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Solar Technology Adoption In Upper Northern Region Of Thailand's Agricultural Sector: Opportunities And Challenges

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A B S T R A C T

The research investigates solar energy utilization and attitudes towards solar energy among Young Smart Farmer in eight provinces in the upper northern region of Thailand. The research employs a stratified random sampling method. 300 YSF members of the Office of Agricultural Extension and Development 6 are selected as participants through a simple random sampling technique based on the membership list. The findings reveal that out of the sampled farmers, 169 do not utilize solar energy, while 131 utilize solar energy in their agricultural practices. Most YSF possess a bachelor's degree, with their degrees predominantly unrelated to agriculture. The participating farmers have an average agricultural experience of 7.73 years and an average age of 37.68 years. Furthermore, their average annual income amounts to 194,940 baht. The investigation demonstrates that solar energy is primarily employed for lighting and charging batteries, operating water pumps, fans, televisions, electric drills, and angle grinders. Additionally, the results indicate that farmers who utilize solar energy display more favourable attitudes towards solar energy technology than those who do not. The study identifies numerous challenges and barriers hindering the widespread adoption of solar technology, such as high costs, lack of technical knowledge, concerns regarding system maintenance, and long-term stability of solar power systems.

Keywords: Solar Energy, Young Smart Farmer, Attitudes, Agriculture, Thailand.

1. INTRODUCTION

Renewable energy has emerged as a vital tool in meeting the energy needs of the agricultural sector. Heightened environmental concerns have spurred technological progress in harnessing energy from natural resources and their accessibility for various energy production domains, encompassing agriculture. (Hernandez-Escobedo et al., 2022) The utilization of solar energy is experiencing a significant global upsurge. Photovoltaic (PV) capacity has witnessed an exponential growth of nearly 20-fold, escalating from 39 GW (Gigawatts) in 2010 to a substantial 760 GW by 2020. This consistent expansion in capacity has persisted annually, with a notable increase of 139 GW compared to the preceding year, 2019. (Vo et al., 2022) According to the 2022 survey conducted on renewable energy research, there exists a consensus regarding the technical and economic viability of renewable energy systems. Notably, wind and solar energy have been identified as pivotal components within renewable energy, holding significant potential in shaping future energy systems. (Østergaard et al., 2022) The expansion of renewable energy capacity is projected to gain momentum in the coming five years. (iea, 2021) Following the 17 Sustainable Development Goals (SDGs), one of the key objectives concerning energy is Goal 7: Ensuring universal access to clean energy. Clean energy, specifically renewable energy, presents a promising avenue to bolster energy efficiency and foster sustainable development. By taking into account its positive environmental impact, diminishing reliance on fossil fuels, and promoting the availability of affordable and accessible renewable energy alternatives, significant strides can be taken towards attaining these objectives. (UN, 2022)

The growing adoption of solar energy in the agricultural sector is driven by escalating energy price volatility and the increasing demand for environmentally friendly and sustainable energy sources. This trend of solar energy integration in agriculture has been observed across numerous countries (Xue, 2017) The European Green Deal on Agriculture-Photovoltaic (Agri-PV) has been proposed as an efficient and cost-effective solution to foster sustainable agriculture and facilitate the transition to clean energy in Europe. Incorporating solar energy systems into farmland not only does it reduce land usage but also aligns with the objectives of agricultural policies and stimulates system modernization. Counter contributes to EU food security and resilience to climate change and promotes the utilization of renewable energy (SolarPowerEurope, 2020) Solar technology, in particular, stands out as a sustainable alternative to the reliance on fossil fuels within farming operations.

Thailand's strategic equatorial location provides abundant sunshine throughout the year, rendering it an ideal setting for solar energy development. The country has implemented a range of policies to foster the utilization of renewable energy, including solar energy. Notably, the Alternative Energy Development Plan (AEDP) was established in 2012 to promote renewable energy sources and reduce the nation's reliance on fossil fuels. The plan targets achieving a 25 per cent share of renewables in the energy mix by 2036. Moreover, the government has introduced various incentives, such as import tariffs and tax exemptions, to encourage the adoption of solar energy in diverse applications (AEDP, 2015) These government policies have facilitated significant growth in renewable energy, with an annual increase of 16.3 per cent observed between 2012 and 2014. During this period, the use of solar energy contributed to a decline in the proportion of crude oil equivalent consumption, reducing from 33,000 tones to 25,000 tones (DEDE, 2018)

In agriculture, a crucial need remains to enhance the adoption and practical implementation of renewable energy technologies. It is imperative to tailor local energy production and utilization to specific contexts, mainly subsistence and agricultural solar energy (Thongchai & Parnuwat, 2021) Despite efforts invested and support garnered in the past decade, widespread implementation is yet to be achieved. However, integrating solar energy within Thailand's agricultural sector presents notable challenges, primarily in high initial costs (Chimres & Wongwises, 2016) Limited access to financial resources significantly hinders numerous farmers, particularly small-scale practitioners. Moreover, technical and operational obstacles arise, such as more technical expertise and resources required to maintain and optimize solar photovoltaic (PV) systems (Aroonsrimorakot et al., 2020) These challenges underscore the importance of addressing barriers and providing appropriate support to drive the adoption of solar energy in agriculture.

