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Room for residential solar PV?

Exploring the socio-technical system narratives and barriers of the residential solar PV diffusion in Thailand.

Sawinee Galaputh

Supervisors

Bernadett Kiss

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Tel: +46 222 00 00.

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Abstract

In working to reduce this increasingly intensified effect of climate change, one of the key strategies employed by different countries around the world is to reduce Green House Gas (GHG) emissions from the energy sector. As they are one of the biggest contributors, the strategies include the employment of different mitigation actions and fading away from the conventional fossil fuel source to a more renewable source of energy production. In recent years the Thai government has had a growing interest in increasing the share of renewable energy, this is included in many of the national strategies launched. As Thailand is located near the equator where the solar power potential is relatively high, solar power is expected to have the most potential. Thailand has experienced a high rate of solar PV adoption at an industrialised and commercial scale. But the share of residential solar PV was less than 1% of the total installed capacity.

This thesis aims to understand the diffusion of solar PV in the residential sector in the context of Thailand. This includes the understanding of the current socio-technical systems and identifying possible barriers that may be slowing down the diffusion. Lastly, exploring if a widely used solar model such as community solar would have potential roles in addressing some of the identified barriers in Thailand and the real-life context of this model. The thesis approaches the aims through the condition's analytical framework, establishing the different existing conditions in each dimension and identifying how this may affect the diffusion. The thesis study was conducted through various data collection methods such as an online survey sent to members of a community, semi-structured interviews with stakeholders and desktop research.

Findings reveal that there are different types of barriers that are slowing down the diffusion of solar PV in the residential sector. Some barriers identified are shared with all the respondents to the study despite the difference in cultural background, while others are found to be group specific. The study further uncovers that the designed set of procedures for the adoption of solar PV is often not followed in practice. Furthermore, the study was able to demonstrate the potential of the community solar model in the context of Thailand. However, future studies are recommended to explore the full possibility of this model in Thailand.

Keywords: Socio-technical systems, solar photovoltaics, adoption barriers, community solar

Executive Summary

Background and problem definition

In the past decades, the impact of climate change has intensified and the primary cause of the climate change was the high level of Green House Gases (GHG) emitted into the atmosphere. (Chaianong & Pharino, 2015). One of the biggest contributors to the increasing emission of GHG is the energy sector worldwide. To combat the climate change issues, the level of GHG must be reduced and there are several ways that the energy sector can help including shifting from conventional energy generation of fossil fuels to more renewable sources.

Thailand is another country that is faced with severe consequences of climate change. Hence, the government's growing interest to mitigate and respond to climate change. Similarly, to the global GHG emission pattern, 70% of the country's GHG emission in 2011 was from the energy sector. In the past decades, Thailand has been working towards the goal of reducing the country's GHG emissions by 7-20%. However, the data collected by the Energy Policy and Planning Office (EPPO) have suggested that the share of energy generated by renewable sources is still low, and the country must increase the locally installed capacity for renewable sources to meet the set goals. Solar energy is expected to be the largest renewable source for electricity generation because of the geographical location of Thailand which allows high PV power potential. (Chaianong & Pharino, 2015; Energy Policy and Planning Office, 2022)

Most of the installed capacity of solar PV systems in Thailand are centralised commercial-scale models and the share of residential solar PV generation is approximately 1% of the total generated energy. (Chaianong & Pharino, 2015; IRENA, 2017) It is important to increase the share of residential solar PV adoption in Thailand, as this allows residents to be more self-reliant. As the increasing number of solar PV adoption in the residential sector signifies that there will be less burden on the electricity on the national grid. (Tongsopit et al., 2019). There are different models to support the diffusion of solar PV in the residential sector and one of them is the community solar model. This model has proven to be successfully implemented in other countries around the world.

Research aims and questions

The thesis's overall aim is to gain a better understanding of the diffusion of solar PV in the residential sector and potentially support the diffusion. However, it is necessary to first understand the existing barriers that may be slowing down the diffusion and explore how the community solar model works in a real-life context. The findings from this study are intended to be used as guidance for further development of the sector, taking the necessary measures or providing support for the residents in Thailand and gaining their interest.

The thesis addresses the following questions, establishing the current socio-technical system, identifying the barriers within the process of solar PV diffusion, and lastly exploring the potential roles that the community solar model may have in the diffusion of solar PV in Thailand.

RQ1: How does the socio-technical systems look like for residential solar PV adoption in Thailand?
RQ2: What are the key barriers of the diffusion of solar PV in the residential sector?
RQ3: What is the role of community solar in addressing the barriers of residential solar PV diffusion?

Figure 0-1. The research questions in this thesis.

The scope of this study is based on a community of residents on Koh Samui. The island is one of Thailand's biggest tourist attractions and has a relatively high energy consumption in comparison to its population. As the national strategy moves forward toward encouraging renewable energy generation, the island plans to follow the strategy by committing to reduce 40% of its carbon emission by the year 2030 and become the first low carbon island in the Asia Pacific. (Asia Pacific Economic Cooperation, 2013)

Research designs and methodology

In this thesis, there are multiple stakeholders that must be addressed, in the process of answering the research questions. The initial plan for the study was to interview the residents of the community on the island, the solar companies, and the utility company. However, after beginning the data collection process it was realised that the community that will be studied for this thesis is an expatriates' community and for this study to be relatable to other parts of Thailand. The data must be triangulated through the introduction of Thai residents as the fourth group of stakeholders. The method for data collection in this thesis includes semi-structured interviews conducted both face-to-face and via phone calls, an online survey sent out to the members of the studied community and desktop research that include documents such as scientific peer review studies, grey literature, and official policies and regulations.

The data collected from these methods are then analysed using an adaption of the 5 steps analytical framework developed by Ulsrud et al. (2015). The framework provides an analytical step that can be taken by looking at a different dimension of the energy system implementation such as the framework condition, local condition, socio-technical in design, socio-technical in practice, and the accessibility and quality dimensions. Furthermore, the thesis identifies the different barriers to solar PV diffusion found in the different dimensions.

Findings

The 5 steps framework has been adapted into the condition's analytical framework, focusing on only four of the dimensions.

In the dimension of framework conditions, currently, there are many supporting programmes provided by the government and the utility company to the residents. These supporting programmes include Feed-in-Tariff schemes launched by the government, pilot projects launched with the purpose of understanding some underlying mechanisms to provide more support and a one-stop service application launched by the Provincial Electricity Authority to provide convenience for the residents. However, in this dimension, the barriers such as the lack of communication, no readily accessible information, no economy for solar PV and lack of appealing incentives have been identified.

The local conditions have shown that the demographics and cultural differences can influence the perception or concerns residents may have regarding the adoption of solar PV. The collected data has shown that there are group-specific barriers, between the two groups of Thai residents and expatriates. In the group of expatriates, more concerns were about the effect of solar PV systems on their property's aesthetics. While the Thai residents are more concerned about being the first mover in this sector and rather prefer for others to lead the adoption and they'd follow when it is more common.

The socio-technical design dimension shows that there was a need for the studied community to introduce a new system within the community, due to the old infrastructures. For the new system, setting up a pilot project for the community solar model to use the energy for the common area usage was suggested. The barriers to the design process were the low awareness of the limited capacity amongst the community members. As this could lead to low motivation for changes in the community.

In the dimension of the socio-technical system in practice, the study establishes that there are 5 steps standard procedures for the residential solar PV adoption in Thailand. However, the interviews with the solar companies have revealed that this set of procedures is not always followed. The submission of the approval document for the solar PV system is compulsory for all the on-grid and hybrid systems. Many residents perceive the document submission process to be complex and complicated.

Recommendation for the community

The thesis provides a set of practical recommendations to the studied community, such as the directions of sustainability practices that they can take. As it was observed through the survey that some members of the community were not interested in discussing the topic of energy. The recommendations for the community were to first work with other sustainability-related practices such as a rainwater collection system, where the rainwater can be used to water the garden at the property. And to consider setting up a pilot project for a community model solar PV system, where the energy generated will be used by the community's common facility.

Conclusion

The thesis aims to establish an understanding of the current socio-technical systems of the solar PV sector in Thailand, identify barriers which may be slowing down the diffusion and seek to see if the community solar model could contribute to solving the barriers or would it create other barriers. The thesis reveals that the experiences of the residents may be different depending on where they are, although the framework condition is shared by all residents living in Thailand. The local condition still contributes to a big part of the experience, to resolve the barriers to the diffusion of solar PV these conditions should be studied and established prior. Although the comparison between the existing barriers in the diffusion of solar PV and the advantages of the community solar have been compared. The study was only able to reveal that there is potential for the community solar model. However, there is potential for future studies to explore deeper into the topic of community solar in the context of Thailand exploring whether there are opportunities or barriers for this model in the future. Furthermore, there's a potential for future studies to look deeper into the influence of the different cultural backgrounds and values that could affect the decision making in the adoption of solar PV. Another potential study would be looking at the influence of local politics on the solar PV adoption processes.

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Abbreviations

AEDP	Alternative Energy Development Plan
ASEAN	Association of Southeast Asian Nations
BAU	Business-as-Usual
EGAT	Electricity Generating Authority of Thailand
FiT(s)	Feed-in-Tariff(s)
GHG	Green House Gases
IPCC	Intergovernmental Panel on Climate
kWh	Kilowatts per hour
kWp	Kilowatts peak
MEA	Metropolitan Electricity Authority
MMTCDE	Million Metric Tonnes of Carbon Dioxide Equivalents
MW	Megawatts
MWTP	Marginal Willingness to Pay
NAMA	Nationally Appropriate Mitigation
NDC	Nationally Determined Contribution
PEA	Provincial Electricity Authority
REDP	Renewable Development Plan
THB	Thai Baht
UNFCCC	United Nations Framework Convention on Climate Change

Introduction

1.1 The Issue

1.1.1 Climate change

In the past decades, the impact of climate change has intensified and is causing more damage around the world. One of the root causes of climate change has been identified as the increasing level of Green House Gases (GHG) that have been emitted into the atmosphere (Chaianong & Pharino, 2015). Furthermore, the impact of climate change can be observed through the increasing severity of natural disasters in the last decades such as the Typhoon Bopha that has caused more than 1100 fatalities in the Philippines in the year 2012 and Hurricane Sandy in the United States of America. These impacts are predicted to worsen in the upcoming future if no initiatives are taken to combat the issue. (Chaianong & Pharino, 2015) According to Intergovernmental Panel on Climate Change, the energy sector accounts for more than 78% of the total global GHG emission.(Intergovernmental Panel on Climate Change & Edenhofer, 2014). These statistic shows the urgency of mitigation actions that should be taken by all the countries, specifically to reduce the level of global GHG and especially control the nation's energy sector(Chaianong & Pharino, 2015). Hence, one of the key strategies employed by the countries is the encouragement of a transition within the energy systems moving from conventional to renewable sources. The importance of renewable sources is not only in reducing GHG emissions but also in contributing to reducing the risks of energy security issues in the countries.

1.1.2 Climate change and energy sector

As a primary contributor to GHG emissions, the energy sector remains to be one of the focuses of many international initiatives to mitigate climate change, such as the Intergovernmental Panel on Climate Change (IPCC) or the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC has divided countries into different groups such as Annex I, Annex II, Non-Annex I, and least developed countries (LDCs). These divisions are done mostly focusing on the level of development of the countries, where Annex I countries include industrialised countries.(*Parties & Observers | UNFCCC*, n.d.) In the Annex I countries, the energy sector is responsible for more than 80% of the anthropogenic GHG where the emission can come from any of the processes such as the production, handling and the consumption of energy supplies. In working with the problem of climate change around the world, the GHG level must be stabilised and reduced. (Sawangphol & Pharino, 2011) Different measures can be taken by the sector to reduce the level of GHG emissions such as reducing fossil fuel extraction, switching to low carbon fuels and improving the efficiency of energy transmission. Although the sector trend has been shifting towards the low carbon transition, in 2012 more than half of the net investment in the electricity sector was in low-carbon electricity generation. It was mentioned in the summary of the key findings from the IPCC Fifth Assessment Report that, to achieve the agreed international goal the energy sector will need to transform and increase the share of low-carbon electricity generation by triple or quadruple of the current share. This indicates that more work is still needed in the sector to achieve the international target of limiting the global warming temperature to 2 °C by 2050. (Brian Statham et al., 2014)

1.1.3 Thailand

In 2014 Thailand was ranked the 9^{th} out of 10 countries that have experienced severe consequences of climate change, especially in the economy and geographical impacts such as coastal erosion and extreme weather events affecting the agricultural sector. This is a key motivation for the government to commit to mitigation action and respond to climate change. The case of Thailand shows an urgent need to work with the energy sector as it contributed to more than 70% of the total GHG emissions of Thailand in 2011. (Green Climate Fund, 2017) The country began working on the issue of climate change by incorporating climate change into its social and economic development plan and the issue was also addressed in the National Strategy (2018 – 2037). Thailand, as a member of the UNFCCC, has previously submitted documents such as the Nationally Appropriate Mitigation Action (NAMA) in 2014 and the Nationally Determined Contribution (NDC) in 2017. In the 2014 NAMA, Thailand has committed and pledged to reduce the country's GHG emissions in the energy and transportation sector by 7 – 20% based on the business-as-usual (BAU) projection. The first 7% is expected to come from the domestic initiative and the rest filling up to 20% was subject to sufficient international support under UNFCCC. Following this, the country has submitted the first NDC which eventually led to the first endorsement of the NDC Roadmap (2021 – 2030) in 2017. This was developed under a participatory approach and through a national consultative process and the roadmap identifies mitigation actions that can be taken in the energy, transportation, industrial process and product use, and waste management sector in the country. The goal is to reduce up to 20.83% of emissions by 2030 based on the BAU projection. The energy sector was set with the biggest share of the expected reduction of 72 million metric tonnes of carbon dioxide equivalents (MMTCDE) out of the expected 115.6 MMTCDE equivalent to more than 60% of the expected reduction. There is a total of 5 mitigation measures for the energy sector listed in the roadmap and they have been divided into 3 groups: energy generation, energy consumption in households, and energy consumption in buildings. The mitigation measures under each group can be found in Table 1-1 below.

Table 0-1. The energy sector's mitigation measures as listed in the NDC Roadmap

Group	Mitigation Measures
Energy Generation	1. Increase power generation efficiency
	2. Renewable energy generation
Energy Consumption in Households	3. Increase energy efficiency in households
	4. Renewable energy in households
Energy Consumption in Buildings (Commercial and Public)	5. Increase energy efficiency in buildings

Source: Adapted from the information from Thailand Mid-Century, Long-Term Low Greenhouse Gas Emission Development Strategy Report (2021)

Following the mitigation measure in the NDC, the Thai government announced another goal of increasing the share of renewable energy in their energy supply through the Alternative Energy Development Plan (AEDP) in 2015. The country expects that the plan will help to increase the share of their generated energy from renewable sources to 30% by the year 2036. (IRENA, 2017) However, according to the dataset provided by the Energy Policy and Planning Office (2022), the total share of electricity from renewable sources generated in Thailand combined with imported electricity is around 24% of the total power generation in the month of January and February of 2022. This indicates that in the following decade, Thailand will have to increase its locally installed capacity for renewable sources to meet the set goals.

Alongside the commitment from the energy sector, the Thai government began supporting the development of a sustainable lifestyle and encouraging the population to be more aware and lead a lifestyle with the least CO2 emission(Office of the National Economic and Social Development Council, 2019). Hence, the commitment to making one of their biggest tourist destination Koh Samui a low carbon island(Asia Pacific Economic Cooperation, 2013). The island is in the south of Thailand with more than 65,000 registered population and approximately 180,000 non-registered population. (Sirasoontorn & Koomsup, 2017) The plan for this transition includes 9 categories: economy member level policy and strategy to reduce CO2 emissions, town structure, eco-lifestyle, area energy planning management, environmental planning, low-carbon buildings, transportation, renewable energy, and untapped energy planning. However, the sector with the biggest share of the island's total emission is identical to the national level, placing the energy sector as the highest contributor(Asia Pacific Economic Cooperation, 2013). According to the presentation given by Ramnet Jaikwang & Supinya Srithongkul (2013), the island has many potential electricity generation sources such as solar photovoltaic (PV), wind and hydropower with a total potential installed capacity of 86.45 MW, which is equivalent to almost 50% of the current supplied electricity through the submarine cable from the mainland. However, after a decade of planning this potential electricity generation installed capacity have yet to be achieved.

And similarly, to the island's potential capacity, the geographical characteristic of Thailand provides the country with multiple possible alternatives for renewable energy sources, such as biomass, hydropower or even wind power. However, these alternatives may not be suitable for all areas of Thailand. For example, hydropower in Thailand is currently limited to smaller projects due to possible impacts on the surrounding environment and the country's overall wind speed is in the middle to low range.

1.1.4 Solar PV potential in Thailand?

Solar energy is expected to be the largest renewable source for electricity generation in the country with a target for an installed capacity of 6000MW, which is approximately triple the installed capacity in 2015. This target is expected to be fulfilled by the year 2036 due to its free and abundant supply in Thailand. (Chaianong & Pharino, 2015; IRENA, 2017; Tantisattayakul & Kanchanapiya, 2017; Yoomak et al., 2019) The map of the photovoltaic power potential of Thailand generated by the *Global Solar Atlas* (2019) in Figure 1-1 illustrates the PV power output of Thailand from the year 2007 (1999 for the South) to 2018. This map illustrates that most of the areas in Thailand hold the high PV power potential of the country. And some parts have more potential than others such as the central and north-eastern areas where the potential exceeds 4.2 kilowatts hour per installed kilowatts of capacity (kWh/kWp), enough to boil 25 litres of water(*Global Solar Atlas - Thailand*, 2019; *Solar Photovoltaic Power Potential by Country*, n.d.). The map further indicates that there is a distribution of potential electricity generation amongst provinces around Thailand. From looking at the map, also indicates moderate to high potential in the southern region, ranging from around 3.8 – 4 kWh/kWp. Additionally, looking at the settlement distribution and urbanization rate in Thailand solar PV systems are considered to be a suitable solution as a new source of electricity generation and replacing the old conventional source (Chaianong & Pharino, 2015).

