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Aquavoltaics Feasibility Assessment: Synergies of Solar PV Power Generation and Aquaculture Production

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Abstract: The negative effects of climate change have burdened humanity with the necessity of decarbonization by moving to clean and renewable sources of energy generation. While energy demand varies across the sectors, fisheries, including fishing and aquaculture, are among the most energy intensive processes in the food production industry. The synergistic opportunities for co-located aquaculture and renewable energy can thus provide a multifunctional use of space and resources, creating opportunities to meet the identified energy demands of a variety of aquaculture operations. This study has investigated a sustainable energy model for a small-scale shrimp farm in western Taiwan with synergies for the dual use of the water area for solar photovoltaic electricity generation and aquaculture. Based on the simulation results and SWOT analysis, recommendations have been made for the design and operation of a solar-powered aeration system for shrimp farms. The average monthly energy production of 32 MWh is attainable at the estimated canopy space on a carport by installing 896 solar modules on the proposed site, fully covering the power demand of the shrimp farm. These findings have significance for encouraging effective practices in deploying solar techniques in aquaculture and making them replicable in global settings.

Keywords: aquavoltaics; solar photovoltaic; power generation; shrimp farm

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1. Introduction

Among the many available sources of renewable energy, solar is clearly a promising option, and its market has seen outstanding growth in recent years [1]. The transition to renewable energy will require participation from the public and private sectors, as well as from citizens and landowners. Incorporating solar energy production into urban planning scenarios is thus essential as cities of the future become the centers of energy production and consumption. Several studies have previously integrated energy considerations into urban planning, with the primary objective of reducing the direct energy expenditures that are caused by land-use activities [2–4], confirming the importance of solar accessibility in the built environment.

With an expected annual growth rate of 13%, the International Energy Agency (IEA) estimates that photovoltaic (PV) technologies will supply around 33% of the projected increase in energy consumption by the year 2030 [5]. Even though PV technology is favored, owing to its compatibility, constructing a PV system in an urban setting is challenging. Cities block more sunlight than rural areas because of their high population density, and the abundance of buildings, roads, and trees in metropolitan areas may create intricate patterns of shade [6]. One possible way around this issue is identifying suitable roof surfaces for PV integration, which is an alternative with a market share of 40% in 2020 [7]. However, the installation of such systems in urban environments, particularly on vertical facades, is challenged by variables such as inter-building solar reflections and overshadowing effects [8,9], as well as energy- and climate-related challenges, such as high surface temperature [10] and the risk of fire [11]. The socio-cultural sensitivity impact and land ownership issues should also be considered [12–14]. Moreover, most roofs are not oriented or sloped in a way that maximizes the effectiveness of solar panels, and there is always the risk that adding solar panels would cause leaks by impeding water drainage. Therefore, identifying the potential of solar energy, the economic viability, and an appropriate tilt angle in a particular region should be carefully considered in order to enhance the generation capacity of solar energy [15].

Floating solar and agrivoltaics/aquavoltaics are other promising options that represent fast-growing, but still small, markets [16]. These methods allow for less land use for solar systems and, with proper design, can provide a number of benefits, such as reducing evaporation, providing shade to livestock, crops, or farmed fish, and, more importantly, providing clean electricity for small-scale applications [17]. As a result of society's continuing urbanization and the increased food demand in cities, urban aquaculture has become more popular in recent years [18] and it can relate to a variety of production areas, species involved, habitats, and production intensities. Aquaculture in Taiwan has been practiced for almost 400 years, and the country has a wide variety of culture target species, including milkfish [19].

Despite the misconception that aquaculture requires very little energy, the rapid productivity gains over the past several decades have forced aquaculture systems to rely increasingly on nonrenewable energy, mainly for their pumps and aerators, which are integral parts of an aquaculture setup.

Solar energy is one of the clean energy sources for aquaculture, and it is used to farm both freshwater and saltwater aquatic species in many regions of the world without relying on the main power grid [20,21].

Due to its low operational cost, extended life cycle, environmental compatibility, absence of CO_2 emissions, and low soil contamination, solar energy is increasingly being used in aquaculture today [22] for different purposes, including power production for aerators to oxygenate the water, feed dispensers, pumps, and water-heating systems. To keep the dissolved oxygen (DO) level in fishponds at an optimal level, Applebaum et al. [23] built an aeration system that used solar energy to power a paddle wheel. Prasetyaningsari et al. [24] developed an aeration system to provide power for aeration equipment in Indonesian fishponds. A 1 kW PV panel, eight batteries of 200 Ah, and a 0.2 kW inverter were utilized to power the system for both the ventilation and the lighting. Using solar energy as its primary power source, Liu et al. [25] created a device to manage the water quality in freshwater fishponds.

Although the concept of creating an elevated solar power system that allows aquacultural use underneath it has been discussed before, the dramatic cost reductions that PV technology has undergone over the past decade have put this application into a new perspective and have made economically viable solutions a real possibility [26–28].

Small-scale PV integration with fish farms is an emerging field that has not been well addressed. To that end, this work makes an effort to give a detailed analysis of a sustainable energy model for a small-scale shrimp farm. Based on the findings, recommendations are made for the design and operation of a solar-powered aeration system for shrimp farms in western Taiwan, which serves as a fishing center for the country. The findings of this study are expected to optimize DO levels in the shrimp ponds of small farmers, raise the quality and the output of the ponds, and lower the cost of electricity on the power grid.

2. Methodology

2.1. Site Description

The optimal site for a solar PV system depends on a number of criteria, including the amount of available solar irradiation, its proximity to the grid station, and the type of land use in the area. After a visual evaluation of various fish farms with regards to shadowing impact, a small-scale shrimp farm in western Tainan City, Qigu district, was selected (Figure 1). The Qigu area is well known for its many types of fish, shrimp, and other aquatic seafood, with fish farming being the principal profession of the residents. Table 1 summarizes the biophysical features of the shrimp farm under consideration here.

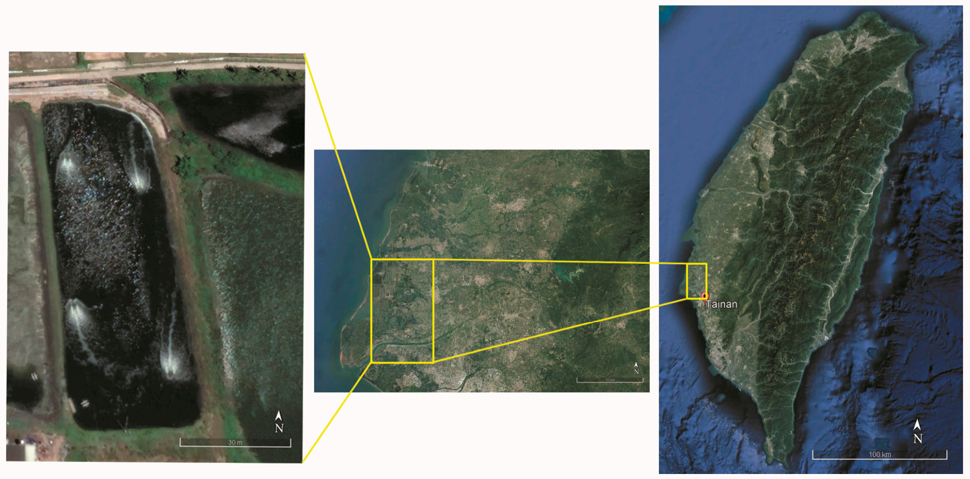

Figure 1. Geographical location of the studied fish farm in Qigu, Tainan, (Google Earth Pro 7.3.3.7786 (2021)).

Table 1. Biophysical characteristics of the shrimp farm.

Parameter	Value	Ref.
Surface area of the fish farm (m^2)	3450	[This study]
Water depth (m)	2.0	[This study]
Salinity (ppt)	15	[This study]
Average water temperature (°C)	25	[This study]
Average shrimp weight (g)	35	[This study]
Stocking density (shrimp/m^2)	200	[This study]
Water respiration rate ($mgL^{-1}h^{-1}$)	0.4	[29]
Sediment respiration rate ($mgL^{-1}h^{-1}$)	0.43	[29]
Chlorophyll-a concentration (mg/L)	0.15	[30]

2.2. Analysis

Helioscope software was used as a simulation and design tool for this study. The package includes a tool for estimating the shadows cast by structures such as towers, trees, and buildings. It also requires input data, such as plant capacity, solar panel information, inverter requirements, and PV panel information, to estimate energy production.

PV panels generate the most energy when they are mounted or positioned away from the sun [31,32]. The best strategy to maximize a PV array's energy production is to tilt it at the correct tilt angle. In order to obtain the best PV energy output, several tilt angles were assessed.

