Development of Renewable Energy Sources to Serve Agriculture in Vietnam: A Strategic Assessment using the SWOT Analysis

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ABSTRACT

Agriculture plays an important role in the economy of many countries, including Vietnam. Traditional agricultural manufacturing processes are inefficient in energy and material consumption and generate substantial carbon emissions. In recent decades, environmentalists and policymakers have been actively involved in the transition from conventional fossil fuels to renewables. This study investigated the potential Strengths, Weaknesses, Opportunities, and Threats (SWOT) associated with developing Renewable Energy sources to serve agriculture in Vietnam. The results of the analysis revealed that renewable energy sources have numerous strengths, including reducing greenhouse gas (GHG) emissions and the cost of electricity, accessing new technologies, and providing economic benefits to farmers. However, the system also faces several weaknesses and threats, such as policy mechanisms, infrastructure, investment capital, foreign-dependent technologies, and potential environmental impacts. This study provides strategic recommendations to maximize the potential of agrivoltaic systems while mitigating their weaknesses and threats. The findings can help stakeholders make informed decisions and take appropriate actions in the development of renewable energy sources in agriculture.

Keywords-renewable energy; agricultural energy; internet of things; smart agriculture; SWOT analysis

I. INTRODUCTION

Agriculture plays an important role in the economy of many countries, including Vietnam. Agricultural activities require direct and indirect energy consumption to perform daily operating processes, such as irrigation, lighting, heating, cooling, and drying. The use of traditional energy sources has caused serious environmental problems, as the increase in mechanized activities in agriculture increases the use of fossil fuels [1]. The use of fossil fuels in agriculture causes high carbon emissions that lead to global warming. In such a context, the conversion of energy from one form to another is very necessary to run a process. Renewable energy sources are potential solutions to reduce environmental effects and meet current agricultural energy demands.

Several countries have launched strategies to develop renewable energy sources and provide clean energy sources for agriculture. For example, China is planning to implement photovoltaic systems in rural areas to avoid the use of fossil fuels using incentive policies regarding financial subsidies and taxation [2]. In general, this energy policy is important in optimally adapting energy management initiatives, adopting energy saving to reduce carbon emissions, and applying green technology to improve energy efficiency. However, such policies have advantages and disadvantages for the development and application of renewable energy sources for agricultural production. In Vietnam, renewable energy production sources, such as the sun, water, wind, and biomass, can help achieve the energy production goal cleanly and sustainably for the power consumption of different sectors, such as agriculture. Replacing conventional energy with low-carbon renewable electricity is one of the easiest ways to reduce emissions. As an integral part of energy policy, governments enact renewable energy policies to achieve a more rapid transition to sustainable energy. The Vietnamese Government considers energy-related policies a major concern, since unexpected economic, social, and environmental impacts may severely affect the country's economy and its people [3]. In [4], a green scenario was proposed for electricity generation in Vietnam by 2030. Vietnam needs to have access to secure energy supplies and sustainably shift its energy resources from fossil fuels to renewable energy sources. However, Vietnam has not been able to make the best use of its renewable energy potential and development policies for agricultural production activities.

This paper adopted an integrated Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis to evaluate strategies for the development of agricultural energy systems in Vietnam. This study not only identifies key factors that affect the Vietnamese agricultural energy sector but can also serve as a guide for various energy stakeholders and policy-makers to better understand the challenges and opportunities of the agricultural energy sector and prioritize key strategies for the development of renewable energy systems in agriculture in Vietnam. Moreover, since the adoption of technology in Vietnam's agriculture is much slower than in any other developing country, a detailed SWOT analysis will be helpful. The results of the analysis are an important guide to designing long-term strategies and plans.