Despite the numerous advantages of solar technology, its acceptance and adoption among Young Smart Farmer in Thailand still need to be improved. In response to the declining number of youths engaging in farming, the Thai government introduced the Young Smart Farmer (YSF) program in 2014. The YSF initiative aims to achieve three primary outcomes: firstly, enhancing the financial independence of participants; secondly, promoting the adoption of innovative farming methods; and thirdly, ensuring the long-term engagement and satisfaction of program members (Jansuwan & Zander, 2021) This study specifically focuses on Young Smart Farmer in the upper northern region of Thailand. These farmers possess the potential to leverage modern agricultural technologies and have received government training to enhance their skills, knowledge, and access to agricultural and financial resources. (DOAE, 2018) This study investigates solar energy utilization and attitudes towards solar energy among Young Smart Farmers. Moreover, to explore potential strategies for overcoming obstacles related to adopting solar energy technology among Young Smart Farmer in the upper northern region of Thailand.

2. LITERATURE REVIEW

Solar energy has emerged as a progressively favored alternative for powering agricultural systems and equipment. Extensive research has underscored the advantages offered by this technology. Notably, a comprehensive review by Khan et al. (Agarwal & Mustafi, 2021) elucidated that solar-powered irrigation systems can enhance crop yields and optimize water efficiency while mitigating greenhouse gas emissions and reducing energy expenses. Furthermore, investigations by Khatun et al. (Zhao et al., 2019) and Pandey et al. (da Silva et al., 2019) have demonstrated the efficacy of solar dryers in preserving crops and minimizing post-harvest losses. These studies collectively emphasize the substantial benefits derived from the utilization of solar energy in agricultural applications.

Solar power exhibits excellent potential in powering various agricultural machinery and equipment. Ramesh et al.'s study, highlights the effectiveness of solar-powered crop protection devices, such as light traps, bird repellents, sprayers, lawnmowers, and fences, in safeguarding crops from birds, weeds, and insects.

These solar power plants offer advantages like lower operational costs, simple designs, and no requirement for fuel (Ramesh et al., 2022) Another study by Paul et al. demonstrates the feasibility of utilizing solar-powered tractors for soil cultivation and transportation, potentially reducing fuel costs and emissions (Dong et al., 2019) Furthermore, the drawbacks of diesel pumps for irrigation are discussed, emphasizing the clean and cost-effective nature of solar power systems for water pumping. Solar water pumps save on fuel costs, produce no carbon emissions, and operate silently (Aliyu et al., 2018**)** DIOP, L. et al.'s research on the technical and economic viability of solar pumping systems further supports the cost-effectiveness of solar water pumps as an alternative solution (DIOP, 2023) Solar energy has also been explored for regulating temperature and humidity levels in greenhouses and climate-controlled farming systems. Akhtar et al.'s study reveal that solar energy can maintain optimal growing conditions for cucumber plants, resulting in improved productivity and quality compared to conventional greenhouses (Jing et al., 2019) In Thailand, a research study examines the factors influencing consumer acceptance and usage of renewable energy. By employing the theory of planned behaviors, the study collects data through consumer surveys in five major cities and employs structural equation modelling (SEM) for analysis. The findings indicate that environmental concerns, awareness of renewable energy, and beliefs in its benefits positively influence consumers' intention to use it. Conversely, the cost has a negative but insignificant effect, while risk perception and trust have positive but insignificant effects. The study suggests that promotional campaigns promoting renewable energy usage in Thailand should consider these influencing factors (Wall et al., 2021)

Overall, the findings indicate that solar power holds considerable potential for enhancing the sustainability and efficiency of agricultural production. Nonetheless, further research is required to tackle various challenges associated with its implementation, including high initial costs, maintenance demands, and vulnerability to inclement weather conditions.

The Planned Behavior Theory, formulated by Icek Ajzen (Ajzen, 1991) in the late 1980s, posits that human behaviors is influenced by three key factors: attitude, personal norm, and cognitive behavioral control. Attitude involves the evaluation of one's behaviors as positive or negative. Personal norms encompass perceived social pressures to engage or abstain from a particular behavior. Perceived behavioral control pertains to an individual's belief in their capability to perform a specific behaviors (Hasheem et al., 2022) These concepts draw upon principles from Environmental Psychology and Marketing.

Drawing on the research conducted by Huijts et al. (Huijts et al., 2012) this paper examines the development of sustainable energy technologies as a response to environmental and social challenges associated with energy consumption. It highlights the crucial role of public acceptance in ensuring the successful implementation of these technologies. While previous studies have explored factors influencing technology adoption, they often need a comprehensive framework. In light of this, the present paper proposes an integrated framework for understanding the adoption of energy technologies, drawing on psychological theories and empirical investigations. This framework encompasses various elements, including attitudes, social norms, behavioral control, perceptions, and personal norms. Perceived costs, risks, benefits, positive and negative sentiments, trust, fairness of processes, and equitable distribution influence these factors. The paper concludes by discussing the applicability of this framework in explaining individuals' willingness to support or oppose new sustainable energy technologies. Notably, behavioral theories have found wide application within the agricultural domain in studying farmer behaviors across diverse contexts. (Ataei et al., 2021; Despotović et al., 2019; Van Hulst & Posthumus, 2016; Yang et al., 2022; Zhang et al., 2020)

The Young Smart Farmer project, initiated by the Department of Agriculture in Thailand, seeks to promote agricultural. The project endeavors to enhance participants' knowledge and skills through theoretical instruction and practical fieldwork in various domains, including crop production, livestock management, marketing, and business administration. The project also incorporates technological advancements such as innovative farming practices to equip Young Smart Farmer with the necessary tools for modern agricultural practices. As of 2021, the project has attracted over 50,000 participants and garnered recognition from international organizations for its innovative approach to fostering youth involvement in the agricultural sector. (DOAE, 2016)

3. MATERIALS AND METHODS

This research integrates the concepts of attitude theory, personal norms, and perceived behavioural control, drawing from the work of Icek Ajzen (Ajzen, 1991) Additionally, a framework based on Huijts' study is employed. Furthermore, certain independent factors derived from analogous studies conducted in different countries are incorporated, ensuring contextual relevance and applicability to the agricultural conditions in Thailand.