2.3. Climatic Conditions

South Taiwan (7920 km^2) experiences tropical weather, with year-round average temperatures of about 24 °C [33]. Sunlight is one of the most abundant natural resources in the country, since it is located in a subtropical area that is surrounded by ocean (Figure 2). Central

Taiwan is traversed by the Tropic of Cancer, hence there are many lengthy daylight hours and little sunlight deflection [34]. Taiwan's surface receives an estimated 1.71011 kW/h of solar energy per day [35].

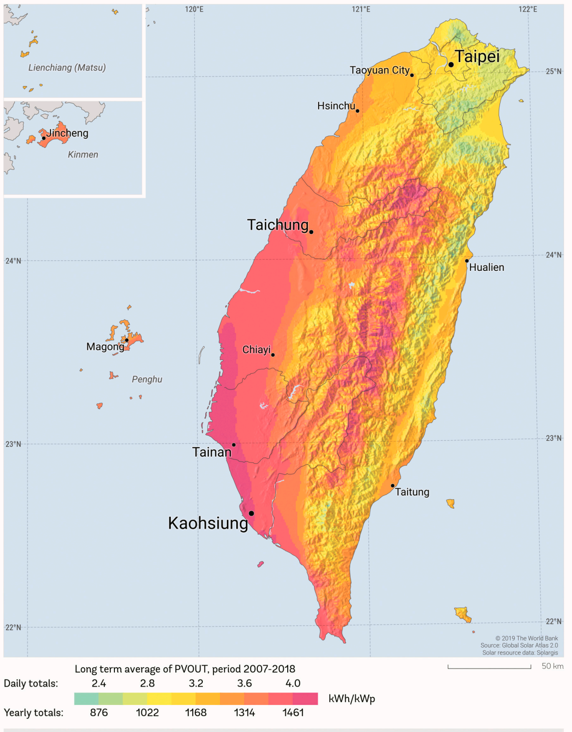

Figure 2. Photovoltaic power potential across Taiwan (© 2020 The World Bank, Source: Global Solar Atlas 2.0, Solar resource data: Solargis).

2.4. Solar Aquaculture Canopy

Electric aerators use around 80% of the energy needed for farming, followed by water pumping at 10%, and other uses at 10% [36]. Compared to other major aquaculture systems, the energy efficiency of marine shrimp aquaculture is exceptionally high, as assessed by the ratio of industrial energy input to food protein production [37]. Mechanical aeration systems that are driven by internal combustion engines or electric motors are commonly used in aquaculture ponds to regulate DO levels and distribute oxygen throughout the pond's water.

While aeration systems are commonly employed in shrimp farming due to their numerous advantages, they have significant operating expenses, particularly when it comes to the electricity that is necessary to operate the aerators. This is due to the fact that the aerators must run constantly during the 100-day production cycle of marine shrimp farming [37]. As a result, aeration systems should be adjusted in terms of their design and operation in order to enhance the energy management in aerated ponds [38].

Aeration System Design

The key components of the system at the shrimp farm are the ponds where the shrimp are held, solar panels, batteries, alkaline electrolyzers, the oxygen and hydrogen storage systems, micro-bubble-producing systems, water treatment systems, and the associated loads (Figure 3).

The typical three-month rearing cycle for white leg shrimp, which are raised extensively in the Qigu region, consists of the hatchery, the nursery, and the grow-out phases. The majority of the energy utilized throughout all three phases is accounted for by aeration (60%) and water pumping (20%).

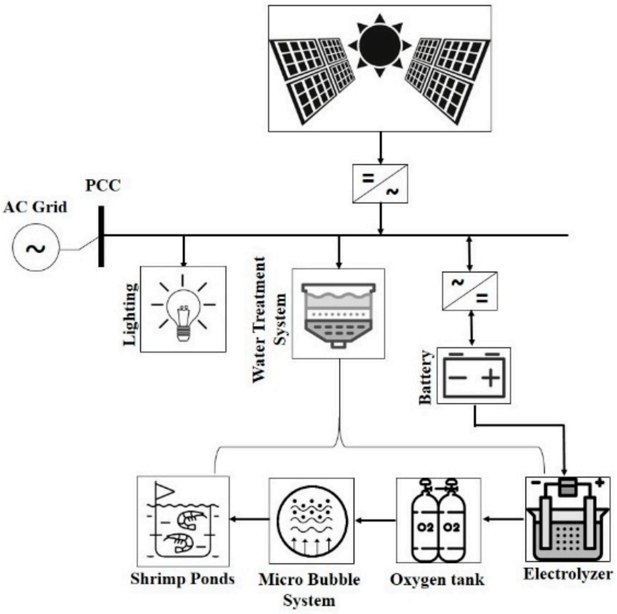

Figure 3. Solar-Energy-based model configuration for shrimp farms.

Long-lasting power outages can have a devastating effect on the output of a shrimp farm. Consequently, it is essential to properly design the solar energy system's size. To maximize efficiency, the PV panels, electrolyzers, batteries, and fuel cells at a shrimp farm must be sized in relation to the farm's total oxygen requirement. The following equation [29] depicts the total oxygen demand, which takes into account the respiration rates of the cultured organisms, water (phytoplankton), and sediment (decaying organic matter):

$$OD = ShR + WR + SR \tag{1}$$

where OD is the oxygen demand (mg O_2 L^{-1} h^{-1}), ShR is the shrimp respiration rate (mg O_2 L^{-1} h^{-1}), WR is the water respiration rate (mg O_2 L^{-1} h^{-1}), and SR is the sediment respiration rate (mg O_2 L^{-1} h^{-1}).

Oxygen is produced by electrolysis and stored in a tank before being pumped to the shrimp ponds. The aeration system's foundation is micro-bubble creation, which is employed for gas diffusion in the water. Due to the typical oxygen transfer efficiency of around 9%/m, this system has a high oxygenation efficiency. However, the amount of oxygen generated by the electrolyzer is practically greater than the whole amount of oxygen required by shrimp farms, matching the high input power required by the electrolyzer [39].

The amount of PV energy required for the aeration system, which includes component efficiencies such as micro-bubble generation (η_μ), the electrolyzer (η_e), the battery (η_b), the power converters (η_c), and the photovoltaic arrays (η_{pv}), is calculated using the total oxygenation system's efficiency as follows:

$$\eta = \eta_\mu \eta_e \eta_b \eta_c \eta_{pv} \tag{2}$$

The DO levels in shrimp ponds should be maintained at around 5 mg/L to promote the best possible growth conditions and prevent a sharp decrease in DO concentrations, especially during cloudy weather. The PV panels generate AC electricity during daylight hours. The water treatment system, and the other associated loads, at the shrimp farm are powered by the stable electricity, while the fluctuating electricity is stored in a battery and then sent directly to the alkaline electrolyzer, which produces oxygen [40].

The oxygen-rich tank's supply is pumped into the pond via a series of pipes built at the pond's base. The micro-bubbles used in the aeration system have much greater oxygen transfer efficiencies than larger bubbles [39].

2.5. SWOT Analysis

The strengths, weaknesses, opportunities, and threats analysis (SWOT) was developed initially for use in business [41]. SWOT analysis is a technique that can provide important information about the future viability of the investigated system by analyzing the strengths (S), weaknesses (W), opportunities (O), and threats (T) of a given situation [42]. Although SWOT analysis is used in many different contexts [43], it is most commonly used in the energy sector. Chen et al. [44] applied SWOT analysis to examine the renewable energy policies in three East Asian economies: Republic of Korea, Japan, and Taiwan. Lupu et al. [45] performed a SWOT analysis of Romania's solar energy potential and identified the important variables for its development. Using a SWOT analysis of the various forms of solar energy in the UAE, Salimi et al. [46] addressed the trends of solar energy production and consumption in the UAE and developed strategies as a result.

Digital libraries and databases such as IEEE Xplore, Google Scholar, Springer, Elsevier, and Multidisciplinary Digital Publishing Institute (MDPI) are typically searched using keywords to collect the relevant literature on the topic and to classify the literature in order to determine the topic's strengths, weaknesses, opportunities, and threats.

In addition to the conventional methods of collecting keyword data (searching digital libraries and publications), this study makes use of Google Trends, which is an open online infoveillance tool developed by Google™ that displays the relative popularity of different search terms in Google search results in real time. Google Trends has been widely used by the scientific community, not just for monitoring, but also for producing quick forecasts about a topic's future [47]. It measures users' web interest in a term (for example, "renewable energy") by returning a normalized number ranging from 0 to 100, known as the relative search volume, which is proportionate to the ratio of keyword-related searches to total web inquiries. The user may also limit the study to certain geographical locations (continents, states, regions, cities, and so on) during a set time period [48]. In the current study, the keywords of "solar farming", "aquaculture", "smart aquaculture", and "smart cities" were used for Google Trend analysis using worldwide and Taiwan mode from 10 October 2017 to 10 October 2022.

