which become operational once internal temperature conditions in the chick and hen house reach a pre-determined level, in this case 30ºC. This is managed through an automated system which Mr. Chhouden can adjust as needed. Upon activation sprinklers run for 15 minutes. The distribution of water across the roof creates an internal cooling effect and adjusts the internal microclimate to an optimal level for poultry. The pattern of using the cooling system can be described as follow:

	Chick House	Hen House
Running window	9am to 5pm	9am to 5pm
Activation Temperture	30 Degrees Celsius Range (28º - 32º)	30 Degrees Celsius Range (30º - 35º)
Running Time	15 minutes	15 Minutes

Table 13 - Operations of the Solar Smart Cooling System.

6.1 Farmer Profile

Mr. Chhouden is an entrepreneur who incorporates several farming components at his farm, Green Farming Community (GFC), located in Prasat Sambour District, Kampong Thom Province. This includes chicken (eggs, chicks, chicken meat, and hens) raising and selling, operation of a cashew farm, cricket raising and selling, and paddy rice cultivation, which is mainly for household consumption. This analysis will only focus on the chicken raising portion of Mr. Chhouden's business.

Mr. Chhouden produces chickens (adults) and chicks (juveniles) to sell within the local market. GFC is a self-sustaining business, meaning the hens produce the eggs for the chicken and chick production. Adult chickens and processed chicken meat are sold at the local market and to restaurants in Kampong Thom. Chicks are sold to local chicken farmers who raise the chicks to be sold as adult chickens in the local market. Mr. Chhouden can also sell adult hens as egg laying chickens, these fetch a premium market price. A threat to GFC is high chick mortality rates as a result of inadequate housing conditions, particularly high temperatures. Additionally, high internal temperatures within the hen house create stressful environments for egg-laying hen, thereby limiting their production.

Location	12.904247, 105.060966
Coordinates	Sambour Village Sambour Commune Prasat Sambour District Kampong Thom Province, Cambodia
Contact	Mr. Chhim Chhouden
Phone	+855 70 442 666
Value chains	Chicken
Plot size	100 m x 13 m
Chicken house size	15m x 6m (Chicken house), 6m x 0.5m (Chick house), 6m x 15m (Hen's house), 6m x 18m (Rooster's house)
Workforce	3 to 4 people max including Mr. Chhouden; occasionally student volunteers

Table 14: Farmer Profile

The chicken raising operation utilizes several different components and facilities, this includes:

- **Chick House**: The main function of this building is chick raising after hatching. Chicks are place in a group cage for approximately 14 days. Each cage contains a heating element, either charcoal in clay pots or light bulbs. After 14 days chicks are then released into the chick house for another 26 to 31 days. After this period the chickens are moved to the chicken house. Solar panels have been installed on this building as well as the SSCS sprinklers.
- **Chicken House**: Once chicks reach 40-45 days, they are moved to the chicken house to continue growing. This building has a capacity of 1,200 chickens. SSCS was not installed on this building, as adult chickens are less susceptible to high temperatures.
- **Hen House**: This building can hold 150-200 adult hens. These hens are egg producing and supply the chick production. Egg laying hens are very sensitive to heat, impacting their overall health and egg producing capacity.
- **Egg Incubator**: There are three functioning incubators which provide a capacity of about 3,000 eggs. Mr. Chhouden has decided to limit egg production until mortality rates are reduced. Egg incubators provide consistent temperatures needed to optimize egg hatching. This requires continuous power supply. To achieve this Mr. Chhouden has installed 3.5 kWp of solar and 19.2 kWh of batteries to power the egg incubator. The genset on site works as backup if the solar energy is disrupted or insufficient.
- **Water Tower**: Adjacent to the chick and hen house, it holds two 1500 litre water tank that supply water to the rooftop sprinklers.

- **Azolla Ponds**: Any excess solar power generated powers a water pump in the Azolla ponds. Azolla is a green plant grown in water which can be used as animal feed.

