Ministry of Foreign Affairs

Solar-driven aquaculture

Solar-driven aquaculture technology Vietnam - Netherlands

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Solar-driven aquaculture

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Netherlands Enterprise Agency

Netherlands

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Abbreviations

Ah- Ampere-hour

COD- Cash on Delivery (Back to the grid)

EVNSPC- Vietnam's Southern Power Corporation

FiT- Feed in Tariffs (Amount of money received for supplying solar energy to the state grid)

GW- Gigawatt (A measure of power for 1 billion watts)

GWh- Gigawatt per hour

Ha- Hectare

HP- Horsepower

KW- Kilowatt (A measure of power for 1 thousand watts)

kWh- Kilowatt per hour

kWp- Kilowatt peak (A measure of maximum potential output of power expressed in Kilowatts)

M2- meters squared

MT- Metric Ton

MW- Megawatt (A measure of power for 1 million watts)

MWp- Megawatt peak (A measure of maximum potential output of power expressed in Megawatts)

MW- Megawatt (A measure of power for 1 million watts)

MWp- Megawatt peak (A measure of maximum potential output of power expressed in Megawatts)

NEA- Netherlands Enterprise Agency

NL- Netherlands

PDP- Power Development Plan

PPA- Power Purchase Agreement

ROI- Return on Investment

SDG- Sustainable Development Goals

USD- United States Dollar

VN- Vietnam

VND- Vietnamese Dong

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Executive Summary

Solar and its application in Aquaculture in Vietnam

This study was commissioned by the Netherlands Enterprise Agency ('NEA') to explore the potential of solar-powered technologies in aquaculture in Vietnam. The study was conducted by Larive International, OpenAsia and Rynan Aquaculture. The study focused on two main aquaculture species: **shrimp** and **pangasius**, and assessed the **business case** for **extensive**, **semi-intensive** and **intensive farming** systems in the Mekong Delta.

Vietnam has witnessed a rapid growth of solar energy from 2017 to 2020, thanks to the Feed-in-Tariffs government incentive. The installed solar capacity increased from 0.7 GW in 2019 to 17.6 GW in 2021. However, from 2020 onwards, no solar power could be sold back to the grid, which prompted a **shift** towards solar **power generation for own use**.

The main energy consumption in aquaculture comes from **aeration**, which accounts for **80 to 90%** of the total **energy use**. Aeration is mostly needed during the night, when oxygen levels in water drop. This creates a mismatch between solar energy supply and aquaculture energy demand and necessitates the use of energy storage solutions (batteries). However, **batteries** are still expensive and have a **limited lifespan**, which hinders the adoption of solar power in aquaculture.

The study found that solar-driven aquaculture solutions are **not viable** for **extensive** and **semi-intensive Pangasius** farmers and **extensive shrimp farmers**, as they have low day-time energy demand and insufficient means and incentives to invest in solar power. For these farmers, household solar solutions may be more suitable, as their electricity demand for farming is limited. The study also found that solar-driven aquaculture solutions have an opportunity for intensive Pangasius farming, but the return on investment is less attractive, as energy costs are only ~1% of the revenue.

The most **promising opportunity** for solar-driven aquaculture solutions lies with **semi-intensive and intensive shrimp farming**, as these farms have high energy requirements, stable demand for energy, and higher profitability, which makes them more likely to invest in solar power for their farms.

To increase the feasibility and attractiveness of solar-driven aquaculture solutions, the study recommends the following **actions**:

- **Aligning farming practices** with solar energy usage: Farmers should adjust their feeding schedules and other operations to increase their daytime energy usage and reduce their nighttime usage. This would help them utilize more solar power and save on battery costs. Currently, the average solar generating time in Vietnam is around 4 hours.
- **Demonstrating a proof of concept** for solar-driven products: Farmers are reluctant to invest in solar power due to concerns about availability, lifespan, and reliability of solar products. Power cuts can pose a serious risk to production, as a short interruption of aeration can result in death of shrimp or fish. Therefore, it is important to demonstrate the performance and benefits of solar products to farmers through pilot projects or field trials.
- Exploring new **affordable battery solutions**: Batteries are a key component of solar power systems, especially for aquaculture farms that need continuous aeration. Therefore, it is recommended to conduct further research on developing cheaper and more durable battery solutions for aquaculture farms.

The study also presents two **business cases** for solar-powered aquaculture systems. One case was for a solar grid that could supply electricity to a 1000 m2 pond. The return on investment (ROI) for this case is estimated to be about 4.1 years for semi-intensive farming and 2.7 years for intensive farming. The other case is for a solar-driven paddle wheel that could improve water circulation and oxygenation in the pond. The cost of this device is 950 USD and the ROI was calculated to be 1,440 operating days, which can be suitable for extensive shrimp farming.

Introduction

Introduction

Vietnam holds the title of the world's largest producer and exporter of pangasius and ranks as the third largest producer of shrimp. Despite this achievement, the country faces obstacles due to climate change, which requires the industry to transition and adopt more sustainable practices. Groundwater quality is declining due to an increase in surface water contamination, which, combined with domestic and agricultural water extraction, creates mounting pressures. Renewable energy offers a viable solution to help the aquaculture sector develop while safeguarding the environment.

There are currently over 500,000 aquaculture farms in Vietnam, most of which are in remote areas. These rely (partially) on diesel generators, for farm operations The Southern Power Corporation reports that electricity demand from the aquaculture sector has been increasing by 10% annually. The lack of long-term planning and coordination between electric power suppliers and environmental management agencies has also hindered EVNSPC's (Vietnam's Southern Power Corporation) power supply to the aquaculture industry.

The shift from fossil diesel generators to solar-driven technology on aquaculture farms in Vietnam can significantly reduce CO2 emissions and support SDG 13's aim to combat climate change. However, the initial investment required for applying solar solutions to aquaculture farms is substantial, which can be a deterrent for traditional smallholder farmers.

Energy consumption in the aquaculture sector varies depending on factors such as farm size, production methods and the type of species cultured. By adopting renewable energy, the aquaculture sector in Vietnam can ease pressure on the national power grid and reduce emissions.

This study provides an overview of the energy usage demand from aquaculture farmers and available solar-driven aquaculture technology, highlighting potential gaps between demand and supply that offer opportunities for Dutch and Vietnamese aquaculture technology companies.

Till date, there has been little focus on practical solar implementation for smallholder and mid-size farmers (extensive & semi-intensive farming). This study provides important input for the existing program(s) on aquaculture farm management and the opportunities provided by solar to lower the farming footprint, reduce energy costs and improve production.

The Netherlands Enterprise Agency ('NEA') engaged Larive International and its Vietnamese representative OpenAsia and Rynan Aquaculture to conduct this study and present cost-effective solar-powered technologies that can be utilized in aquaculture, enabling Vietnamese farmers to operate without relying on conventional energy sources and diesel generators.

The study of solar-driven aquaculture technology is part of the embassy of the Netherlands in Hanoi's long-term nexus strategy, which aims to make aquaculture more sustainable in the Mekong Delta by using renewable energy sources. This would reduce the environmental impact of aquaculture production in Vietnam.

Project method

Desk research and interviews

The project team conducted this study through extensive desk research, interviews and field visits to study the different hypotheses within the research tree. In total, the team carried out N=25 interviews including N=6 field visits across both pangasius and shrimp farmers in Vietnam.

During the field visits, the team performed detailed case assessments to explore business case opportunities for extensive, semi-intensive and intensive shrimp and Pangasius farmers in the Mekong Delta. The project team was also able to identify and elaborate on N=2 business cases of solar investment projects during the field visits.

Next to the interviews with pangasius and shrimp farmers, the team conducted N=7 interviews with aquaculture equipment providers and solar energy solution providers in Vietnam. The aim of these interviews was to gather both market and technical insights into the available solutions regarding solar-driven aquaculture equipment.

The team also conducted interviews with several Dutch stakeholders to explore the potential of solar energy in aquaculture as a collaborative venture between Vietnam and the Netherlands. The interviews provided insights into the current innovations and the future prospects of this emerging field.

Interview overview

Interviewees	
Farmers interviews N=25	Minh Nhat Solar Co. (VN)
Field visits N=6	ShrimpVet (VN)
HCP Pumps Vietnam (VN)	ACEN Energy (VN)
Energy Technology (VN)	Viqon B.V (NL)
FARMX.VN (VN)	Landing Aquaculture (NL)
NAYA Ltd. (VN)	ShrimpInsights (NL)

Farmer interactions

Interviews and field visits

This research involved interviewing 25 farmers as provided in the table on the right, who cultivate pangasius and shrimp in Vietnam. These farmers are classified into three categories based on their aquaculture methods: extensive, semi-intensive, and intensive. Each category has distinct features that characterize it.