Two stages of SWOT analysis were completed. First, a list of contributors was compiled by a thorough examination of the relevant scholarly literature and Google Trends data. Within the framework of the SWOT analysis, these elements were properly categorized. Second, semi-structured interviews were conducted to further explore each aspect and pattern that had been identified. The communication with the interviewees was accomplished by telephone or videoconference. To provide a well-rounded and representative collection of interviews, a convenient sampling strategy was applied to select 54 participants from a wide range of sectors, including government, business, academia, and civil society. The participants were given the original list of criteria and asked to rate the importance of each item during the interviews. The final SWOT only included those variables that were rated as either significant or highly important.

3. Results and Discussion

3.1. Analysis of Solar Radiation

The monthly solar radiation and the averaged sunshine duration (h) of Tainan city have been depicted in Figure 4, confirming that southern Taiwan is an ideal place for solar panel installation.

3.2. Energy Consumption Profile of the Shrimp Farm

For the pacific white shrimp, the nursery and grow-out periods cover around 90 days. The shrimp larvae are first reared in the indoor nursery tank with bottom aeration. This phase requires around 20–30 days before the juvenile shrimp are transferred to the full-size grow-out pond. The grow-out pond must have constant surface and bottom aeration [49]. A single 3400 m^2 pond uses an average of 16 MWh/month of energy during the growing stage. Figure 5 shows the typical monthly pattern of electrical energy use.

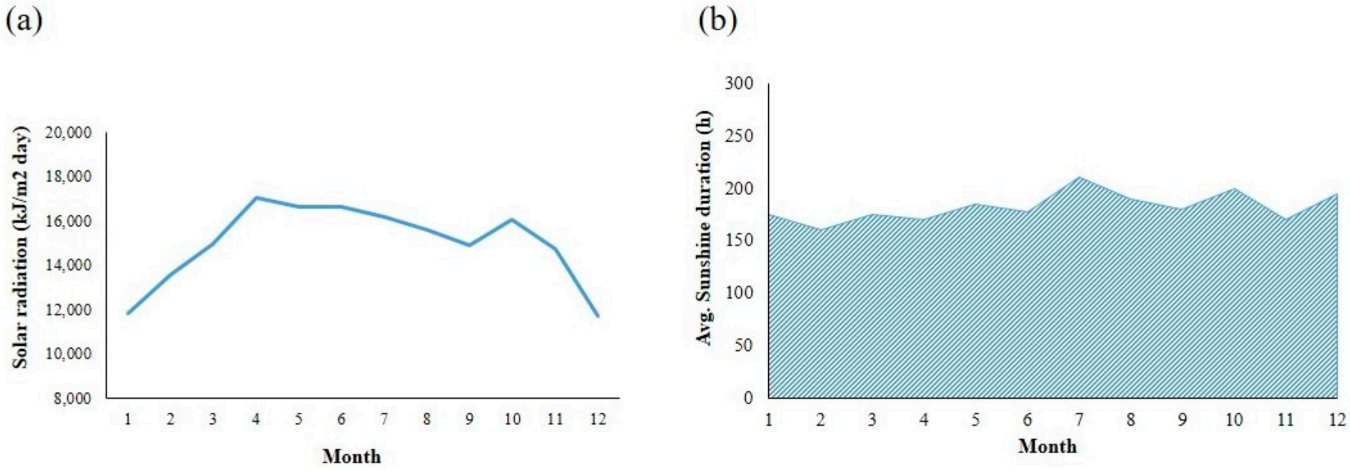

Figure 4. Monthly solar radiation (**a**) and averaged sunshine duration (**b**) of southwest of Taiwan.

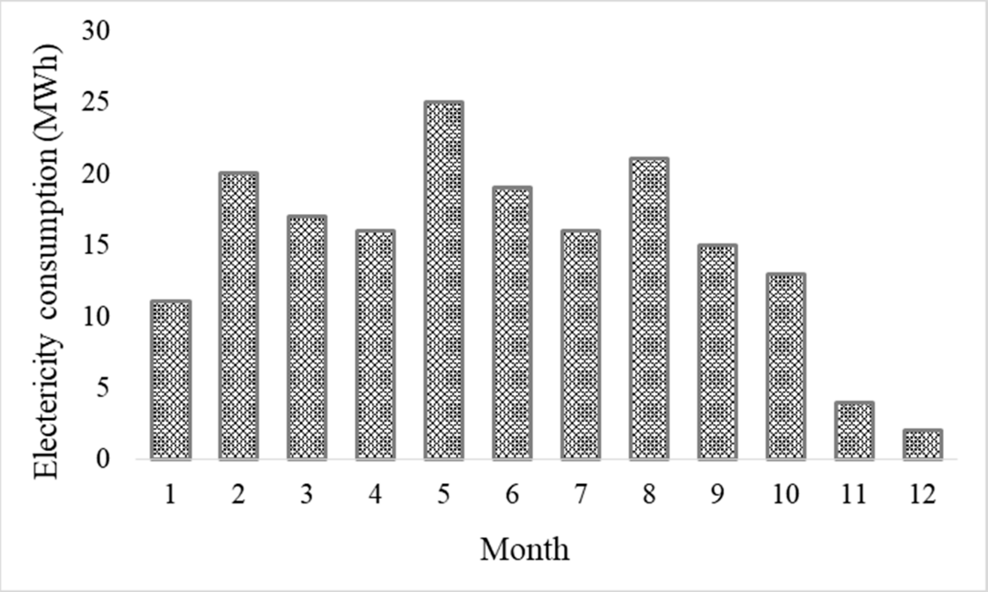

Figure 5. Monthly electricity consumption profile of the single shrimp farm.

3.3. Configuration of Photovoltaic (PV) Panel for the Shrimp Farm

The quantity of the electricity that is generated by a PV panel per hour is determined by a variety of parameters, including the intensity of the sun, the ambient temperature, the velocity of the wind, and the module's efficiency. The PV system's hourly output power can be estimated as follows [50]:

$$P_{\mathrm{PV}} = \eta_{\mathrm{PV,\,STC}} \cdot \left[1 + \frac{\mu}{\eta_{\mathrm{PV,STC}}} \cdot (T_a - T_{\mathrm{STC}}) + \frac{9.5 \cdot \mu \cdot (NOCT - 20) \cdot (1 - \eta_{\mathrm{PV.STC}})}{800 \cdot \eta_{\mathrm{PV,STC}} \cdot (5.7 + 3.8 \cdot \mathrm{v})} \cdot G_g \cdot A_{\mathrm{PV}} \cdot G_g \right] \quad (3)$$

where P_{PV} is the hourly power output from the PV system (W), $\eta_{\mathrm{PV,\,STC}}$ is the efficiency of the PV module in standard test conditions (STC) (%), μ is the temperature coefficient of the output power (%/°C), T_a is the ambient temperature (°C), T_{STC} is the standard test condition temperature (25 °C), v is the wind speed (m/s), $NOCT$ is the nominal operating cell temperature (°C), A_{PV} is the PV array area that is related to the array power peak (m^2), and G_g is the global solar radiation on the tilted surface (W/m^2). The PV module that has been considered in this study with technical specifications is presented in Table 2.

Table 2. Specifications of the selected PV module for the aquavoltaic system.

Parameter	**Value**
Standard test condition efficiency (%)	19
Temperature coefficient of open circuit (%/°C)	−0.30
Voltage at point of maximum power (V)	38.87
Standard test condition temperature (°C)	25
Nominal operation cell temperature (°C)	45 ± 2
Area of the module (m^2)	2.56
Maximum power (W_P)	305

3.4. Simulation Results for Aquavoltaic System

The amount of oxygen that is required to maintain life in the grow-out ponds with the biophysical qualities that are specified in Table 1 determines how effectively the electrolyzer will perform. The power consumption of the electrolyzer is governed by the oxygen losses that are caused by the organisms in the grow-out ponds, as well as the oxygen that is generated by photosynthesis in the ponds. As a result, the electrolyzer's electrical consumption varies during the day, peaking at night due to the drop in oxygen generated by photosynthesis (Figure 6).