II. METHODOLOGY

This study used the SWOT analysis decision-making methodology to investigate strategies for the development of renewable energy sources for agriculture in Vietnam and evaluate their structural relationships. SWOT analysis is a well-known model in the business analysis of the enterprise [5]. A SWOT analysis is a well-structured strategic plan to assess the current status of the business in the market by evaluating strengths, weaknesses, opportunities, and threats [6]. Strengths are one of the key categories that highlight the positive effects of the scenario compared to others. Weaknesses are negative factors that lead to unfavorable scenarios. Opportunities are external influences that can positively affect the scenario in the future. External factors that could reduce performance and lead to insecurities are captured under threats [7]. The findings of a SWOT analysis help companies build on their strengths, realize new opportunities, and work toward minimization or elimination of any possible threat [8]. Figure 1 shows the step-by-step procedure of SWOT analysis.

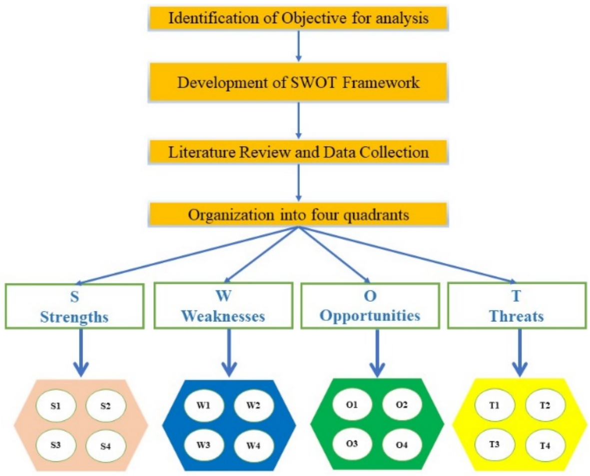

Fig. 1. SWOT analysis framework.

III. RESULTS AND DISCUSSION

Figure 2 presents the framework and a summary of the evaluation in quadrant form of the 24 factors identified by the SWOT analysis.

A. Strengths

The Vietnamese government cares about the development of clean energy and smart agriculture. Agriculture received the close attention of the State in the energy transition process of the country. Vietnam has prioritized the investment and use of renewable energy and has encouraged organizations and individuals to participate in its development and use in all production areas, including agriculture. In 2007, the Vietnamese government formulated the national energy development strategy up to 2020 with a vision for 2050 [9]. To meet these growing energy demands and ensure energy security, the government has taken various initiatives to diversify energy sources, including renewable energy sources. For instance, Vietnam's 2030 renewable energy development strategy, with a vision for 2050, was approved in 2015. Under this decision, the total electricity generation from renewable sources is expected to reach 101, 186, and 452 billion kWh in 2020, 2030, and 2050, respectively, compared to 58 billion kWh in 2015 [10]. In this context, in early 2020, the government developed and issued a strategic national energy development orientation for 2030, with a vision for 2045, with revised guidelines for the energy sector [11]. In May 2023, the Power Development Plan (PDP8) was approved, reflecting the results of numerous drafts and revisions for nearly three years [12].

1) Potential for Renewable Energy Sources

Vietnam has a diverse range of renewable energy resources, including biomass, solar, wind, hydroelectricity, and geothermal. Vietnam has a high solar energy potential, ranging from 4 to 5 kWh/m^2 daily average for the entire country, while the average sunshine hours range from 1600 to 2600 h in a year [13-15]. The average annual sunshine hours are 1500-1700 h in the northern part, while in central and southern Vietnam they are 2000-2600 h. Solar power in Vietnam developed very quickly in the period 2019-2021 and was ranked 10th on the list of countries having the largest solar power capacity with a total installed solar power capacity of 17.4 GW [16]. Compared to all renewable energy sources, solar energy has the greatest potential. For wind energy, Vietnam has the largest wind potential in Southeast Asia, as its total wind power potential is approximately 513,360 MW, with more than 8% of Vietnam's area having a very promising wind power potential [17-18]. More than 39% of Vietnam's area has an average annual wind speed of more than 6 m/s at an altitude of 65 m, and more than 8% of Vietnam's area has an average annual wind speed of more than 7 m/s, corresponding to a wind resource potential of 512 and 110 GW.