(a) Extensive farms

Extensive farms are usually traditional family-run farms that are easy to manage and require minimum inputs. They range from 1 to 100 hectares of earthen ponds and are located in low-lying reservoirs, where the tide is used for farming practices. They typically produce pangasius and monodon shrimp, and have only one harvest per year, with the smallest output and energy demand.

(b) Semi-intensive farms

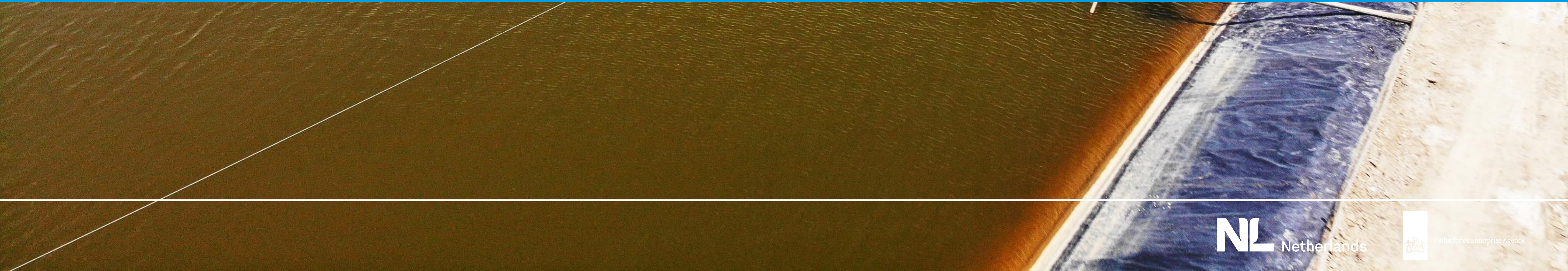
Semi-intensive farms do not use the tides and rely on electric pumps for their aquaculture practices. They require more inputs as the stocking density of the farms is higher than extensive farms. This also includes aeration for shrimp production and mud extraction for pangasius farming. They have an average farm size of 1 to 5 hectares of earthen ponds. They usually have two harvests per year, producing vannamei shrimp and pangasius fish.

(c) Intensive farms

Intensive farms require the most farming operating activities of the three categories. The stocking density of the aquaculture produce is the highest, requiring more water exchange and aeration in the ponds. The shrimps can survive in such crowded conditions thanks to technological innovation that pumps oxygen into the pond throughout the day. The ponds are typically plastic-lined and range from 0.1 to 1 hectare in size. There are three harvests per year, and this category only works for vannamei shrimp and pangasius fish. The output for the intensive farms is the highest of the three categories.

	Province	District	Farmer Name	Kind	Type
1	Bac Lieu	Nha Mat	Mr. Duong	Monodon	Extensive
2	Bac Lieu	Hoa Binh	Mr. Duoc	Monodon	Extensive
3	Vinh Long	Long Ho	Mr. Bay	Pangasius	Extensive
4	Vinh Long	Long Ho	Mr. Tan	Pangasius	Extensive
5	Ben Tre	Thoi Lai	Mrs. Phuong	Monodon	Extensive
6	Ben Tre	Thoi Lai	Mr. Long	Pangasius	Extensive
7	Ben Tre	Binh Dai	Thuy San	Pangasius	Extensive
8	Dong Nai	Nhon Trach	Mr. Tam	Vanamei	Semi intensive
9	Vinh Long	Long Ho	Mr. Viet	Pangasius	Semi intensive
10	Ben Tre	Binh Dai	Gia Hy farm	Vanamei	Semi intensive
11	Bac Lieu	Nha Mat	n/a	Vanamei	Semi intensive
12	Bac Lieu	Vinh Thanh	n/a	Vanamei	Semi intensive
13	Bac Lieu	Dong Hai	Mr. Hoang	Vanamei	Semi intensive
14	Bac Lieu	Dong Hai	Mr. Ngoc	Vanamei	Semi intensive
15	Dong Nai	Nhon Trach	Mr. Loc	Vanamei	Semi intensive
16	Ben Tre	Thoi Lai	Mr. Minh	Vanamei	Intensive
17	Ben Tre	Thoi Lai	Go Dang Company	Pangasius	Intensive
18	Ben Tre	Thoi Lai	Go Dang Company	Pangasius	Intensive
19	Ben Tre	Binh Dai	Mr. Tuan	Vanamei	Intensive
20	Bac Lieu	Hoa Binh	Mr. Ut Thuan	Vanamei	Intensive
21	Bac Lieu	Nha Mat	Mr. Khuynh	Vanamei	Intensive
22	Bac Lieu	Nha Mat	n/a	Vanamei	Intensive
23	Soc Trang	Hoa Tu	Mr. Hong	Pangasius	Intensive
24	Soc Trang	Hoa Tu	Mr. Chien	Vanamei	Intensive
25	An Giang	Phu Tan	Nguyen Van Nhan Company	Pangasius	Intensive

Energy demand aquaculture Vietnam



Electricity & solar energy in Vietnam

Electricity prices 80% higher during peak-hours

Electricity network

The Mekong Delta provinces have achieved almost universal access to the national grid since the Rural Electrification programme was launched in the 1990s. Moreover, the number of renewable energy projects that have started commercial operation has increased significantly. This ensures that the electricity supply in the region can meet the demand, including power demand from aquaculture farms.

Additionally, since 2016, EVN Southern Power Corporation (EVNSPS) has implemented projects to help shrimp farmers save electricity. The power company has offered free guidance and training on how to use farming equipment more energy-efficiently. This has helped to maintain the stability of the electricity grid in the region.

Electricity prices

The electricity prices in Vietnam vary depending on the type of end-user and time of usage. Whereas there are different energy prices for household, businesses, schools, hospitals and for industry. Electricity for business purposes is more expensive compared to electricity for household purposes. Therefore, some small-scale farmers use household electricity to reduce costs. For the purpose of this research, the business tariffs for electricity are considered. Regarding the time slots, there are three categories with different prices:

Time of Kwh Usage		Prices/KwH
Normal Hours	from 04:00 to 09:30, 11:30 to 17:00 and 20:00 to 22:00	0,10 USD
Idle Hours	from 22:00 to 04:00	0,06 USD
Peak Hours	from 09:30 to 11:30 and 17:00 to 20:00	0,18 USD

Electricity & solar energy in Vietnam

25-fold solar capacity increase since 2019

Solar energy in Vietnam

Vietnam leads the solar energy market in Southeast Asia, with an impressive capacity of 17.6 GW in 2021. This is far ahead of Indonesia, the second-largest market in the region, with a capacity of 3.9 GW in the same year. Vietnam's solar capacity grew by more than 25 times since 2019, when the capacity was only 0.7 GW. This achievement was driven by generous incentives for rooftop solar installations, such as a feed-in tariff that guaranteed a fixed price for 20 years for selling excess power to the grid (elaborated upon on slide 14).

Solar energy companies in Vietnam.

Several large companies are involved in the solar sector, various solutions and services. These include:

- TTC Energy, a subsidiary of the Vietnamese conglomerate TTC Group. This company provides rooftop solar solutions and other renewable energy services to households and businesses. It also operates several solar farms across the country, with a total capacity of over 300 MWp.
- CP Energy, a joint venture between Australia's CP Group and Vietnam's Petrovietnam, established in 2022. The company focuses on developing and operating renewable energy projects in Vietnam, such as solar. It has invested in a 100 MWp solar power plant in Ninh Thuan province, which is expected to generate about 164 GWh of electricity per year.
- RY Solar, a Vietnamese company that specializes in designing, installing, and operating solar power systems for various applications. RY Solar offers both off-grid and grid-connected solar solutions for residential, commercial, industrial, and agricultural customers. It has completed more than 500 projects nationwide, with a total installed capacity of over 50 MWp.

Investment cost of solar energy.

Solar energy is a source of power that can reduce electricity costs significantly over the long term. However, installing a solar system requires an upfront investment in Capex that will pay off gradually. The average cost of a solar system is about 547 USD per kilowatt peak (kWp), the maximum power output under ideal conditions.