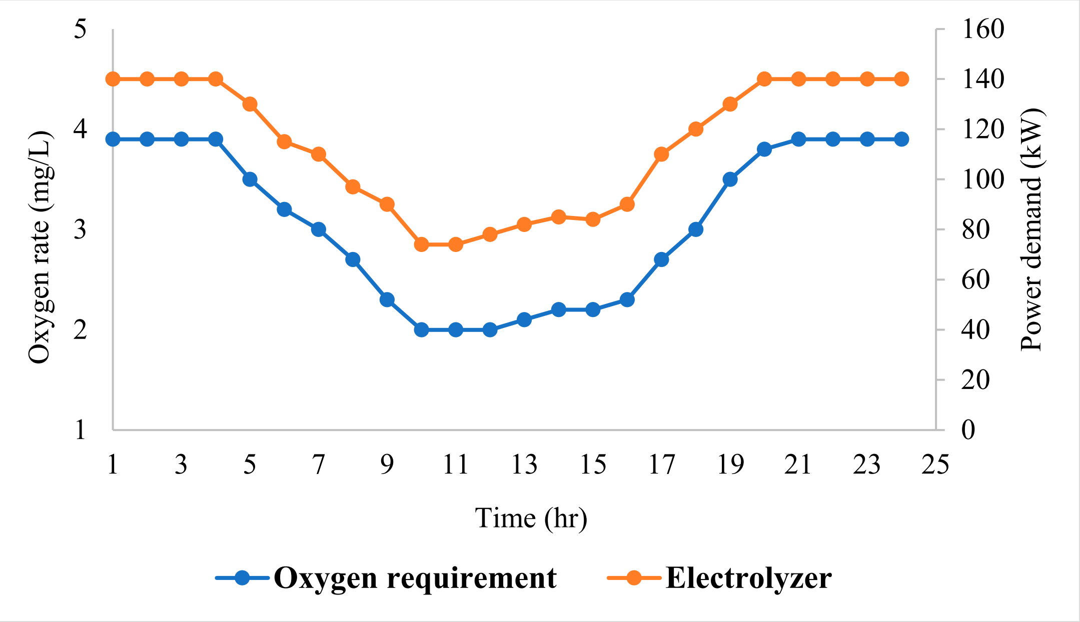

Figure 6. Hourly oxygen requirement and power demand at the shrimp farm with a base load of 1.2 mg/L.

The average monthly energy production of 32 MWh, (Figure 7a) is attainable at an estimated canopy space on a carport by installing 896 solar modules at a 180° azimuth angle facing south with 10° tilt angles, according to Helioscope, with July being the most energy efficient month of the year (Figure 7b).

3.5. SWOT Analysis of Aquavoltaics

To efficiently administer any innovative energy generated system, gathering society's perspectives is critical in order to gauge their attitudes toward the proposed system [51]. Since the objective of the SWOT analysis is to consider the internal and external factors, therefore maximizing the potential of the strengths and opportunities while minimizing the impact of the weaknesses and threats, a list of Google search terms that reveal the consumers' interest in adopting solar/PV panels in aquaculture activities was selected to further investigate the effect of the stakeholders or the experts who are involved in the strategy. Using Google Trends data for a certain location and time period, data on the search volume of the relevant phrases were collected in order to calculate the normalized proportion of searches. The values in the Google Trends statistics represent the search interest as a percentage of the peak search volume during the selected time period and area. In other words, a value of 100 indicates that the highest search volume occurred at this time in the specified location and time period, whereas a value of 0 indicates that the search term accounts for less than 1% of the peak search volume [52,53].

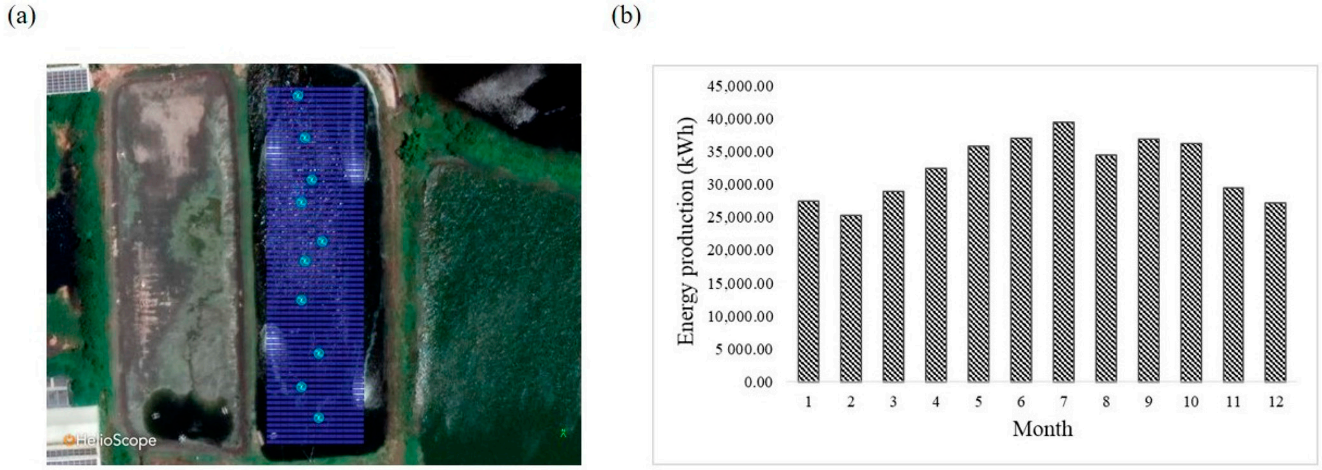

Figure 7. Mono-pitch farm canopy without shading effects at an optimum tilt of 10° (**a**) and the monthly energy production (kWh) of the study site (**b**).

The yearly variation of "solar photovoltaic" in the worldwide search and in Taiwan was plotted and has revealed a notable upward trend in both of the regions, as shown in Figure 8. Although they have similar trends, the solar PV web search in Taiwan is about five times less than that of the worldwide scale. The conflict in Ukraine may have served as a harsh wake-up call for governments to take action and lessen their reliance on Russian fossil fuels. It has increased the online search interest in renewable energy sources, notably solar PV, to lessen their dependency on Russian fossil fuels. Taiwan, on the other hand, showed a more cumulative web search in 2021, followed by a decreasing trend starting from 2022. This could be possibly due to the increase in the costs of raw materials and supply chain issues as a result of the pandemic. Moreover, solar power costs around USD 130/MWh in Taiwan compared to USD 40 or less in the United States [54]. Moreover, because solar has a cost premium of around 75% above traditional power sources, there is an urgent need to increase solar capacity while lowering the costs as rapidly as possible. As Taiwan adds more baseloads of renewable energy to the grid, these prices will have a significant impact on economic performance and public interest. Cost-cutting should thus be an especially important focus [54]. Furthermore, with rising tensions across the Taiwan Strait occurring around the summer of 2022, renewable infrastructures may encounter unprecedented interruption, which, given the highly concentrated supply chain, will almost certainly have global ramifications in the near future [55].

Based on literature reviews, and Google Trend analysis, different factors affecting aquavoltaics in Taiwan are classified in various categories in the SWOT analysis, as shown in Figure 9.

3.5.1. Strengths

There is great potential for solar farming in Taiwan because of the country's low latitude. As shown in Figure 4, the daily solar radiation in Taiwan typically ranges from 3 to 5 kWh/m^2. The solar radiation increases as the latitude decreases. The sun radiation in southern Taiwan is 1.2–1.5 times higher than in northern Taiwan [56], making it an ideal site for solar panel installations.

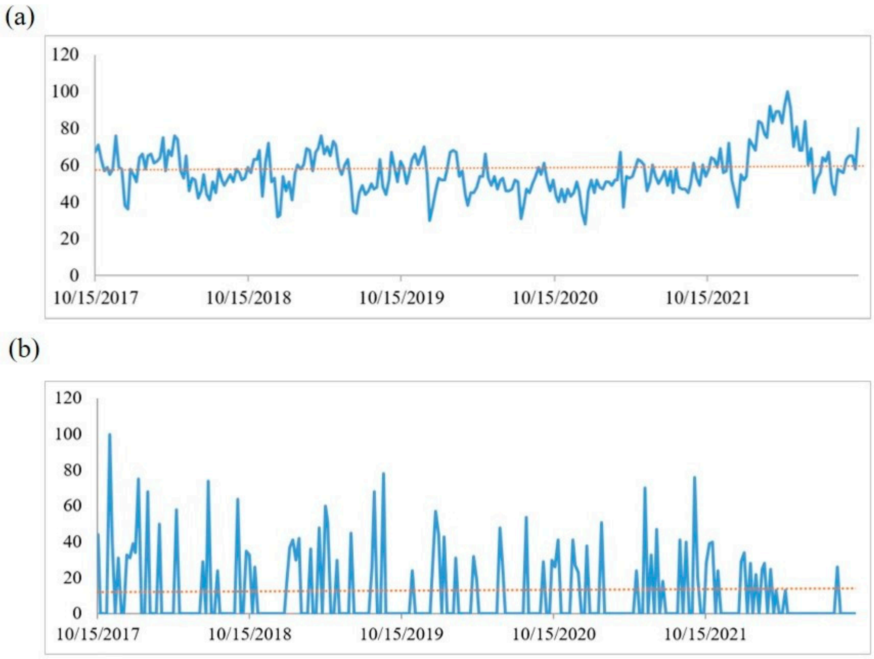

Figure 8. Time series of solar photovoltaic count in (**a**) worldwide and (**b**) Taiwan.