2) Rapid Development in Information Technology

A digital revolution has been spreading through all parts of the economy and society in the past few decades due to the rapid development of information and communication technologies [19]. In recent years, Vietnam has developed strongly in information technology to meet the needs of society. The Government promulgated the National Strategy on the development of the digital economy and digital society to 2025, with a vision to 2030, including the application of information technology in agriculture and energy [20].

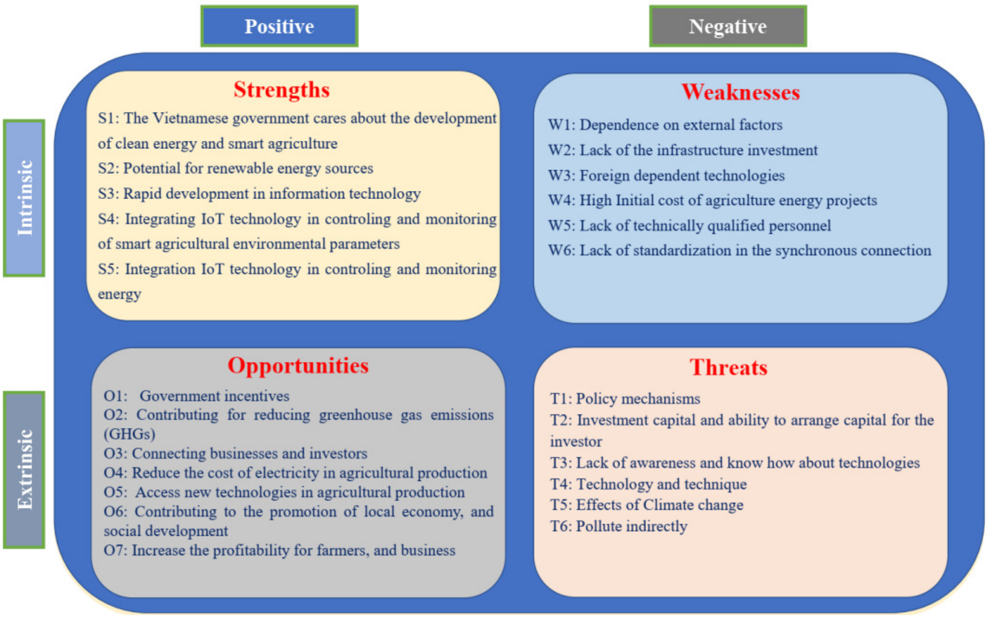

Fig. 2. Summary of the SWOT analysis for the development of an agricultural energy IoT system in Vietnam.

B. Weaknesses

1) Dependence on External Factors

The natural energy sources are highly dependent on weather conditions, terrain, climate, etc. In bad weather conditions, renewable energy technologies, such as photovoltaics or wind turbine generators, will be used less often. Wind speed variations alter the power generated through wind turbines, whereas the power produced through photovoltaics is affected by deviations in solar radiation and varying temperatures [21]. Therefore, weather conditions affect the stability, reliability, and quality of the power supplied to agricultural production. In addition, renewable energy systems respond rapidly to grid disturbances and increase the instability of the grid due to the fast response characteristics of power electronics [22].

2) Lack of Infrastructure Investment

Infrastructure plays an important role in an agricultural energy Internet of Things (IoT) system, as it includes broadband telecommunication networks (optical cables and new generation mobile network infrastructures), information technology, electricity grid, digital technology equipment, construction of main roads, IoT connections, and other essential infrastructure works related to renewable energy projects and hi-tech agriculture. The technical infrastructure for renewable energy exploitation has not yet developed, showing that investors must spend a large amount of capital to invest in initial infrastructure (roads, electricity, water lines, etc.). Furthermore, in rural areas, many establishments providing telecommunications services and Internet access are still weak, the means of information transmission are relatively outdated, and the covered areas are very limited.