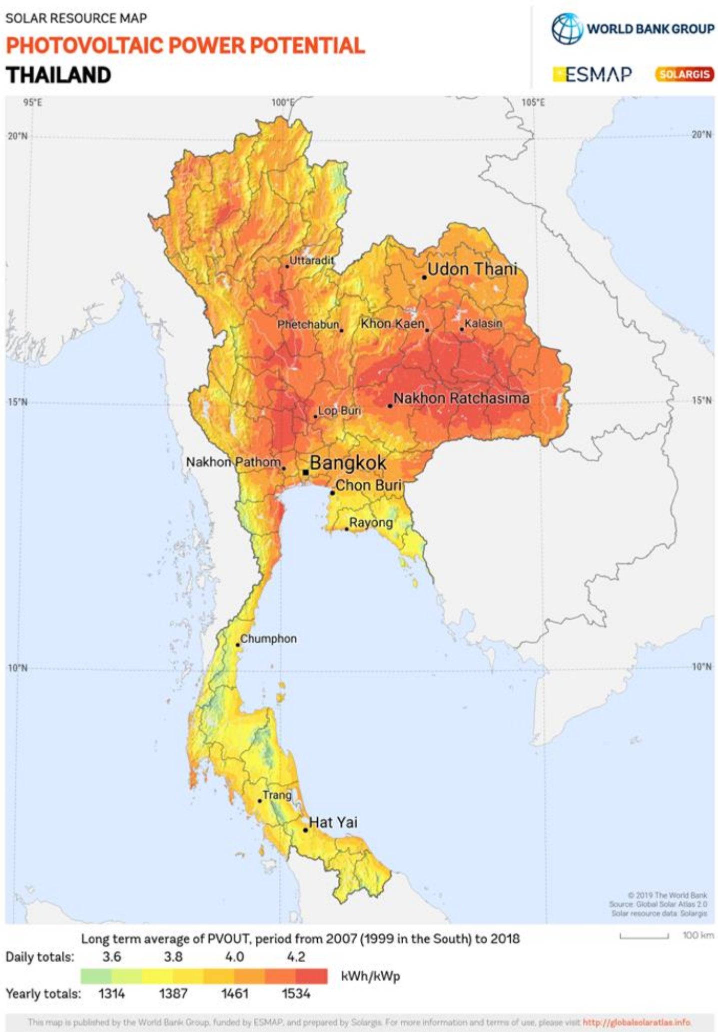


Figure 0-1. The Photovoltaic Power Potential of Thailand

Source: Solar Resource Map Photovoltaic Power Potential of Thailand obtained from the "Global Solar Atlas 2.0, a free, web-based application is developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info

When it comes to generating electricity from solar energy, the authorities in Thailand have shown interest and initiatives in contributing to the transition to solar as a source of energy. For example, a sandbox project for electricity trading and on-grid selling was initiated in 2021 by the Energy Regulatory Commission of Thailand (ERC). According to the Energy News Centre (ENC), this sandbox project will be divided into 6 smaller projects with the objective to study different aspects of the mechanisms such as peer to peer trading, microgrid systems and net metering (Nitsara S, 2021). Although the sandbox project is currently applied to industrial settings, the authority expects that the energy trading opportunities will soon open to the public and encourage more participation from the residential sector. In the past years, there has been an increase in the generating capacity of solar PV in Thailand as illustrated in Figures 1-2. Between the years 2010 to 2015, the total installed solar PV generating capacity has increased more than 10 times. However, the support from the government was more focused on the commercial scale in the past. This results in more than 99% of those capacities being from centralised models installed at commercial scales by utility companies, which leaves the current share of residential installations to be less than 1% of the total generated energy. (Chaianong & Pharino, 2015; IRENA, 2017)

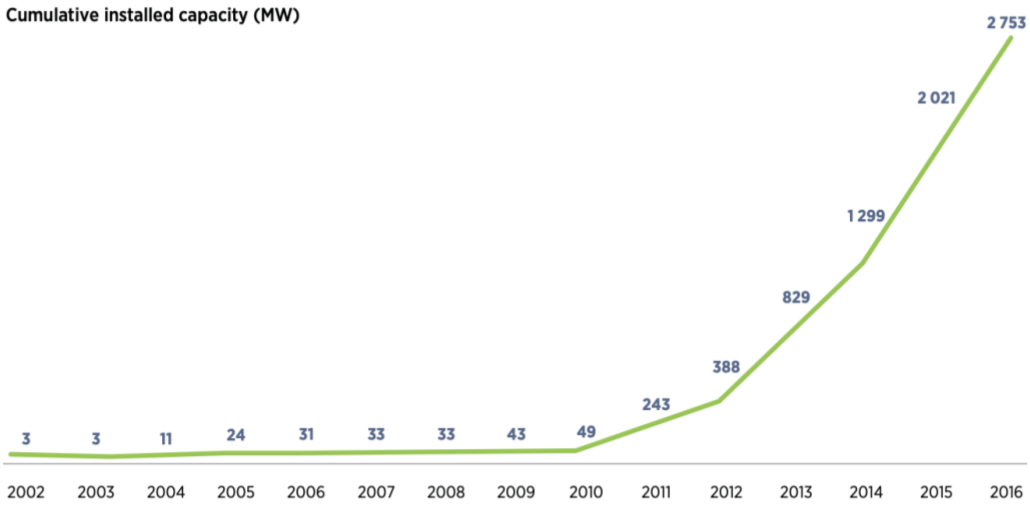


Figure 0-2. The cumulative installed capacity of solar PV, 2002 - 2016

Source: Illustration from the Renewable Outlook Report by IRENA (2017)

Despite the growth of the country's cumulative installed capacity, the residential solar PV sector remains to be untapped (IRENA, 2017). The solar PV systems installed at home would allow the consumers in this sector to become a prosumer where they can generate electricity for self-consumption. Furthermore, the benefit of self-consumption expands beyond the cost savings for individuals. As the increasing number of prosumers in the residential sector signifies that there will be less burden on the electricity on the national grid. (Tongsopit et al., 2019). According to the previously conducted studies by Chaianong & Pharino (2015) and Tongsopit et al. (2019), residential solar holds great potential and could benefit both the individual consumers and the utility company. Yet, the sector's growth remains to be slow and limited, with no clear indicators as to why the sector is unable to pick up its pace.

1.1.5 Community solar model

The residential solar PV system is an important technology that enables consumers to become prosumers and allows a higher level of self-reliance, in comparison to only utilising electricity from the national grid. Furthermore, the residential solar PV systems have relatively lower maintenance cost in comparison to other electricity-generating systems in the same sector. (Chaianong & Pharino, 2015) To encourage more adoption of residential solar PV, apart from the conventional purchasing model of system per household there are multiple models that can be utilised. According to a study by Tongsopit et al. (2016), the available models that may be suitable for the Thailand context are models such as roof rental, solar power purchase agreement, solar leasing, community solar and solar loans. These varieties of models represent the increasing interest in renewable energy in Thailand. Although the accessibility to these models is not all equal and due to the current socio-technical scheme there are some models which are not yet available to the public. Each model can involve a different group and level of actors. For example, the roof rental model refers to the set-up where the purpose of the installation is not for self-consumption at home but rather to utilise the available space for a third party such as a utility company to rent the roof of your home and set up solar PV panels and generate electricity which is directly fed back to the grid(Tongsopit et al., 2016). The study by Tongsopit et al. (2016) has further indicated that, to encourage more involvement from the residential sector the room for improvement related to incentives and model alternatives for solar PV should be addressed. As technological innovation continues and more opportunities are available, the country should consider a model that is suitable not only technologically but also socially.

One of the models that are widely gaining attention around the world is the concept of community energy initiatives. The concept is complex and has no fundamental definitions however it can be seen as a community-based initiative for reorganizing the local energy system and fostering the deployment of efficient energy resources and practices (Daphne Ngar-yin Mah, 2019). The community solar varies depending on the initiatives and depending on the conditions of the community, some can be a top-down initiative organized by utility companies to provide access to renewable energy for the residents while keeping their customer profiles or it could be a bottom-up community-owned system. Despite the different models of community solar, the benefit of this model remains to be constant for all models. The shared responsibility of community solar is found to be less costly than implementing individual solar PV systems (Schunder et al., 2020). The community solar systems are not only beneficial economically, but they can provide the household with spatial constraints, access to solar energy and with the size of the systems the project enables the community to explore new options of technology, designs, and financial plans (Daphne Ngar-yin Mah, 2019; Schunder et al., 2020). Globally, the model has been used in addressing the issue of inequality in the access to energy, which in some cases is the access to renewable energy. In the context of Thailand, this inequality of access is critical as the statistic has shown that in 2019, almost all the population in the country have access to electricity. However, the level of renewable electricity consumption was only 16.5%. (International Trade Administration, n.d.; World Bank, 2020). The benefits of the model found in these case studies from other countries can indicate that the model might have a role in supporting the diffusion of solar PV. However, to provide further support for the diffusion of solar PV in the residential solar, it is first necessary to establish an understanding of the existing barriers which may be slowing down the diffusion and explore how community solar might work in a real-life context, including understanding the processes of the model and difficulties that might occur.

1.2 Aim and Research Questions

1.2.1 Goals and Aims

Despite the supporting policies and initiatives from the government in encouraging the diffusion of solar PV in the residential sector, it has yet to receive an enthusiastic response. This indicates that there may be room for different approaches or possibly room for introducing other models for solar PV, apart from the individual system model. The study aims to explore the practices and procedures of the existing residential solar model in Thailand and identify factors that are deemed as barriers to the diffusion of solar PV in the residential sector. The next step to be taken after the identification of barriers is to see if community solar models might have a role in helping to overcome these barriers or would the introduction of this model creates additional barriers to the diffusion. The findings from this study are intended to be used as guidance for further development of the sector, taking the necessary measures or providing support for the residents in Thailand and gaining their interest. In the hope that it will contribute to more diffusion of solar PV in the residential sector, providing residents with a reduced burden in the monthly spending on electricity and enabling them to become more self-reliant with a stable supply of electricity. Furthermore, the growth of solar PV in this sector can contribute to the national achievement of the previously committed renewable energy and climate change mitigation targets.

1.2.2 Research Questions

To achieve these aims, three research questions are asked. The first, questioning the existing systems and procedures and identifying what the stakeholders see as barriers to residential solar PV. The second question builds from the first and focuses on how to overcome the existing barriers and move forward. The third question is then to determine the possible roles that community solar may have in addressing the identified barriers. The three research questions asked in this study are as follows:

RQ1: How do the socio-technical systems look like for residential solar PV adoption in Thailand?

RQ2: What are the key barriers to the diffusion of solar PV in the residential sector?

RQ3: What is the role of community solar in addressing the barriers to residential solar PV diffusion?

In the process of answering these questions, a set of recommendation have been developed and outlined in the Discussion (Chapter 5).

1.3 Scope and Delimitations

The study will focus on identifying the barriers to deploying solar PV for the residential sector with the current model and systems. In parallel, it also looks to uncover the possibility of using the community solar model to overcome some of the barriers found.

1.3.1 Definition of Residential Solar PV systems in this study:

This study follows the definition of residential solar PV from the definition given in the royal gazette published in 2015 by the ERC, regarding the regulations of the fixed Feed-in Tariff (FiT) for solar PV which was introduced in 2013. The definition included in the royal gazette was "a system that have been implemented by residents in their homes with the generation capacity of less than 10kWp"(Energy Regulatory Commission, 2015, p.1)

1.3.2 Scope of the study conducted

The empirical part of the study will focus on an area that is under the jurisdiction and authority of the Provincial Electricity Authority (PEA), a state enterprise that is responsible for most of the provinces' electricity distribution in Thailand. The status quo or existing systems that are referred to in this study can be seen as the procedures and regulations set by the PEA. Additionally, the residents' interviews conducted are done on Koh Samui because of the variety of communities on the island and the growing interest in solar PV systems. The research is conducted focusing on a community of properties on the island, identifying the barriers to the installation and implementation of solar PV. Furthermore, as one of the most famous tourist destinations in the country, the island of Koh Samui has relatively high energy demands in comparison to its population (Asia Pacific Economic Cooperation, 2013). According to the mayor, the island is looking to reduce their carbon emission by 40% by the year 2030 and this should be a collaboration between the residential, commercial, transportation and other sectors on the island (Ramnet Jaikwang & Supinya Srithongkul, 2013). Despite the data collection being done on a local level and not in the capital city, due to the nationwide regulations from the Ministry of Energy and under the authority of PEA, it can be expected that the suggestions and solutions will be applicable to other parts of Thailand.

To achieve the aim, it is crucial to be as inclusive as possible and to get the whole picture of the factors that may be identified as barriers to residential solar deployment. The stakeholder in this study includes the residents, the solar company, and the utility authority. The respondents for this study can be divided into two groups based on their locations and the estimated number of respondents in each group can be found in Table 1-1 below.

The first group of respondents are the ones located on Koh Samui, these include residents of the community, solar companies, and local PEA officers. This study will be conducted at a private residential community on Koh Samui, which will be referred to as Community S in this report. Community S is a residential community built on the hillside overlooking the ocean. The total area owned by this community is around 66 Rai which is equivalent to 105,600 km^2. There are more than 20 villas within this community and around 10 plots of empty land. From the beginning, Community S was built around the core message of nature preservation and trying to disturb their surroundings as little as possible, hence the maximum capacity of land usage is around 20% of the total area. The estimated number of respondents from the solar company is 3, which is relatively on the higher side as there are only 3-4 available solar companies on the island.

The second group is the respondents from the PEA headquarters office located in Bangkok. This group of respondents can be expected to provide viable information and insights into how the organization has been operating and what are the support provided for the residents

Table 0-2. Number of Respondents in this study

Groups		Number of Respondents
Group 1: Koh Samui	Residents	12
	Solar Companies	3
	Local PEA	1-2
Group 2: PEA (HQ)	Officer and management levels	3-5

Source: own estimation based on the available resources

In the process of this study, some delimitations are expected to partially affect the scope of the study, the primary delimitation being the limited accessibility of some of the data, as with dealing with other external organizations and requesting help. There were no guarantees that all the requested data would be received.

1.4 Ethical Considerations

The ethical consideration of this research primarily focuses on the treatment of the respondents both in the interview sessions and the treatment of their privacy and data. Participation in this research was voluntary and the respondents are informed both during the set-up process and at the beginning of the session. The respondents are given information about the research projects and how their participation will contribute to the research. Each respondent is also offered the option of anonymity from the beginning of the interview sessions. The notes from the interviews are stored in a separate folder on an external hard disk and are only accessible by the author. The selection of respondents is not subject to stereotypes or other conditions, apart from the homeownership or residency on the island. Furthermore, this research has not been funded by an external organization and is conducted to answer the proposed research questions. The research design has been reviewed against the criteria for research requiring an ethics board review at Lund University and has been found to not require a statement from the ethics committee.

1.5 Audience

The first group of audience that may be able to benefit from this research is the utility state enterprises such as the Provincial Electricity Authority (PEA) and Metropolitan Electricity Authority (MEA). The findings from this research could contribute to their development plans and programmes to enable more residents to participate in renewable energy generation. It is also helping them to understand the voices of the stakeholders, which they as a centralized utility authority may not have the time to do. The barriers identified in the study may help to guide and use Koh Samui as an example to move forward.

The second group of audience that could benefit from the research are the communities located in Thailand, both expatriates and local communities. As this study discusses real-life examples from a community like Community S, the other communities can benefit from this study by taking into consideration some of the lists of recommendations listed in the discussion chapter.

1.6 Disposition

Chapter 2 provides a background understanding of the current electricity regime in Thailand and looks at some of the available supporting schemes that are available in the country. The chapter further review some barriers to solar PV that have been identified in different contexts around the world. The chapter concludes with an explanation of the conceptual framework used in this study.

Chapter 3 illustrates the research designs, materials, and methods for conducting the study and the analysis process. In this chapter, the different processes are illustrated and described including the justification for the selection of the methods through the study. The chapter includes the total number and description of data collected and concludes with the methods employed for data analysis.

Chapter 4 presents the analysis of the results through the conceptual framework, describing the conditions in each dimension. The chapter further organises the identified barriers to the diffusion of solar PV in the residential sector according to the dimension that they are in.

Chapter 5 discusses some of the significant results found through the study, including observations that have been made throughout the process of the study. The discussion includes the reflection by the author regarding the choices in the research process.

Chapter 6 concludes the study with key knowledge gained through the study and provides practical recommendations for the studied community or other communities that may fit in a similar context. This chapter further provides suggestions on the topics of potential future research that could be done.

2 Literature Review

2.1 Thailand's Energy systems

In the past decade, Thailand has incorporated renewable energy development into many of its national strategies and 10 years goals. These initiatives are not only important for the goal achievements and reduction of GHG emissions, but they are also key to reducing the risks to the energy security of the country. According to data provided by the Energy Policy and Planning Office (2022), Thailand's total annual electricity consumption has increased from 148,855 GWh in 2011 to 190,468 GWh in 2021 which is approximately a 28 % increase rate. While the annual total electricity generation has increased from 164,090 GWh to 209,684 GWh, equivalent to a 28 % increase rate. The data shows that the increase rate of the country's electricity demand and supply are almost identical. However, when looking at the share of electricity generation the share of imported electricity from neighbouring countries such as Myanmar and Malaysia have gone from 7% in 2011 to 17% in 2021(Energy Policy and Planning Office, 2022; IRENA, 2017). This shows that Thailand's current electricity generation regime is not enough to meet the increasing demand in the country and must rely on the imported source. If Thailand continues at this rate, the lack of self-reliance could indicate that there are increasing risks of severe energy security issues in the upcoming years. Therefore, it is important for Thailand to shift away from the current regime of electricity generation and introduce new systems that may help to increase the supply of electricity (Chaianong & Pharino, 2015). The renewable sources of electricity generation are deemed important for this goal as the source of renewable energy are often more abundant in comparison to conventional sources. This transition to a new electricity generation system could also contribute to a higher level of self-reliance and stability in the sector. The urgency of this transition is becoming increasingly clear as there have been reports of multiple blackouts in Thailand, during the time when there are maintenance of gas production systems in Myanmar or Thailand and Malaysia joint development area(Chaianong & Pharino, 2015).