Samples

The sample for this study consists of members of the Young Smart Farmer from eight provinces located in the upper northern region of Thailand, namely Chiang Mai, Chiang Rai, Phrae, Nan, Phayao, Mae Hong Son, Lamphun, and Lampang. The total number of potential participants is 1,193 (based on data for net members in 2019) (NDOAE, 2019) The researcher employed the Taro Yamane method (Yamane, 1973) to determine the sample size, considering a 95% confidence level and an acceptable margin of error. Consequently, a sample size of 300 Young Smart Farmer from the upper northern region was determined. Using a stratified sampling method, the researcher allocated the sample numbers across the different provinces as follows: Chiang Mai (58 cases), Chiang Rai (54 cases), Phrae (41 cases), Nan (39 cases), Phayao (11 cases), Mae Hong Son (25 cases), Lamphun (42 cases), and Lampang (30 cases). The list of members of the new generation of farmers, organized by province, is provided with a total sample size of 300 (n=300).

Research Instruments

The selection of appropriate research tools is an important aspect often overlooked by researchers. This study's primary research tool is a structured questionnaire consisting of closed-ended and open-ended questions. The questionnaire was developed with three main sections: 1) Gathering basic information on the utilization of solar energy in agriculture among Young Smart Farmer in the Lower Northern Thailand region 2) Assessing the respondents' attitudes towards solar energy using a Likert scale with five levels of agreement (Likert, 1932) 3) Identifying the obstacles encountered in implementing solar energy practices through open-ended questions

In order to assess the reliability of the questionnaire, a pilot test was conducted with a sample group of 30 respondents who were similar to the target population. The analysis of the pilot test data yielded a Cronbach's alpha coefficient of 0.914, indicating high internal consistency and reliability. This coefficient demonstrates that the questionnaire items are strongly interrelated, enhancing confidence in the instrument's ability to measure the intended constructs accurately.

Data Analysis

The data analysis process employed various descriptive statistics to comprehensively describe the essential personal characteristics and the context of solar energy technology adoption among the new generation of farmers in agriculture. Descriptive statistics such as percentages, frequencies, means, and minimum and maximum values were used to summarize the data.Furthermore, the analysis used weighted averages and standard deviations to examine the attitudes of two distinct groups of farmers: those who do not utilize solar energy and those who do, specifically in the agricultural sector. The assessment of perceptions regarding solar energy technology encompassed five aspects: 1) Perceived Benefits 2) Problems Perception 3) Outcome Efficacy 4) Perceived Risks and 5) Perceived Opportunity.

In addition, the study employed the independent-samples t-test, an inferential statistical method, to compare the attitudes among the farmer above groups. This statistical test enabled a rigorous examination of any significant differences in attitudes towards solar energy adoption.

A categorization approach was employed to analyze problems, obstacles, and suggestions for using solar energy in agriculture. The researcher grouped and categorized the responses provided by farmers in open-ended questions, allowing for the identification of common themes and generating guidelines for the continued utilization of solar energy in agriculture.

4. RESULTS

4.1 General Information of Farmers

The study revealed that out of 300 farmers, 169 from the new generation category did not employ solar energy technology in their agricultural practices. In comparison, 131 farmers belonged to the group that utilized solar energy technology in agriculture. Most Young Smart Farmer (60.67%) hold a bachelor's degree, while a significant portion of farmers (84.00%) have not obtained a degree specifically in agriculture.

Table 1. Personal data of YSF (qualitative data).

Personal Data	Do not utilize. solar energy (n=169)		Utilize solar energy. (n=131)		Total (n=300)	
	Samples	Percentage	Samples	Percentage	Samples	Percentage
Education						
High school	17	10.05	16	12.21	33	11.00
Diploma	19	11.25	30	22.90	49	16.33
Bachelor's Degree	109	64.50	73	55.73	182	60.67
Postgraduate degree	24	14.20	12	9.16	36	12.00
Educational Qualification						
Graduated in Agriculture	147	86.98	105	80.15	252	84.00
Did not graduate in agriculture	22	13.02	26	19.85	48	16.00

Table 2 presents farmers' personal information, including their membership duration in the Young Smart Farmer project, age, income, and farming experience. The average membership duration for utilize solar energy group was higher than do not utilize solar energy group, with an overall average of 2.79 years. Furthermore, the average age of utilize solar energy group was higher than that of do not utilize solar energy group, with an overall mean of 37.68 years. The median income for do not utilize solar energy group was higher than that of utilize solar energy group, with an overall average of 194,940.00 baht per year. Additionally, the utilize solar energy group had a higher level of agricultural experience than do not utilize solar energy group, with an overall mean of 7.73 years.

Table 2. Personal data of YSF (quantitative data).

Personal Data	**Do not utilize. solar energy (n=169)**		**Utilize solar energy. (n=131)**		**Total (n=300)**	
	Mean $\bar{x}$	S.D.	Mean $\bar{x}$	S.D.	Mean $\bar{x}$	S.D.
Become a member of YSF (years)	2.75	1.463	2.84	1.677	2.79	1.558
Age (years)	37.06	5.723	38.48	6.770	37.68	6.232
Income (THB per year)	212,094.67	254,654.183	172,809.16	174,156.213	194,940.00	223,617.529
Agricultural Experience (years)	7.36	4.805	8.19	5.651	7.73	5.199

4.2 Context of Solar Energy Usage

The study examined the usage patterns and purposes of solar energy among a sample of 131 respondents, who were Young Smart Farmer utilizing solar technology in their agricultural practices. The respondents were categorized based on the amount of solar energy they used, specifically as follows: over 3,000 W/h, 1,000-3,000 W/h, and low (under 1,000 W/h).