3) Foreign Dependent Technologies

The technologies needed are mostly imported and depend on foreign suppliers, while the customization, adjustment, and mastery of the technology are very limited. In addition, technologies depend greatly on international prices and the prevailing policies of partners. Therefore, more support is needed from international organizations and governments related to technology transfer and financial and human support.

4) High Initial Cost of Agricultural Energy Projects

The exploitation of renewable energy resources in Vietnam has a high cost compared to traditional energy sources. The cost of installing, building, monitoring software, maintenance, and equipment for high-tech agricultural farm models is expensive compared to fossil fuels. It is difficult to attract investors to this sector, especially in countries that have some risks [23]. Several studies claimed that renewable energy projects are competitive with fossil fuel technologies based on their Levelized Costs Of Electricity (LCOE), the most common indicator to compare the cost competitiveness of electricity generation technologies [24].

5) Lack of Technically Qualified Personnel

The agricultural production and labor forces cannot meet the requirements for applying novel technologies in agriculture. Especially in regions with underdeveloped economies [25].

6) Lack of Standardization in the Synchronous Connection

The installation of renewable energy power systems in some construction projects and farms is not guaranteed. Furthermore, the capacity to implement solutions and investment projects is still limited. The deployment and installation of rooftop solar power systems at livestock and cropping farms have not met the regulations on farm economic criteria, planning, and land use plans. There is also a lack of standardization in synchronous connections between data transmitters and a difficulty in integration and IoT communication between devices from different manufacturers.

C. Opportunities

1) Government Incentives

Governments offer incentives to promote the use of renewable energy in agriculture, including grants, tax credits, and subsidies. In 2017, a very generous Feed-In Tariff (FIT) rate was introduced, approximately 10.5% higher than the average retail tariff, through a combination of net metering and a FIT-type scheme of 2086 VND/kWh or 0.0935 US$/kWh [26]. In April 2020, the government announced reduced FITs of 83.8 US$/MWh for new rooftop solar projects, 70.9 US$/MWh for new ground-mounted solar photovoltaics, and 76.9 US$/MWh for new floating solar projects [27].

2) Contribution to Greenhouse Gas Emission Reduction

Agriculture is one of the key drivers of environmental deterioration, linked to GHG emissions and labeled as ultrasensitive to climate change. Many recent studies have shown that renewable energy contributes to environmental sustainability and reduces GHGs through the transition from fossil fuels. The transition from fossil energy to renewable energy can achieve a win-win situation by resolving the trade-off between environment, poverty, and energy poverty [28]. Several studies considered the relationship between Research and Development (R&D) and GHGs. R&D investment in renewable technologies has a significant positive effect on environmental quality by reducing a variety of pollutants, including carbon dioxide, methane, and other pollutants [29]. To overcome these limitations, recommendations on sustainable and climate-smart agriculture would improve productivity and resilience while reducing emissions [30].

3) Connecting Businesses and Investors

Creating favorable conditions to connect businesses and investors in the fields of renewable energy and high-tech agriculture can lead to knowledge exchange and system operation experiences.

4) Reducing the Cost of Electricity in Agricultural Production

Modern agriculture requires a much greater energy input than conventional agriculture. Solar energy can be used in agriculture in numerous ways, resulting in reduction in electricity costs, increased independence, and reduced emissions. Solar energy applications in agriculture are on the rise for irrigation, lighting, heating, cooling, and drying. For example, 100% renewable energy is becoming technically feasible and economically viable with decreasing costs every year [31]. Solar heat inside a greenhouse can be stored for later use using a heat storage material/phase and reduce heating costs [32].