Incentives and motivation for solar energy

Rise in solar panel projects before 2021 after implementation of government incentive; stopped when incentive expired

Government incentive for solar investment

- With Vietnam facing an increase in energy demand with a forecasted growth of 10% annually, the State issued mechanisms in 2017 and 2020 to encourage investments of solar projects in Vietnam. These are the so-called Feed-in-Tariffs (FiT), where people/companies received money for supplying solar energy to the State grid.

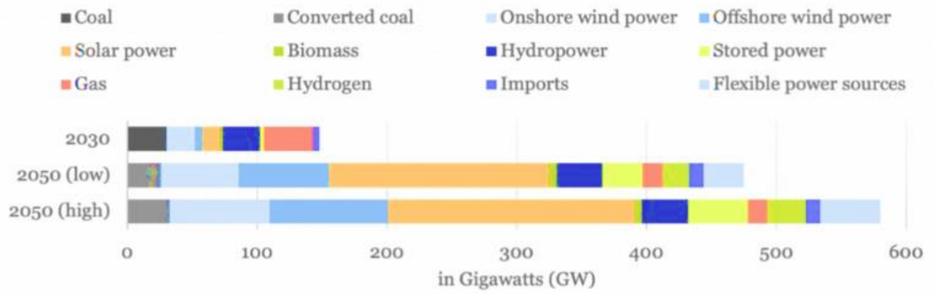
The 2 Feed-in-Tariffs mechanisms on solar power projects

Types	VND/kWh	USD/kWh
Decision 11/2017 (expired on 30/6/19)		
Solar	2,086	0.0935
Decision 13/2020 (excluding in Ninh Thuan province, expired on 31/12/20)		
Floating solar	1,783	0.0769
Ground mounted solar	1,644	0.0709
Rooftop solar	1,943	0.0838

- The FiT was applicable for solar projects which (i) achieve COD before 31/12/20 (Decision 13), (ii) with a capacity not exceeding 1MW and (iii) connected to EVN's grid and sold to them. The term of a PPA (for both grid-connected and rooftop solar projects) shall be 20 years from the COD.
- Based on the above FiT, ROI was estimated to be 5-6 years if 100% capacity is reached. The attractive FiT consequently lead to a spurt in solar projects were grid-connected and most was classified as rooftop solar.
- However, after Decision 13/2020 expiration, EVN stopped buying from solar projects with COD after the expired date. Furthermore, EVN is not committed on the purchased capacity. In practice, they occasionally cut down on the electrical output during the peak sun hours of current grid-connected projects.
- Farmers with existing grid-supply contract are guaranteed a revenue stream, farmers that aspire to invest in solar capacity no longer have this guarantee as they cannot sell back to the grid. The presence of a strong business case will determine whether investments will continue to grow.

- The "National Power Development Plan for the period 2021-2030, with a vision to 2050" (PDP 8) have been approved in May 2023. It provides outlines the future of power production and distribution in Vietnam.

National Power Development Plan for the period 2021-2030, vision to 2050



- According to the plan, Vietnam aims to develop (without capacity limitation) self-produced and self-consumption rooftop solar power. It is expected by 2030, 50% of office buildings and 50% of household consume self-produced solar power.
- Thus, after the approval of PDP8, grid-connected solar power projects are no longer prioritized for development promotion as before. Instead, the priority will be to promote the development of self-produced and self-consumption rooftop solar power.

- After expiration of the Feed-in-Tariff incentives it is no longer attractive to invest in large solar projects supplying directly to the grid. Since, the opportunity lies in solar investments to become self-sufficient solar powered (power for own usage).

Aquaculture farm energy usage

Aeration techniques during nighttime are key contributors to on farm energy demand.

Aquaculture is the farming of aquatic organisms, in Vietnam mainly pangasius and shrimp. Energy use is an important factor in the business model of aquaculture farmers, as it affects both production costs and environmental impacts. The energy demand of an aquaculture farm depends on the level of intensity at which the organisms are produced. There are four categories of intensity: (a) extensive, (b) semi-intensive, (c) intensive and (d) super-intensive. Extensive farms require a minimum amount of energy, while super-intensive farms require the most. Energy is used for various equipment on the farm, such as aerators, water pumps, feeders, monitoring equipment and mud pumps for pangasius farming. The amount and type of equipment used on the farm also vary according to the intensity level.

Among all the equipment, aerators are the most energy-consuming devices on aquaculture farms. They account for 80% to 90% of the total energy consumption on the farm. Aerators are used to increase the oxygen content of the water by creating bubbles or splashing water. They are essential for maintaining water quality and organism health in aquaculture ponds. Different types of aerators have different efficiencies and costs. Common types include paddlewheel aerators, vertical pump aerators, diffused aeration systems and propeller-aspirator-pump aerators. The choice of aerator depends on the pond size, depth, shape and species cultured.

The energy use of aerators differs between shrimp and pangasius farms. Pangasius are a hardy species that require less oxygen for their growth. Therefore, they can be produced without aerators in some cases, depending on the stocking density of the fish. Shrimp, on the other hand, require a lot of oxygen to survive in the ponds. Especially at night, when algae consume oxygen in the dark and in lower temperatures, shrimp need more oxygen than during the day. Around 80% of the aeration time is consumed at night and only 20% during the day. However, this also depends on the feeding time, as shrimp and fish require more oxygen when being fed.

The electricity source is another important aspect of aquaculture operations. A reliable and affordable electricity source is essential for running aerators and other equipment on the farm. Power blackouts can be fatal for the organisms in the ponds, as they can cause oxygen depletion and suffocation. In Vietnam, where most of the aquaculture farms are located, grid electricity is widely available and relatively cheap. The prices of grid electricity are 0.10 USD for industry and 0.08 USD for household. On parts of the farm where grid electricity is not available, diesel generators are commonly used.

Given the availability and low prices of grid electricity in Vietnam, investing in solar solutions is optional or most aquaculture farms. However, in some provinces such as Kien Gian, where grid electricity is less available and reliable, solar energy may be an opportunity for reducing diesel consumption and greenhouse gas emissions. Solar panels can be installed on land or floating on water to capture sunlight and convert it into electricity, used to power aerators, pumps and other equipment on the farm.

Energy demanding practices/equipment shrimp farming

Calculating the case

According to data gathered in interviews and desk research, the most energy-consuming practices in aquaculture are the aerators. They account for 80% to 90% of the energy consumption. However, the pumping systems are not used continuously at aquaculture farms. The experts verify that the pumps typically run for two hours a day.

In Vietnam, the most common aerators are floating paddle wheels. These usually have a power of 1 HP or 2 HP. Putting this into usage context, 1 Horsepower (HP) is approximately 0.75 kWh and means that a 1 HP device can lift a mass of 33,000 pounds (~15,000 kg) for 1 foot (0.33 meter) within one minute. In aquaculture, this implies that a paddle wheel of 1 HP can move 15,000 kg of water mass within one minute.

When farmers have to calculate the equipment necessary for their production, they commonly work with the following parameters:

- 1.5 HP is required for 1 MT of stocking density.
- Production cycle of shrimp is 120 days.
- Aeration schedule is 16 hours per day.
- Pumping schedule is 2 hours per day.

Using these parameters, the energy consumption for shrimp production in 1,000 m2 ponds is calculated for semi-intensive and intensive farming methods.

Semi-intensive

- Product cycles: 2 per year
- Stocking density: 7 MT per 1,000 m2

Intensive

- Product cycles: 3 per year
- Stocking density: 10 MT per 1,000 m2

Equipment	Specification	kWh	kWh per day	kWh per cycle	Cost per cycle
Paddle wheel	1 hp	0,75 kWh	12 kWh	1.440 kWh	USD 144
Paddle wheel	2 hp	1,5 kWh	24 kWh	2.880 kWh	USD 288
Pump 30T	3 HP	2,2 kWh	4,4 kWh	528 kWh	USD 52,8
Pump 50T	5 HP	3,7 kWh	7,4 kWh	888 kWh	USD 88,8

Energy Demands – Shrimp farms

Energy demand per shrimp reduces when stocking densities increase.