According to Geels (2005), the breakthrough from niche to the regime level does not happen at once but it requires an accumulation of different factors that can be considered as steps for the breakthrough. Furthermore, it requires elements that have been designed to support the transition such as regulations, policies, or infrastructures. For Thailand, the plan for the development of renewable energy has been begun in 2006 with policy initiation and was one of the first of the Association of Southeast Asian Nations (ASEAN) countries to implement policies to support and promote electricity from the renewable energy source(Tantisattayakul & Kanchanapiya, 2017). The first supporting mechanism implemented by the government was the FiT programme in 2007. The first implemented programme was also known as the 'adder scheme'. It was used as an incentive to power producers to sell the generated electricity from a renewable source for a certain period and the producers are compensated with an additional rate on top of the utility electricity price (Tongsopit et al., 2016). Each type of renewable energy generation had different rates and the contract details for solar power producers of all sizes at the time was 8 Thai Baht (THB) per kWh with a 10-year contract. However, after 2 years of implementation due to the falling prices of PV systems in the market, the government had to stop accepting applications for solar producers due to high anticipation of the generated capacity from solar energy (Tantisattayakul & Kanchanapiya, 2017). This energy source was perceived to be more attractive within the adder scheme in comparison to the other because of the identical rate that is given to all sizes of generating capacity (Tongsopit et al., 2016). The concern has led to an adjustment of the rate of the adder scheme changing from 8 THB to 6.5 THB per kWh and stricter regulations have been implemented as well. The adder scheme was discontinued in 2011 and replaced with a new fixed FiT scheme. This new fixed scheme was introduced in 2013, it was designed specifically for solar to support rooftop solar installation with the total available quota of 200MW. The quota is equally divided for the residential sector with a system capacity of less than 10 kWp and the other is for the commercial sector with a system capacity of 10kWp to 1 mWp. The introduction of this scheme was faced with enthusiasm from the commercial sector where the quota was filled within minutes after opening, while the residential sector was only able to fill 30 out of the 100 MW of available quota. In an attempt to fill the 100 MW quota in the residential sector, the government launched the second round of applications in 2015. Although no modification or adjustments have been made to the FiT offer, the second round of applications has proven to be a success and filled the additional 70 MW quota of the residential sector. (Tongsopit et al., 2016) After both quotas have been filled in 2015, there were no additional supporting schemes for solar PV from the government. Nonetheless, the ENC news agency has reported that after the latest Energy Policy and Planning Office (EPPO) meeting which was held on the 9th of March 2022. They have revealed that EPPO board members have agreed on a power purchase agreement project for the residential sector beginning in 2022 with a quota of 10 MWp per year at the rate of 2.20 THB per unit. This PPA is valid for 10 years. In this meeting, they have also agreed on the quota for rooftop solar for an institution such as schools, hospitals or for agricultural purposes. And like the quota for the residential solar, there are 10 MWp available on a first-come first-served basis and the PPA is valid for 10 years. However, the purchase rate for this group is 1.00 THB per unit. (Nitsara S, 2022) The difference between the two groups' purchase rates is possibly from the difference in system sizes, assuming that solar PV systems in the residential sector are relatively smaller than ones installed at institutions like hospitals and schools.

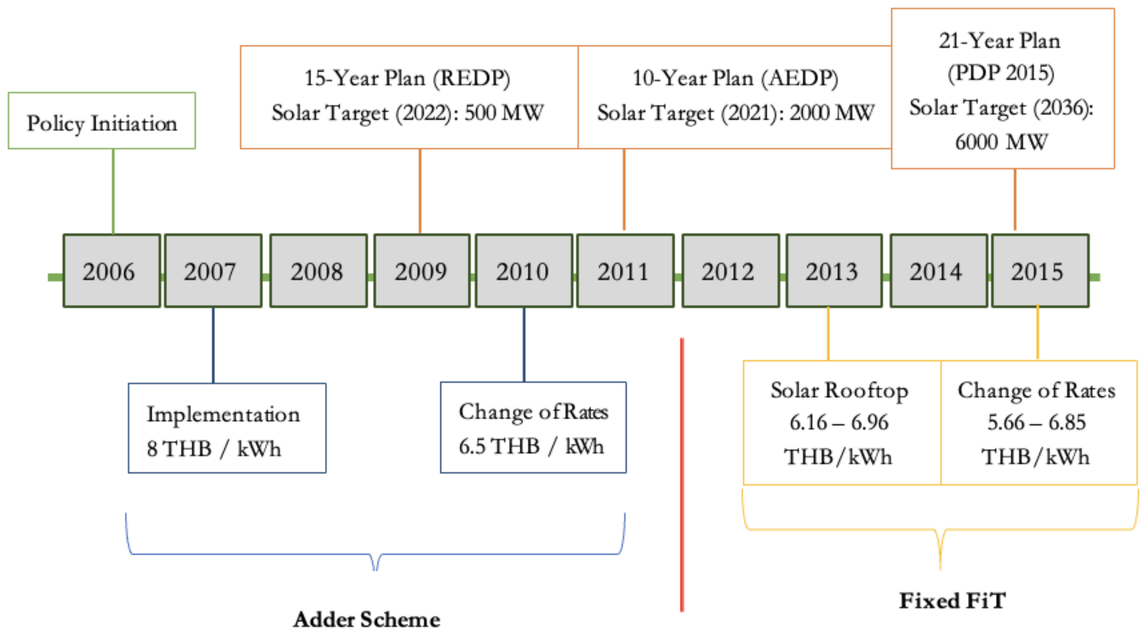


Figure 2-1. The timeline of the FiT schemes and the energy development plans

Source: Adapted from the timeline illustrated in the study by Tongsopit et al., (2016)

In parallel with these introductions of FiT schemes in Thailand, there were announcements of different energy-related plans and commitments such as Thailand's first 15-Year Renewable Development Plan (REDP 2008-2022) in 2009. The performance of the FiT schemes is often connected to the revision of development plans or the announcement of new development plans. For example, the replacement of REDP 2008-2022 in 2011 with the Alternative Energy Development Plan (AEDP 2012-2021) as the adder scheme was able to achieve the set goal of 2000 MW capacity. (Tongsopit et al., 2016) The timeline of the introduction of development plans and the major changes to the FiT programme in Thailand is illustrated in Figure 2-1 above. This timeline presented here is an adaption of the timeline created by Tongsopit et al. (2016)

Amongst the renewable energy sources, solar energy had the highest annual growth rate of up to 104% during the period 2009-2014. However, 99% of the installations are commercial scale while residential installation only makes up 0.003%.(Tantisattayakul & Kanchanapiya, 2017) Despite having the highest rate in the FiT programme, the study has shown that it is financially infeasible for individuals to invest in grid-connected residential rooftop PV systems(Tantisattayakul & Kanchanapiya, 2017). From the study, Tantisattayakul & Kanchanapiya (2017) has concluded that apart from the existing FiT scheme, other incentives from the government are necessary to encourage the implementation of solar PV in the residential sector. The possible measures are ones such as providing an extra tax reduction quota for households that have installed solar PV systems, carbon trading schemes or providing the residential sector with low-interest rate loans that can be used for the purpose of financing the solar PV systems. In 2016, the Ministry of Energy implemented a pilot project of self-consumption solar power generation to help generate an understanding of the mechanisms and provide support for the residents. However, the excess electricity fed back into the grid after consumption from this project was not compensated. The compensation was not available for this pilot project due to the consumption behaviour pattern, as most excess electricity was available during the day and peak loads were during the night, which is when the solar PV system was not able to generate electricity. From this project further studies have been conducted, suggesting that the self-consumption scheme is not yet considered as appealing and compensation for excess generation is preferred. Nonetheless, it was concluded that compensating for the on-grid system without a battery could contribute to an imbalance of the loads and generation profile. (Chaianong et al., 2020) These types of projects are continuously carried out by the governments, to understand and create the most suitable supporting systems for residential solar PV in Thailand.

2.2 Review of barriers to solar PV

Solar PV technology is one of the key solutions which contributes to the low carbon society transition and the reduction of carbon dioxide emissions (Osorio-Aravena et al., 2021). Despite being widely accepted and promising, the uptake of this technology has been slow. It is observed that the share of solar PV systems is only on average around 10% even in the most developed market like Europe. For example, in 2021 the share of solar PV systems was at 8.8% of the total generated electricity in Germany, a country that is committed to solar PV. (*EU Solar Power Hits New Record Peak This Summer*, 2021; Mah et al., 2018; Team, 2022)

In the past, there have been researches and studies conducted to identify barriers to the diffusion of solar PV in the residential sectors in different countries around the world. Much of the literature reports on studies that have been conducted identifying the existing barriers in the context of the studied countries with Bawakyillenuo (2012) looking at the dichotomies of solar PV in Ghana, Kenya, and Zimbabwe. The study conducted by Chaianong & Pharino (2015) seeks to understand the outlook and challenges in promoting solar PV rooftops in Thailand, while D’Agostino et al. (2011) reviewed China's REDP. Mah et al. (2018) studied the barriers and policy enablers for solar PV potential in Hong Kong and Rai & Beck (2017) focused on understanding and finding methods to break the informational barriers in residential solar energy in the United States.

Another type of existing literature is a review of others' literature. Karakaya & Sriwannawit (2015) review case studies around the world, with the purpose of understanding barriers to the diffusion of solar PV. Through these case studies, the researchers have concluded that the barriers to solar PV implementation can generally be divided into four categories as follows: technical barriers, economical barriers, social barriers, and policy barriers. These barriers can be found in different processes of the diffusion process such as the decision making, installation or maintenance. However, there may be more barriers existing apart from the categories and this section discusses and provide examples of the types of barriers that have been identified in previously conducted studies and from the literature review by Karakaya & Sriwannawit (2015).

2.2.1 Technology-related Barriers

The first category of barriers identified in past studies is the technical barrier. These barriers are often related to difficulties experienced in the installation or maintenance process. The cause of these barriers is not only limited to the development of PV technology, but this also includes external factors such as climates, available technology, and existing infrastructures.

The local conditions such as *climate patterns* and availability of technology options have influenced the solar PV installation and maintenance processes. The local climate conditions can affect the *efficiency* of the solar PV in the area, which is directly linked to the level of *consumers' satisfaction* with their investment choices. And one customer's low satisfaction level can often affect the *decision making of the next customer*. The effect of climate conditions can be observed in the case of the United States where the country has an extreme variation of climatic conditions in different areas, leading to different levels of solar PV potentials (Sarzynski et al., 2012). Additionally, the geographical regions are just as important, the solar PV technology may face a *competing technology* that is more suitable for electricity generation (Karakaya & Sriwannawit, 2015). For example, a study by D'Agostino et al. (2011) has shown that increasing access to hydropower as a source of energy generation in China has a negative effect on the rate of diffusion for solar PV.

Space constraints have also been previously identified as one of the contributing factors making solar PV a much more expensive option for cities, in comparison to the suburb where there is more space available for residents (Mah et al., 2018). In a study of potential PV adopters in Hong Kong published in 2018, they discovered that there is limited space on the rooftops. These spaces are usually preoccupied with big water tanks or have been used as storage spaces for the residents in the building, limiting the plausibility of installing panels to be used by the residents.

In recent years, the development of technologies has contributed to major growth in the adoption of solar PV worldwide including the adoption of this technology in sectors such as residential (Mah et al., 2018). During the years between 2008 to 2012, mature markets have experienced a 60% price drop. However, this accessibility to affordable PV systems may not be true for all markets. (Mah et al., 2018) A study conducted in Ghana has revealed that one of the barriers in their local market was the *accessibility of sizeable residential PV systems*. Bawakyillenuo (2012) revealed that the capacity of the solar PV systems available was too high and had a high wattage system. This lack of availability of options in the market is interconnected to the *affordability* barrier, where overqualified systems often mean that they are sold at a higher price. These barriers are stopping the adoption of the PV systems by lower-income households as they are not able to afford the systems. (Bawakyillenuo, 2012)

Chaianong & Pharino (2015) have found that Thailand's diffusion of solar PV in the residential sector is facing similar barriers to the other countries. However, the main technology-related barrier found in Thailand was the lack of sufficient skilled workforces and domestic solar PV production capability. Solar PV technology often relies on local knowledge of the climate and radiation commission, the technology should be customised and adapted to best suit the condition of the installation site. However, as Thailand lacks the capability to produce solar PV and relies on imported technology, this customisation has been limited. Another barrier identified in the study was the limited workforce in the solar sector in Thailand, including workers, companies, and research and development (R&D) centres. The researchers have revealed that these two barriers are closely connected as R&D centres play a big role in developing and creating innovations which can provide competitive advantages for the domestic solar PV technology over the imported technology. (Chaianong & Pharino, 2015)

2.2.2 Economic Barriers

There is one set of barriers that have been mutually identified in different studies conducted around the world, despite the geographical differences the common factor of these studies was the identification of economic barriers in the diffusion of solar PV systems. The prices and payback periods are usually different in each country as this depends on external factors such as climate conditions and available financing schemes. However, this category of barriers has been identified as a major barrier to deployment (Mah et al., 2018). The factors included in this category are often concerned with a *high upfront cost* and the *long payback period.* (Mah et al., 2018) The initial investment made to adopt the solar PV systems is often seen as an upfront cost, as they are paid prior to the utilisation of the system. And payback period refers to the time it takes for the investment, in this case, the installation of a solar PV system to recover the cost.

In Nigeria many residents find the technology appealing and are interested in adopting the PV systems, however, more than 80% of the respondents to the survey have suggested that high investment costs and *lack of finance* were the main barriers blocking them from installing the system. Some consumers have also experienced a *malfunctioning system as they were not able to afford a sizeable system*. The economic burden continues further as system failures occur and it is required for them to *change their household appliances* to low energy appliances to accommodate and optimise their installed PV systems. This spending on both the PV systems and required changes within the house was the reason why many households in Nigeria have continued to use their gasoline generators. (Ugulu, 2019) The lack of finances does not only affect the installation process, as the people of Bolivia have experienced the inaccessibility of repairment due to the *high fixing* and *components cost*, creating an issue of inequality in terms of access to the technology. (Karakaya & Sriwannawit, 2015).

Similarly, Thailand is faced with economic barriers to the diffusion of solar PV in the residential sector, in 2012 the average installation cost of a 10 kWp solar PV system was approximately 630,000 THB (~18,500 USD). With this average installation cost, the payback period at the time was calculated to be around 7 years. Although the payback period of the installation seems short, in a developing economy like Thailand where the average household monthly income at the time was 24,000 THB, many residents were hesitant in adopting the technology at home. (Chaianong & Pharino, 2015; *Revenue and Household Expenditure*, 2019)

2.2.3 Social Barriers

The social barrier in this study refers to a barrier that is non-economic factors which are linked to people as an individual or to the environment around them. These factors are often related to the lack of information which leads to misunderstandings or perceptions that may affect the decision-making choices for themselves and others.

A decision to adopt PV systems requires an extensive amount of *information* including financial, social, or technical factors. However, all this information is often not made available or easily accessible by the residents. Furthermore, the accumulation of this information requires an extensive amount of resources which can be considered a barrier to PV systems adoption by some. (Rai & Beck, 2017) In a study by Karakaya & Sriwannawit (2015), the authors have discussed the example of solar PV adoption in China. The researchers have stated that there is a high level of dissatisfaction with the low performance and efficiency in China. While this performance may be caused by the *improper usage* and not the functionality of the system. If there is no information or knowledge provided to the potential adopters about the durability of the standard procedure, the other potential systems adopters may have already developed a dissatisfaction based on the experience of others which is the negative effect of word-of-mouth and leads to a low number of PV systems adoption in the country (D'Agostino et al., 2011). The availability of information does not only help to make it easier for potential adopters to decide but it could also correct some of the *misunderstandings* they may have regarding the systems. The misunderstandings may include *negative perception* of some of the system attributes or it could be based on the potential adopters' *past negative experiences* with other solar systems such as solar heating. Without the provision of correct or appropriate information, these factors may discourage potential adopters to adopt the PV systems.

2.2.4 Market and Institutional Barriers

This subset of barriers refers to the factors that are rooted in the structure of the country, in terms of the market, the institutions and the government's strategies related to solar PV or the renewable energy source.