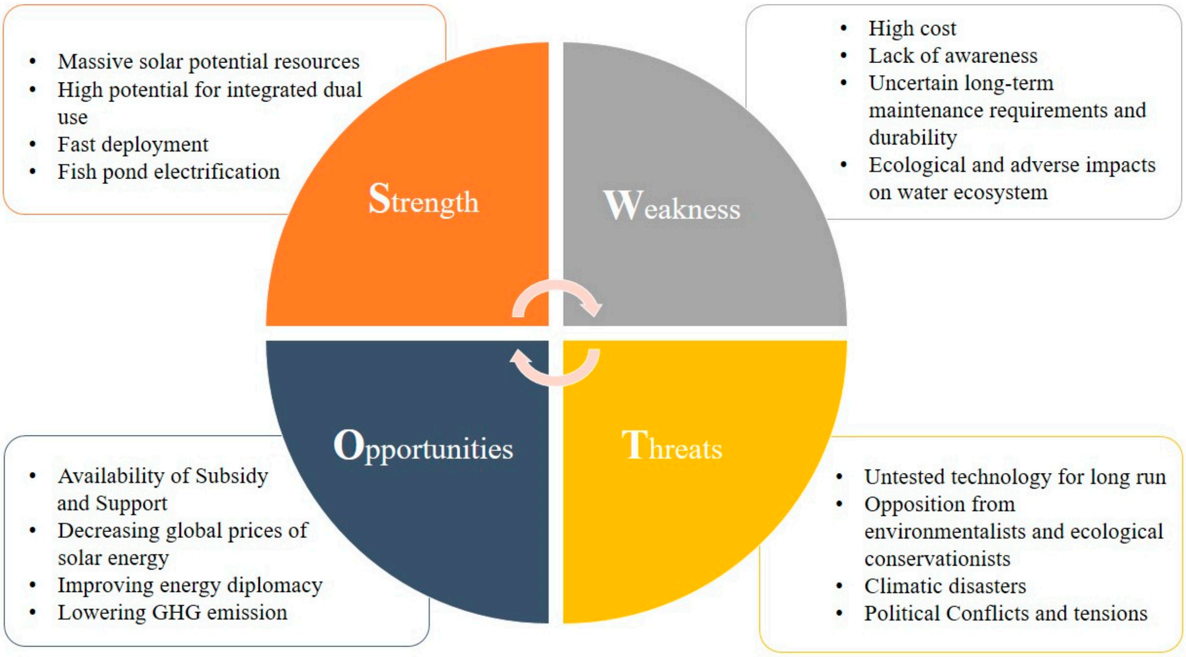

Figure 9. Factors identified in the SWOT (strength, weakness, opportunity, and threat) analysis for aquavoltaics.

Since Taiwan has a high population density, dual-use strategies with promising applications in agriculture and aquaculture are becoming increasingly important. When solar PV technology is integrated with aquaculture, synergies are created, as aquaculture may benefit from the module shadowing effects at peak temperatures and the solar panels' efficiency values are increased due to the proximity to cold water [57].

To encourage PV growth in Taiwan, the government has suggested a number of initiatives. Research and development (R&D) activities have been ramped up in order to lower prices and guarantee PV preparedness for rapid deployment, with legislative and regulatory backing for technological advancements in the medium and long term. The government has proposed several plans to stimulate PV development in Taiwan [58]. An increase in renewable energy from around 5% in 2016 to 20% by 2025 was announced by the government [59]. It is anticipated that 20 GW of PV and 4.2 GW of wind power (WP) will be made available by 2025 [60,61] as part of the two-year solar PV promotion plan and the four-year WP promotion plan, respectively. In addition, the government of Taiwan has instituted the highest feed-in tariff (FIT) in the world in an effort to attract international investors. Compared to the UK's 15-year FIT (74.75 and 57.50 GBP/MWh), following tendering in 2017 and 2019, respectively, and Germany's 12-year FIT [62], Taiwan's FIT is not only higher but is also applicable for a longer period.

Renewable energy sources may be used in a variety of ways as an energy source for aquaculture because of the advantages that have been outlined above. Aerators, water pumps, automated dispensers, and other devices may all be operated with the help of solar energy, which is particularly useful for power generation, as well as illuminating fish and shrimp farms [63].

3.5.2. Weaknesses

When combined with the development of social and economic infrastructure, solar-based power generation has the potential to electrify aquaculture, assuring economic prosperity [64]. High capital and installation costs are, however, one of the obstacles to the widespread adoption of solar-based power generation [65,66]. According to the interviews with the relevant companies in the off-grid solar industry, the large initial investment that is required by low-income households is a major obstacle to the widespread adoption of their technology. Aquavoltaic projects have uncertain economic feasibility because of the difficulty in estimating the costs and capital that are needed.

Even if the coexistence of fisheries and electricity is a trend, education is still necessary to convince people that an energy transition is necessary. The coordination between the solar industry, the landlord, and the fisherman is crucial, since most of the fish farms that the fishermen maintain are leased. For example, in Qigu, the land price has increased since the PV installation companies have paid 10 times the rent to the owner of the fishing ponds. As a result of the increased land rent and a lack of fishponds for aquaculture farmers, some pond owners are considering canceling their contracts with the original rented farmers and renting to PV installers [67].

Furthermore, the cooperation of farmers is crucial to the success of aquavoltaic projects. Due to a lack of education, experience, and infrastructure, some fish farm operators are hesitant about installing solar panels, despite the fact that doing so might greatly benefit their businesses [68]. Aquavoltaic systems are still a very new technology, thus there has not been much progress on any significant projects in the area. Since the actual impacts of the installation of solar panels on aquaculture are unknown, the cost of such a project is more than that of a standard solar project, and the risk is higher as well. Indeed, data on the effectiveness, the durability, and the reliability of the dynamic aquavoltaic system are lacking at the present time.

Nevertheless, potential environmental damage is a major shortcoming of aquavoltaics. PV installations may alter the region's environment, since most fish farms are situated in coastal locations that are known for their rich ecosystems and industrial features. Aquaculture practices may need to be modified as a result of the widespread installation of PV systems in rural regions, which will affect the surrounding landscape and change the habitats of the local animals and water birds. In the absence of clear communication, local opposition is also likely to grow [69].

There may be ecological, economic, political, and social conflicts as a result of the shift to renewable energy, according to Sovacool's political ecology framework [70]. Over the last decade, researchers have paid more attention to the environmental effects of utility-scale renewable energy (USRE) development, particularly when USRE expansion conflicts with animal habitat protection [71–73].

Qigu for instance, where the majority of the fishery and electricity symbiosis projects are located, is a nationally protected and ecologically sensitive wetland that is home to numerous endangered terrestrial and marine species, including black-faced spoonbills, peregrine falcons, oriental white storks, and Kishi velvet shrimp [74]. Bird mortality, biodiversity and habitat loss, and aesthetic consequences are only some of the environmental concerns that were emphasized by Dhar et al. [75]. Preventing further damage to the environment and keeping the ecosystem in good condition afterward is of primary importance. New insights into how such tradeoffs might be resolved by long-term commitments and the variables influencing the locals' willingness to support ecological conservation could be derived through studying the residents' preferences for ecological conservation, aquaculture fisheries, and renewable energy development [74].

3.5.3. Opportunities

In many countries, nonprofits and other organizations can qualify for grants and tax breaks from the government. To encourage the use of solar energy instead of fossil fuels, the government of Taiwan has also established incentive programs. In addition to FIT, legislation was passed in 2009 in response to the Kyoto Protocol that aimed to encourage and support the growth of renewable energy in order to accelerate the transition to a low-carbon energy economy [76]. The private sector has generated energy since the 1980s, but they can only sell it to Tai-power at the average electricity rate. The private sector incentives have increased with the new FIT institution, receiving a larger profit margin than 2009's average power cost. This measure has also created a 20-year contract between the government's Tai-power company and renewable energy providers. This deal assures Tai-power's purchasing of renewable-generated electricity at a predetermined price [77]. As the price of solar panels continues to drop worldwide, and tax incentives continue to increase, more farmers are making the switch to solar power.

One of the less well-known advantages of pursuing renewable energy is the chance to strengthen energy diplomacy, which may help a nation to deal with the geopolitical repercussions of an energy crisis. Energy diplomacy refers to the practice of conducting international relations with the goals of securing reliable energy supplies and expanding commercial possibilities in the energy industry [78]. Increased energy diversity and resilience is the result of energy trading, which in turn promotes greater competition, security, and prosperity in the energy sector by allowing for exports and investment, decreasing emissions, boosting economies, and providing market opportunities for innovative energy technologies and supplies [79].

The energy diplomacy between Singapore and the United Arab Emirates, for instance, led to discussions about improving bilateral relations and increasing collaboration in areas including commerce, investment, tourism, and food security, despite Singapore's lack of domestic energy production [80]. Obviously, each of the aforementioned opportunities has the potential to greatly cut global carbon emissions. While the electricity-intensive solar PV manufacturing industry today is mostly supported by fossil fuels, solar panels only need to be operational for 4–8 months to offset the emissions that were generated during their production. The typical lifespan of a solar panel of 25 years or more, making this payback period seem rather short in comparison [81].