Figure 12: Farm Layout

6.2 Expected Benefits

At this point, GFC's main goals are ensuring business sustainability, and maintaining quality and quantity of production all year round. To achieve that, GFC decided to implement a Solar Smart Cooling System to optimize the chicken raising environment.
The main expected benefits of the technology include:

- **Mortality Reduction & Production Increase:** SSCS should increase chicken production (chicks & hatched eggs) by reducing mortality rates and creating better living conditions for adult egg laying hens.
- **Increase in Operational Efficiency:** Automated system should save on farm labour, allowing staff to focus on other priority tasks.
- **Reduction in Operational Expenses:** Solar powered system should offset costs related to other sources of energy such as grid and/or diesel.
- **Reduction in CO2 Emissions:** Switching to solar should offset CO2 emission, which would be expected if operations were powered by grid or diesel.
- **High Visibility:** GFC is well known throughout the region offering substantial promotion activities for the technology

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6.3 Chicken Farming Practices (Before SSCS Installation)

Mr. Chhounden started chicken production in 2018 after participation in an UNDP incubation programme which provided grant funding to purchase a solar powered egg incubator, this was installed by SOGE. He then soon established Green Farming Community (GFC) to promote sustainable chicken farming practices and expanded operations to include chick, chicken and hen raising, and eventually small-scale chicken processing. However, throughout the existence of the farm, Mr. Chhounden has struggled to reduced chicken mortality. On average, the chicken mortality rate is approximately 30%, Mr. Chhouden attributes this to the high internal temperatures of the chick and hen houses. An attempt to control temperatures was made through the installation of fans, unfortunately this proved ineffective due to excessive noise and dust generation both of which caused stress within the chick and hen populations.

6.4 Chicken Production Operations

When the farm is functioning at or near full capacity, the production cycle and supply chain can be described by the following flow chart:

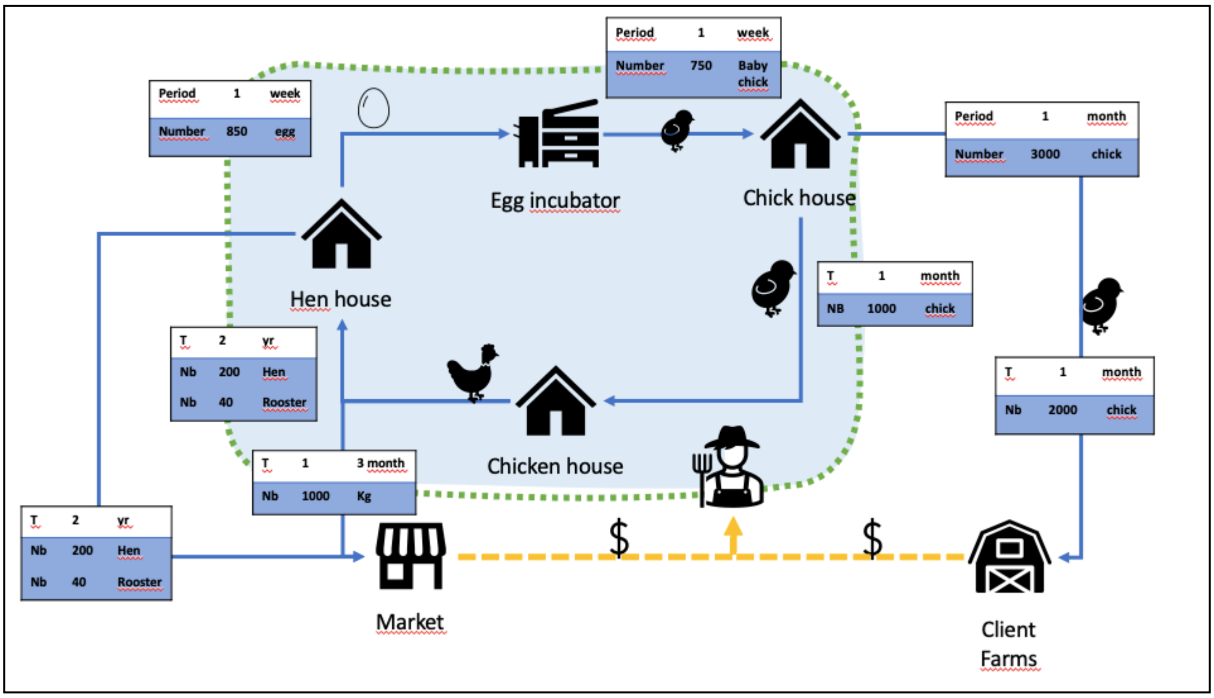

Figure 13: Production Cycle and Supply Chain

Egg incubator

The farm is equipped with solar egg incubators installed by SOGE and funded through an UNDP grant received in 2018. It was installed in a separate building from the chick house, with total capacity of 3,000 eggs. It includes lights, fans, and a fridge to store vaccines. Fans are not in use now because of dust. This maximum capacity (3,000 eggs) is not utilized at a full potential due to high mortality rates; currently they fill in about 200 eggs in every 5 days. After hatching, the chicks are move to the chick house.

Figure 14: Solar Powered Egg Incubator

Chick House

From the egg incubator, baby chicks are moved to the chick house to continue growing, it typically takes 40-45 days to for the chicks to reach a point where they can be sold, or moved to the chicken house to continue growth. The chick house occasionally needs heat which is provided through two methods, either with charcoal from Khmer Green Charcoal (KGC) which are placed in clay pots located within each chick cage or through the use of light bulbs. Heating is required mostly at night when the temperature drops to 20ºC. Chicks require temperatures between 28-32ºC for the first 14-21 days of their life.

The main challenge at this stage is achieving an optimal growing environment for the chicks, this will reduce mortality rates. Temperature conditions within the chick house should be maintained below 32ºC. If the temperature rises beyond 32ºC, chicks will become stressed and lose their appetite, if prolonged, this scenario leads to death. The farmer first installed fans to control the internal temperature; however, the noise associated with the fans further stressed the chicks and did not reduce morality rates.

Figure 15: Chick Cages Located in Chick House

Chicken House

The chicken house is a building designed to grow female chicks that are 40-45 days old into replacement egg laying hens, once they obtain a certain weight, they are transferred to the hen house. Additionally, chicks are raised here into chickens that can be sold at market. It takes around 3 months for chicks to reach a weight where they can be sold.

It is divided in 12 compartments that are filled each cycle with a new batch of mature chicks. The chicken house is built on stilts and designed to allow natural ventilation, and for chicken excrement to fall on to the ground which facilitates a cleaner internal environment, and easier cleaning. The space underneath the chicken house also offers a shelter against the sun for free-range chickens.

Hen House

The hen house can accommodate between 150 to 200 hens which are replaced every two years. They produce the eggs which are then taken to the egg incubator to hatch.

When conditions in the hens' house are not optimal, the hens tend to eat less and produce eggs of lower quality. The best temperature for hens to be the most productive should be below 32°C, when it rises above that level, their egg producing productivity is only 40%. The expected production in healthy environment is between 60% to 70%. Currently the temperature in the hen's house gets very high in the early afternoon, especially in the dry season. Some solutions have been implemented by the farmer - trees have been planted around the hens' house to provide shade, there was also an attempt to install fans, but the effect was the same as with chicks - it caused further stress for hens.

Figure 16: Hens in the Hen House

Water Tanks

The water supply to the farm comes from an underground source. The water tower is 10 m high and holds two water tanks with a capacity of 1,500 litres each. Water is pumped to the tanks from a 18m deep well. An old diesel generator was used to run the 1.5 hp pump – there was an attempt to use DC submersible pump from local supplier, but the pump broke after installation. Before SSCS installation, pumping occurred every two days for 1.5 hrs. The water from the tanks is used in a variety of functions at the farm, this includes cleaning the buildings, providing chickens with drinking water, and Azolla production.