Barriers are not always related or connected to the customers only, but they could be rooted in the nature of the market itself that becomes a barrier to the diffusion of solar PV. A low adoption rate in the market often means that there is a lack of demand for electricity in the market. Karakaya & Sriwannawit (2015) had suggested that the lack of demand in the market can be divided into two types. The first is that there is a lack in the usage of electricity-related activities. In the low-income household market, there might be a lower usage of electricity appliances due to the lower accessibility to the related services. For example, a household with no access to TV signals has fewer needs for electricity in comparison to a household with access to the signals. The second type is when the market has a small customer base. This is often the case for a market with a lower number of high-income households, as these are the potential adopters with the purchasing power for PV systems or have higher demands for electricity use. In a market that is missing this demand for electricity, it is more likely that the market will not be able to grow. In the case of solar PV systems, this lack of demand is reflected in the low adoption rate in the market. (Karakaya & Sriwannawit, 2015)

The history of the country can also affect the diffusion of technology such as solar PV. Banks or financial institutions in countries with experience of the economic crisis may be more sceptical in the process of approving loans and investments for a mid- or long-term project. This difficulty in gaining financial support can be seen as a barrier for some in the residential sector. Furthermore, if a country's economy is declining it is likely that the demand for electricity use will decrease alongside the economy. This creates a loss of interest for the residents to adopt PV systems in their homes, as they no longer feel the need for high electricity usage and their household spending is affected by the declining economy. (Karakaya & Sriwannawit, 2015)

In the context of Thailand, the researchers Chaianong & Pharino (2015) have discovered that Thailand was facing a social barrier on a national scale. As there has not been a nationwide energy shortage, the researchers believed that the Thai public has lost interest and concern for the issue of energy security. Although there are warnings sent out by the government annually regarding the possible power outage, the warnings are often sent with a message encouraging the public to conserve energy rather than to seek long term solutions. The researchers have revealed that there is a lack of education programmes provided by the government regarding the issue and the knowledge on the alternative energy source. With these factors missing, the public is unable to understand the urgency and impact of the issue. (Chaianong & Pharino, 2015)

2.2.5 Policy Barriers

Apart from technical and social factors, there is another key contributor to the diffusion of solar PV systems. Many studies have identified that governmental supports play as important of a role as any other factor. The support is not limited to financial subsidisation or compensation scheme like FiT, but it could be other policies which encourage a preferable condition for residents to invest in solar PV systems. However, these supports can become barriers to the diffusion of solar PV when they do *not align with the market's demand* and are perceived as unattractive or when there are *conflicting regulations* or policies regarding the adoption of solar PV.

In the past, South Korea's government have introduced multiple supporting schemes to support the adoption of renewable source energy residential micro-generation systems with some policies that are specific to solar PV and some that include other types of renewable energy generation. The Korean government launched their first solar PV supporting the programme in 2004, providing residents with a partial subsidy for the installation cost and revised the subsidy programme in 2009. The revision was an expansion from a solar PV specific subsidy to covering the adoption of other technology as well. These subsidies have proven to be a great success at the time, resulting in an increase from 310 solar PV systems in 2004 to 26,360 micro-generation solar PV systems in the year 2010. But providing direct subsidies to residents can be a burden for the government financially, the government began to look for ways to transition from direct subsidies to loans. Hence, the introduction of an additional loan programme was designed specifically for the adoption of solar PV systems. Through this programme, households that consume more than 600 kWh of electricity per month are eligible for low-interest loans from financial institutions. This loan is designed to be used as the installation cost for the solar PV system, helping to lessen the financial burden of the household. (Jeong, 2013) However, the results of an assessment through the study of Marginal Willingness to Pay (MWTP) by Jeong (2013) show that although the government have tried to transition away from the previously provided subsidy, the households show a stronger preference for the direct subsidy. This *mismatch in interest* between the government and residents can cause a delay in the adoption rate of solar PV in Korea as the supporting schemes to become less appealing (Karakaya & Sriwannawit, 2015).

In some cases, it has been discovered that other policies or regulations can often affect the diffusion of solar PV. Blum et al. (2013) have discovered through their cost competitiveness analysis of renewable energy technology in Indonesia that the existing energy price subsidies affect the attractiveness of solar PV for the potential adopters. The energy prices in Indonesia have been subsidised since 1967, making the retail price of diesel 33% lower than the global price. This previously implemented subsidy has pushed the abatement cost of solar PV in Indonesia from negative to approximately 200 EUR /tCO_2, making it *less appealing* to the potential adopters. (Blum et al., 2013) According to Chaianong & Pharino (2015), the diffusion of solar PV in the residential sector in Thailand is to experiencing an effect from the *conflict with another regulation*. The Factory Act, B.E. 2535 of Thailand has defined and classified any system with an installed capacity of more than 3.73 kW as a factory. This classification directly affects some of the potential solar PV adopters if their homes are in the factory restricted zone which has been defined according to the City Planning Ministerial Regulations of Thailand. This is conflicting between the attempts to encourage more diffusion of solar PV in the residential sector and potential adopters who must suspend their solar PV adoption plan due to the location of their homes. (Chaianong & Pharino, 2015)

2.3 Theories and conceptual frameworks

This section of the literature review aims to provide a background understanding of the socio-technical transition framework, which is the foundation theory used in this thesis study. It also introduces the analytical framework that will be used for the analysis of collected data in this study.

2.3.1 Socio-Technical Transition

The concept of a socio-technical system was introduced in the late 1940s after the Second World War in the coal industry. According to Trist (1981), the concept was first used in a research project of an organisation in the coal industry. At the time, machines were introduced to help with increasing productivity. However, it failed in doing so and the organisation was also struggling in their human resource management. Through this project, the researchers were able to identify the complex working systems where there is an interaction between humans, machines, and the environmental aspects of the system. The researchers have realised the importance of the interconnected aspects, and how separate approaches toward the social or technical system within the work systems are no longer a sufficient solution to issues that may occur within the system. (Trist, 1981) Although the concept originated from the context of industrialisation and management of an organisation, this concept can also be used in another context as well such as when dealing with sustainability. The term sustainability includes a symbiosis of the partnership between the social, environmental, and economic factors. The concern of social inclusiveness, economic resilience, and environmental protection for the current and future generations. (Elkington, 1998; World Commission on Environment and Development, 1987) There has been a growing interest in the topic of sustainability as more issues begin to rise such as, pollution, climate change and the widening inequalities in societies around the world. As these issues are interconnected between the different dimensions, working to solve them from a single dimension will no longer work. Hence the need to approach the issues from several dimensions. (Savaget et al., 2019)

In the past decades, many environmental problem solutions utilise clean technology, and this technology has been developing over time and is expected to continue evolving. However, it is expected that a change or transition from the existing system is required to deal with newer environmental problems. From the perspective of the socio-technical system, it is believed that this transition consists of both technological advancement and changes in society. To create a transition from conventional to new, it is necessary to make changes within both co-evolving dimensions. Although the transition is expected and needed, these existing systems are often embedded with lock-in mechanisms such as sunk investment costs or supporting policies. Nevertheless, transitions needed to deal with the challenges can take place at different levels from practical use of technology to macro-level policies and infrastructures. There are different dimensions within the transition that can be studied including the political, social or technological dimensions. (Geels, 2004, 2010; Ulsrud et al., 2015).

The transition of energy sectors around the world towards a more sustainable source of energy generation often involves interdisciplinary fields such as the socio-technical transition. This interdisciplinary concept focuses on how different dimensions are connected and how they shape each other to enable this evolution, not only in the technological dimensions but in others such as political or social as well. When there is a need for change or transition away from the fossil fuel conventional energy generation to a renewable source. Many factors should be addressed, to achieve the goal of change in the sector. These factors include social or cultural, economic, political, and existing infrastructures for each of the processes that have been built and used prior. For example, to reach the global target of keeping the global temperature rise under 2°C more actions are needed than just optimizing the transport or energy systems. This target can only be achieved when there is an 80% reduction in GHG emission, and this much reduction can only happen if there has been a bigger change than optimization. There must be a transition from the fossil-fuel dependent production and consumption processes to a more sustainable one. (Rohracher, 2018)

In this study, the diffusion of solar PV in the residential solar is a part of a socio-technical transition in the energy sector in Thailand. The study focuses mostly on the social and political dimensions of the diffusion of solar PV systems and identifying barriers which may be slowing down this transition process in Thailand

2.3.2 The conditions analytical framework

In the attempt to understand the diffusion of solar PVs in the residential sector of Thailand, an understanding of the socio-technical system is needed. Through this knowledge of the current socio-technical system in Thailand, the author can explore the different dimensions that are connected to the structure of the systems and understand how each dimension may affect the diffusion of solar PVs in the residential sector. In analysing the collected data from this research, the thesis follows a five steps analytical framework developed by Ulsrud et al., (2015). This framework has been developed and used in their research on the acceleration of electricity access at the village level in Africa through solar power. The study has defined the village as a decentralised system at a micro level, using this sample to observe the mutual co-evolution of technology and society. According to the researchers, their past studies of power supply for communities have revealed that sometimes there are unpredictable developments that happen due to local context and factors (Ulsrud et al., 2015). The conducted study described the related factors that may affect the designing, implementation, and operation process of a centralised community solar system. Due to the trends of electricity demand in this community, where the need for electricity is mostly for lighting and phone charging. The solar PV system was installed and operated in the form of a community energy centre where they provide services related to electricity needs such as lantern rentals for lighting, phone charging services and IT services such as printing or photocopying (Ulsrud et al., 2015).

The five steps framework was developed and used to provide an understanding of the system, its characteristics, the reasons behind these characteristics, and the equitability of access to these systems and services. These characteristics are presented under different dimensions which influence processes such as the planning, adoption, and usage of a new energy system (Ulsrud et al., 2015). The following section includes the definition of each dimension given by the researchers and the example of how they have used this framework in their study. The definition of each dimension given by the researchers is illustrated in Figure 2-1. Furthermore, the planned usage of this framework in this thesis study is also included for each dimension.

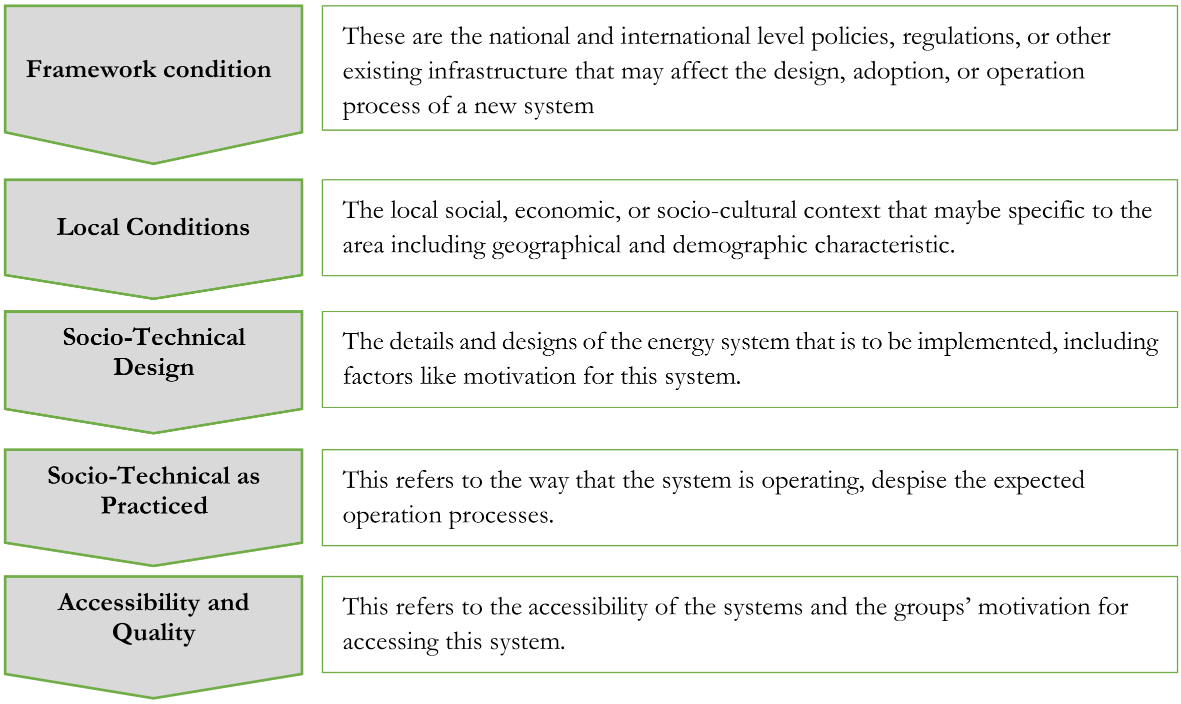


Figure 2-2. The dimensions of the five steps analytical framework and definition

Source: generated by the author with the definition adapted from Ulsrud et al., (2015)

The first dimension is the framework condition, this refers to regulations, policies, financing schemes, availability of technology and maintenance infrastructure that affect the adoption process. Even though the factors in this dimension are focused on the bigger picture, it is still important to look at them because often local systems can also be affected by the existing regime (Ulsrud et al., 2015). In the study by Ulsrud et al. (2015), the researchers discuss the current operations in Kenya's energy sector and the possible opportunity for adopting solar PV in remote villages. Most of the electricity generated in Kenya is from diesel power generators, the high price of diesel has also affected the price of electricity in Kenya. This was a key opportunity for the search for alternative energy generation. And the existing electricity infrastructure is only able to reach around 19% of the population (Ulsrud et al., 2015). The researchers have found that these factors are the main factors that should be noted, while there were not any relevant policies that would affect the diffusion of solar PV. Following the definition given to this dimension, the thesis study aims to follow the similar steps taken by Ulsrud et al. (2015) and explore the existing condition such as the current share of electricity generation in Thailand, defining the related financial schemes and policies or exploring into the roles of national strategies related to renewable energy. These factors are expected to have an influence on the diffusion of solar PV in the residential sector in Thailand.

The second dimension is the local conditions, referring to the process of understanding the dynamic between society and technology. The dimension explores the question of whether the characteristics of the local community will affect the design and decision making related to the types of suitable systems. The factors in this dimension are not only limited to the socio-economic but they can also include demographical and geographical characteristics. The study by Ulsrud et al. (2015) began with the geographical and demographical characteristics of the village they are studying and explained how the distributed settlement characteristics of the village have influenced the design of the systems to be adopted. Furthermore, the high rate of poverty in this village has influenced the design choices to include fewer numbers of batteries in an attempt to lower the cost and make the service more accessible for all. These conditions were also relevant in the prioritisation of options in terms of the services that would be available at the energy centre. (Ulsrud et al., 2015) In the thesis study, the author aims to look at the characteristics such as demographic of the island and of the community to determine if they influence or affect the behaviours of the residents which may lead to an effect on the diffusion of residential solar PV.

The socio-technical design dimension refers to the details and designs of the energy system, including the intention and motivation set by the actor responsible for the adoption of the system. This dimension in the context of community solar systems in the Kenyan village was the system and operational designs which were modified to accommodate the local conditions such as a minimal system with a small number of batteries in the attempt to lower the cost and operational design in the context of recruiting requirements for the staff. The community solar project aims to provide an equal opportunity to men and women in the recruitment process by removing some requirements that may be more favourable toward male applicants. (Ulsrud et al., 2015) However, as the thesis aims to look at the diffusion process of solar PVs in the context of Thailand, the study will focus more on exploring a suitable model for adopting the systems rather than the technical design aspects. And the suitable model should reflect the conditions described in the first two dimensions.

The fourth dimension is the socio-technical as practised, it is emphasised by the researchers that the actual operation of the systems is always different from the intended procedures and that they often deviate away from the initial plans. This is one of the most crucial dimensions to understand and observe, as the results of this deviation can determine the outcome and affect the future adoption of the system. In the study of a community solar centre in a Kenyan village, the researchers have experienced that the service provided was also getting interested from residents from the nearby community and that a business opportunity has evolved from their services. Some of the residents in the village started to act as rental agents and provide the rental service from the centre to the nearby villages. Furthermore, they have also discovered that despite their attempts to make this service available for everybody in the village, there were still people who were not able to afford the services provided. (Ulsrud et al., 2015) Following the study conducted by Ulsrud et al. (2015), this thesis study aims to identify the procedures needed for the adoption of residential solar PV systems in Thailand and analyse the effect this may have on future adoption.

The last dimension identified by the researchers is the combination of factors which overlooks the accessibility, quality and reliability of services provided by the systems. The dimension focuses on the motivation for the assessment of the systems. The dimension also looks at the results of the analysis or assessment of the project to see if there are any future indications that can be made. An example given in the study by Ulsrud et al. (2015) was the assumption that if there were a high frequency of rentals and services utilised it can indicate that the system adoption was successful. However, this dimension requires long term observation before the researchers can make any indication. For this thesis study, the last dimension is not applicable to the aim and goals because this dimension is applicable only to systems which have been adopted prior and can be observed in the long term.

Nevertheless, the analysis of the findings in this study will follow the dimension as a steppingstone in looking at the holistic picture of the residential solar PV in Thailand. For example, understanding the framework conditions and local conditions may provide an insight into the suitable designs of the energy system for the specific community. Furthermore, the observation of socio-technical system functions can help to determine the viability and potential for scaling up from the micro-level (Ulsrud et al., 2015).

Although this framework has been developed for a study focusing on a micro-level system transition, it is expected that these dimensions can provide an insight into a macro-level energy system such as the residential solar PV sector. In this study the author has utilised the frameworks in different steps throughout the study. It has been used as both the theoretical framework, acting as guidance for the data collection process by outlining the scope that should be considered. And it has been used as an analytical framework in understanding the data which have been collected. This framework provides a guiding step for this study to explore and identify barriers to residential solar PV in Thailand, providing a holistic analysis of different dimensions within the much-needed transition to a renewable energy source in Thailand. The preliminary research of previously conducted studies in other countries and of the related theories provide a foundation for the analysis of the socio-technical system of solar PVs in Thailand and a better understanding of the barriers to its diffusion. And through this, shedding light on potential approaches to overcome the barriers, for example through community solar models.

3 Research Design, Materials and Methods

3.1 Research Design

Much of the solar PV capacity in Thailand right now is from centralised solar PV installations, but with the rising trends and interest, it is expected that the number of residential solar PV will increase as well. This project aims to study and identify a possible supporting model for residential solar PV through a study site in Koh Samui. To achieve this aim, the study should be carried out through these sequences. Firstly, the study should establish the existing conditions. These existing conditions refer to the current status quo of how residential solar PV systems can be adopted in Thailand. After establishing the existing conditions, the study then moves forward to the process of identifying barrier for the stakeholders. This identification process is crucial to the study as it become a baseline for suggestions, ensuring that the suggestion is relevant to what is missing or should be modified to encourage more adoption of solar PV systems in Thailand. The study will employ the following flows of research aligning with the previously stated sequences. The flow of research is illustrated in Figure 1 below.