3.5.4. Threats

The successful implementation of renewable energy technology requires not only capitalizing on the many advantages but also taking into account the risks or threats that are involved and developing ways to mitigate them. Recent policy uncertainties and instabilities confronting the global economy have raised doubts about renewable energy's ability to bring about long-term economic growth [82]. For instance, when energy costs are unstable, profit-maximizing businesses may delay or abandon investment plans, leading to a fall in total production [83]. In addition, questions remain about how well these technologies will be received by the general public. When new technologies are actually installed, there may be limited social approval due to potential concerns or uncertainties [84].

Promoting renewable energy sources is challenging due to their potential adverse effects on the environment. Over the past decade, there has been increasing discussion over the environmental effects of USRE growth, especially when it conflicts with the efforts to protect wildlife habitats [72,73,85–87].

In addition, inequitable planning and decision making can result in the privatization of public assets [70]; for example, the salt pan wetlands in Taiwan that were once owned by the government were converted into private solar farms, depriving the locals of the financial benefits that had previously accrued by them [88].

Bird habitat overlaps with several fishponds, salt pans, farms, and reservoirs in Taiwan. One of the biggest challenges to the country's energy transition, particularly in the southwest, is that the Budai Wetlands in Chiayi, which are Taiwan's greatest wintering area for migrating waterbirds, has already had solar panels constructed upon it, disrupting the wildlife habitat. In Taiwan, many fishponds, salt pans, farms, and reservoirs overlap with bird habitat [89]. Wetland ecosystems and aquaculture land are particularly vulnerable to the harmful effects of the government's recent solar development expansion. That concern is exacerbated by the fact that solar projects with an installed capacity of less than 500 MW are exempt from environmental impact assessment (EIA) requirements [90].

Climate change effects on renewables, on the other hand, are a rapidly expanding field of study. Heat waves and heavy rains are only two examples of how climate change is threatening the reliability of renewable energy sources. Solar panels perform best between 15 °C and 35 °C, and extreme heat can reduce their effectiveness [91]. Introducing climate change vulnerability and adaptation considerations into projects' prioritization and site selection, as well as developing screening tools to identify at-risk proposed projects, can assist the energy sector and power utilities in evaluating their implementation strategies [92].

Finally, the significant changes in the industrial regimes that are required by these energy transitions are likely to meet resistance from the existing organizations. Concerns about the technological viability and socioeconomic costs of the energy transition, as well as the perceived threat to profitability and organizational stability, are among the reasons for opposition [93].

SWOT analysis is an effective method for assessing the situation of a market for the technology that is under consideration. It may be utilized on its own, tailored to certain contexts or locations, and serve as a platform for the establishment of individualized objectives [94].

4. Conclusions

Relying on alternative energy sources to cultivate aquatic creatures is a remarkable step forward in environmentally responsible aquaculture. Solar panels that are installed atop the fish farm can filter out extensive sunlight, generate power, and keep the pond at a comfortable temperature all at once, making "Fishery and Electricity Symbiosis" a novel paradigm of cross-industry collaboration. This method of production not only gives the land area a second look at being put to use, but it also helps to reduce the load on the power grid. The shrimp farm's case study has revealed that all of the solar power that is supplied by the solar canopy would be used internally, which makes the farm an energy efficient system. Moreover, since they will be sitting above the water, the solar panels will assist in reducing the water loss due to evaporation and protect the aquatic life from piscivorous birds. This is a practical and sustainable strategy to reduce the costs of aquaculture output globally, but notably in East and Southeast Asia. The increased large-scale development of renewable energy sources will further reduce energy prices in the future. A lot of advantages and possibilities exist for solar PV integration with fish farming practices in coastal locations, and the SWOT analysis that has been described in this study may be used as a tool for the future development of aquavoltaic systems. The system has been shown to have technological advantages, being an innovative and efficient system with room for development given its present market phase. Aquavoltaics may contribute to a sustainable future for the world's economy and the environment by addressing the interconnectedness of the food, energy, and water systems.

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References

1. Devabhaktuni, V.; Alam, M.; Shekara Sreenadh Reddy Depuru, S.; Green, R.C., II; Nims, D.; Near, C. Solar energy: Trends and enabling technologies. *Renew. Sustain. Energy Rev.* **2013**, *19*, 555–564. [CrossRef]
2. Bulkeley, H.; Broto, V.C.; Maassen, A. Governing Urban Low Carbon Transitions. In *Cities and Low Carbon Transitions*; Routledge: Abingdon, UK, 2010; pp. 45–57.
3. Newman, P.W.G.; Kenworthy, J.R. *Cities and Automobile Dependence: An International Sourcebook*; Gower Publishing: Brookfield, WI, USA, 1989.
4. Sijmons, D. *Landscape and Energy, Designing Transition*; Nai010: Rotterdam, The Netherlands, 2014.
5. *IEA World Energy Outlook*; IEA: Paris, France, 2020; p. 214.
6. Zhou, Y.; Verkou, M.; Zeman, M.; Ziar, H.; Isabella, O. A Comprehensive Workflow for High Resolution 3D Solar Photovoltaic Potential Mapping in Dense Urban Environment: A Case Study on Campus of Delft Universityof Technology. *Phys. Status Solidi-Rapid Res. Lett.* **2022**, *6*, 2100478.
7. REN21 Secretariat Renewables. *Global Status Report*; REN21: Paris, France, 2021.
8. Lobaccaro, G.; Carlucci, S.; Croce, S.; Paparella, R.; Finocchiaro, L. Boosting Solar Accessibility and Potential of Urban Districts in the Nordic Climate: A Case Study in Trondheim. *Sol. Energy* **2017**, *149*, 347–369. [CrossRef]
9. Lobaccaro, G.; Lisowska, M.M.; Saretta, E.; Bonomo, P.; Frontini, F. A Methodological Analysis Approach to Assess Solar Energy Potential at the Neighborhood Scale. *Energies* **2019**, *12*, 3554. [CrossRef]
10. Lobaccaro, G.; Croce, S.; Vettorato, D.; Carlucci, S. A Holistic Approach to Assess the Exploitation of Renewable Energy Sources for Design Interventions in the Early Design Phases. *Energy Build.* **2018**, *175*, 235–256. [CrossRef]
11. Mazziotti, L.; Cancelliere, P.; Paduano, G.; Setti, P.; Sassi, S. Fire Risk Related to the Use of PV Systems in Building Facades. *MATEC Web Conf.* **2016**, *46*, 05001. [CrossRef]
12. Probst, M.M.; Roecker, C. Criteria for Architectural Integration of Active Solar Systems IEA Task 41, Subtask A. *Energy Procedia* **2012**, *30*, 1195–1204. [CrossRef]
13. Florio, P.; Peronato, G.; Perera, A.T.D.; Di Blasi, A.; Poon, K.H.; Kämpf, J.H. Designing and Assessing Solar Energy Neighborhoods from Visual Impact. *Sustain. Cities Soc.* **2021**, *71*, 102959. [CrossRef]
14. Lingfors, D.; Johansson, T.; Widén, J.; Broström, T. Target-Based Visibility Assessment on Building Envelopes: Applications to PV and Cultural-Heritage Values. *Energy Build.* **2019**, *204*, 109483. [CrossRef]
15. Xu, L.; Wang, Y.; Ahmed Solangi, Y.; Zameer, H.; Ali Shah, S.A. Off-Grid Solar PV Power Generation System in Sindh, Pakistan: A Techno-Economic Feasibility Analysis. *Processes* **2019**, *7*, 308. [CrossRef]
16. Adam, M.; Pringle, R.M.; Handler, J.M. Aquavoltaics: Synergies for dual use of water area for solar photovoltaic electricity generation and aquaculture. *Renew. Sustain. Energy Rev.* **2017**, *80*, 572–584.
17. Pascaris, A.S.; Schelly, C.; Rouleau, M.; Pearce, J.M. Do agrivoltaics improve public support for solar? A survey on perceptions, preferences, and priorities. *Green Technol. Resil. Sustain.* **2022**, *2*, 8. [CrossRef]
18. Bunting, S.W.; Little, D.C. Urban aquaculture for Resilient Food Systems. In *Cities and Agriculture: Developing Resilient Urban Food Systems*; de Zeeuw, H., Drechsel, P., Eds.; Routledge: Abingdon, UK, 2015; pp. 312–335, ISBN 978-1-317-50662-1.
19. Liao, I.C.; Chao, N.H. Brief-history, Problems, and Prospects of Aquaculture on the Both-sides of the Taiwan Strait. In Proceedings of the 6th Cross-Strait Conference on Fish Physiology and Aquaculture, Guangzhou, China, 23–25 November 2012; pp. 1–4.
20. Tanveer, M.; Mayilsamy, S. A conceptual approach for development of solar powered aeration system in aquaculture farms. *Int. J. Environ. Sci. Technol.* **2016**, *5*, 2921–2925.
21. Ghoniem, A.A. Design optimization of photovoltaic powered water pumping system. *Energy Convers. Manag.* **2006**, *47*, 1449–1463. [CrossRef]