Figure 17: Elevated Water Tanks with Solar Panels

6.5 Commercial Practices

Mr. Chhouden started his business in 2018, constantly evolving and growing it. He has not yet had an accurate breakdown of the farm costs and profitability. However, he and his team estimate that their expenses for vaccination, feed and inputs represent roughly 40% of their revenue. Based on the financial data provide to Sevea the following financial breakdown was produced to create a baseline financial scenario.

Chicks, adult chickens, processed chickens and egg laying hens are currently sold locally to the markets in Kampong Thom province, to hotels, guest houses, and restaurants in the area that cater to visitors of the local historical site Sambor Prei Kuk, and to individuals who order directly from GFC. Mr. Chhouden also sells processed chicken through the GFC Facebook page to individual clients in Phnom Penh.

Revenues from Jan - May 2022	Units [Head/Kg]	Units price [$/head/Kg]	Total [USD]
Chicks	1063 (Head)	$1.13	$1,201.94
Chicken	279.62 (Kg)	$3.75	$1,048.60
Total Revenue			$2,250.54
COGS			
Feeding			$1,924.25
Vaccination			$240.88
Eggs			$0.00
Total COGS			$2,165.14
Expenses			
Diesel			$13.00
Labor			$250.00
Transportation			$0.00
Feed Equipment & Supplies			$186.63
Total Expenses			$449.63
Monthly Revenue			$(364.23)
Average Monthly Earnings			$(72.85)

Table 15: Commercial Practice Baseline (2022)

The table above describes the finances of GFC's commercial practice before using the Solar Smart Cooling System. It should be noted that it was difficult to collect historical financial information from GFC. The small business employs a rudimentary accounting system which includes revenues and expenses from multiple business lines. For the purposes of this study, only revenue and expenses associated with the chicken business was considered.

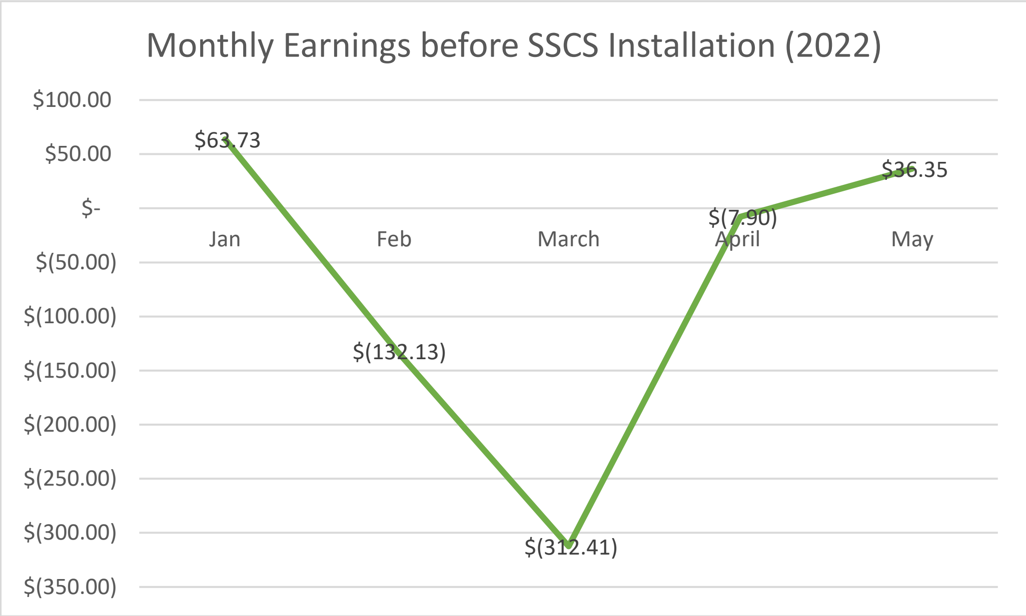

Figure 18: Monthly Earnings before SSCS Installation (2022)

As illustrated above, GFC's chicken business for the time period consider within this study lost money. GFC was significantly impacted by COVID, due to the fact that his main buyers were restaurants and guest houses which served the local tourists. Prior to COVID, Mr. Chhouden stated that this business line was profitable. Moreover, it's important to understand that this is just one of several businesses line that make up GFC, these have not been considered as part of this analysis.