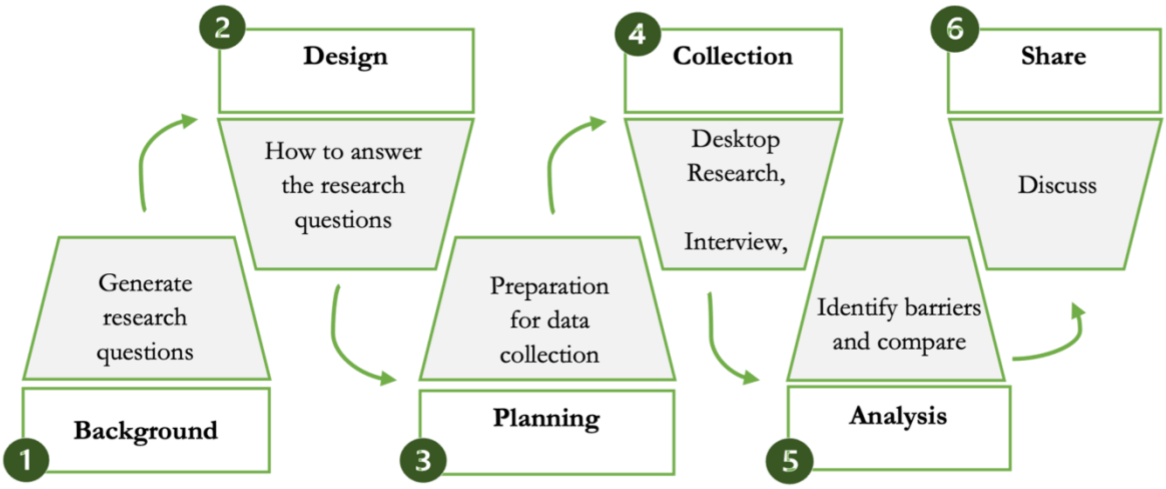


Figure 3-1. Research Design and Process

Source: generated by the author following the flow of the research

The first step is to search for previously conducted studies on the topic of the residential solar adoption process via the preliminary desktop research. The goal of this step is to provide the author with the background and foundation of this topic and to explore the possible knowledge gaps. After identifying the knowledge gap, the author is then able to generate the research questions for this study. A detailed description of this process will be discussed below in section 3.2. The primary expected output from this step is the research questions.

The process continues to the step of designing a study that could help to answer the research questions which were generated from the first step. The design of the study is done by using the research questions and the background research as a foundation, taking into consideration the characteristics of these questions. This study follows the approach of qualitative research as it looks to understand the socio-technical systems of residential solar in Thailand, identifying the existing barriers and exploring the role of community solar in addressing these barriers. This process of trying to identify and understand problems fit in with the qualitative research definition provided by Creswell & Creswell (2018). Additionally, the characteristics of this study is in line with some of the characteristics of qualitative research mentioned by Creswell & Creswell (2018) as this takes place in a natural setting with no controlled environment or variables and does not require other equipment or instrument for data collection apart from the researcher. In the process of answering the three research questions of the study, different data collection methods have been used. The summary of data collection methods and utilisation is listed in Table 3 below.

Table 3-1. Research questions, data collection methods and utilisation of data

Research Question 1 (RQ1) How does the socio-technical systems look like for residential solar PV adoption in Thailand?	
Data collection methods	- Desktop research: • Official documents – FiT regulations, royal gazette regulating the adoption of solar PV in Thailand • Websites – information on the PEA and Electricity Generating Authority of Thailand (EGAT) websites and the industry's news outlet such as ENC • Literatures – grey literatures such as consultancy reports for the ministry or reports submitted in international forums and scientific peer reviewed publications of previously conducted studies of the topic. - Semi-structured Interviews: • Officers from the local PEA office and Head Quarter • Thai residents on Koh Samui
Utilisation of data	The data from both sources are analysed through the conditions and practiced framework, where the information is categorised into different dimensions such as framework condition, local condition, socio-technical designs, and socio-technical system as practiced. Furthermore, the primary data collected from websites and interviews are used for establishing the current procedures for solar PV adoption in the residential sector in Thailand.
Research Question 2 (RQ2): What are the key barriers of the diffusion of solar PV in the residential sector?	
Data collection methods	- Desktop research: • Official documents – FiT regulations, royal gazette regulating the adoption of solar PV in Thailand • Websites – information on the PEA and Electricity Generating Authority of Thailand (EGAT) websites and the industry's news outlet such as ENC • Literatures – grey literatures such as consultancy reports for the ministry or reports submitted in international forums and scientific peer reviewed publications of previously conducted studies of the topic. - Semi-structured interviews: • Thai residents on Koh Samui • Residents from the studied community - Survey: • Online survey sent to residents of the studied community
Utilisation of data	A comparative analysis is conducted between the secondary data from previous studies and primary data collected. This analysis is expected to generate a list of both identified barriers and new barriers experienced by the stakeholders.

Research Question 3 (RQ3): What is the role of community solar in addressing the barriers of residential solar PV diffusion?	
Data Collection Methods	- Desktop research: • Literatures –scientific peer reviewed publications of previously conducted studies of the topic of community solar. - Semi-structured interviews: • Thai residents on Koh Samui • Residents from the studied community - Survey: • Online survey sent to residents of the studied community
Utilisation of Data	This question is related to RQ2 and utilizing the list of barriers that have been listed and described through the first two dimensions of the framework and using knowledge gained from the published scientific literature to illustrate the potential roles of community solar in the diffusion of solar PV in Thailand.

Source: own study outline

Although the three research questions rely on three main methods of data collection, the data collected can be utilised differently according to each question. In RQ1, the most important process is establishing and illustrating what a socio-technical system looks like for the specific sector of residential solar PV in Thailand, hence the importance of collecting data not only from the previously conducted studies but also from information published by the authorities in Thailand regarding this topic. Furthermore, the interviews with someone from the PEA provide the study with more in-depth operation information. After establishing the existing socio-technical systems in the Thai residential solar PV sector, the study moves on to identifying barriers which may be responsible for limiting the growth of the sector. The second RQ can be answered by comparing data collected data from both primary and secondary sources. This can provide the study with the knowledge of whether there are other barriers that might exist in the sector but have yet to be identified by other researchers. It is crucial for the author to answer the first two questions prior to answering the third research question. The expected outcome from answering these questions is the identification of the potential that community solar could play in the diffusion process. Hence, the importance of understanding the existing socio-technical systems by looking at the framework and local conditions.

Moving along, the process continues with the planning and preparation prior to data collection. Despite the difference in methods of data collection, the planning process entails the same big picture. In preparing each method, the question of "How can this data contribute to the research question?" is always asked and kept in mind. The preparation details and data collection examples will be discussed in Section 3.2. The step also includes activities like retrieving potential interviewees' contact information and contacting them to make an appointment. The fourth step of the collection includes additional desktop research of previously conducted studies, face to face and phone call interviews and sending out surveys to the residents of the studied community. After collecting most of the necessary data, they must be analysed. The process includes establishing the status quo of the sector and a comparison between identified barriers from previous studies and the new finding. Then bringing these findings to compare with the characteristics of community solar to possibly suggest how this might be useful to the residential solar PV sector in Thailand. The last step is to collect the comparison and analyses, presenting them in Chapter 4 as part of the discussion. This aims to initiate a conversation and possibly provide suggestions to help increase the growth of the residential solar PV sector in Thailand.

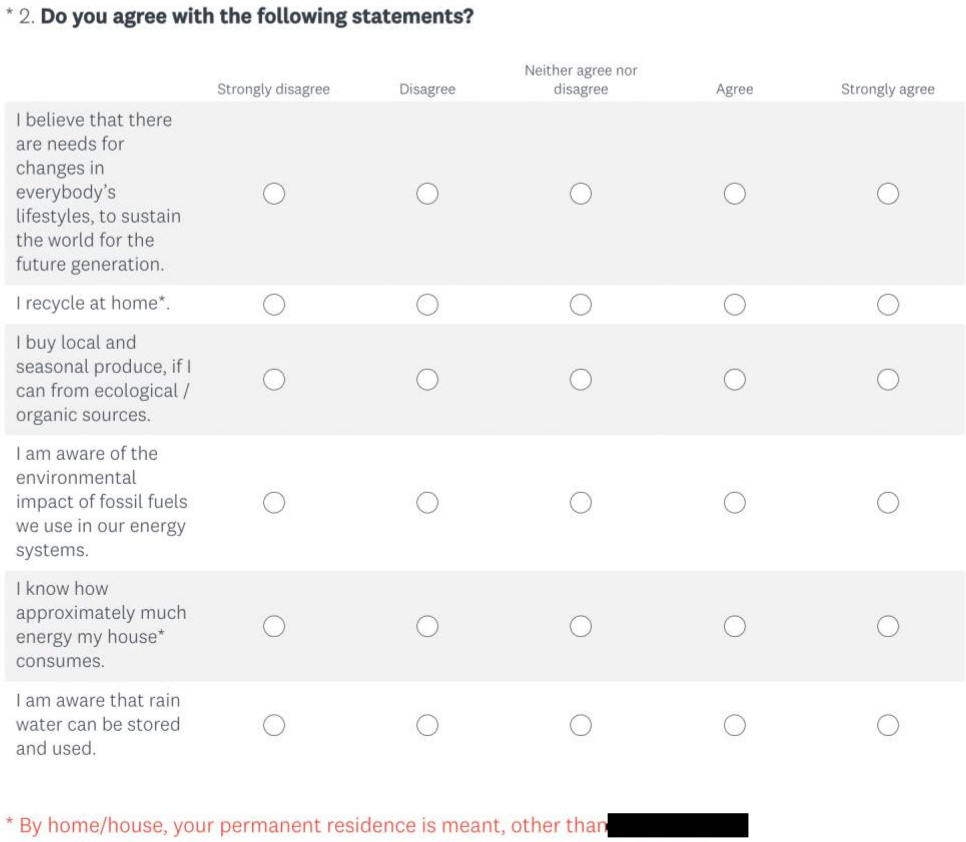
3.2 Data Collection

As listed above in Table 3, this study consists of multiple methods and is conducted through the qualitative approach. The methods used for this study can first be divided into two categories of primary and secondary source data. Primary source data refers to data which have been collected by the researcher, while secondary source often refers to data which has been collected by other researchers in the past or has been analysed and interpreted. In this study, it is important to have both types of data as the analysis process requires both knowledge of the local sector and knowledge of the larger concepts and frameworks. The initial estimation and plan of the study included data collected only from the members of the community intended to be studied (hereinafter Community S). However, after visiting the community the author realised that even though the community is in Thailand, it was an expatriate community with non-Thai members. The author expects that there might be a limited view on the topic if it was collected only in the community and through this realisation, the study has shifted naturally away from the initial research plans. Additionally, to ensure that the data collected can be applicable to the context of Thai residents outside of the expatriate community, the introduction of a new group of respondents for the interviews was done for the purpose of triangulation and to observe the differences between the two groups.

3.2.1 Primary Source

The primary source data collection methods include face to face interviews, phone call interviews and survey responses. For the interview methods, two types of interviews have been conducted. The selection of interview types is based on the availability and preferences of the interviewees. Despite the different settings of interviews, they are both conducted in a semi-structured format. The interview begins with clarification and information about how this data will be used and their right to choose which questions they would prefer not to answer. Prior to conducting the interviews, three groups of stakeholders were identified, encouraging the author to create three different interview guides in the hope of capturing the different perspectives of these interviewees. The three groups of identified stakeholders are residents, solar companies, and the authorities i.e., PEA. The translation of interview guides into the Thai language was only done for the resident's interview guides. As research has indicated that most of the solar companies on the island are English speaking companies, hence the use of English interview guides. For PEA the interview is shorter and more precise, as these interviews are more focused on hearing about the organization's plan and perspectives. In the process of data collection, the interviews were conducted in both Thai and English depending on the preference of the interviewees. The interviews of some Thai nationals living in Koh Samui and all the interviews with the PEA were conducted in Thai and the interview notes were translated by the author into English to be used in this study. The interview guide and questions were written with the underlying foundation that each interview question should feed into answering the research questions of this study.

The second method for collecting primary source data was an online survey. As the study includes a group of residents of the studied community, it was important to find a way in collecting data from these residents. It is important to note that most of the owners and residents in this community are from higher-income households and do not live in the community full time. Hence, the choice of using an online survey can be sent via email and require less time from the respondents. The design process took into consideration some site-specific factors such as the diverse backgrounds of residents and age groups. These factors have influenced the choices of questions and how they are displayed, most of the questions are stated in simple language and avoid open-ended questions which require a lot of writing. An example of the questions from the survey is illustrated in FigFigures2 below.



* 2. **Do you agree with the following statements?**

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I believe that there are needs for changes in everybody's lifestyles, to sustain the world for the future generation.	○	○	○	○	○
I recycle at home*.	○	○	○	○	○
I buy local and seasonal produce, if I can from ecological / organic sources.	○	○	○	○	○
I am aware of the environmental impact of fossil fuels we use in our energy systems.	○	○	○	○	○
I know how approximately much energy my house* consumes.	○	○	○	○	○
I am aware that rain water can be stored and used.	○	○	○	○	○

* By home/house, your permanent residence is meant, other than [redacted]

Figure 3-2. Sample Question from the online survey

Source: author

The survey was designed by the author with the aim of capturing the residents' thoughts and perspectives on renewable energy sources. The online survey consists of three pages with a total of 20 questions. Although the survey tackled broader issues of sustainability and stretched beyond the topic of solar PV, it was expected that this could be a good collection of data regarding the perspective and tendency of potential adopters. As this was an online survey, screenshots of the survey can be referred to in Appendix E. Similarly, to the interview questions, the online survey has also been designed based on the foundation of how they can contribute to the three research questions. The online survey was created using the functions provided on the website Survey Monkey. The question of how this online survey can be sent to the residents without exploiting their personal information was discussed repeatedly between the author and the representatives from the community. It was concluded that for this data collection, the author will be working with their locally established 'Sustainability Practices Committee' (SPC). The SPC members are residents of the community who are interested in introducing sustainability practices to their community. The choice to send out the survey via the SPC members was made to ensure that the author did not receive the residents' personal data such as their email addresses without their consent. Furthermore, it was the most efficient way to send out this survey as the SPC members are also on the emailing list in the community. The survey was sent out to the residents on the 7th of March 2022 with a deadline of the 25th of March. As mentioned above, most of the owners and residents are from higher-income households, and it can be assumed that they would be preoccupied with other tasks. This 2 – 3 weeks period for the residents to fill in the survey is likely to help increase the response rate as they are not rushed.

3.2.2 Secondary Source

The secondary source data collection is done through desktop research and synthesizing past conducted studies on this topic or published reports by organizations. The research for secondary data was not conducted throughout the study period as there are different sections and needs for data such as preliminary research prior to generating the research questions and the research to look for other identified residential solar PV barriers. The literature selected and used in this study is found in online databases. The search process began with inserting keywords such as 'residential solar PV' 'Community Solar' 'Residential Solar Thailand' on the publicly accessible search engine Google Scholars. After inputting the keywords, the search engine often generates up to thousands of previously published reports and studies which are available for download via different websites such as ScienceDirect or are available on their organization's website. Due to the large numbers of generated results, it was necessary to choose and consider the relevance of each result to the study. For literature about community solar, the concept can sometimes be used in another context such as community solar installed for schools or other shared facilities. It was important in the literature selection process to look for literature that is in the context of the residential sector. This was done by first looking for words that may indicate the context of the use of community solar in the title and if found, the author continued to read the abstract to determine the relevance to this thesis. This can help to pre-select and limit the research to focus only on the relevant literature. Similarly, the selection of literature regarding the barriers to solar PV adoption in the residential sector was also done through the search for studies that have been conducted in different countries around the world. There are some aspects that were considered in the process of choosing the relevant literature. As the thesis focuses on the solar PV system as a secondary source of electricity for the household. Hence, it the importance of choosing literature which discusses residential solar PV in a similar context.

Furthermore, much of the literature found during the research process is previously conducted literature reviews and this has led to a snowball effect that led to the discovery of various additional literature apart from the ones found through search engines. Another crucial factor in the data collection process was the temporal validity of the reports, as the solar PV sector involves an ever-changing and fast-growing technology and is price sensitive. Hence, it is important to look for the most recent studies to be used as a reference point. However, not all the older studies are eliminated as they can still provide a valid and ground understanding of the topic. Additionally, as the project is based in Thailand some of the documents collected were written in Thai and have been translated to be used in this research.

3.3 Materials collected

Through the data collection methods described above, the author was able to collect the necessary data to be used for this study. The information on the number of sets of data collected has been summarised in Table 3-2 below. The literature collected for this study has been collected over a period, some are literature that has been used as a source of information for the pre-study report. Many of the literature collected include reports from previously conducted studies on the topic such as the deployment of residential solar PV, community solar models and identified barriers to residential solar PV. These reports and studies are included mostly in Chapter 2 of this study, the literature reviews. The secondary source data are crucial to the study as it provides a foundation of understanding, and the interpreted data could be used for comparison with the findings from the primary source data in this study.

In this study, the author has travelled to Koh Samui for the purpose of collecting data. However, not all the interviews can be conducted face to face due to some precautions regarding the Covid19 pandemics. A total of 12 interviews were conducted with a combination of 6 phone interviews and 6 face to face interviews. There are different interview guides specifically for each group of the stakeholders, as some information may be specific to their group.

For the residents' interviews, the same guideline is used for both Thai and foreign nationals interviewees. The residents' interviews are mostly focused on their perspectives and opinions on renewable energy. The interview guide is divided into five sections with the following headings: introduction/general questions, electricity usage, renewable energy, solar PV and supports. The interview guide used can be found under Appendix A for the English version and Appendix B for Thai. The guide further discusses their interests in the installation of solar PV systems for their homes and the motivations or barriers which are encouraging or stopping them from doing so. This information is useful to the study in helping to establish whether there are potential adopters in the market and what could be the factors that are slowing down or stopping their decision to deploy solar PV systems for their homes.