5) Accessing New Technologies in Agricultural Production

Farmers have the opportunity to access new technologies in agricultural production to improve crop production and the quality of agricultural products, such as IoT technology with accurate data collection sensors on climate, growing conditions, and the health of plants or animals, and intelligent automation technology with robots and machinery in farming activities [33]. Smart agriculture that incorporates advanced Internet-based information technology can help in the intelligent management of agricultural production [34-35]. With an improved design, farmers can easily understand how to self-integrate, self-troubleshoot, and self-maintain the IoT environmental monitoring system without requiring expertise on the farm site. As a result, it can increase farmers' willingness to accept innovative technologies and help them gain control over growing crops. In the end, such technologies will allow them to run more predictable, efficient, and profitable agribusiness [36].

6) Contributing to the Promotion of Local Economy and Social Development

The road system serves the construction of the rural transport system. Renewable energy projects and high-tech agriculture also contribute to multitarget economic development and increase budget revenue for localities, as they help create jobs, increase income for farmers, contribute to economic restructuring, increase the value of industrial production, and promote social and economic development.

7) Increasing Profitability for Farmers and Businesses

Smart agriculture can create opportunities for entrepreneurs, investors, scientists, and farmers to research and develop digital transformation and digital technology applications in agriculture, support automated and optimized production processes, and help farmers increase productivity and reduce production costs.

D. Threats

1) Policy Mechanisms

Although Vietnam has great potential for renewable energy sources (wind, solar), the number of projects implemented is still very small due to the lack of strong enough and synchronous policies, including regulations to investigate and evaluate the potential for their exploitation and use. The oversimplification of the FIT price mechanism issued by the government has led to uneven development of solar power systems, as most grid-connected solar power systems are concentrated in the central and southern regions [37]. Institutional barriers, such as market-controlled mechanisms and unstable supporting policies, also limit investment in renewable power sectors. As a result, although energy policies and plans are being established towards cleaner energy production, progress is slow. However, Vietnam faces other challenges when it comes to solar energy, which cannot be simply addressed by providing financial incentives. High population density, land morphology, and geography make land allocation for renewable energy, particularly solar farms, quite challenging [38].

2) Investment Capital and the Ability to Arrange Capital for Investors

The demand for energy in agriculture is increasing day by day. Investors are moving towards the development of renewable energy sources for agricultural production purposes, making renewable energy more competitive, leading to a high level of capital investment in renewable energy projects. Wind power production costs have become more competitive due to the rapid development of technologies and the reduction of installation costs. The capital costs of a wind power project can be listed as follows: turbine cost, civil works (including construction costs for site preparation and foundations for the towers), grid connection costs (including transformers and connections to local distribution), project planning costs, and others such as road construction, building, and control systems [39]. In addition, high-tech agriculture requires a huge capital investment. A high-tech agricultural project can require much more investment than traditional methods, such as initial costs for infrastructure investment, design consultancy, operation and maintenance of renewable energy systems, and design and development of the equipment for monitoring and controlling smart agricultural farm models.

3) Lack of Awareness and Technology Know-How

The human resources qualifications of training institutions that specialize in the operation, maintenance, and repair of electrical equipment related to renewable energy have not yet developed strongly, leading to low labor productivity in some areas. This leads to a lack of awareness and know-how of renewable energy technologies, IoT technology, control automation equipment, and smart electronic equipment in high-tech agricultural models. Many areas lack Internet access, creating many challenges in applying technology and deploying IoT applications to automate production. Human resources in the agricultural sector are currently not trained in technological and technical advances. Although labor in rural areas is abundant, industrial discipline is not high and requires a lot of training time. Farmers are still familiar with traditional methods, do not use technology proficiently, and have limited discipline in organizing production, complying with processes, using chemicals, and caring for short-term profits.

4) Technology and Technique

Exploiting, accessing, and using renewable energy technologies and smart electronic devices depends on technology transfer from foreign countries. There are also difficulties in controlling and regulating the power system when the proportion of renewable energy sources in the system increases, due to unstable power generation and weather dependence. The sudden increase in this type of energy source causes many problems in the operation of the power system, such as full load, local overload, and a decrease in system inertia. With increasing penetration of renewable energy, the frequency stability of the system will gradually deteriorate [40]. In addition, there is a lack of capacity to manage, operate, maintain, and repair renewable energy equipment, a lack of software expertise, a lack of assessment information on the potential of renewable energy sources, and the ability to connect renewable energy projects to the grid after completion. Domestic contractors do not have much experience in the construction and utilization of new technology and complicated techniques.