Semi-Intensive shrimp farms

For comparison purposes, a pond of 1000 m2 is detailed in this example:

Production details
Stocking density: 7 MT
Min required HP: 10,5 HP
Amount of Aerators: 6 aerators (2 HP)
Amount of Pumps 1 Pump (5 HP)

Cycles: 2 cycles
Days in Operation: 240 days

Required demand
Daily required kWh Aerators: 144 kWh
Daily required kWh Pumps: 14.8 kWh
Total kWh: 158.8 kWh

Daily energy cost: 15,88 USD
Cycle energy cost: 1,905,6 USD
Total energy cost 2 cycles: 3.811,2 USD

Shrimp Production
Output per cycle: 7 MT
Price per MT Vannamei: 5.600 USD

Revenu per cycle: 39.200 USD
Revenu per year: 78.400 USD

Intensive shrimp farming

For comparison purposes, a pond of 1000 m2 is detailed in this example:

Production Details
Stocking density: 10 MT
Required HP: 15 HP
Amount of Aerators: 8 aerators (2 HP)
Amount of Pumps 1 Pump (5 HP)

Cycles: 3 cycles
Days in Operation: 360 days

Required demand
Daily required kWh Aerators: 192 kWh
Daily required kWh Pumps: 14,8 kWh
Total kWh: 206,8 kWh

Daily energy cost: 20,68 USD
Cycle energy cost: 2481,6 USD
Total energy cost 3 cycles: 7.444,8 USD

Shrimp production
Output per cycle: 10 MT
Price per MT Vannamei: 5.600 USD

Revenu per cycle: 56.000 USD
Revenu per year: 168.000 USD

Solar solutions

Solar-driven aquaculture solution providers

3 types of solution providers accessible to Vietnamese farmers.

The project team conducted interviews with aquaculture equipment suppliers to assess the market potential for solar driven solutions in aquaculture. The research team found that this market is still in its infancy stage, mainly due to the difficulties of battery storage at night and the high initial investment cost. Saltwater corrosion of the solar equipment is another practical challenge for application of solar at aquaculture farms.

We identified three types of solar solutions providers in aquaculture: Chinese technology, EU-solar equipment, and Vietnamese custom-made solar solutions.

Chinese equipment: Some Chinese companies integrate solar panels with aquaculture equipment, such as aerators and pumps. Examples of these companies are Ecowaterchina, Aquaculture Systems Technology Co. Ltd, Jntech Renewable Energy Co. Ltd, and Taizhou Qianmei Machine Co. Ltd. Their products can be purchased online through platforms like Alibaba.com. The price of the Chinese aerators ranges from 900 to 1,100 USD.

EU-solar equipment: In Europe, there are also companies that offer solar-driven aquaculture products, especially in the UK. For instance, Solar Aeration Systems and Fishkit Ltd provide solar-driven aerators. The EU-manufactured solutions (paddle wheels) are more expensive and cost around 3,150 USD. They also have aerators that pump oxygen into the water for 1,250 USD. From the Netherlands, no solution providers focused on solar driven aquaculture equipment appeared in the research.

Vietnamese custom-made solar solutions: In Kien Gang, Vietnam, there are cases that farmers create their own solar solutions by procuring solar panels, batteries, inverters, and controllers, and applying them to paddle wheels. They buy the solar equipment from companies like Minh Nhat Solar and install it themselves. A typical custom-made solar solution costs around 950 USD, including:

Equipment	Typical market Price
Paddle Wheel	300 USD
3x Solar panels (300 watt)	150 USD
Solar charger controller 12V	200 USD
2x Battery 12V 75Ah	150 USD
Motor 2 HP	150 USD
Total	950 USD

(Solar) Aquaculture solution providers

Interviewed companies

HCP Pumps Vietnam

Pump supplier

Solar equipment: ✗

- Express concern regarding cost and efficiency of solar application on their pump products , which not used consistency.
- Remain neutral to include into product portfolio due to limited opinion on solar applications.

FARMX.VN

Paddle wheelers, aerator, aquaculture feeder

Solar equipment: ✗

- Emphasize that solar-powered feeding machine without battery storage are not efficient enough to ensure continuous operation

Minh Nhat Solar Co.

Distributor of low-capacity solar power systems

Solar equipment: ✓

- Solar panels >200 kWp
- Solar Energy charger
- Battery 12v
- 1 – 2 HP motor

RYNAN Aquaculture

Blue Green Algae Control floating Device and Shrimp pond monitoring station.

Solar equipment: ✓

- SAK300 algaesonic which blocks algae's light and nutrient access via low-power coherent ultrasonic vibrations.
- Monitoring system model M3067SA

Note: Equipment is not yet commercialized.

Energy Technology

Paddle wheeler, Aerator

Solar equipment: ✗

- Concern that saltwater can cause damage to the solar panels, rapidly reduce its efficiency and be a cost burden instead.

Case studies energy consumption aquaculture

Conclusions solar-driven aquaculture solutions case studies

Overall

- The most applied solar-driven aquaculture solution is solar (rooftop) panels. None of the 25 farmers interviews applied other solar-driven solutions (e.g. solar powered paddle wheels).
- Most farms with solar panels are intensive farms owning to their high energy demand and ability to invest. The main investment rational is to receive an additional revenue stream by selling the solar energy to the State. Rational is not to become solar-powered farm.
- Extensive/semi-intensive farms invest in solar panels in case their (remote) location lacks grid connection/ grid is unstable.
- Solar energy can only be sold to the grid in case the panels were in operation before 2021 (with a contract for 20 years). Companies receive USD 0.08 per kWh.
- Solar project installed after 2021 cannot sell back to the grid.
- Shrimp farming is more energy demanding as compared to fish farming. This is due to the farming complexity and the nature of shrimps.
- Shrimp peak energy demand is at night: 80% of the energy is consumed during the night as oxygen levels in water drop. For fish farming energy demand is around 50% during nighttime. This amplifies the need for energy storage solutions (battery). Given the costs and lifespan of batteries, this is (still) considered a limiting factor hampering the application of solar.
- Solar investments become more feasible in case farms can increase their day-time energy demand.
- Semi-intensive shrimp farms have higher energy demand as compared to extensive farms. However, the demand is inconsistent as they may stop farming when market price decrease significantly. The inconsistency further lower farmer's ability and willingness to invest in solar.

Shrimp farms

Extensive

- Species: Monodon
- Low energy demand
- Energy costs: 19% of revenue

Solar-based farming: Not viable due to low day-time energy demand and insufficient means and incentives to invest.

Semi-intensive

- Species: Vannamei
- Low and inconsistent energy demand with peak at night
- Energy costs: 9.6 % of revenue

Solar based farming: Minimum day-time energy demand. Business case only feasible with proper solar energy storage capacity (battery). Current battery solutions available are not feasible for semi-intensive farms due to high prices and short lifespans.

Intensive

- Species: Vannamei
- Intense and consistent energy demand
- Energy costs: 1.7% of revenue without solar, 0.34% of revenue with income stream from solar.

Business case is feasible in case investments in energy storage are made and/or when solar energy is sold to government (only when installed prior to 2021) or an energy demanding company near the farm location.

Pangasius farms

Extensive & semi-intensive

- Low energy demand
- Energy costs: ¬1.7% of revenue

Solar-based farming: As energy demand is significantly lower as compared to shrimp farming demand, a business case for solar investments is not viable.

Intensive

- Consistent energy demand
- Energy consumption during daytime accounts for 50% of total consumption.
- Energy costs: 1% of revenue without solar and 0.5% with income stream from solar.

Business case is feasible in case capacity of solar energy, without battery, can be utilized in farming activities.

Case study 1: Extensive shrimp farm

Low energy usage mainly at nighttime from stable energy grid causes lack of motivation from farmer and missing business case

Case 1	Extensive Monodon shrimp farm Mr. Duoc
Location	Nha Mat, Bac Lieu province
Farm	Extensive Monodon, 0.2 ha water surface, 4 ponds, 2 employees
Stocking	15-20 heads/m2
Output	1.5 harvest/year – 0.15 MT/harvest
Cycle time	7-8 months
Purchasing channels	Local suppliers and agents.
Energy usage	a) Lightning & household activities b) Paddle wheel; operating for 10 hr/day (2 hr daytime, 8 hr nighttime)
Energy source	National grid
Energy costs	USD 125/month
Revenue	USD 5,200/harvest/pond – USD 8,420/MT
Growth ambitions	Aim to maintain same output level
Willingness & ability to invest	Farmer is aware of solar energy and its implications. Farm is located next to major solar and wind projects. However, given their low energy consumption and costs, the farmer lacks motivation and interest to invest in solar. Additionally, the farmer lacks the capability to finance the investment in solar. In case financial support would be available, the farmer is willing to consider solar solutions.