6.6 Energy Consumption

The farm is not connected to the grid due to its location. To power the egg incubator SOGE installed solar panels in 2018 with battery backup. For pumping activities, a diesel generator and pump were used. In an interview conducted with Mr. Chhouden, the average monthly spending on disel before installing SSCS was around $13. The diesel pump was used for a variety of activities across the farm, one of which was supporting the chicken operation.

Based on the information provided by farmer and PV size, it is estimated that the equivalent of power usage is as follow:

- Power for egg incubators, lights and fans, fridge for vaccines averages: **455.4** kWh/month
- Power for SSCS averages: **32.5** kWh/month
- Back-up power generated by diesel generator averages: **42.7** kWh/month

Total power consumption at the farm per month in average: **530.6 kWh/month**
Annual power consumption for the SSCS is: **390 kWh/year.**

6.7 Impact of Commercial SSCS

To understand the SSCS's commercial impact on GFC's chicken business, Sevea collected data related to monthly production and related expenses. It was decided to collect data across both the dry and wet seasons, given the fluctuation in weather and the corresponding impact on the SSCS's performance. Data was collected over a seven-month period, starting from June (wet season) until January (dry season). As best as possible, the data collection mirrored the financial baseline analysis to ensure a proper comparison. The Solar Smart Cooling System does not operate continuously, it is only in operation when temperatures rise above 30°C. On the other hand, when temperatures are too low, chicks need an extra heating element. The heat is provided through two different methods – charcoal in clay pot which is typically done during the day, and through light bulbs which are also powered by batteries connected to the installed PV system at the farm, this option is preferred during the evening hours. Although the SSCS is only in operation periodically, given the impact high temperatures have on chicks' and chickens' well-being, the impact is significant.

The tables below represent the breakdown of earnings for the months when the Solar Smart Cooling System was in use.

Month	Monthly Net Income [USD]
June 2022	$49.13
July 2022	($110.75)
August 2022	$36.50
September 2022	$217.87
October 2022	$1,511.00
November 2022	$153.47
December 2022	$652.74

Table 16: Monthly Net Income after SSCS Installation

Given the nature of the chicken business, revenue fluctuates on a monthly basis. This is a result of the time it takes for different sales products (chicks, adult chickens, and hens) to reach a point at which they can be sold. This is illustrated in the above table, where monthly revenue fluctuates from ($110.75) to $1,511.00.

June to December 2022

Description	Number	Unit	Unit Price	Total [USD]
Revenue				
Chicks	2067	Head	$1.13	$2,335.71
Chicken Meat	298.9	Kg	$3.75	$1,120.87
Hens	350	Kg	$5.00	$1,750.00
Unhatched Egg	958	Eggs	$0.06	$57.48
Total Revenue				$5,264.065
COGS				
Eggs				$0.00
Transportation				$62.00
Total COGS				$62.00

Expenses				
Equipment (Heating Light)				$12.25
Labour	7	Months	$150.00	$1,050.00
Vaccine				$54.75
Feeding				$1,576.25
Total Expenses				$2,693.25
Total Earnings				$2,508.82
Average Monthly Earning				$358.40

Table 17: Commercial Practice Results after SSCS Installation (June – Decemeber 2022)

The table above describes the finances of the chicken production business with the addition of a SSCS. The data was collected in accordance with the monitoring and evaluation plan designed and implemented by Sevea, and with the current market prices of chicken. It is important to note that GFC began selling two additional products during this time period that were not sold during the time of the baseline. These products are adult egg laying hens and unhatched eggs. Adult egg laying hens sell at a premium price, $5.00 USD per head and add significant revenue. The ability to sell adult egg laying hens is a result of mortality reduction and general well-being improvements as a result of the SSCS.