5) Effects of Climate Change

Renewable energy sources primarily depend on climatic conditions. The intermittency and randomness of renewable energy affect the operation of the power system. Wind power has the characteristics of being completely dependent on weather and climate, uncontrollable, fluctuating with a large amplitude within the range of installed capacity, and generating very different amounts of electricity from month to month and year to year. As solar power is only generated during the day, skyrockets at noon and then rapidly decreases, it is unable to cover the demands during the peak hours in the evening.

6) Indirect Pollution

The production and use of renewable energy sources can pose environmental risks, such as pollution and habitat destruction, which must be carefully managed. Although photovoltaic power generation technology is more environmentally friendly than traditional energy industries and can achieve zero CO_2 emissions during the operation phase, the waste generated during the production process and after the end of life harms the environment and cannot be ignored [41]. The waste of old solar panels poses a global environmental problem. The disposal of solar panels, which include lead, chromium, and cadmium, is prevalent, but little is done to mitigate its detrimental impact [42].

IV. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

Developing intelligent agricultural systems in general and in agriculture is a key goal of Vietnam. SWOT analysis provided some strengths, weaknesses, opportunities, and threats in the development of renewable energy sources to serve agriculture in Vietnam, and strategic recommendations were provided to maximize their potential. However, the system has several weaknesses, including its lack of infrastructure investment, high initial cost, and the lack of technically qualified personnel. The adoption of renewable energy sources to serve agriculture may face challenges in areas with limited policy mechanisms, inadequate technical capacity, low investment capital, and a lack of technically qualified personnel. Despite these weaknesses, the analysis identified several opportunities for the development of renewable energy sources to serve agriculture, including government incentives, connecting businesses and investors, and access to new technologies in agricultural production. To maximize the potential of renewable energy sources, several strategic recommendations were provided, such as increasing public awareness and support, developing innovative financing mechanisms, and conducting further research to address potential negative impacts. This analysis demonstrated that renewable energy sources have the potential to provide a sustainable solution for both energy and food production. However, to fully realize this potential, policymakers, farmers, and energy companies must work together to address the challenges and opportunities presented. However, the future looks bright for the development of renewable energy sources to serve agriculture, which are both technically and commercially feasible.

B. Recommendations

Renewable energy sources are the best option for rural areas, as they not only contribute to the development of intelligent agriculture systems but also provide benefits, such as sustainability, decreased GHG emissions, improvement in social structure, and local development, in addition to other trivial benefits. The results of this study lead to the following recommendations to decision-makers to help in the development of agricultural renewable energy IoT systems:

- As the cost of consulting, equipment, design, and construction of agricultural renewable energy IoT models is very high, it is necessary to have tax incentives for organizations and businesses, creating favorable conditions for farmers to develop renewable energy sources to provide electricity for agricultural production and expand the model in rural areas far from the center.
- Creating a favorable legal framework for investors in rural energy projects.
- Developing standards for the development of renewable energy sources for agricultural and rural farm models.
- The government should offer incentives, including low-interest financing for businesses and farmers, to stimulate growth and expand the use of renewable energy sources for agricultural models.
- Build centers for effective research, reception, and application of technical advances and new technologies in production and technology transfer in the field of renewable energy and high-tech agriculture for the development of current and future projects.
- Provide education and training to the rural population on the maintenance of renewable energy sources.
- Strengthen international cooperation to attract capital and promote technology transfer in the fields of renewable energy and high-tech agriculture.
- Encourage non-state investors to invest in smart grids to ensure efficient and economical use of electricity.

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