Revenue vs energy costs

Revenue/year: USD 7,800

Revenue/month: USD 650
Energy cost: 19% of revenue
Monthly revenue after energy costs: USD 525

Case study 2: Semi-intensive shrimp farm

Battery is crucial for a business case, however short lifespan and high battery prices make investments unattractive

Case 2	Semi-intensive Vannamei shrimp farm – Gia Hy
Location	Binh Dai, Ben Tre province
Farm	Semi-intensive Vannamei, 0.6 ha water surface, 4 ponds, 6 employees
Stocking	200 heads/m2
Output	2 harvest/year – 28 MT/harvest
Cycle time	4 - 5 months
Purchasing channels	Local suppliers and agents.
Energy usage	a) Lightning & household activities b) Paddles (4 per pond) c) Oxygen aerator (1 per pond) d) Feeding machine (1 per pond)
Energy source	National grid (single-phase), 2HP diesel engine and diesel power generator as the single-phase electricity is not stable.
Energy costs	Electricity: USD 760/month, Diesel: 1,800/month
Revenue	USD 160,000/harvest for the whole farm – USD 5,700/MT
Growth ambitions	Apply greenhouse farming systems to move towards intensive farming and reduce spread of diseases.
Willingness & ability to invest	Willing to invest in solar as the 1-phase power supply does not meet usage demand and diesel is expensive. Currently use 20% of all energy during daytime, and 80% during the night (paddles & aerators), making solar storage capacity crucial. A storage system (e.g. battery) will double the solar panel investment costs. Current available solutions have short lifespan (3-5 years). Owner will only invest when the price of batteries decrease, and their lifespan increases.

Revenue vs energy costs

Revenue/year: USD 320,000
Revenue/month: USD 26,667
Energy costs: 9.6% of revenue
Monthly revenue after energy costs: USD 24,107

Case study 3: Intensive shrimp farm (with solar implementation)

Investment in solar energy using 50 kWp capacity for farm and 70 kWp capacity as additional revenue stream

Case 3	Intensive Vannamei shrimp farm Mr Khuynh
Location	Nha Mat, Bac Lieu province
Farm	Intensive Vannamei, 0.4 ha water surface, 2 ponds, 5 employees
Stocking	300 – 400 heads/m2
Output	3 harvest/year – 32 MT/harvest
Cycle time	Months
Purchasing channels	Local suppliers
Energy usage	a) Lightning & household activities b) Paddles (4 per pond operating 16hr/day) c) Oxygen aerator (1 per pond 24hr/day) d) Feeding machine (1 per pond)
Energy source	50 kWp solar energy (~6,000 kWh/month/ USD 600/month), national grid (3-phase), diesel engine.
Energy costs	Solar energy: free. Grid Electricity: USD 760/month. Farm earns 630/month from supplying solar energy (installed capacity of 70 kWp) to grid. Leaving USD 130/month on energy bill. Diesel: 25/month
Revenue	USD 182,000/harvest – USD 5,683/MT
Growth ambitions	Exploring diversification in intensive Pangasius farming
Willingness & ability to invest	Invested in solar system in 2020 (see next slide). By using day-time solar energy at the farm and sell the excess day-time solar energy to the grid the farm reduced its electricity costs by 83%. Does not have a battery; make use of grid energy at night.

Revenue vs energy costs

Revenue/year: USD 546,000

Revenue/month: USD 45,500

Revenue/month from electricity sales to grid: USD 630

Energy costs without solar project: USD 1,385

Realized energy costs per month (minus 50 kWh solar): USD 785

Energy bill month: USD 155

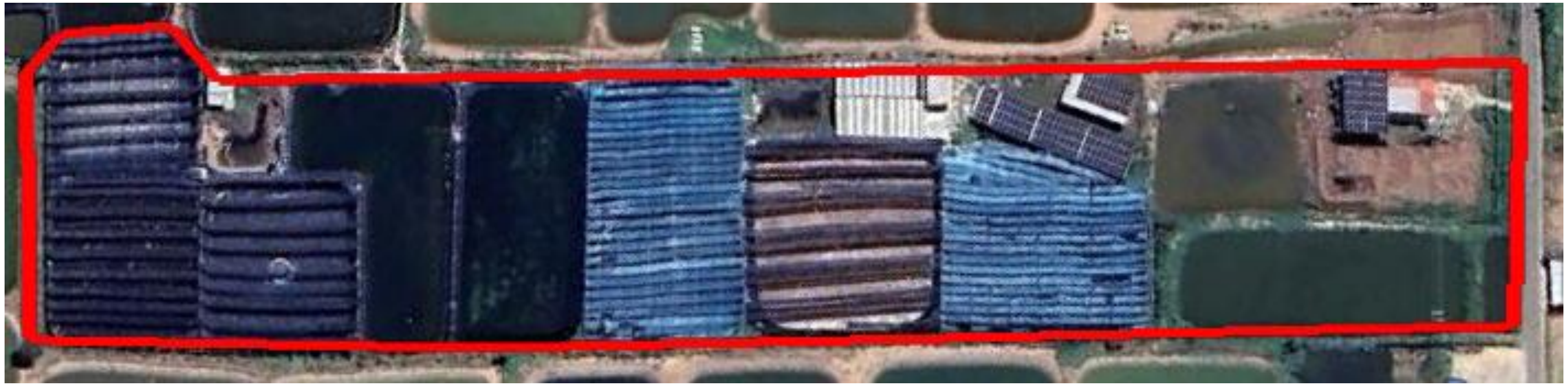
Energy bill: USD 0.34% of revenue

Monthly revenue after energy costs: USD 44,715

Case study 3: Intensive shrimp farm (with solar implementation)

Solar project installed in Mr. Khuynh farm

Case 3: Solar installation Mr Khuynh's farm	
Year in operation	Before 2021
Design capacity	120kWp; 50kWP for farm 70kWp to sell to grid
Total initial investment	USD 67,000 USD 47,000 for 70kWp grid sell capacity USD 20,000 for 50 kWp for farm usage
Revenue	USD 630/month from sales to grid Using 50 kWp on farm saves ~USD 600/month
PPA price	USD 0.08
On revenue	Maximum USD 40 - 45/day; On average USD 20-25/day
Financing	50% bank loan - The purpose of loan is for shrimp farming
Return on investment	Grid- sell capacity: 6.2 years Total capacity: 4.5 years



Case study 4: Semi-intensive Pangasius farm

Insignificant electricity usage at farm level with incidental peaks

Case 1	Semi-intensive pangasius farm Mr. Viet
Location	Long Ho, Vinh Long province
Farm	Semi-intensive, 0.2 ha water surface, 1 pond, 2 employees
Stocking	20-30 heads/m2
Output	1 harvest/year – 40 MT/harvest
Cycle time	10-11 months
Purchasing channels	Local suppliers
Energy usage	a) Lightning & household activities b) Water pumping (electricity; only occasionally when tidal is not sufficient for water discharge). c) Mud Extractor (diesel)
Energy source	National grid and diesel
Energy costs	USD 60/month
Revenue	USD 40,500/harvest – USD 1,000/MT
Growth ambitions	Increase output
Willingness & ability to invest	No interest in investment as electricity consumption is low.

Revenue vs energy costs

Revenue year: USD 40,500
Revenue month: USD 3,375
Energy costs: 1.7% of revenue
Monthly revenue after energy costs: USD 3,315

Case study 5: Semi-intensive Pangasius farm

Ponds at same water level as Mekong River makes energy demanding pump redundant resulting in low energy usages

Case 2	Semi-intensive pangasius farm Go Dang Co.
Location	Binh Dai, Ben Tre province
Farm	Semi-intensive, 1.5 ha , 6 ponds, 7 employees
Stocking	30-40 heads/m2
Output	1 harvest/year – 42 MT/harvest
Cycle time	9-10 months
Purchasing channels	Local suppliers.
Energy usage	a) Lightning & household activities b) Mud Extractor (diesel)
Energy source	National grid (single phase) and diesel
Energy costs	USD 60/month
Revenue	USD 44,200/harvest for the whole farm – USD 1,052/MT
Willingness & ability to invest	Farm is located downstream of Mekong River, ponds are at same level as the river allowing for relatively easy water exchange. This keeps the energy demand low (no pumps required).