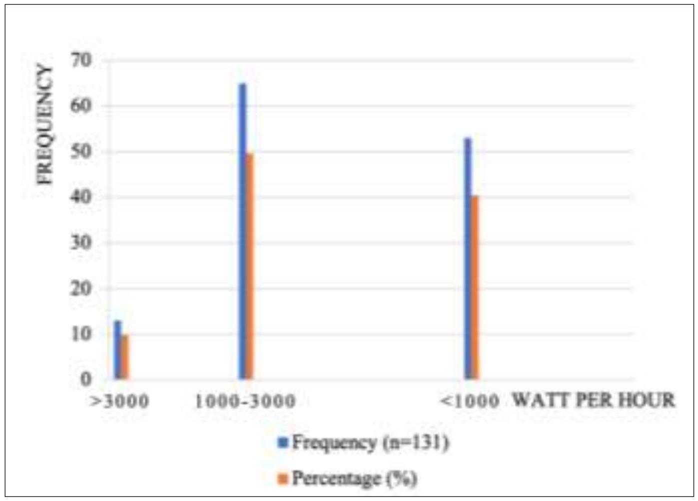
For usage exceeding 3,000 W/h, 13 respondents accounted for 9.92% of the sample. They employed off-grid systems to provide lighting, charge batteries, and operate water pumps and power fans. This usage was motivated by the desire to reduce costs and ensure a reliable power supply during daytime outages. In the case of on-grid systems connected to the Provincial Electricity Authority, the primary purpose was to contribute to global warming mitigation and achieve an average 60-70 per cent reduction in electricity bills.

In the 1,000-3,000 W/h usage range, 65 respondents represented 49.62 per cent of the sample. Similar to the previous category, they used off-grid systems for lighting, battery charging, water pumps, fans, televisions, electric drills, and grinders. Additionally, the on-grid system connected to the Provincial Electricity Authority was deemed convenient, easy to maintain, and self-reliant, as users could assemble and install the system without relying on fuel. However, some respondents in this category faced challenges due to a lack of electricity access on their farms. These farmers used solar energy to conserve electricity, resulting in an average reduction of 40-50 per cent in consumption and fuel savings. Furthermore, solar energy eliminated the need for manually cranking the tractor to generate electricity.

For usage below 1,000 W/h, 53 respondents accounted for 40.46 per cent of the sample. Their utilization of off-grid systems primarily focused on farm lighting, mini water pumps, pathway lights, mobile phone charging, and cooling fans in residential spaces. This type of usage was twofold: to compensate for the lack of electricity infrastructure reaching their farms and to leverage clean energy sources with minimal environmental impact. Adopting solar energy in this context gave farmers the advantage of not having to bear monthly electricity bills.

Overall, the findings shed light on the diverse applications and purposes of solar energy usage among Young Smart Farmer tailored to their specific agricultural contexts. The considerations encompassed cost-effectiveness, environmental sustainability, and self-reliance.

Fig. 1 Solar energy usage context



4.3 Attitudes of Young Smart Farmer towards Solar Energy Technology

Table 3 presents the mean (x̅) and standard deviation (S.D.) of five attitude factors related to solar energy for two distinct groups: the do not utilize solar energy group (n=169) and the utilize solar energy group (n=131).

Perceived Benefits, the utilize solar energy group an average score of 4.60, while the do not utilize solar energy group had a mean score of 4.21. To indicate a strong agreement between both groups of farmers regarding the perceived benefits of solar technology.

Problems Perception, the utilize solar energy group scored an average of 4.12, while the group did not obtain an average of 3.88. To suggest a consensus among both groups regarding the challenges associated with solar energy.

Outcome Efficacy, the utilize solar energy group achieved a mean score of 4.67, whereas the do not utilize solar energy group attained a mean score of 4.38. To indicate a strong agreement between both groups regarding the perceived effectiveness of solar technology.

Perceived Risks, both groups displayed similar mean values. The average score for both utilize solar energy group and do not utilize solar energy group was 3.51, suggesting comparable concerns about the risks associated with solar energy.

Perceived Opportunity, the utilize solar energy group had a mean score of 4.00, while the do not utilize solar energy group obtained a mean score of 3.86. To indicates that both groups of farmers agreed to recognize opportunities in using solar energy.

The results reveal that the utilize solar energy group in agriculture exhibited a more positive attitude across the five factors than the do not utilize solar energy group. Specifically, the attitudes regarding problem perception and the effectiveness of results differed significantly and negatively between the two groups ($p < .001$). Similarly, the attitudes towards perceived risk and opportunity recognition also showed negative differences; however, only the difference in attitudes towards opportunity recognition was statistically significant ($p < .05$).

These findings suggest that the utilize solar energy group holds a more positive attitude towards solar energy than the do not utilize solar energy group, as evidenced by higher average scores across all five attitude factors.

Table 3. Attitudes of Young Smart Farmer towards Solar Energy Technology

Attitude of YSF	Do not utilize. solar energy (n=169)		Utilize solar energy. (n=131)		t	Sig (2-tailed)
	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
Perceived Benefits	4.21	0.465	4.60	0.339	-8.355*	.000
Problems Perception	3.88	0.352	4.12	0.473	-4.680*	.000
Outcome Efficacy	4.38	0.606	4.67	0.412	-4.849*	.000
Perceived Risks	3.51	0.598	3.51	0.891	-.033	.974
Perceived Opportunity	3.86	0.565	4.00	0.677	-2.008*	.046

* Means Statistically Significance at The Level Of 0.05;
Note of attitude levels: 4.21–5.00 means strongly agree; 3.41–4.20 means agree; 2.61–3.40 means unsure; 1.81–2.60 means disagree; and 1.00–1.80 means strongly disagree.