During the visit to the island, two of the 4 local solar companies agreed to an interview session. The first solar company is operated by a German owner who has been living and working on the island for decades. The second company is relatively a newer company with a share of both Thai and foreign executives. Despite their difference in the years of work and management structures, the same interview guide was used for both companies. After notifying them of their rights and getting their consent to use the data, the interview begins with introductory questions such as the interviewee's role at the company and their customer profile. The general procedures are also discussed during the interview, to gain an understanding of whether there are potential interests in the market or if additional marketing and promotion are needed to get the interests. The companies are also asked about their customers' profiles, this can provide the author with more information on which group of customers have installed the systems. Other questions discussed with the companies include knowledge of how they persuade their customers to make the decision and what have they identified as common barriers stopping or slowing down their customers. The conversation often leads to discussing the identified barriers from other research and asking if they agree with these identified barriers. The interview guide used can be found in Appendix C.

The interviews with the other stakeholders have been conducted in a semi-structured condition, however, the interviews with the PEA were less so. The difference in structure is due to the interview cultures in Thailand, especially with officers or representatives from the organization. A semi-structured interview can be considered a burden for the officers or representatives, as they are concerned about what they should or should not say. Furthermore, PEA is a state enterprise and does require multiple official documents and papers works to set up an interview. After realising this barrier, it was clear that referring to this as a conversation was more appropriate and easier to communicate to the officers. Although the interviews have changed from semi-structured interviews to a conversation, it is not without a guiding document. The guiding document used for conversation with the PEA can be found in Appendix D. There are two separate sets of topics to be discussed, depending on which organization the officer belongs to. In the conversation with the local officers, the general information on the island's systems is asked about and their general experiences with the local trend of renewable energy. While topics that are discussed with the officers from HQ that are based in Bangkok are more of the outlook and what they think the PEA is or can be doing to support this shift to renewable energy.

The online survey is another method used to collect data for this study. The survey was sent via email to the emailing list of the owners and residents of the studied community. This survey is divided into three pages with a total of 19 questions. The questions are a combination of multiple-choice, short answers and ranking their level of agreement with the statements. The first page of questions in the survey includes general questions regarding their residency status in the community and ranking their agreement to some statements, determining their interest and awareness in the topic of sustainability. The second-page questions specifically about renewable energy. The questions on this page are there for the purpose of understanding the level of awareness residents have. Additionally, there are questions about their personal interest and experiences with solar PV systems. The last page of the survey focuses on the residents' needs for change. The statement listed on the last page is from a discussion with the manager of the community who has expressed concerns regarding the current electricity and water systems infrastructure in the community. The concerns were that the existing infrastructure may not be able to support all the residents of the community at the same level of electricity consumption continues at this rate. Hence, this section aims to understand whether the resident of the community realises that there is a need for them to start considering alternative sources for some of their electricity consumption. The full screenshots of the pages from the online survey can be found in Appendix E.

Table 3-2. Summary of the total collected data

Methods		**Targets / Stakeholders**		**Total**
Literatures		Background and additional research	20	20
Interviews	Phone	Thai Residents on Koh Samui	3	12
	Face to face	Thai Residents on Koh Samui	1	
	Face to face	Residents of the studied community	2	
	Face to face	Solar companies on Koh Samui	2	
	Face to face	PEA officers on Koh Samui	1	
	Phone	PEA officers from HQ	3	
Survey		Residents of the studied community	17	17

Source: author own summaries

3.4 Methods used for data analysis

Data analysis is one of the most crucial sections of a study, as it presents the audience with a summary of the collected data and potentially provides new findings to the to provide this study the research follows a qualitative approach with the aim of understanding the situation of residential solar diffusion in Thailand and the possible roles that community solar PV could play in the sector. The collected data include notes from interviews, official documents from organizations' websites and the answers to the survey. Following this qualitative approach, the study aims to take information and data collected from the specific case of a community in Koh Samui and seek patterns to identify the common barriers experienced by the residents.

According to Creswell & Creswell (2018), theories in qualitative studies can be used and interpreted in several ways. Some can be used as an explanation for behaviours and often are supported by variables and hypotheses. The analysis process of this study is influenced by the grounded theory design, which allows the researcher to derive general theories or patterns from the views of participants. The process includes different stages of data collection, coding and categorization (Charmaz, 2006 ; Corbin & Strauss, 2008) Although it is influenced by the grounded theory, it does not follow the procedures stated exactly. As this study is more focused on identifying patterns which may indicate barriers to the diffusion of solar PV in the residential sector of Thailand and searching for new types of barriers to feeding into an analytical framework of previously identified barriers. The analysis process includes a combination of both deductive and inductive methods by utilising the initial research as a starting point for data analysis.

The analysis of the surveys is based on pattern-seeking, the author looks for a connection between different factors. These factors are listed as questions in a different section of the surveys. This process takes influence from the initial research of the topic where some connections between factors have been identified and to see if this connection is also applicable to the case of this community. However, the analysis process includes the identification of other connections or patterns which may have not been identified in previous studies. The pattern-seeking method can help provide the author with in-depth information on the relationships between each factor. The relationship and connection between factors are an important point for the discussion and suggestions section, for example, an improvement made to one factor could positively affect the related factor or vice versa.

Due to the small sample of the studies, the analysis of each interview note could be done manually without utilising external tools. The analysis process includes taking the interview notes and looking for recurring keywords. These keywords are then grouped into categories such as social, financial or support. These keywords have been created from the context of the previously identified barriers which have been reviewed in Chapter 2. However, due to the small sample and the semi-structured interviews. The notes from these interviews often contain context-specific barriers and may not be as clearly categorised into detailed sections as the previously reviewed barriers. Nonetheless, there are sub-group of barriers within these broader keywords. For example, within the support tags, there are sub-groups of barriers linked to the local or national level support. Through this process, the author can identify common barriers which may be shared by different stakeholders. The list of groups and their description are as follows:

- Financial: This tag includes any information which indicates concerns about the monetary factors such as the price of installations, the price for maintenance or the initial investments.

- Social: This tag includes any information which indicates concerns about existing structures such as the availability of knowledge or pressures from their social groups.

- Supports: This tag includes any information which indicates concerns about supporting systems such as supporting policies or availability of the supporting organization.

4 Findings

The data collection process has enabled the author to understand and gain further insights into the research topic. This chapter attempts to provide answers to the three research questions, describing the socio-technical system of residential solar PV adoption in Thailand, identifying the barriers to adoption that can be found in each dimension of the analytical framework and lastly establishing the potential roles of community solar in addressing the previously identified barriers.

4.1 Framework conditions

In the process of reviewing previously conducted studies, it can be observed that there's a difficulty in identifying an accurate number representation of the residential solar PV systems' capacity and these systems are usually included under the non-utility system capacity and rooftop solar PV system. Due to the difference in system sizes, the difference in the capacity of these systems is significant. For example, in the third quarter of 2017 the rooftop PV both large and small systems contributed to 5% of the total installed capacity of solar PV systems in Thailand (Junlakarn & Kokchang, 2020). Hence, it can be assumed that the solar PV in the residential sector contributes to a small fraction of the percentage of installed capacity.

4.1.1 Rate revision and pilot projects

Since the announcement of the 20 years national strategy, there have been multiple projects and supporting systems that were established by the government or the authorities to encourage more adoption of residential solar PV in Thailand. In recent years projects such as the self-consumption pilot projects or sandbox projects have been introduced and carried out in Thailand, due to the growing interest of the government is pushing for an increase of solar PV installed capacity in Thailand. These projects alongside supporting policies and schemes such as the FiT can be seen as the framework conditions which are supporting the adoption of residential solar PV. These conditions are ones that are determined at a bigger level such as the government or the related authorities. This continuous interest and efforts to push for an increase in the residential solar PV sector are also reflected in the modification they have made to the 10 years contract household solar rooftop scheme launched in May 2019. The National Energy Policy Council (NEPC) has decided and announced in December 2020 that from January 1st, 2021, the FiT rate will be 2.20 baht per kWh which is a raise of around 0.50 baht per kWh (Bangkok Post Public Company, 2020). This raise was expected to better compensate the system owners and to create a more suitable condition for other residents to follow.

Another policy expected to facilitate more diffusion of solar PVs in the residential sector is a policy framework, known as the 'Quick Win Project'. The framework has been discussed and approved by the National Reform Council (NRC) in 2015. The purpose of this project was to support a free market for solar rooftops by encouraging the net metering scheme. The participants of the project were divided into two groups: the residential rooftop with an installed capacity of less than 10kWp and the commercial buildings with an installed capacity of 1000kWp. This policy framework was launched as a pilot project in 2016 and unlike the other previous solar PV supporting scheme, this was a self-consumption scheme. The policy focused on supporting on-site consumption of electricity and excess electricity generated was to be fed back into the grid without compensation. The government expected to gain insights regarding the compensation for excess electricity from this project and launch new supporting schemes that fit the needs of the public. (Chaianong et al., 2019; Tongsopit et al., 2019) However, there have yet to be finalised compensation schemes or supports rooted in this pilot project until now.

4.1.2 Additional support and information barrier

Apart from the FiT schemes and pilot projects, there are other types of support for the transition available in Thailand. PEA is one of the key actors involved in this transition and has developed a mobile application in assisting residents who are interested in the adoption of solar PV at home. This application is called the "PEA Solar Hero Application", it was launched in 2018 to provide fast, safe, stable, and sustainable solar PV systems for the customers' homes. The service of this application ranges from calculating system size from satellite imaging to providing information about loans from different banks. After the customer has chosen their systems and finalised the financing aspects, the installation of systems will be done by the PEA themselves and ensure that the customer will receive the approval document. The PEA believes that this application is the answer to some of their customers' concerns and demands, using Solar Hero as a one-stop service. ("'PEA Solar Hero" "One Stop Service" เพื่อการผลิตไฟฟ้าจาก "Solar Rooftop"', 2019) Although the application was developed with essential elements to provide the most convenience for the customers, the existence of this application was unknown to many people including the interviewees of this study. Residents found it *difficult in accessing information* and felt that this makes them hesitant in the adoption of solar PV at home. This implies information regarding programmes such as the PEA Solar Hero application or access to knowledge about the adoption processes. All the Thai residents interviewed in this study have discussed the topic of *difficulty in accessing information and knowledge* regarding solar PV. Likewise, more than half of the respondents of the community agreed with the statement 'I don't think I have enough information to make the decision' in the survey. This implies that there exists a *barrier in the communication* between the responsible authority and the public. Nonetheless, when the interviewees were asked about their opinions on the application Solar Hero, they showed a positive response and were interested in the services offered.

4.1.3 Lack of incentives and barriers

Although, there are many available supporting programmes for the adoption of residential solar PV, not all these programmes have been successful in encouraging the residential sector. For example, Interviewee A mentioned in the interview that they do not feel that apart from the cost-saving on electricity bill spending, there are any appealing programmes from the government to help them make the decision. Additionally, *the lack of available financing aids or financing programmes* such as solar loans for the residential sector was identified as a barrier to the adoption. Despite the supporting scheme, it is felt by the respondents that the primary barrier for them was the *financial barrier* which includes factors like the initial investment needed for the installation, the cost-benefit calculation and return on investment. This barrier was present in both groups of respondents, the members of Community S and the locals on Koh Samui. For example, one of the interviewees stated that they have been interested and considered installing solar PV systems at home. However, the cost of a system that is sufficient for their household exceeded their initial budget and they had to put this project on hold until the prices in the market dropped to fit their budget. Similarly, to other solar PV sectors around the world, Thailand's solar PV systems have declined continuously. According to the national survey report by Thailand PV Status Report Committee 2018 & Ministry of Energy (2018) the average price of solar PV systems excluding sales tax was 120 THB/W in 2015 and decreased to 52 THB/W in 2018. If a homeowner wanted to install a 5kW solar PV system at home, they would have to pay approximately 600,000 THB for the system alone excluding tax and installation cost, in comparison to paying 260,000 THB in 2018. (Thailand PV Status Report Committee 2018 & Ministry of Energy, 2018) In the period of 5 years the system's price had declined more than 50%. Although the price of the system is expected to continue dropping, it is observed that the price to pay for a solar PV system is still considered a burden.

In relation to the lack of available financing programmes or loans for the residents, some of the respondents of this study have brought up comments that some of the available supporting schemes are *not appealing enough* to make the final decision of adopting the system. The interviewees felt that it would be more convincing for their household to install solar PV systems if there were monetary supports or benefit such as annual income tax reduction for a household with installed solar PV systems in addition to the monthly electricity cost savings. The concern regarding the *lacking incentives* was more evident amongst the Thai respondents, in comparison to a 30% of respondents from community S who agreed that subsidies from the state would be a good motivator in installing solar PV.

4.2 Local conditions

4.2.1 Island and the community demographics

These different backgrounds and local conditions are expected to influence the perception and experience of adopting solar PV. Koh Samui is one of Thailand's biggest tourist destinations with more than 65,000 registered population and up to 180,000 non-registered population in 2016 (Sirasoontorn & Koomsup, 2017). It can be implied that the non-registered population are tourists, short term visitors to the island or residents who are not native to the island. Although there has not been an official recording of how many foreigners are residing on the island, it is observed that there is a mixed demographics of Thais and foreigners. It is observed on the island that the two demographic groups have different types of living arrangements. Many foreigners or expatriates live in expatriate communities, while the Thai population on the island lives in standalone houses with agricultural land. This settlement pattern is most likely a result of Thailand's expanding agricultural sector in the past, which has been passed down to the current generation. Furthermore, Thai laws prohibit foreigners from purchasing a property. As a result, they frequently acquire property through the supporting system of the expatriate community.

At the time of this study, there are no official records of how many expatriate communities are on the island. However, the author has estimated that there are more than 20 communities in a similar structure to Community S on Koh Samui. The calculation of this estimation is from the knowledge that, there are around 5 general areas where most of the expatriates reside on the island and in each of the areas, it can be assumed that there are up to 4 communities per area. Hence, the estimation of around 20 or more communities on the island. The distribution of the areas is illustrated in Figure 4-1 below.

The property acquisition process for foreigners is different from the Thai citizens, as it is regulated by law that foreigners are not permitted to purchase property in Thailand. (*Hire of Immovable Property for Commerce and Industry Act*, 1999) There are two ways for foreigners to acquire property in Thailand, the first is to set up a Thai limited company and purchase through a legal entity. And the more common practice is the acquisition through a 30 year-long leasehold contract. (*Buying Property in Thailand | ThaiEmbassy.Com*, n.d.) In facilitating the acquisition and management of the community, the support of the lease contract, the set-up of these expatriate communities often has similar infrastructures, with a company limited that is responsible for issuing the lease contracts for the acquisition and to manages the common area of the community. As most of the owners of the properties in the community are expatriates, not all the members of the community are full-time residents. From the responses to the survey, only one-quarter of the respondents are residing full time in the community and the others are part-time residents as this property may be their holiday home or they are renting the property. These specialised conditions of the members' residency types may influence their perceptions of the adoption of solar PV for their households.

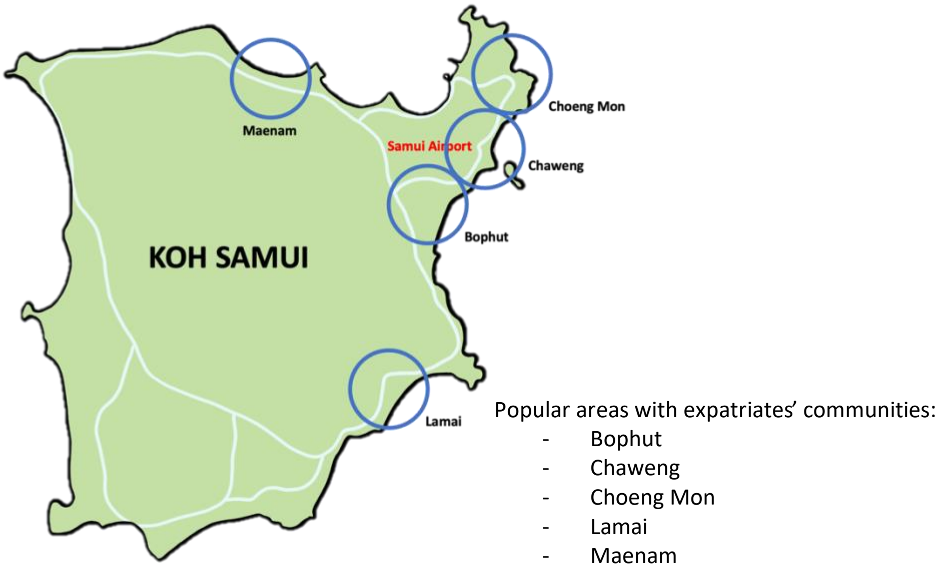


Figure 4-1. Distribution of popular areas with expatriates' communities

Source: illustrated by author

4.2.2 Attitude and motivations of community members

Even though each member has a different type of residence in the community, it was clear from the survey responses that the members have a positive attitude and extensive knowledge on topics related to sustainability. More than 90% of the respondents agreed that there is a need for changes in their current lifestyles, to sustain the world for the future generation. The positive attitude towards sustainability is supported by their actions, where more than two-thirds of the residents recycle at home and prefer to buy local and seasonal produce from ecological or organic sources. Most of the respondents have also stated that if they were to improve or renovate their homes, they would consider taking more sustainable measures regarding their homes. The respondents demonstrated not only a positive attitude toward sustainability but also extensive knowledge of renewable energy, specifically solar PV systems. All the respondents have answered that they know what renewable energy is and in one of the questions from the survey where they were asked to select which of the sources of energy are considered renewable. The following list is the source of energy selected as renewable by the residents in the order of most selected to the least. The list of energy sources is as follows: solar, wind, hydropower, geothermal, biofuel, waste incineration, natural gas, nuclear and coal. Furthermore, all the residents know of the solar PV systems that are used for electricity generation. Additionally, more than 90% of the respondents agree that they are aware of the environmental impact of fossil fuels we use in our energy systems. However, when asked whether they are aware of the level of energy consumption in their own home, only two-thirds of the respondents know how much energy is consumed at home. In addition, only 80% of the respondents know about the capacity of electricity supply at Community S. This can be implied that the residents in Community S may have high awareness and knowledge about the topic of renewable energy but not as much attention has been given to the energy systems around them.