The detailed breakdown of earnings and its fluctuations is shown in

Figure . It can be observed that in July the chicken business was not making any profit. This happened due to the age of hens, they were old and egg quantity and quality were insufficient, and most of the chicks produced were kept to replace the old hens instead of being sold on the market. Additionally, the SSCS was not fully in operation during the month of June (approximately two weeks) due to maintenance issues. SOGE was contacted and they resolved the issue promptly.

Figure 19: Monthly Earnings from June - Dec 2022

The bar chart below illustrates the net income comparison before and after the installation of SSCS. Based on the data obtained through this analysis, it is clear that there have been significant net revenue improvements that have occurred after the installation of the SSCS. It is fair to say that the baseline data was collected during a time that the business was still adversely impact by COVID. But a major driver of GFC's revenue increase was a reduction in chick mortality and an increase in hen well-being. A larger number of chicks were sold after the SSCS installation and the healthier hens increased egg production, both improvements led to an increase in revenue.

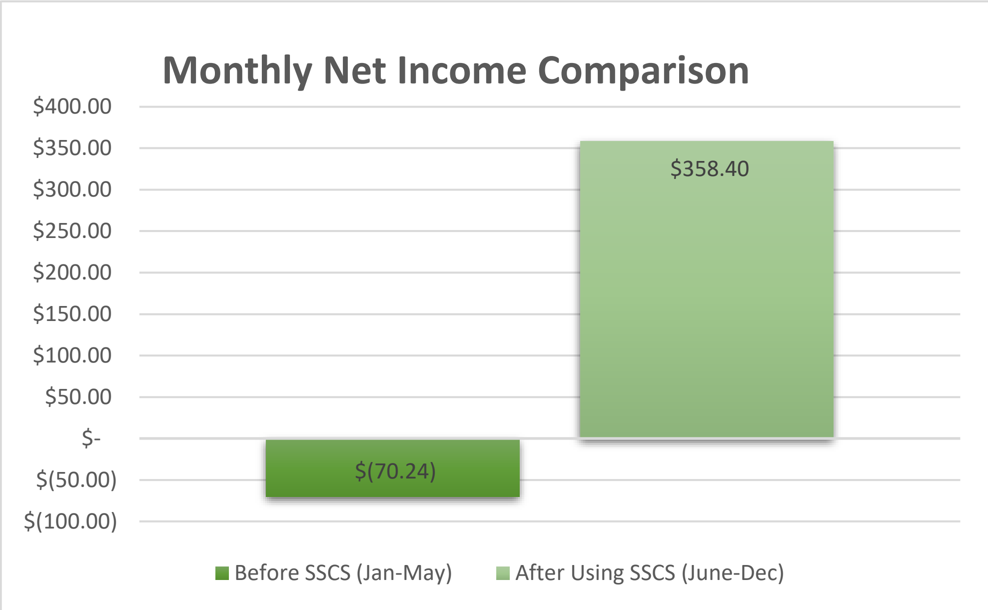

Figure 20: Monthly Net Income Comparison

6.8 Return on Investment

Based on the data collected over a seven-month period a simple return on investment calculation was performed. The results show that the ROI for the SCSS technology Mr. Chhouden installed is approximately 4.5 months.

- The total investment of GFC's SCSS that was installed to service the chick and hen houses was $1,588 USD. This cost included equipment, labor and installation.
- GFC's average monthly earning from the chicken production is approximately $358.56/month.
- After the SSCS installation, GFC began selling two products which were not sold during the time period of the baseline financial assessment, these are adult egg laying hens and unhatched eggs. The selling of adult egg laying hens which sell at $5/head, had a significant impact on GFC's revenue.