4.4 Challenges of Using Solar Energy for Agriculture

Using solar energy for agricultural purposes presents several challenges and obstacles for Young Smart Farmers. These include:

1. High initial installation costs: Farmers face significant expenses when installing solar energy systems, compounded by increasing labour costs for private companies.

2. Installation costs affected by distance: Agricultural regions far from urban centres experience higher installation costs due to logistical factors, such as transportation and accessibility. Consequently, overall installation expenses are elevated in these areas.

3. Limited access to solar cell products and equipment: Some regions need more convenient access to essential solar cell products and equipment, necessitating reliance on third-party alternatives to acquire the necessary resources.

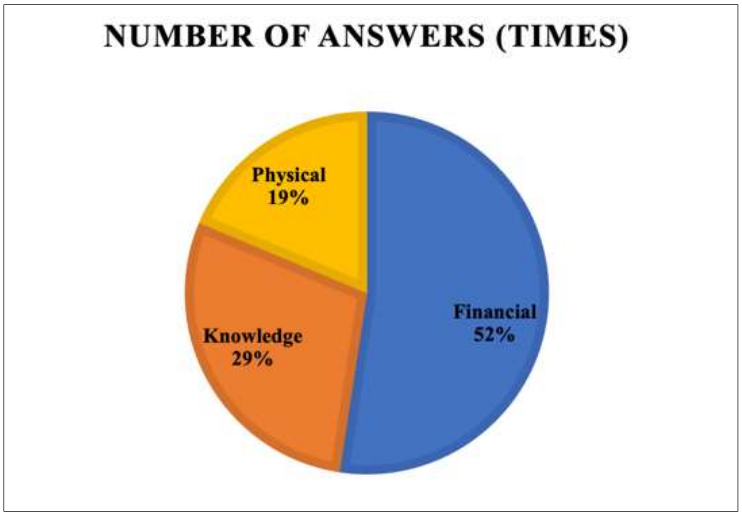
In addition, inadequate e-literacy among farmers poses challenges in effectively utilizing solar energy for agricultural purposes. The farmers' limited understanding of electronics and lack of expertise in operating and maintaining equipment hinder their ability to optimize solar energy usage. Consequently, external electronics technicians are often required for maintenance and support.

Furthermore, malfunctioning electrical systems in agricultural areas restrict solar energy usage to off-grid system applications only, limiting the potential benefits of solar technology.

Lastly, uncertainties arising from seasonal changes, sun angles, and the need for frequent repositioning present challenges in achieving optimal exposure for fixed solar installations in the future.

Addressing these challenges will be crucial in facilitating the widespread and effective adoption of solar energy technology in agriculture by Young Smart Farmers.

Fig. 2 Challenges of Using Solar Energy for Agriculture



5. DISCUSSION

This study aimed to investigate the utilization of solar energy technology in agriculture among Young Smart Farmer in Thailand. The study aimed to gather general information about the farmers, explore the context of solar energy usage in agriculture, examine attitudes towards solar technology, and identify the challenges and obstacles associated with its adoption. Similar studies with comparable objectives have been conducted previously (Izam et al., 2022; Yaseen et al., 2023) This study contributes by providing valuable insights into the application of solar energy technology in agriculture, shedding light on its potential benefits and challenges.

The usage context of solar power among Young Smart Farmer reveals that the off-grid system (Simpson et al., 2021) is the most prevalent method for various purposes, such as lighting, battery charging, water pumps, fans, televisions, electric drills, and angle grinders. This finding aligns with research conducted in other countries (Sunny et al., 2022) On the other hand, adopting the on-grid system, which is connected to the Provincial Electricity Authority, mitigates global warming (Elahi et al., 2022) and reduces electricity expenses. Moreover, solar energy usage enables farmers to save on electricity and fuel costs (Gorjian et al., 2021) By incorporating solar energy into their agricultural practices, farmers can enhance sustainability (Gorjian et al., 2021) and contribute to environmental preservation by preventing encroachment on land and forests. Solar energy is regarded as a secure and clean energy source that aids in reducing and mitigating climate change. Furthermore, sunlight, the origin of solar energy, is projected to persist for another hundred billion years (Electric, 2023) Extensive research has also demonstrated the long-term viability of solar energy, showcasing its economic feasibility with a break-even point that renders it a worthwhile investment (Pascaris et al., 2021)

The study also investigated the attitudes of Young Smart Farmer toward solar technology. The results indicated that farmers belonging to the solar-powered group exhibited more positive attitudes toward solar energy technology than those in the do not utilize solar energy group. These findings align with previous research (Rana et al., 2021) , as evidenced by higher mean scores across five attitude factors: perceived benefits, problem perception, the effectiveness of the results, risk perception, and opportunity recognition. Consistent with similar studies (Alipour et al., 2021; Cheam et al., 2021; Luo et al., 2023; Maradin, 2021; Poier, 2021), the positive or negative perceptions of these factors influence individuals' intention to adopt solar energy.

However, the study also identified several challenges and obstacles Young Smart Farmer face when utilizing solar technology. These challenges encompass a lack of access to information and technical support, which aligns with previous research (Jayaraman et al., 2017) Insufficient technical expertise and environmental concerns also negatively impact farmers' intentions to purchase solar panel systems. Additionally, high initial investment costs (Falchetta et al., 2022) and the necessity for regular maintenance pose further challenges. To enhance the sustainability of solar panels, four strategies are recommended 1) minimizing surface scratches, 2) implementing self-repair mechanisms or preventing infestation by animals or insects, 3) avoiding the use of harmful materials during installation and maintaining a safe distance from trees or structures that could cause damage, and 4) embracing recycling practices to mitigate technological waste (Daily, 2021) These challenges and obstacles may impede the widespread adoption of solar technology among young farmers, necessitating the development of strategies to address them. One policy example (Jayaraman et al., 2017) suggests that individuals seeking to install solar cells could utilize employee provident fund disbursements to support the use of renewable energy.