Revenue vs energy costs

Revenue year: USD 44,200
Revenue month: USD 3,683
Energy costs: 1.6% of revenue
Monthly revenue after energy costs: USD 3,623

Case study 6: Intensive Pangasius farm (with solar implementation)

1 MWp solar project installed as extra income stream, not to utilize in farming activities.

Case 3	Intensive pangasius farm Nguyen Van Nhan Co
Location	Phu Tan, An Giang province
Farm	Intensive, 95 - 100 ha water surface, 75 ponds
Stocking	>50 heads/m2
Output	1.2 harvest/year – 20,000 MT/harvest
Cycle time	9-10 months
Purchasing channels	Suppliers recommended by network
Energy usage	a) Lightning & household activities b) Water pumping (1 pump 3-36 HP/3 ha pond) c) Mud Extractor (diesel)
Energy source	National grid and diesel
Energy costs	USD 21,000/month
Revenue	USD 21,000,000/harvest for the whole farm – USD 1,050/MT
Growth ambitions	Improve farming efficiency
Willingness & ability to invest	Installed solar capacity of 1 MWp at the farm to generate additional income stream (USD 8,000 – 10,000 /month). 2 more solar project on site (both 1 MWp), belonging to partners.

Revenue vs energy costs

Revenue year: USD 25,200,000
Revenue month: USD 2,100,000
Energy costs: 1% of revenue
Revenue from sales to grid month: USD 8,000-10,000
Monthly revenue after energy costs: USD 2,079,000 + 8,000-10,000

Case study 6: Extensive Pangasius farm (with solar implementation)

Solar project installed at Nguyen Van Nhan Co. farm resulting in revenue stream of ~USD 8,000 - 10,000/ month

Solar installation farm Nguyen Van Nhan Co	
Year in operation	Before 2021
Design capacity	1MWp
Total initial investment	USD 589,350, no battery
Revenue	USD8,000- 10,000/month
PPA price	0.08
On revenue	Maximum USD330-350/day; Lowest USD 150-170/day (during rainy season)
Financing	Own capital
Return on investment	After 4.7 – 7 years

Recommendations

Opportunities solar-driven aquaculture solutions case studies

Shrimp farms

Extensive

- Species: Monodon
- Low energy demand

Opportunity: investment in low-capacity solar panel for household and lightning electricity demand. Investment costs are around USD 700. This solution cannot be used to power paddle wheels or aerators.

Semi-intensive

- Species: Vannamei
- Low and inconsistent energy demand with peak at night

Opportunity: Maximize day-time energy usage to create business case for solar without battery by adding value-addition activities to the farm operations. For example: Further processing, feed milling. Focus on solar-driven equipment solutions and less on panels.

Intensive

- Species: Vannamei
- Intense and consistent energy demand

Opportunity: Maximize day-time energy usage, invest in durable battery solutions.

Pangasius farms

Extensive & semi-intensive

- Low energy demand

Opportunity: investment in low-capacity solar panel for household and lightning electricity demand. Investment costs are around USD 700. This solution cannot be used to power paddle wheels or aerators.

Intensive

- Consistent energy demand

Opportunity: Maximize day-time energy usage, invest in durable battery solutions. Focus on solar-driven equipment solutions and less on panels.

Recommendations solar-driven aquaculture solutions

1. Target Shrimp Sector

As shrimp production is more energy demanding as compared to fish, the biggest impact can be made by focusing on energy shifts within the shrimp sector. Therefore, targeting the semi-intensive and intensive shrimp farms with a bankable business case for solar-driven solutions is recommended.

2. Shift from Night Operation to Day-Time

To better utilize solar-driven solutions, it is key for farmers to increase their daytime energy usage while lowering their nighttime usage. Therefore, training and demonstrations on aligning farming practices with solar energy usage is recommended.

3. Market Positioning and demonstrations

Solar energy from panels installed after 2021 cannot be sold to the state, energy consumption is high at night, and batteries are expensive, the attractiveness of (rooftop) solar panel investments is significantly reduced. However, this opens the door to boost investments in reliable, affordable solar-driven technology with battery storage (e.g. solar-powered paddle wheels or feeders). Investments in these products are still low, as availability and lifespan are being questioned. Proper market positioning and demonstrating proof of concepts of these products are recommended.

4. Proven Reliability

Reliable solar product guarantees are key to boost the uptake in Vietnam. Power cuts are severely putting production at risks (e.g. short aeration stops can result in dead of shrimp/fish), therefore reliability of the solar products should be proven. Focus on proof on concept is recommended to boost the uptake of solar-driven solutions.

5. Substituting diesel generators

As the prices of diesel are relatively high, it is recommended to focus on substituting diesel-using equipment with solar-driven solutions first. Afterwards focus should switch to substitute grid electricity- using equipment.

6. Affordable battery solutions

Since 2020 Vietnam does not have the option anymore of selling electricity back to the grid. Therefore, the electricity generated by solar panels cannot be stored and becomes unused if not consumed by farming operations. On the other hand, excess electricity cannot be stored for farming operations outside the solar generating hours. Currently, battery solutions are expensive and therefore not viable for solar solutions in combination with batteries. It is recommended to research the field of affordable battery solutions for aquaculture farmers in Vietnam.

7. Access to finance

A high initial investment in solar energy solutions is required for farmers to transition their farm to renewable energy sources. This is not feasible for the majority of extensive and semi-intensive aquaculture farmers. Therefore, it is advisable to explore the opportunities for access to finance for solar solutions for this target group, enabling them to invest in renewable energy solutions for their farms.

8. Eel farming opportunities

The research has focused on pangasius and shrimp farming, where the opportunities for solar energy solutions for pangasius farming are limited. However, at the AQUA conference in Aquaculture Vietnam 2023, solar opportunities for eel farming were discussed. Therefore, it is recommended to further explore the potential of solar-driven solutions for eel farming.