There could be different reasons why residents may feel the need for adopting solar PV systems at home, the factors could include their experiences with the past or current electricity supply, or it could be the need to reduce the household's financial burden on the monthly electricity bill. More than half of the respondents from Community S have expressed that they experienced electricity shortages at home and approximately 90% of the respondents believe that the current electricity supply is not stable and that a change is needed. As a result, more than 60% of the respondents have considered adopting the solar PV system at home and in their own words the reasons for consideration were factors such as the availability of products in the market, becoming more environmentally friendly, cost reduction and more than half of the responses included the idea of being self-reliance and independent from the national grid. Surprisingly, when asked to rate the most motivating factors that may encourage them to adopt a solar PV system. The same group of respondents expressed a strong desire to adopt a solar PV system to reduce their environmental impact and to use free energy sources such as the sun. And only moderately agree with the statement about ensuring a steady supply of electricity. This could imply that self-sufficiency and independence from national grids are factors to consider in the decision-making process, but it is not strong enough to motivate them to adopt the solar PV system.

4.2.3 Influence of local conditions on the barriers

Through the interviews of Thai residents outside of the Community S and the responses from the survey, the data have suggested that local conditions such as the purpose of the property and cultural values can influence the residents' decision-making process and result in group-specific barriers to the adoption of solar PV. In Community S, many of the properties were built to serve as the members' vacation homes and were designed to be architectural masterpieces. The responses from the survey have revealed that more than two-thirds of the respondents believe that solar PV systems such as solar rooftops may affect the aesthetic essence of their properties. This could suggest that, while they are aware of the benefits of solar PV, the current appearance of the solar panels is *aesthetically unappealing* to them, preventing them from adopting the solar PV system. Additionally, another barrier that prevented the adoption of the systems was found to be the *architectural designs* of the property themselves. A representative from the solar company B shared during the interview that, there have been multiple cases where the potential customers were interested in the adoption of the solar PV system. However, they came across some limitations due to the design of the property where the roof was not suitable for a rooftop system and ground-mounted options were not possible either. This set of architectural factors related to barriers is expected to be connected to the initial intention of building a vacation home with unique aesthetic designs and the current model of solar PV systems may not be suitable for the complex design. However, this concern was not shared with the Thai residents interviewed in this study. This could imply that the two groups of respondents in the study have varying degrees of concern about the aesthetics of their properties.

The condition-specific barriers were not only present in the expatriate community, as there was a barrier specific to the group of Thai respondents. This barrier was the *reluctance to be the 'first mover'* in adopting a solar PV system. In the interviews of Thai residents, 3 out of the 4 respondents stated that they were still reluctant about the systems, considering the efficiency and the maintenance of the systems. They expressed that they would prefer to wait until the solar PV is more widely used before adopting one for themselves. This could be a result of the cultural values that people in Thailand have, particularly in the context of investment, as observed through the author's previous work experience in the financial sector in Thailand. Furthermore, Chaianong & Pharino (2015) have discovered that in the past, the Thai government has dealt with potential energy shortage crises by instructing the public to conserve energy. And as a result, residents are more *hesitant to use and explore alternative energy* sources such as the installation of a solar PV system.

4.3 Socio-technical design

In this dimension, the design of a suitable model to be used for Thailand should take into consideration the conditions that have been identified in the first two dimensions, it should be able to first lessen the financial burden for the residents by appealing to potential adopters and secondly provide stable electricity for all the residents. Furthermore, the design should be flexible and possible for adaptation nationwide with little restriction from the local conditions. In the process of the study, solar PV adoption barriers for residents were found in the different conditions such as the lack of incentives and appealing schemes to support the adoption from the government which was found in the framework condition. And barriers that have been identified in specific conditions of the two groups of respondents, such as the barrier rooted in the architectural and aesthetic aspects of the property found in the expatriate community and cultural values and past experiences that are making Thairesidentst hesitant in adopting new technology. These barriers must be addressed to increase the diffusion of solar PV in the residential sector. Some barriers, such as those found in the framework condition are directly related to the revision of supporting schemes or the introduction of new and more appealing schemes that meet the needs of the public. The design for the new system should be able to overcome some of the existing barriers and the different conditions in both framework and local dimensions should be included within the design.

4.3.1 Needs for a change in Community S

Although there is a high level of awareness about the benefits of renewable energy in Community S. According to the survey responses, there is still some uncertainty about the electricity supply at their property in Community S. This was demonstrated by the survey's contradictory responses. More than half of the respondents agreed to experience electricity shortages and difficulties. But in the next section of the survey, more than 80% of the respondents agreed that they are satisfied with the community's current electricity supply. And yet in the same section as the statement above, almost all the respondents state that the current supply is unstable and that a change is necessary. This inconsistency could imply a *lack of awareness of the topic of their energy systems,* although 80% of the respondents have stated that they are aware of the community's system capacity. It is possible that the members may not be aware of the constraints the community's system is facing. During an interview, the manager of the community expressed concerns about the status of the current electricity supply infrastructure within the community. As Community S is located on Koh Samui, where the national grid's electricity is supplied through submarine cables from the mainland. They are vulnerable to island-wide electricity shortages. Additionally, the transformers and cable infrastructures within the community were installed more than a decade ago. The infrastructure was designed for medium size household consumption without energy-intensive activities such as water pumps for the swimming pool. The community is concerned that not all members are aware that there is a growing risk of system failure due to excessive consumption within the community. The less awareness there is about the capacity of the infrastructure, the less motivation each community member would have to consider an alternative source of energy to lessen the burden of the current electricity system within the community. The discussion with the manager has further revealed that if there was a system failure that occurs relating to the distribution system from the excessive consumption. It would require extensive resources to fix, as the cables are buried under concrete roads within the community. This is a primary motivator for the community to start thinking about alternative electricity sources for common areas to reduce the burden on the infrastructure or the residents within the community. From the interviews and analysis of the conditions at Community S, a potential model that could help the community overcome some of the barriers is the community solar model.

4.3.2 Community Solar

According to Schunder et al. (2020), the core of the community solar concept is to provide access and equality to solar energy for all residents. This concept has been designed to be flexible for each community's needs and the systems can be set up through various financing models. This concept can be used to address the key financial barriers which have been previously identified and confirmed through this study. (Schunder et al., 2020) In the context of Thailand, the community solar should be a bottom-up approach where the initiatives come from the residents. This is to ensure that the needs for change in the energy systems are from the residents and not from the government. Through the set-up of a community solar model, residents can reduce the financial burden per household in the investment cost in comparison to the cost of setting up individual solar PV systems. Additionally, the physical design of the system could answer to some of the communities that are facing the same barrier as Community S. The mini grids in a central area could provide access to solar energy for residents who have previously been hesitant and concerned about the effect the panels on the aesthetics of their homes or for the residents whose home might not be suitable for the individual systems due to a spatial constraint.

In an interview with Interviewee F from the PEA, he was asked about their opinions on the introduction of community solar in the context of Thailand. He agreed that the community solar model holds potential for addressing the existing barriers to solar PV diffusion in Thailand. However, it must be noted that if the community was to set up a community solar project, they are not allowed to utilise the electricity cables installed by the PEA to distribute this electricity as there are billing charges for each unit of electricity transmitted through the PEA's cables. A study of the community's energy systems and infrastructure is advised before the set-up of a community solar project.

4.3.3 Suggestion for community solar model in Community S

When considering the local conditions of Community S, the community solar model has a lot of potentials. The community was found around the core of nature conservation hence, the set limit of land usage for building properties of 20% and having the other 80% of the total land be green space and nature. In the discussion with some of the community's members, there are some flexibilities in this ratio. If Community S was to consider starting a community solar model, it would require some space from the common area for the panels to be installed. Because there are no existing community solar models in Community S, a pilot project for the common area with a medium-sized solar PV system could help to reduce the burden of electricity usage from the existing infrastructure. It would also be convenient for the Community S's office to set up a community solar model because they are structured as a limited company with a legal entity. Furthermore, the electricity generated by the community solar model could be used by common facilities such as swimming pools, shower rooms, administration offices, and clubhouses, among others. In the support of this, the respondents from the surveys have shown positive feedback regarding the questions that ask about their thoughts on using renewable energy for electricity consumption in the common area. Additionally, more than two-thirds of the survey respondents could imagine using part of their annual payment as an investment for renewable energy to be used in the common area. Furthermore, the pilot project could gain the interest of the members living in the community to set up community solar models that can be shared with their neighbours. As all the properties in the community are connected to an existing electricity supply, the community solar system can be installed as an additional source of energy to first help reduce the burden of the community's infrastructure and second supply the member with a more stable supply.

4.4 Socio-technical system in practice

Although the system should have taken into consideration the prior mentioned condition and barriers, they have not been done so. The current system shows that it might have been established independently and based on the ground of regulations. The current residential solar PV systems are found to be individual systems for households and different available models can be installed such as on-grid, off-grid, or hybrid models. The on-grid refers to systems that are still connected to the utility grid and are only able to utilise the solar energy as the production is happening and the off-grid model refers to a system that is completely disconnected from the utility grid. The hybrid model refers to a system that has a battery for storing excess electricity generated and is still connected to the utility grid. In the context of Koh Samui, the interviewed solar companies have revealed that most of their consumers have chosen to install the individual hybrid model for their property, even though these often cost more than the on-grid model due to the price of the battery. After choosing the appropriate model for the home, the residents must follow the procedures to acquire the approval document that has been certified by the PEA.

4.4.1 Standard procedures for residential solar PV adoption

From the interviews with officers from the utility company and the author's personal experience, the initial understanding was that each residential solar PV system owner must receive an approval document from the local utility provider in the area either, the MEA or PEA. This approval document request is necessary for households that are looking to install the on-grid or hybrid system, while the residential off-grid system is exempted from this procedure. Figure 4-1 illustrates the procedures for applying for an approval document for a residential on-grid or hybrid solar PV system, including the responsible authority and estimated cost.

The procedures begin with the residents contacting a solar company for a site visit, receiving a quotation for the systems, and agreeing to install. According to the interviewed solar companies, the first step often takes up to one week. After agreeing on the suitable system for the resident, the homeowner must apply for inspection and request an approval document from the utility company or give the document processing rights to the solar company to proceed for them. The application includes information such as the homeowner's personal information, size and details of the home or property and information about the installed solar PV systems including the size and the models with the signature of the engineer in charge. This information is to be submitted to the utility company's local office and the documents will be forwarded to the regional office for further inspection. This process usually takes around 1-2 months before the initial approval or decline is given for the submitted system. However, due to the long waiting period, it is common for homeowners or solar companies to proceed with the installation before receiving the initial approval. If the approval has been given and the solar PV systems have been installed, the homeowners must pay the processing fees and set up an inspection appointment with the local utility office. In this inspection process, an engineer is dispatched to inspect the system. The last step of the procedure is receiving the approval document from the utility company. Although, the procedures are only compulsory for the on-grid and hybrid systems. In the interview with some if the engineers from a local PEA office, they have suggested that off-grid system owners should also receive an inspection by the utility company, to ensure that standardised systems have been installed and to reduce risks of malfunctioning in the future.

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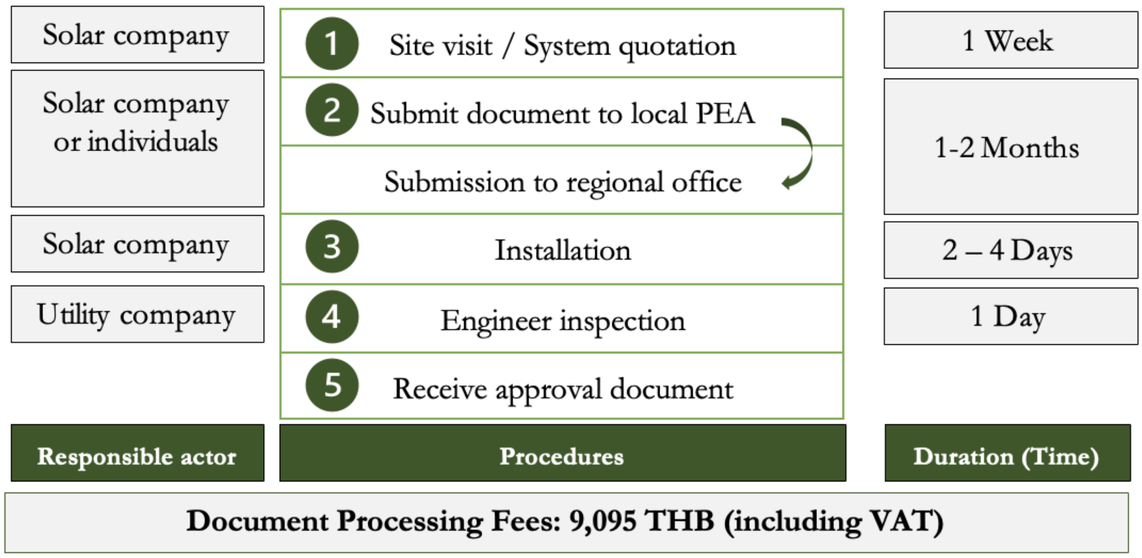

Figure 4-2. 5 Steps standard procedures for residential solar PV adoption

Source: generated by the author

However, the data from Koh Samui suggested that the practices do not always follow the standard procedures described above. In the case of homes that are connected to private transmitting cables and transformers, such as the infrastructure available in most expatriate communities the homeowners do not need to seek approval documents and receive an inspection from the PEA. This enables the solar company and homeowner to finish the installation of solar PV and utilise the system without necessarily notifying the PEA. This type of system infrastructure can often be found in private communities of houses, which are common in some parts of Thailand.

This exception heavily relies on the specific condition of where the house is and its local electricity infrastructure and systems. This indicates that some residents may be more willing or interested in installing the solar PV system as they will have to go through fewer procedures in comparison to other houses that are directly connected to the PEA's infrastructure. Koh Samui is an island that consists of multiple communities which fit into the exception condition. According to the solar companies, this exception is one of the reasons why they find it relatively easier to work with customers from these communities in comparison to working with houses that are directly connected to the PEA's infrastructure. This suggests that the *document submission process* is perceived by many to be time-consuming and there is a possibility of *complications in the process*. In addition to the interviews with the solar companies, the statement is an observation from the author's own experience with document submission and the application process for approval documents.

4.5 Summary of the four dimension and existing barriers

This section provides a summary of the analytical framework's dimension in the context of Thailand, specifically from the studied community, Community S on Koh Samui. The summary table also provides the list of barriers that have been identified in the four analytical dimensions. The summaries of conditions and barriers in each dimension can be found in Table 4-1 below.

Table 4-1. Summary of the findings for each dimension and the barriers identified.

Dimensions	Summary	Barriers
Framework conditions	- There are multiple supporting schemes from the government, including a revised FiT rate at 2.20THB / kWh and different pilot projects and policy frameworks to understand the necessary supports needed. - Support from utility company, the PEA's 'Solar Hero Application' that aims to provide a one stop service for consumers.	- Information barriers: no readily available information for the public and limited communication between authority and public. - No economy for solar PV - Lack of appealing incentives.
Local conditions	- The island consists of mix between officially registered population and non-registered population, where many of the non-registered population are expatriates. - An estimation of more than 20 expatriate communities like Community S on the island. - The members of Community S have positive attitude towards sustainability and have extensive knowledge on the topic.	- There are group specific barriers. - Expatriate: In the group of expatriate respondents, more emphasis has been given to the effect of the solar PV systems on the overall aesthetics of their property. - Thai: They did not want to be the first mover in this new trend. They'd prefer others to lead and follow.
Socio-technical system in design	- The Community S's current infrastructure is old and there are needs for changes. - The benefits of community solar. - Suggestion for a community solar pilot project in Community S.	- The lack of awareness of the current system's capacity have led to lack of motivation for changes in the community.
Socio-technical system in practice	- The 5 steps standard procedures for residential solar PV adoption. - These standard procedures do not always apply.	- The document process for the standard procedures is complicated and complex.

Source: generated by the author

5 Discussion and Reflection

The previous section of this chapter reveals the findings from the data collected in this study, but this section discusses the significance of these findings and reveals some of the new insights gained through the study. The section also seeks to provide answers to the possible role of community solar in the context of Thailand and lastly discusses some of the limitations that this study has.

5.1 Significance

This study was conducted with the purpose of establishing an understanding of the current socio-technical system of the residential solar PV sector in Thailand and identifying the existing barriers in the system. Through the analytical framework developed by Ulsrud et al. (2015), this study has explored four of the dimensions including the currently available support at a national level and discovering experiences and barriers faced by different groups of residents belonging to different groups of demographics. Furthermore, through this study, a potential role for community solar was discussed and lastly, it was able to reflect how the socio-technical systems for solar PV in the residential sector have been designed and how it is in the real-life context. This knowledge from the study provides responsible actors to locate where and what they could be doing to further support the diffusion of solar PV.

5.1.1 Different Conditions and Different Experiences

The data analysis process of this study has revealed that the local conditions of each respondent may have more effect on their decision making. In the research process, there have been questions regarding whether there is a difference in behaviours or attitudes between the Thai respondents and the foreigners. The section on local conditions has illustrated that even though the two groups are subject to the same national-level frameworks but the difference in conditions for Thai nationals and expatriates such as the property acquisition processes could affect the choices of the individuals. As expatriates are prohibited from purchasing properties in Thailand, it is more convenient for them to find properties within an expatriate community in comparison to the standalone properties owned by Thai nationals in the other part of Thailand. From this preference in the location of the property, the specialised conditions may also enable one group to have an advantage over the other in terms of overcoming the barrier. This is observed through the exceptions that have been made for the installations of solar PV systems for properties owned by expatriates on Koh Samui. According to the interviewed solar companies on Koh Samui, all their customers' properties are in an expatriate community with separate electricity distributing infrastructure and the systems can be installed on the property without going through the standard procedures and contacting the utility company.