In conclusion, these findings suggest that solar technology holds the potential to generate positive outcomes, as supported by studies conducted in other countries (Irfan, Elavarasan, et al., 2021; Irfan, Zhao, et al., 2021) However, some challenges must be addressed to enhance its acceptance among young farmers. Future research endeavours could explore strategies to overcome these challenges and utilize the findings of this study to foster the adoption of solar energy technology in agricultural practices.

6. CONCLUSIONS AND RECOMMENDATIONS

This study offers valuable insights into the usage context and attitudes of Young Smart Farmer in the upper northern region of Thailand towards solar energy technology in agriculture. Most farmers surveyed do not currently employ solar technology in their agricultural practices. While most of these farmers possess a bachelor's degree, their education is not explicitly related to agriculture. It was observed that farmers who utilize solar energy earn lower incomes compared to those who do not adopt this technology in agriculture. Despite the high installation costs, ongoing maintenance expenses, and challenges faced in areas with limited access to electricity, users perceive long-term economic benefits associated with solar technology.

Regarding Young Smart Farmers' attitudes, the study identified five distinct attitude factors: Perceived Benefits, Problems Perception, Outcome Efficacy, Perceived Risks and Perceived Opportunity. It was found that farmers who integrate solar energy technology into their agricultural practices exhibit positive attitudes towards perceived benefits, performance or results, and opportunity recognition when compared to those who do not use solar energy.

The study suggests that Young Smart Farmer are willing to embrace solar technology in their agricultural activities to reduce costs and achieve energy self-sufficiency. Furthermore, promoting solar energy for agricultural purposes could positively influence the attitudes of farmers who have yet to adopt this technology, increasing acceptance and utilization in their agricultural practices.

Based on these findings, the researchers recommend that policymakers in Thailand take specific measures to encourage the adoption of solar energy in agriculture. These measures include providing financial incentives to young farmers, such as equipment and installation costs subsidies, and implementing loan programs to promote energy projects. Additionally, Methods Demonstration and Result Demonstration of solar energy technology should be organized for farmers who have yet to decide, allowing them to witness the process and the potential outcomes of implementing such technology. This study provides significant insights that can inform policymakers and stakeholders in the energy and agricultural sectors, enabling them to work towards sustainable development goals (SDGs) while promoting environmentally friendly practices.

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REFERENCES

AEDP. (2015). Alternative Energy Development Action Plan and alternative energy 2015 - 2036. 555/2 Energy Complex, Building B, 24th Floor, Vibhavadi Rangsit Road, Chatuchak Subdistrict, Chatuchak District, Bangkok

Agarwal, A. K., & Mustafi, N. N. (2021). Real-world automotive emissions: Monitoring methodologies, and control measures. Renewable and Sustainable Energy Reviews, 137, 110624.
https://doi.org/https://doi.org/10.1016/j.rser.2020.110624

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), 179-211.
https://doi.org/https://doi.org/10.1016/0749-5978(91)90020-T

Alipour, M., Salim, H., Stewart, R. A., & Sahin, O. (2021). Residential solar photovoltaic adoption behaviour: End-to-end review of theories, methods and approaches. Renewable Energy, 170, 471-486. https://doi.org/10.1016/j.renene.2021.01.128

Aliyu, M., Hassan, G., Said, S. A., Siddiqui, M. U., Alawami, A. T., & Elamin, I. M. (2018). A review of solar-powered water pumping systems. Renewable and Sustainable Energy Reviews, 87, 61-76.
https://doi.org/https://doi.org/10.1016/j.rser.2018.02.010

Aroonsrimorakot, S., Laiphrakpam, M., & Paisantanakij, W. (2020). Solar panel energy technology for sustainable agriculture farming- A review. International Journal of Agricultural Technology, Vol. 16(3), 553-562.

Ataei, P., Gholamrezai, S., Movahedi, R., & Aliabadi, V. (2021). An analysis of farmers' intention to use green pesticides: The application of the extended theory of planned behavior and health belief model. Journal of Rural Studies, 81, 374-384. https://doi.org/https://doi.org/10.1016/j.jrurstud.2020.11.003

Cheam, W.-Y., Lau, L.-S., & Wei, C.-Y. (2021). Factors influencing the residence's intention to adopt solar photovoltaic technology: a case study from Klang Valley, Malaysia. Clean Energy, 5(3), 464-473. https://doi.org/10.1093/ce/zkab021

Chimres, N., & Wongwises, S. (2016). Critical review of the current status of solar energy in Thailand. Renewable and Sustainable Energy Reviews, 58, 198-207. https://doi.org/10.1016/j.rser.2015.11.005

da Silva, L., Marques Prietto, P. D., & Pavan Korf, E. (2019). Sustainability indicators for urban solid waste management in large and medium-sized worldwide cities. Journal of Cleaner Production, 237, 117802. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.117802

Daily, T. O. (2021). Four strategies to make solar panels even more sustainable. The Optimist Daily. https://www.optimistdaily.com/2021/08/four-strategies-to-make-solar-panels-even-more-sustainable/

DEDE. (2018). Thailand's energy situation. Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, No. 17 Rama 1 Road, Pathum Wan District, Bangkok 10330 Retrieved from https://www.dede.go.th/download/stat62/sit_2_61_dec.pdf