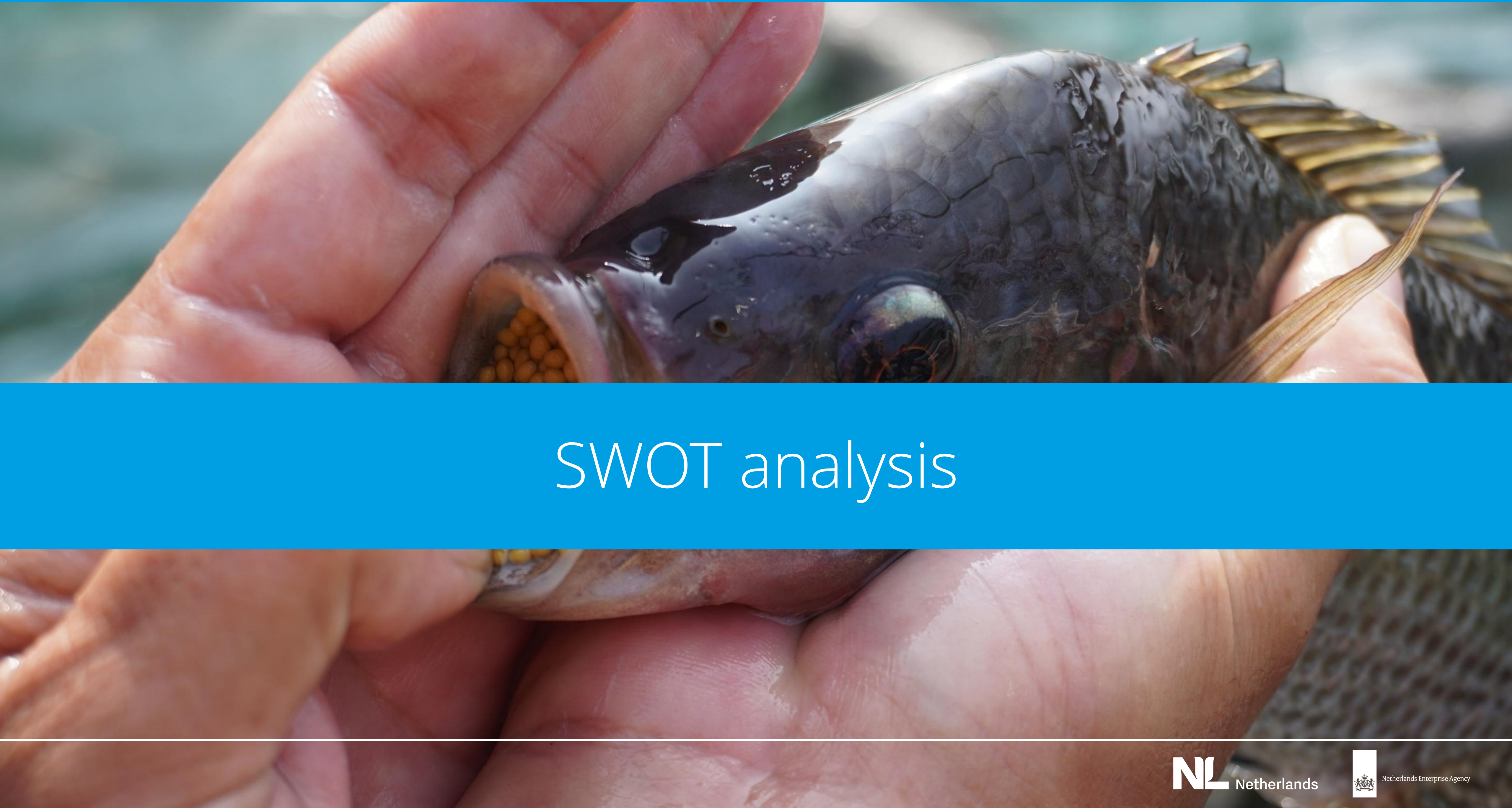
Recommendations NL - VN matchmaking

According to interviews with ShrimpInsights, Landing Aquaculture and Viqon, there are no solutions offered from the Netherlands for small to mid-scale farm equipment in the aquaculture sector. This was also confirmed by the desk research that aimed to identify opportunities for matchmaking between Vietnamese and Dutch companies on the topic of solar-driven aquaculture equipment.

However, there seems to be potential for matchmaking on larger solar projects at aquaculture farms. Independent Energy, a Netherlands-based company, has experience in setting up a complete solar system for aquaculture farms. A possible opportunity is to establish a demonstration farm that showcases a solar-driven system including batteries for backup power. Additionally, the idle solar energy could be used to power cooling systems that could benefit not only the aquaculture farm, but also the surrounding farmers.

To ensure the success of the solar energy-driven demonstration farm, training on the accompanying farm practices should be provided to the farmers as well. For example, a training module on shifting farm practices from night-time to day-time could be developed with the help of Dutch aquaculture expertise.

Another area of potential matchmaking is the financing of solar-driven energy solutions for aquaculture farmers. Access to finance from the Netherlands could help extensive and semi-intensive farmers make the initial investment in solar energy for their farms.



SWOT analysis

SWOT analysis - investment in solar-driven aquaculture solutions

Potential business case is present under the right conditions.

Strengths

- High level of awareness about solar energy.
- Large scale solar panel project install base.
- Sustainable growth: solar-powered aquaculture solutions are in line with sustainable development goals.
- Continuous innovations are making solar solutions more efficient and affordable.
- Solar energy applications are in line with the national Vietnamese strategy to achieve net-zero carbon emissions by 2050.

Weaknesses

- Need for batteries to store electricity for nighttime usage is limiting investments by the shrimp and aquaculture sectors.
- Inconsistent farming activities extensive & semi-intensive farmers. Farms are vulnerable to short term market price fluctuation. They often stop farming for several months when the market price decrease significantly. This will have a significant impact on the energy demand and capacity utilized from solar.
- High energy demand during nighttime.
- The high risks involved in aquaculture farming results in lower long-term farm investment by extensive and semi-intensive farmers.
- Extensive and semi-intensive farmers need to pre-finance all farming inputs at the beginning of the cycle. Long cycle times cause farmers to be reluctant towards big investments, even if it potentially could result in savings in the long-run.
- Currently solar solutions in Vietnam only generate energy 4 to 5 hours a day.
- Less solar energy available during the 3 months of the rain season.

Opportunities

- Affordable battery solutions to guarantee stable electricity during nighttime.
- Align energy usage with solar peak hours.
- Add value-adding daytime energy demanding activities to farm operations to increase revenue and make use of solar power.
- Focus on proof of concept for solar-driven products and techniques vs investments in solar panels.
- Offer solar solutions with a business case even without governmental incentive (as solar energy cannot be sold to the State grid anymore).
- Offering stable solar-driven solutions to replace expensive diesel solutions. This requires the solar energy to be extremely reliable, stable and available at nighttime.
- Offer household solar solutions for extensive farmers as electricity demand for farming is limited.
- Focus on Kien Giang region, as grid connections of aquaculture farms are not widely available.

Threats

- Solar solutions are competing with stable and affordable grid energy accessible in almost 100% of the Mekong Delta. Therefore, low motivation amongst farmers to switch.
- Long lifespan of solar solutions should be guaranteed.
- Impact of floating solar solutions on water temperature and lightning. Correct water temperatures are key for farm performance any impact lowering or increasing the temperature can be harmful.
- Ensuring proper system operation and maintenance.
- Solar solutions are targets for theft at aquaculture farms.
- Environmental impacts (e.g. smog) are lowering solar energy generating hours of solar solutions.
- Theft of solar-driven equipment at farm level.

Business cases

1. Solar Energy business case – Solar grid

The first business case presented is a solar grid structure that can be installed on a rooftop or a single structure next to the aquaculture ponds. This solar panel structure could provide a large surface area of solar panels that could generate power for the operations on the farm. The number of solar panels needed is calculated based on the size of the pond or ponds. Therefore, a business case is presented for the 1000m2 pond, which can be scaled up or down for aquaculture farms of different sizes.

A solar panel grid would have the advantage of generating solar power for all farm operations, but this would only apply to the time when solar energy can be generated, which is on average 4 hours per day. This average varies depending on the season, as there is less solar energy available during the rainy season than during the dry season. Considering the high demand for energy throughout the day, a hybrid system of solar and grid power is required for the aquaculture farms.

Currently, it is not possible to sell excess energy back to the grid, so all energy has to be utilized. Therefore, an affordable battery system to store solar power and use it outside of the peak hours would be recommended. However, such battery systems are not yet available.

Another challenge for adopting solar power at farm level is the high investment cost associated with the transition. This makes it difficult for many farmers to access finance and afford the initial capital expenditure.

Shrimp farming

With respect to the target group of this solar business case, the focus would mainly be on semi-intensive and intensive shrimp farms. This is because these farms have high energy requirements, stable demand for energy, and higher profitability. The solution would not be suitable for extensive farming, as these farmers commonly struggle with access to finance and have irregular operations, as the ponds are not always stocked. This would result in underutilization of the solar-generated energy for a large period during the year.

Pangasius farming

Regarding pangasius farming, we see that there is less energy use compared to shrimp farming. This makes the business case for solar driven aquaculture less attractive for pangasius farming. In particular, there is no business case for extensive and semi-intensive pangasius farming. For intensive pangasius farming, some activities such as water pumping and mud extraction can potentially be aligned with the times of solar generation, making use of the available energy. Alternatively, an affordable battery system for solar power would be an option for further research.

Considering the largest potential, the business case for semi-intensive and intensive shrimp farming is developed. This group accounts for ~ 90% of the total volume within the 4.3 billion USD worth industry.

1. Solar Energy business case – Solar grid

Solar driven aquaculture practices

The solar energy generating time within Vietnam ranges from 08:00 to 12:00. This implies that the kWp for solar panels in Vietnam 1 kWp, which equals 4 kWh per solar panel per day.