ROI = Cost of investment / additional revenue generated*****
ROI= $1,588/$358.56
ROI= 4.5 months

*Additional revenue generated = (average earnings after installation of SSCS) – (average earnings before installation of SSCS). It needs to be noted that before installation, the chicken farm was actually losing money and the average loss per month was $72.85.

Based on GFC's business case, an investment in a Solar Smart Cooling System yields a short payback period.

6.9 Photovoltaic Solar Performance and CO2 Emissions

Solar technology installed at the demonstration site powers a smart solar cooling system, egg incubators, few appliances such as bulbs in the chick's house and other appliances. The installed total PV solar capacity of a 3.75 kWp realized by 15x250Watt panels generates around 488 kWh of energy under the Cambodian sun on a monthly basis. The excess power is stored in batteries of 20.7 kWh total capacity to ensure a backup for the cooling system and other electrical appliances.

As with all solar technology, during cloudy or rainy days, the PV solar technology will have insufficient irradiation to properly power the cooling system. However, during these days temperature is relatively low, and the cooling system is not expected to be necessary, and, in addition, batteries should have sufficient power stored to ensure operation. Other appliances will be powered by generator, which was originally in use on site.

Reduction of CO2 is not expected to be massively impacted by this technology given the relatively small size of PV system installed.

Technology	Consumption/ production	Forecasted daily usage ratio	Total annual power production	Conversion factor of tCO2 for Cambodia	Annual emission added/saved tCO2
PV solar	3.75 kWp	100%	5855 kWh	0.745 diesel	4.36

Table 18: CO2 Emissions and Reductions from SSCS & Solar Egg Incubator

CO2 reduction as a result of powering the farm with PV solar: **4.36 tCO2**
TOTAL avoided CO2 emissions: **4.36 tCO2/year**

Solar installation allows Mr. Den to power his chicken farm and some of the home appliances on site, which offsets diesel usage for the generator.

SSCS ONLY:

The installed PV solar capacity for SSCS only is realized by 1x250Watt panel which generates around **32 kWh** of energy under the Cambodian sun monthly. The excess power is stored in batteries of 1.6 kWh total capacity to ensure a backup for the cooling system.

Reduction of CO2 is expected to be slightly impacted by this technology given the relatively small size of PV system installed.

Technology	Consumption/ production	Forecasted daily usage ratio	Total annual power production	Conversion factor of tCO2 for Cambodia	Annual emission added/saved tCO2
PV solar	0.250 kWp	100%	390.3 kWh	0.745 diesel	0.3

Table19: CO_2 Emissions and Reductions from SSCS

CO_2 reduction as a result of powering the SSCS for chick and hen house with PV solar: **0.29 tCO_2/year.**

7. The Way Forward for SOGE

Solar Smart Cooling Systems have the potential to play an important role in Cambodia's agricultural sector. Climate change impacts are expected to have considerable impact on SE Asia's agriculture sector, including a higher prevalence of hotter days and nights. The ability of small holder farmers to mitigate climate change impacts, through technologies such as the SSCS, will play a crucial role in ensuring rural livelihoods and the ability to meet food security requirements at local and national levels. As proven in these case studies, SSCSs are effective technologies and important tools small holder farmers can use to increase productivity, reduces chick mortality, and guard against future climate change impacts.

Based on the results of these case studies, SOGE now has the necessary data to promote and market SSCS to the larger agricultural community and aligned stakeholders. Partnership development has already begun with key farmer associations, include the Cambodian Livestock Raisers Association. Additionally, SOGE is seeking partnerships with financial intermediaries to develop relevant financing mechanisms for end-users. As Ms. Chin Ol points out, these case studies are only the beginning, "Having the data to support the impact of SSCS is an essentially first step, now the goal is to build partnership and a marketing strategy to create more visibility for the technology, and thankfully, we have SWITCH to Solar to assist with this." The company's efforts will not stop here, as they continue to expand their business and offerings to provide more value to their customers. SOGE is well-positioned to further empower the farming communities in Cambodia.

SWITCH TO SOLAR FOR A THRIVING AGRI-FISHERIES MARKET

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