Despotović, J., Rodić, V., & Caracciolo, F. (2019). Factors affecting farmers' adoption of integrated pest management in Serbia: An application of the theory of planned behavior. Journal of Cleaner Production, 228, 1196-1205. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.04.149

DIOP, L. (2023). TECHNICAL AND ECONOMIC FEASIBILITY OF SOLAR IRRIGATION PUMPING SYSTEM: A REVIEW. Knowledge-Based Engineering and Sciences, 1(01), 1-22. https://doi.org/https://doi.org/10.51526/kbes.2020.1.01.1-22

DOAE. (2016). Young Smart Farmer: The future and direction of the Thai agricultural sector. Printing House of the National Buddhism Office: Department of Agriculture Extension Retrieved from https://esc.doae.go.th/wp-content/uploads/2018/10/young-smart-farmer.pdf

DOAE. (2018). young smart farmer. 2143/1 Phaholyothin Road, Ladyao Subdistrict, Chatuchak District, Bangkok 10900 Retrieved from https://esc.doae.go.th/wp-content/uploads/2018/10/young-smart-farmer.pdf

Dong, Y. X., Wang, X. L., Jin, E. M., Jeong, S. M., Jin, B., & Lee, S. H. (2019). One-step hydrothermal synthesis of Ag decorated TiO2 nanoparticles for dye-sensitized solar cell application. Renewable Energy, 135, 1207-1212. https://doi.org/https://doi.org/10.1016/j.renene.2018.12.062

Elahi, E., Khalid, Z., & Zhang, Z. (2022). Understanding farmers' intention and willingness to install renewable energy technology: A solution to reduce the environmental emissions of agriculture. Applied Energy, 309, 118459. https://doi.org/https://doi.org/10.1016/j.apenergy.2021.118459

Electric, F. S. (2023). How Solar Energy is a Cornerstone to sustainability. Forme Solar Electric. https://formesolar.com/how-solar-energy-is-a-cornerstone-to-sustainability/

Falchetta, G., Adeleke, A., Awais, M., Byers, E., Copinschi, P., Duby, S., Hughes, A., Ireland, G., Riahi, K., Rukera-Tabaro, S., Semeria, F., Shendrikova, D., Stevanato, N., Troost, A., Tuninetti, M., Vinca, A., Zulu, A., & Hafner, M. (2022). A renewable energy-centred research agenda for planning and financing Nexus development objectives in rural sub-Saharan Africa. Energy Strategy Reviews, 43, 100922. https://doi.org/https://doi.org/10.1016/j.esr.2022.100922

Gorjian, S., Ebadi, H., Trommsdorff, M., Sharon, H., Demant, M., & Schindele, S. (2021). The advent of modern solar-powered electric agricultural machinery: A solution for sustainable farm operations. Journal of Cleaner Production, 292, 126030. https://doi.org/https://doi.org/10.1016/j.jclepro.2021.126030

Hasheem, M. J., Wang, S., Ye, N., Farooq, M. Z., & Shahid, H. M. (2022). Factors influencing purchase intention of solar photovoltaic technology: An extended perspective of technology readiness index and theory of planned behaviour. Cleaner and Responsible Consumption, 7. https://doi.org/10.1016/j.clrc.2022.100079

Hernandez-Escobedo, Q., Muñoz-Rodríguez, D., Vargas-Casillas, A., Juárez Lopez, J. M., Aparicio-Martínez, P., Martínez-Jiménez, M. P., & Perea-Moreno, A.-J. (2022). Renewable Energies in the Agricultural Sector: A Perspective Analysis of the Last Three Years. Energies, 16(1). https://doi.org/10.3390/en16010345

Huijts, N. M. A., Molin, E. J. E., & Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. Renewable and Sustainable Energy Reviews, 16(1), 525-531. https://doi.org/10.1016/j.rser.2011.08.018

iea. (2021). Renewables 2021 Analysis and forecast to 2026. https://www.iea.org/reports/renewables-2021/executive-summary

Irfan, M., Elavarasan, R. M., Hao, Y., Feng, M., & Sailan, D. (2021). An assessment of consumers' willingness to utilize solar energy in China: End-users' perspective. Journal of Cleaner Production, 292, 126008. https://doi.org/https://doi.org/10.1016/j.jclepro.2021.126008

Irfan, M., Zhao, Z.-Y., Rehman, A., Ozturk, I., & Li, H. (2021). Consumers' intention-based influence factors of renewable energy adoption in Pakistan: a structural equation modeling approach. Environmental Science and Pollution Research, 28(1), 432-445. https://doi.org/10.1007/s11356-020-10504-w

Izam, N. S., Itam, Z., Sing, W. L., & Syamsir, A. (2022). Sustainable Development Perspectives of Solar Energy Technologies with Focus on Solar Photovoltaic—A Review. Energies, 15(8).

Jansuwan, P., & Zander, K. K. (2021). Getting Young People to Farm: How Effective Is Thailand's Young Smart Farmer Programme? Sustainability, 13(21). https://doi.org/10.3390/su132111611

Jayaraman, K., Paramasivan, L., & Kiumarsi, S. (2017). Reasons for low penetration on the purchase of photovoltaic (PV) panel system among Malaysian landed property owners. Renewable and Sustainable Energy Reviews, 80, 562-571. https://doi.org/10.1016/j.rser.2017.05.213

Jing, J., Yang, Y., & Tang, Z. (2019). Effects of formation dip angle and salinity on the safety of CO2 geological storage - A case study of Shiqianfeng strata with low porosity and low permeability in the Ordos Basin, China. Journal of Cleaner Production, 226, 874-891. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.04.038

Likert, R. (1932). A technique for the measurement of attitudes. Archives of Psychology, 22 140, 55-55.