22. Vo, T.T.E.; Ko, H.; Huh, J.H.; Park, N. Overview of Solar Energy for Aquaculture: The Potential and Future Trends. *Energies* **2021**, *14*, 6923. [CrossRef]
23. Applebaum, J.; Mozes, D.; Steiner, A.; Segal, I.; Barak, M.; Reuss, M.; Roth, P. Progress in Photovoltaics: Research and application. *Photovoltaics* **2001**, *9*, 275–301.
24. Prasetyaningsari, I.; Setiawan, A.; Setiawan, A.A. Design optimization of solar powered aeration system for fish pond in Sleman Regency, Yogyakarta by HOMER software. *Energy Procedia* **2013**, *32*, 90–98. [CrossRef]
25. Liu, X.; Xu, H.; Ma, Z.; Zhang, Y.; Tian, C.; Cheng, G. Design and application of a solar mobile pond aquaculture water quality-regulation machine based in Bream Pond aquaculture. *PLoS ONE* **2016**, *11*, e0146637. [CrossRef] [PubMed]
26. Goetzberger, A.; Zastrow. A. On the coexistence of solar-energy conversion and plant cultivation. *Int. J. Sol. Energy* **1982**, *1*, 55–69. [CrossRef]
27. Dupraz, C.; Marrou, H.; Talbot, G.; Dufour, L.; Nogier, A.; Ferard, Y. Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes. *Renew. Energy* **2011**, *36*, 2725–2732. [CrossRef]
28. Marrou, H.; Wéry, J.; Dufour, L.; Dupraz, C. Productivity and radiation use efficiency of lettuces grown in the partial shade of photovoltaic panels. *Eur. J. Agron.* **2013**, *44*, 54–66. [CrossRef]
29. Fast, A.W.; Boyd, C.E. Water Circulation, Aeration and Other Management Practices, Chapter 22. In *Marine Shrimp Culture*; Fast, A.W., Lester, L.J., Eds.; Elsevier: Amsterdam, The Netherlands, 1992; pp. 457–495.
30. Romaire, R.P.; Boyd, C.E. The effect of solar radiation on the dynamics of dissolved oxygen in channel catfish ponds. *Trans. Am. Fish. Soc.* **1979**, *107*, 473–478. [CrossRef]
31. Hailu, G.; Fung, A.S. Optimum tilt angle and orientation of photovoltaic thermal system for application in Greater Toronto area, Canada. *Sustainability* **2019**, *11*, 6443. [CrossRef]
32. Liu, W.; Li, J.; Li, S.; Luo, J.; Jiang, X. Research on optimum tilt angle of photovoltaic module based on regional clustering of influencing factors of power generation. *Int. J. Energy Res.* **2021**, *45*, 11002–11017. [CrossRef]
33. Imani, M.; Lo, S.L.; Fakour, H.; Kuo, C.Y.; Mobasser, S. Conceptual framework for disaster management in coastal cities using climate change resilience and coping ability. *Atmosphere* **2022**, *13*, 16. [CrossRef]
34. Ko, L.; Wang, J.C.; Chen, C.Y.; Tsai, H.Y. Evaluation of the development potential of rooftop solar photovoltaic in Taiwan. *Renew. Energy* **2015**, *76*, 582–595. [CrossRef]
35. Huang, W.L. *Distributed Power Technology Application*; Ministry of Economic Affairs energy report; Bureau of Energy: Taipei City, Taiwan, 2002; p. 31.
36. Peterson, E.L. Prawn farm energy audits and five star ratings. *Aquac. Asia* **2002**, *7*, 4.
37. Boyd, C.E.; Tucker, C.; McNevin, A.; Bostick, K.; Clay, J. Indicators of resource use efficiency and environmental performance in fish and crustacean aquaculture. *Rev. Fish. Sci.* **2007**, *15*, 327–360. [CrossRef]
38. Peterson, E.L. *Energy-Efficiency Manual for Aquaculture Pond Aeration*; The University of Queensland: Brisbane, Australia, 2003.
39. Tien, N.N.; Matsuhashi, R.; Chau, V.T.T.B. A Sustainable Energy Model for Shrimp Farms in the Mekong Delta. *Energy Procedia* **2019**, *157*, 926–938. [CrossRef]
40. Pascuzzi, S.; Anifantis, A.S.; Blanco, I.; Scarascia Mugnozza, G. Electrolyzer performance analysis of an integrated hydrogen power system for greenhouse heating. A case study. *Sustainability* **2016**, *8*, 629. [CrossRef]
41. Pickton, D.W.; Wright, S. What's SWOT in strategic analysis? *Strateg. Chang.* **1998**, *7*, 101–109. [CrossRef]
42. Paliwal, R. EIA practice in India and its evaluation using SWOT analysis. *Environ. Impact Assess. Rev.* **2006**, *26*, 492–510. [CrossRef]
43. Terrados, J.; Almonacid, G.; Hontoria, L. Regional energy planning through SWOT analysis and strategic planning tools. Impact on renewables development. *Renew. Sustain. Energy Rev.* **2007**, *11*, 1275–1287. [CrossRef]
44. Chen, W.M.; Kim, H.; Yamaguchi, H. Renewable energy in eastern Asia: Renewable energy policy review and comparative SWOT analysis for promoting renewable energy in Japan, South Korea, and Taiwan. *Energy Policy* **2014**, *74*, 319–329. [CrossRef]
45. Lupu, A.G.; Dumencu, A.; Atanasiu, M.V.; Panaite, C.E.; Dumitraşcu, G.H.; Popescu, A. SWOT analysis of the renewable energy sources in Romania—case study: Solar energy. In Proceedings of the 7th International Conference on Advanced Concepts in Mechanical Engineering (ACME 2016), Iasi, Romania, 9–10 June 2016; Volume 147, p. 012138.
46. Salimi, M.; Hosseinpour, M.N.; Borhani, T. Analysis of Solar Energy Development Strategies for a Successful Energy Transition in the UAE. *Processes* **2022**, *10*, 1338. [CrossRef]
47. Mavragani, A.; Ochoa, G. Google Trends in Infodemiology and Infoveillance: Methodology Framework. *JMIR Public Health Surveill* **2019**, *5*, e13439. [CrossRef]
48. Rovetta, A. Reliability of Google Trends: Analysis of the Limits and Potential of Web Infoveillance During COVID-19 Pandemic and for Future Research. *Front. Res. Metr. Anal.* **2021**, *6*, 670226. [CrossRef]
49. Wei, J.; Zhang, X.; Yu, Y.; Huang, H.; Li, F.; Xiang, J. Comparative Transcriptomic Characterization of the Early Development in Pacific White Shrimp *Litopenaeus vannamei*. *PLoS ONE* **2014**, *9*, e106201. [CrossRef] [PubMed]
50. Duffie, J.A.; Beckman, W.A. *Design of Photovoltaic Systems, in Solar Engineering of Thermal Processes*, 4th ed.; Wiley: Hoboken, NJ, USA, 2013; pp. 745–773.
51. Wang, Q.; Wei, H.H.; Xu, Q. A Solid Oxide Fuel Cell (SOFC)-Based Biogas-from-Waste Generation System for Residential Buildings in China: A Feasibility Study. *Sustainability* **2018**, *10*, 2395. [CrossRef]
52. Trends Help. 2022. Available online: https://support.google.com/trends/?hl=en&ref_topic=13762&visit_id=1-636639138191095232-1954776931&rd=3. (accessed on 10 June 2022).