Timing	Prices
Normal Hours	0,10 USD
Idle Hours	0,06 USD
Peak Hours	0,18 USD

Solar investment cost

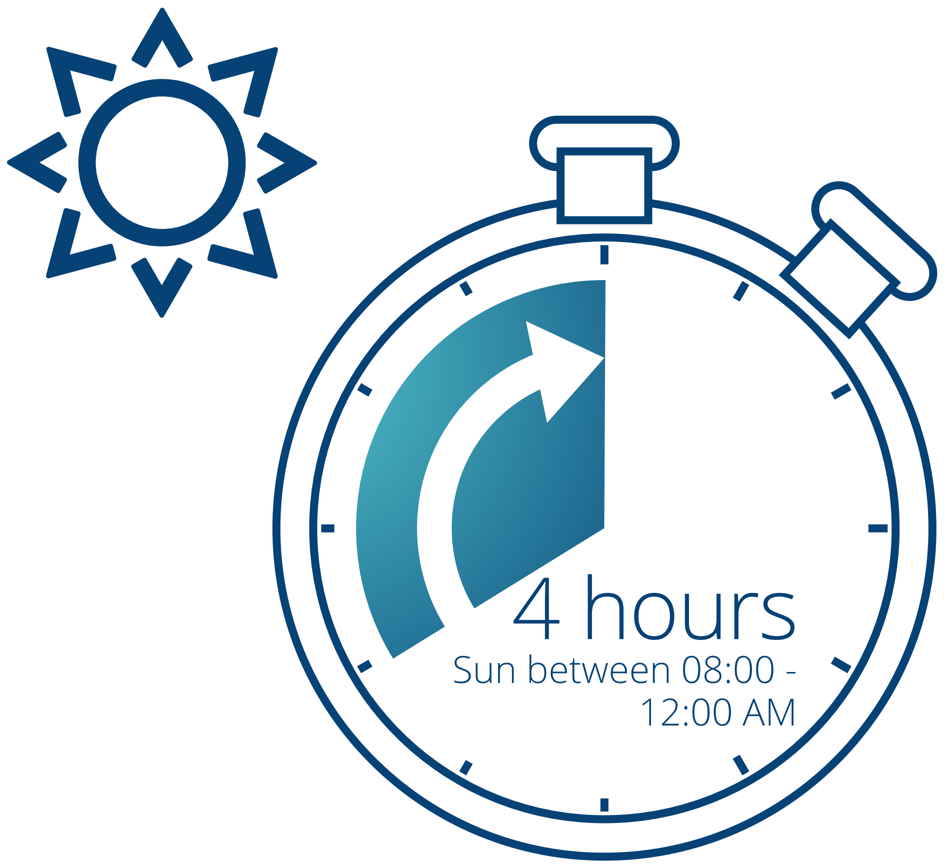
The average investment cost for 1 kWp of solar energy in Vietnam is approximately 547 USD

Cost of energy from 08:00 to 12:00

Normal hours:	from 08:00 to 09:30 and 11:30 to 12:00	0,1 USD
Peak hours:	from 09:30 to 11:30	0,18 USD
Average cost of 1 kWh from 08:00 to 12:00:		0,56 USD (potential saving)

Semi-Intensive – 1000 M2 pond	
Required kWh:	13,5 kWh
Required energy 4 hours:	54 kWh
Required kWp	13,5 kWp
Solar investment:	7.384,50 USD
Daily saving with solar (4 hours):	7,56 USD
Saving for 2 cycles:	1.814,40 USD
Return on Investment:	4,1 years

Intensive - 1000 M2 pond	
Required kWh:	18,75 kWh
Required energy 4 hours:	75 kWh
Required kWp	18,75 kWp
Solar investment:	10.256,25 USD
Daily saving with solar (4 hours):	10,75 USD
Saving for 3 cycles:	3.870,00 USD
Return on Investment:	2,7 years



2. Solar Energy business case– Solar driven paddle wheels

The second business case presented involves a solar-driven paddle wheel, which consists of a solar panel attached to a paddle wheel that can power the aeration of the aquaculture pond. This is an affordable option for aquaculture farmers as it requires a lower initial investment than a fixed solar energy structure.

This solar-driven solution also matches the irregular operation of the ponds, as the solar-driven paddle wheel can be turned on and off depending on when the ponds are stocked with shrimp or fish. This makes the solar-driven paddle wheel more flexible to use than permanent solar structures. The solar-driven paddle wheels have a small battery capacity, which allows them to run for an extra hour after the peak solar hours.

The target audience for this solar-driven paddle wheel are extensive and semi-intensive shrimp farmers, who need aeration for their aquaculture ponds. The extensive and semi-intensive pangasius farmers do not use aeration in their ponds, so the solar solution is not suitable for them. The intensive aquaculture farmers need more powerful aeration systems, so the solar solution is also not suitable for intensive aquaculture.

Since the solar-driven paddle wheel only operates for an average of 5 hours per day, it should also have a hybrid connection to the grid. This is necessary to ensure that the paddle wheel can run for the recommended 10 to 16 hours per day.

The solar-driven paddle wheel, in combination with adjusted farming practices such as feeding schedules during the daytime, can help optimize the farm operations and align them with the peak solar hours of the paddle wheels. This will create a profitable business case for the extensive and semi-intensive shrimp farmers.

Given the difficulty in access to finance for the extensive shrimp farmers, it is recommended to further explore the financing possibilities for extensive farmers to invest in these affordable solar solutions.

Solar Energy business case – Solar driven Aerator

Solar driven aerators

Given that aerators are contributing for 80 to 90% of the total energy cost at shrimp farms, the solar solutions for the paddle wheels for extensive and semi-intensive shrimp farms can be a viable business case. A business case for a 1 HP paddle solar driven aerator is presented.

Solar energy generating	
3 solar panels generating	0,9 kWh
3 solar panels generating (4 hours)	3,6 kWh

Required energy demand	
Required energy 1 HP aerator	0,75 kWh
Required energy 1 HP aerator (~5 hours)	3,75 kWh
Average energy cost 5 hours* 0,66 USD	0,66 USD

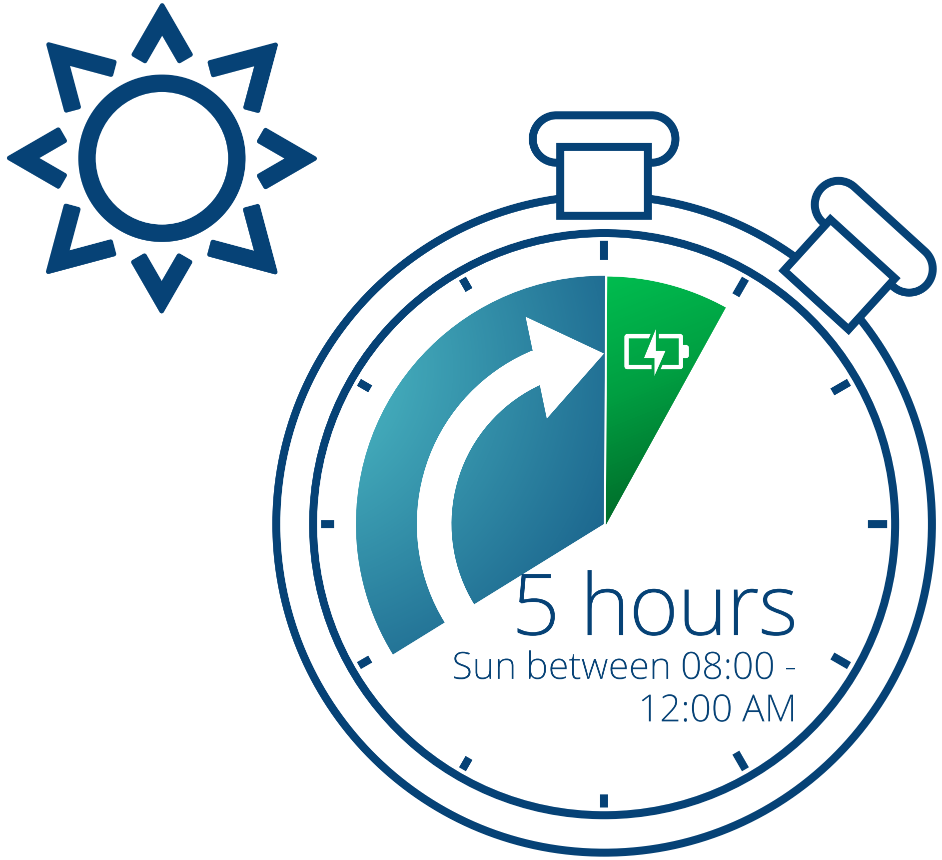
Investment	
Equipment investment	950 USD
Return on investment	1.440 operating days

Equipment	Price
Paddle Wheel	300 USD
3x Solar panels (300 watt)	150 USD
Solar charger controller 12V	200 USD
2x Battery 12V 75Ah	150 USD
Motor 2 HP	150 USD
Total	950 USD

Operating Time

The aeration schedule for extensive and semi-intensive systems is different. Extensive systems require 10 hours of aeration, while semi-intensive systems need 16 hours. However, the solar solutions cannot provide enough power for the full operation of the paddle wheels, so they also need a grid connection when the solar energy is low.

To make the best use of the solar energy at the farm level, some farming practices have to be adjusted to shift the energy demand more to the daytime rather than the nighttime. One way to do this is to change the feeding schedules.



Solar-driven aquaculture

Solar-driven aquaculture technology Vietnam - Netherlands

Netherlands Enterprise Agency

NL Netherlands

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