Luo, X., Zhang, M., & Liu, X. (2023). Analysis of factors affecting rural residents' willingness to adjust energy use behaviors based on a multi-group analysis. Energy Reports, 9, 522-538. https://doi.org/10.1016/j.egyr.2022.12.017

Maradin, D. (2021). Advantages and Disadvantages of Renewable Energy Sources Utilization. International Journal of Energy Economics and Policy, 11(3), 176-183. https://doi.org/10.32479/ijeep.11027

NDOAE. (2019). Minutes of meetings/seminars. http://www.ndoae.doae.go.th/documents.php

Østergaard, P. A., Duic, N., Noorollahi, Y., & Kalogirou, S. (2022). Renewable energy for sustainable development. Renewable Energy, 199, 1145-1152. https://doi.org/10.1016/j.renene.2022.09.065

Pascaris, A. S., Schelly, C., Burnham, L., & Pearce, J. M. (2021). Integrating solar energy with agriculture: Industry perspectives on the market, community, and socio-political dimensions of agrivoltaics. Energy Research & Social Science, 75, 102023. https://doi.org/https://doi.org/10.1016/j.erss.2021.102023

Poier, S. (2021). Towards a psychology of solar energy: Analyzing the effects of the Big Five personality traits on household solar energy adoption in Germany. Energy Research & Social Science, 77. https://doi.org/10.1016/j.erss.2021.102087

Ramesh, D., Chandrasekaran, M., Soundararajan, R. P., Subramanian, P. P., Palled, V., & Kumar, D. P. (2022). Solar-Powered Plant Protection Equipment: Perspective and Prospects [Review]. Energies, 15(19), Article 7379. https://doi.org/10.3390/en15197379

Rana, J., Kamruzzaman, M., Oliver, M. H., & Akhi, K. (2021). Influencing factors of adopting solar irrigation technology and its impact on farmers' livelihood. A case study in Bangladesh. Future of Food: Journal on Food, Agriculture and Society, 9(5). http://www.thefutureoffoodjournal.com/index.php/FOFJ/article/view/427

Simpson, N. P., Rabenold, C. J., Sowman, M., & Shearing, C. D. (2021). Adoption rationales and effects of off-grid renewable energy access for African youth: A case study from Tanzania. Renewable and Sustainable Energy Reviews, 141, 110793.

https://doi.org/https://doi.org/10.1016/j.rser.2021.110793

SolarPowerEurope. (2020).

https://www.solarpowereurope.org/insights/thematic-reports/agri-pv-how-solar-enables-the-clean-energy-transition-in-rural-areas

Sunny, F. A., Fu, L., Rahman, M. S., & Huang, Z. (2022). Determinants and Impact of Solar Irrigation Facility (SIF) Adoption: A Case Study in Northern Bangladesh. Energies, 15(7).

Thongchai, M., & Parnuwat, U. (2021). Developing Microgrids in the Greater Mekong Subregion (GMS) Countries: Policy Implication and Challenges GMSARN International Journal 15 (2021), 269-276.

UN. (2022). The Sustainable Development Goals Report. 300 East 42nd Street, New York, NY, 10017, United States of America. Retrieved from https://unstats.un.org/sdgs/report/2022/

Van Hulst, F. J., & Posthumus, H. (2016). Understanding (non-) adoption of Conservation Agriculture in Kenya using the Reasoned Action Approach. Land Use Policy, 56, 303-314.

https://doi.org/https://doi.org/10.1016/j.landusepol.2016.03.002

Vo, T. T. E., Je, S.-M., Jung, S.-H., Choi, J., Huh, J.-H., & Ko, H.-J. (2022). Review of Photovoltaic Power and Aquaculture in Desert. Energies, 15(9). https://doi.org/10.3390/en15093288

Wall, W. P., Khalid, B., Urbański, M., & Kot, M. (2021). Factors Influencing Consumer's Adoption of Renewable Energy. Energies, 14(17), 5420. https://www.mdpi.com/1996-1073/14/17/5420

Xue, J. (2017). Photovoltaic agriculture - New opportunity for photovoltaic applications in China. Renewable and Sustainable Energy Reviews, 73, 1-9. https://doi.org/10.1016/j.rser.2017.01.098

Yamane, T. (1973). Statistics, an introductory analysis (2nd ed.). NY: Harper & Row.

Yang, X., Zhou, X., & Deng, X. (2022). Modeling farmers' adoption of low-carbon agricultural technology in Jianghan Plain, China: An examination of the theory of planned behavior. Technological Forecasting and Social Change, 180, 121726

. https://doi.org/https://doi.org/10.1016/j.techfore.2022.121726

Yaseen, M., Thapa, N., Visetnoi, S., Ali, S., & Saqib, S. E. (2023). Factors Determining the Farmers’ Decision for Adoption and Non-Adoption of Oil Palm Cultivation in Northeast Thailand. Sustainability, 15(2).

Zhang, L., Ruiz-Menjivar, J., Luo, B., Liang, Z., & Swisher, M. E. (2020). Predicting climate change mitigation and adaptation behaviors in agricultural production: A comparison of the theory of planned behavior and the Value-Belief-Norm Theory. Journal of Environmental Psychology, 68, 101408.

https://doi.org/https://doi.org/10.1016/j.jenvp.2020.101408

Zhao, Y., Ji, W., Chen, L., Guo, J., & Wang, J. (2019). Effect of cryogenic freezing combined with precooling on freezing rates and the quality of golden pomfret (Trachinotus ovatus) [https://doi.org/10.1111/jfpe.13296]. Journal of Food Process Engineering, 42(8), e13296.

https://doi.org/https://doi.org/10.1111/jfpe.13296