53. Jellison, S.S.; Bibens, M.; Checketts, J.; Vassar, M. Using Google Trends to assess global public interest in osteoarthritis. *Rheumatol. Int.* **2018**, *38*, 2133–2136. [CrossRef]
54. Feigenbaum, E.A.; Hou, J.Y. *Overcoming Taiwan's Energy Trilemma*; Carnegie Endowment for International Peace: Washington, DC, USA, 2020; p. 20036.
55. Kwok, M.L. What Would A Potential Conflict Between China And Taiwan Mean for Global Decarbonisation? *Earth Org.* **2022**. Available online: https://earth.org/china-and-taiwan-decarbonisation/ (accessed on 2 November 2022).
56. Yue, C.D.; Huang, G.R. An evaluation of domestic solar energy potential in Taiwan incorporating land use analysis. *Energy Policy* **2011**, *39*, 7988–8002. [CrossRef]
57. Hermann, C.; Dahlke, F.; Focken, U.; MTrommsdorff, M. Chapter 6—Solar Energy Advancements in Agriculture and Food Production Systems. In *Aquavoltaics: Dual Use of Natural and Artificial Water Bodies for Aquaculture and Solar Power Generation*; Elsevier: Amsterdam, The Netherlands, 2022; pp. 211–236.
58. Chen, C.N.; Yang, C.T. The Investability of PV Systems under Descending Feed-In Tariffs: Taiwan Case. *Energies* **2021**, *14*, 2728. [CrossRef]
59. Yu, H.H.; Chang, K.H.; Hsu, H.W.; Cuckler, R. A Monte Carlo simulation-based decision support system for reliability analysis of Taiwan's power system: Framework and empirical study. *Energy* **2019**, *178*, 252–262. [CrossRef]
60. Magazine, P.V. Will Taiwan Meet its 20 GW Solar Goal by 2025? 2018. Available online: https://www.pv-magazine.com/2018/09/07/will-taiwan-meet-its-20-gw-solar-goal-by2025/ (accessed on 15 May 2022).
61. Executive Yuan, Four-year Wind Power Promotion Plan. 2019. Available online: https://english.ey.gov.tw/News3/9E5540D592A5FECD/d603a1bf-9963-4e53-a92b-e6520a3d93ff (accessed on 15 May 2022).
62. Fulbright, N.R. Contracts for Difference: Round 2 Results. 2017. Available online: https://www.nortonrosefulbright.com/en/knowledge/publications/12262a64/contracts-for-difference-round-2-results (accessed on 18 May 2022).
63. Faizullah, M.M.; Abishag, M.M.; Santhoshkumar, S. The Potential for Renewable Energy Sources for Aquaculture. *Vigyan Varta* **2022**, *3*, 37–40.
64. Kamalapur, G.D.; Udaykumar, R.Y. Rural Electrification in India and Feasibility of Photovoltaic Solar Home Systems. *Int. J. Electr. Power Energy Syst.* **2011**, *33*, 594–599. [CrossRef]
65. Sharma, A.A. Comprehensive Study of Solar Power in India and World. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1767–1776. [CrossRef]
66. Urpelainen, J. Energy Poverty and Perceptions of Solar Power in Marginalized Communities: Survey Evidence from Uttar Pradesh, India. *Renewal* **2016**, *85*, 534–539. [CrossRef]
67. UDN. The Price of Land in Yuyuan Rises Dramatically, Retrieved 4 January 2021. Available online: https://udn.com/news/story/121906/5142432 (accessed on 25 January 2021).
68. Manju, S.; Sagar, N. Progressing towards the Development of Sustainable Energy: A Critical Review on the Current Status, Applications, Developmental Barriers and Prospects of Solar Photovoltaic Systems in India. *Renew. Sustain. Energy Rev.* **2017**, *70*, 298–313. [CrossRef]
69. Hsiung, K.H. Policy and Legal Issues of the Environmental and Social Inspection in Fishery-Solar Energy. *IOP Conf. Ser. Earth Environ. Sci.* **2022**, *1009*, 012009. [CrossRef]
70. Sovacool, B.K. Who are the victims of low-carbon transitions? Towards a political ecology of climate change mitigation. *Energy Res. Soc. Sci.* **2021**, *73*, 101916. [CrossRef]
71. Krewitt, W.; Nitsch, J.; Reinhardt, G. Renewable energies: Between climate protection and nature conservation? *Int. J. Glob. Energy Issues* **2005**, *23*, 29–42. [CrossRef]
72. Brunette, C.L.; Byrne, J.; Williams, C.K. Resolving conflicts between renewable energy and wildlife by promoting a paradigm shift from commodity to commons based policy. *J. Int. Wildl. Law Policy* **2013**, *16*, 375–397. [CrossRef]
73. Hastik, R.; Basso, S.; Geitner, C.; Haida, C.; Poljanec, A.; Portaccio, A.; Vrščaj, B.; Walzer, C. Renewable energies and ecosystem service impacts. *Renew. Sustain. Energy Rev.* **2015**, *48*, 608–623. [CrossRef]
74. Chen, H.S.; Kuo, H.Y. Green Energy and Water Resource Management: A Case Study of Fishery and Solar Power Symbiosis in Taiwan. *Water* **2022**, *14*, 1299. [CrossRef]
75. Dhar, A.; Naeth, M.A.; Jennings, P.D.; El-Din, M.G. Perspectives on environmental impacts and a land reclamation strategy for solar and wind energy systems. *Sci. Total Environ.* **2020**, *718*, 134602. [CrossRef]
76. Chen, H.H.; Lee, A.H.I. Comprehensive overview of renewable energy development in Taiwan. *Renew. Sustain. Energy Rev.* **2014**, *37*, 215–228. [CrossRef]
77. Couture, T.D.; Jacobs, D.; Rickerson, W.; Healey, V. *The Next Generation of Renewable Electricity Policy: How Rapid Change is Breaking down Conventional Policy Categories*; Technical Report; National Renewable Energy Laboratory (NREL): Golden, CO, USA, 2015; NREL/TP-7A40-63149.
78. Griffiths, S. Energy diplomacy in a time of energy transition. *Energy Strategy Rev.* **2019**, *26*, 100386. [CrossRef]
79. Leal-Arcas, R.; Grasso, C.; Ríos, J.A. *Energy Security, Trade and the EU*; Edward Elgar Publishing: Cheltenham, UK, 2016; p. 488, ISBN 10-1785366734.
80. Kresnawan, M.R.; Wijaya, T.N. Energy Diplomacy: A Vital Piece to Boost Renewable Energy Investment. Asean Center for Energy. 2021. Available online: https://aseanenergy.org/energy-diplomacy-a-vital-piece-to-boost-renewable-energy-investment/ (accessed on 12 August 2022).

81. International Energy Agency (IEA). Special Report on Solar PV Global Supply Chains. 2022. Available online: https://www.iea.org/reports/solar-pv-global-supply-chains/executive-summary (accessed on 23 October 2022).
82. Lu, Z.; Zhu, L.; Lau, C.K.M.; Isah, A.B.; Zhu, X. The Role of Economic Policy Uncertainty in Renewable Energy-Growth Nexus: Evidence From the Rossi-Wang Causality Test. *Front. Energy Res.* **2021**, *9*, 750652. [CrossRef]
83. Elder, J.; Serletis, A. Oil Price Uncertainty. *J. Money Credit. Bank.* **2010**, *42*, 1137–1159. [CrossRef]
84. Goffetti, G.; Montini, M.; Volpe, F.; Gigliotti, M.; Pulselli, F.M.; Sannino, G.; Marchettini, N. Disaggregating the SWOT Analysis of Marine Renewable Energies. *Front. Energy Res.* **2018**, *6*, 138. [CrossRef]
85. Gasparatos, A.; Doll, C.N.; Esteban, M.; Ahmed, A.; Olang, T.A. Renewable energy and biodiversity: Implications for transitioning to a green economy. *Renew. Sustain. Energy Rev.* **2017**, *70*, 161–184. [CrossRef]
86. Hernandez, R.R.; Easter, S.B.; Murphy-Mariscal, M.L.; Maestre, F.T.; Tavassoli, M.; Allen, E.B.; Barrows, C.W.; Belnap, J.; Ochoa-Hueso, R.; Ravi, S.; et al. Environmental impacts of utility-scale solar energy. *Renew. Sustain. Energy Rev.* **2014**, *29*, 766–779. [CrossRef]
87. Mostegl, N.M.; Probstl-Haider, U.; Haider, W. Spatial energy planning in Germany: Between high ambitions and communal hesitations, Landsc. *Urban Plan.* **2017**, *167*, 451–462. [CrossRef]
88. Wang, H.W.; Dodd, A.; Ko, Y. Resolving the conflict of greens: A GIS-based and participatory least-conflict siting framework for solar energy development in southwest Taiwan. *Renew. Energy* **2022**, *197*, 879–892. [CrossRef]
89. Pursner, S. Let's Get Hei-Pi: A Review of Black-faced Spoonbill Conservation Efforts in Taiwan—Part 2. Taiwan Wild Bird Federation. 2021. Available online: https://www.bird.org.tw/publish/1202 (accessed on 2 February 2022).
90. Ministry of Economic Affairs. Renewable Energy Development Act. 2019. Available online: https://law.moj.gov.tw/ENG/LawClass/LawAll.aspx?pcode=J0130032 (accessed on 5 December 2021).
91. Solaun, K.; Cerda, E. Climate change impacts on renewable energy generation. A review of quantitative projections. *Renew. Sustain. Energy Rev.* **2019**, *116*, 109415. [CrossRef]
92. Asian Development Bank (ADB). *Climate Risk and Adaptation in the Electric Power Sector*; Asian Development Bank: Manila, Philippines, 2012; ISBN 978-92-9092-730-3.
93. Hess, D.J. The politics of niche-regime conflicts: Distributed solar energy in the United States. *Environ. Innov. Soc. Transit.* **2016**, *19*, 42–50. [CrossRef]
94. Benzaghta, M.A.; Elwalda, A.; Mousa, M.M.; Erkan, I.; Rahman, M. SWOT analysis applications: An integrative literature review. *J. Glob. Bus. Insights* **2021**, *6*, 55–73. [CrossRef]