Through the study, another observation made was the difference in the level of enthusiasm to discuss the topic of renewable energy between the two groups of respondents. The first group was willing to discuss their concerns, interest, knowledge, and experiences they had in relation to the topic of solar PV adoption for their property. Whilst the survey responses have demonstrated a noteworthy outcome where more than one-third of the respondents skipped the page of the survey with questions about renewable energy. The type of questions asked on that page were questions about the respondent's knowledge of renewable energy and of the solar PV system, their opinions on the topic, what they think would best motivate them to adopt the solar PV or what they think are the factors that stop them from doing so, and if they have considered installing a solar PV system for their property. This lack of enthusiasm could indicate that this is a topic that community members do not feel comfortable discussing or that it is in the least of their interests. The difference in the level of enthusiasm can be caused by different factors, such as the difference in data collection methods where it was easier to skip questions on a survey than it is in a face-to-face interview. Another factor could be the level of relevance the topic has to the respondents. More than 40% of the respondents in the survey have stated that Community S is their holiday home, and they are not full-time residents. The fact that these are their holiday home may affect their decision-making regarding sustainability choices. In a study of behavioural economics by Barr et al. (2010), the researchers were trying to understand and observe whether individuals who are environmentally conscious at home would still have the same mindset and practices when they are in a tourist setting or are on holiday. The researchers have found that some of the study participants believe that being committed to sustainable choices and environmentally friendly at home is a way of justification for their less-environmentally friendly behaviour when they are on holiday (Barr et al., 2010). This could be implied that there are differences in levels of concern regarding electricity consumption and the stability of the systems, between the part-time and full-time residents.

5.1.2 New Insights to Adoption Barriers

In the past decades, there have been many studies conducted to understand the different aspects of the solar PV systems in Thailand and specifically in the residential sector. In the initial research process, the authors have found multiple studies focusing on analyses of the financial dimension or the framework of the FiT such as studies by Tantisattayakul & Kanchanapiya (2017) and Junlakarn & Kokchang (2020). In addition to those studies, there is a study by Chaianong & Pharino (2015) (herein referred to as *Outlook Study)*, that discusses the barriers and outlook of the residential solar PV sector in Thailand, including reviews of the available strategies regarding the adoption. The researchers were able to develop lists of accelerating factors and barriers to the adoption of solar PV in the residential sector. In the *Outlook Study*, the identified barriers have been grouped into four main categories technical, economic, social, and regulatory. The following section provides a comparative analysis of the *Outlook Study* and this thesis study in terms of the barriers identified.

Although both the *Outlook Study* and this thesis study is addressing the same topic, due to the difference in research methods and research scopes some of the barriers are not discussed in this study. In this sector, it is important to be aware that the findings of this study are based on data collected from groups of respondents and might be looking at the barriers on a different scale than the *Outlook Study*. An example is the discussion of technical barriers, although a similar barrier has been identified it was from the perspective of the stakeholder who was concerned about the system's efficiency and the effect of local weather patterns. In the *Outlook Study*, one regulatory has been identified which was a conflicting regulation that prohibits factories to be built in some places and the definition of a factory that does not have an exception for residential solar PV, making it not possible for residents living in the factory prohibited area to install systems that have higher installed capacity than 3.73 kW. However, no regulatory barriers were identified in this study.

Despite the gap years between the two studies conducted, the high initial investment and the period for return of investment remain to be the top concerns for residents in Thailand for the economic category. One reason why the financial barriers are still relevant in the finding today could also be an impact on national economic performance. At the time when the *Outlook Study* was conducted, the average monthly income per household was 26,915 THB and in the first 6 months of 2021, the average monthly income per household in Thailand was 28,454 THB. In comparison to the previous growth rates of 0.1 – 3% in the average monthly income per household in Thailand, it can be assumed that the growth rate of 5.7% from 2015 to 2021 does not indicate an increase in economic activity, but they are most likely income from various financial supporting programmes during the Covid 19 pandemic in Thailand. (Thansettakij Digital, 2022) The slow growth rate of the household's average income could contribute to the reason why financial barriers are still relevant even today.

The researchers of the *Outlook Study* have suggested that there is a need for the government to step in and provide more support to the residents. In this study, more government support has become available in the past few years and there is a constant modification of the existing schemes. For example, the decision to adjust the FiT rate effective in January 2021 to encourage more adoption. However, these initiatives are still considered to be unappealing to the residents and the government may need to consider more direct supporting schemes to support the diffusion of such subsidies or household tax incentives.

The difference in scope of the two studies has led to a difference in barriers found under the social category. In the *Outlook Study*, the researchers have pointed out a barrier which is rooted in the political strategies and history of the country. The researchers have suggested that Thailand has never experienced a power shortage on a big scale, hence the low interest in having power security or the interest of stability of power supply. Furthermore, the government has been more focused on warning the residents against power shortages in the past and encouraging the residents to conserve energy rather than to look for alternatives which were identified by the researchers as a knowledge barrier. (Chaianong & Pharino, 2015). However, the data collected have suggested that this barrier has been overcome. This was implied by the increasing interest of the Thai public in the adoption of solar PV systems and the increasing understanding of alternative energy's importance.

The findings have indicated that a new barrier which has yet to be identified in the previous study is the lack of centralised information. This can greatly influence the decision-making process of a potential system implementer. When asked whether access to information plays a role in their decision making, many of the interviewees have stated that it was crucial. In most cases, they prefer to receive information or knowledge about the potential investment that they will be making through a centralised body as it is perceived to be more trustworthy.

Another barrier which has not been discussed in other studies is the perception barrier. Through the data collection process, the author has observed that the stakeholders have different opinions and perceptions of the same topic. A strong example of this difference in perception is the topic of high investment cost as a barrier to the adoption of a solar PV system. In an interview with one of the managements from PEA, they have explicitly mentioned that in the last decade there has been a drop in the price of a solar PV systems. This is true when looking at the statistic from the national survey report on solar PV power in Thailand which was conducted by the Thailand PV Status Report Committee 2018 & Ministry of Energy (2018). The net price of a 5kW solar PV system excluding tax and installation fees has dropped from 600,000 THB to 260,000 THB between the years 2015 to 2018. However, from the residents' perspective, the high investment cost remains to be a strong barrier to the adoption. There are two conclusions that can be drawn from this perception barrier. The first is that, despite a price decrease for the system, residents are still unable to find an economy for the system. The second possibility is that, because solar PV has previously been perceived as a luxury item in Thailand, this perception may not have vanished completely, despite growing awareness of the system's cost-saving benefits.

Following these findings, the thesis study contributes to the subject of research by providing updates to some of the previously identified barriers in the study by Chaianong & Pharino (2015), such as the recently increased FiT rates, introducing a new policy framework launched by the government such as the Quick Win framework and the pilot project that was conducted in 2016 and discovering other supports from a utility company such as the one-stop service application, Solar Hero which was developed by the PEA. Furthermore, this study provides examples and explanations of how each barrier was related to the different dimensions of the analytical framework.

5.1.3 Practical recommendation for the Community S

Although the community consists of a mixture of full-time and part-time residents, the total number of responses received for the online survey indicates that most of the community members are engaged and are interested in contributing to the community. The analysis of data collected in this study illustrates that the community members show a positive attitude towards the idea of changes toward a more sustainable lifestyle and are interested in introducing more sustainable practices to their routine. However, one-third of the respondents have completely skipped the questions in the survey about renewable energy. It can be assumed that the topic of energy may still be a burden for some of the members as of now. It is recommended that the SPC which has recently been established at Community S begin working with other smaller projects, before the electricity systems. A potential topic that can be used to discuss with the community members is the rainwater collection system, as most of the properties in Community S have gardens that require constant watering. This topic does not only answer to the interest of the members, as more than half of the respondents from the survey have expressed a strong interest in the topic of water management, the initiative can also be linked to solar power. Currently, there are many solar-powered water pumps available on the market. The introduction of this system to the community members could first help them to preserve water supplied by the central systems and use rainwater to water the garden instead. Secondly, the introduction of smaller related technology to the residents can help to familiarise them with the solar power technologies.

Another recommendation from this study is the planning of utilising the community solar model as a pilot project within the community. The purpose of this pilot project is to firstly release some of the loads from the existing distribution cable and connect most of the community's common area facility to the grids installed. According to the responses in the survey, most of the respondents have agreed that they would consider using some of their annual payments as a common fund for the investment. This project does not only benefit the community with a renewable source of energy for the common area, but this can also serve as a model for other members within the community to follow or better yet if proven successful other similar communities may be able to learn from the model set up by Community S.

5.2 Reflection

The findings from this study have certain limitations which are the results of some constraints present during the research processes. This chapter discusses the different factors that may have affected the findings of this study.

The study utilises the steps framework developed by Ulsrud et al. (2015) as a foundation in the data analysis process, to demonstrate the importance of each dimension of the framework to the diffusion of new technology such as solar PV system. However, due to the difference in scale of what the framework has been developed for and the scope of this study, there may be some aspects of the framework which are missing from this study. An example is the lack of discussion of the last dimension, the access to services. This is because the study focuses on individuals' choices to implement or not implement the solar PV systems while the original use of this framework was for evaluating a community solar project in Kenya with the purpose of accelerating the electricity access. The difference in the scope between examining the potential of a system in a village and the diffusion process of solar PV in a country has influenced some of the data analysis processes, as the data collected in the thesis become more complex than the steps described by the original framework. It can be expected that the diffusion of solar PV in the context of Thailand would have more details and variables than the adoption of the community solar model in the village. For example, the local conditions described by Ulsrud et al. (2015), it was mostly focusing on the demographic conditions and geographical conditions. However, in the thesis, it was unavoidable that the explanation of the different demographics would include some factors from the framework condition such as the regulation that prohibits foreign nationals to purchase property in Thailand, which leads them to live in a more specialised set of expatriate's community. The multi-level perspective (MLP) theory on sustainability transition is another analytical framework that could have been used for this study. Through this theory, the thesis may be able to demonstrate the current socio-technical system of residential solar PV in Thailand in greater detail and possibly identify whether solar PV is on the verge of breaking out of its niche status. However, the MLP theory would be unable to demonstrate the interdependence of various social conditions and their impact on the diffusion of technology.

This study aims to identify and understand the barriers which are stopping residents from implementing solar PV systems from their residents. In the initial research design process, it was thought that having interviews as the primary data collection method would enable the author to engage in the conversation and explore some of the reasoning behind the barriers. However, after discussion with representatives from the community, it was agreed that an online survey may be more helpful in this case and it was expected that there would be more respondents to an online survey than it would be to an interview. In the decision of changing the data collection methods, the formats of the data have also changed along with the methods. This limits some of the data to be percentages or ranking preferences and some of the explanations may not be as elaborated as they would be to data that have been collected through an interview. Furthermore, the experience from collecting data through an online survey in this thesis has shown that using a negative statement for the respondents to provide a degree of the agreement would affect the process of data analysis, as it creates a double negative statement. For example, if the respondent has expressed that they strongly disagree with the statement "I do not feel the need to reduce my electricity bill", it is implied that they strongly feel the need to reduce the bills. These double negative statements can often make the data analysis process more complicated, in comparison to writing out neutral statements for the respondents to express their preferences.

Another limitation which can be found in this study is in the data collection process of the interviews. As the author began to interview different stakeholders, a cultural barrier in the interviewing process was discovered. In Thailand interviews can be perceived as a burden or that the interviewee will be held responsible for what they have said. Hence, they are reluctant in agreeing to do an interview for a research project. It was important that the anonymity of the interviewees is ensured and most of them have asked to be interviewed with no recordings. This limitation of recording the interviews and transcribing them can affect the details of some of these interview data. However, the author always takes notes of every interview and writes down the key messages. These notes are directly transferred to a Microsoft word document right after every interview, to ensure that the author can include any of the comments which have not been written down.

Despite the relatively small sampling size of the non-expatriate community, the findings such as the 5 steps procedures of adoption and the list of barriers are expected to be relevant and valid for other parts of Thailand that are under the management of PEA and not just specific to the context of Koh Samui. Although this study was conducted in a community on Koh Samui, some of the findings have been used to discuss with representatives from the management of PEA to provide a more solid understanding that these barriers are not only specific to certain groups of people and the PEA as a nation-wide utility company have acknowledged that these barriers do exist in the sector. These triangulations of findings with the non-expatriate respondents outside of the community and the PEA contribute to the validity of this study, indicating that it is both internally and externally valid.

This study has three research questions that it seeks to answer through data analyses, and it was able to do so clearly with the first two of them. The literature review and finding chapters describe the socio-technical systems of solar PV, describing the roles of each responsible actor and the current state of solar PV diffusion in the country. The second question was answered in the finding section through the four dimensions based on the analytical framework and the study has further provided a comparison to the previously identified barriers in Thailand. However, the data collected for this study was insufficient to provide definitive answers to the third question, which concerned the potential roles of community solar models in addressing the barriers to solar PV diffusion in Thailand. It is distinguished that the attempt to pair the existing barriers in the diffusion process and the benefits of community solar can only answer the question of whether there are potentials but does not provide specific roles that can be taken.

During the study, another research question has also emerged looking specifically at the effect of local politics on the adoption process of solar PV. Reflecting on the author's personal experience with adopting solar PV systems at home, it would be interesting to find answers to the question of "how does local politics affect the process of solar PV adoption by residents". The local political conditions have not been discussed in the current study. However, observing from the interviews with different stakeholders has indicated that the adoption processes are affected by the local politics. An example of this could be seen in the difference between the interviewees from the headquarter of PEA and the interviewees from the local office. The interviewees at the management level in the headquarters expressed enthusiasm for the spread of solar PV and emphasized the organization's support for the residents. The same cannot be said for the local office.

6 Conclusions

In the past decades, many countries around the world have been working with their energy sector to transition towards more renewable sources as the energy sector is one of the key contributors to high GHG emissions (Intergovernmental Panel on Climate Change & Edenhofer, 2014). Thailand is no exception from this trend, in recent years the government have announced multiple national strategies regarding the transition of electricity generation sources from conventional to more renewable sources such as the 20 years strategic plan announced in 2017. The key strategy related to renewable energy is the goal of increasing the share of renewable energy to 30% by the year 2036. (IRENA, 2017) Following these commitments, the state-owned utility companies were tasked with the mission to increase the share of renewable energy generation by involving private sectors. Thailand has the geographical advantage of having an abundance of sunlight throughout the years, hence the expectation that solar energy will be the dominant source of renewable energy for the country. Thailand was one of the first countries in ASEAN to provide a FiT scheme for electricity generated by solar PV.(Tantisattayakul & Kanchanapiya, 2017) However, the schemes have only succeeded in bringing up the number of industrial-scale systems and not the medium or smaller size systems such as ones in the residential sector.

The study's aim is to look at the current socio-technical system of the residential sector solar PV systems in Thailand and categorises barriers which may be slowing the rate of diffusion, considering the different supporting schemes available from the government. Furthermore, it seeks to identify the role that an emerging solar model such as community solar could play in overcoming some of the barriers in the context of Thailand.

The study has found that Thailand, like many other countries around the world, is facing similar barriers to the diffusion of solar PV in the residential sector such as the financial barriers, the residents often have concerns over the high initial investment and whether the system will be able to provide a return of investment. The barriers to technical knowledge and understanding and more importantly the lack of available information regarding the system itself. Though there is information available across the internet, the residents have expressed a preference for a centralised source of information. Furthermore, this study has uncovered some patterns such as the relationship between the respondents' status in the community and their interest in the topic of energy systems. It is likely that someone who is not a full-time resident of the home will be less interested in the source of their electricity or feel the burden of the monthly electricity bills. After the identification process, the author has taken these barriers and compared them to the characteristics of community solar to see whether community solar would be a suitable model for Thailand. The study indicates that there is potential for community solar to be used in the context of Thailand. However, a deeper understanding and studies should be conducted to identify the specific roles community solar has in the diffusion of solar PV in the residential sector.

This study has provided an initial comparison between the existing barriers and the characteristic of community solar to indicate that some of these barriers could be solved by community solar. However, the complexity of the concept of community solar is an opportunity for future research to explore the different dimensions of implementing the concept as a way of encouraging the transition to renewable energy. Furthermore, this research has indicated that the social dimension of a socio-technical system is not only about the willingness of the residents but there are other contributing factors such as accessibility of information. Taking into consideration the two groups of respondents, future studies might be able to focus on the difference in cultural background and how this may influence their decision making regarding solar PV adoption.

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Appendix

Appendix A: Residents interview guidelines (English)

Interview Guidelines – Residents

Prior to conducting the interview, I would like to remind you about how the information from this interview will be used and remind you of your rights as a participant of this study. This is an independent master's thesis project and is not funded by any organization. The participation of this voluntary and each participant has the right to choose what they would like to answer. The information collected from the interviews will only be used for this study and the transcription of this interview will only be accessible by the author. Your personal information such as your name will not be disclosed and only be referred to in the study by your location or your position in the organization.

Introduction/General Questions:

- What type of housing? – house/town home/standalone/community
- Do you own the house you are living in or is it rental?

Electricity Usage:

- Who is your utility provider?
- How much is your average monthly electricity bill?

Renewable Energy

- Have you heard about renewable energy such as hydropower, solar etc?
- What are your thoughts on the topic?

Solar PV

- Have you heard of solar PV? What is your opinion this topic?
- Have you heard of rooftop solar programs and promotion from PEA? (Solar Hero)
- Have you installed solar PV systems at home?

  → If yes:

  i. what is your experience with the systems?
     a. cost savings?
     b. feel better about electricity consumption behavior?
     Why did you install it?

  ii. how did you get to know about it?

  iii. What were the incentives to install?

  iv. Did you use any support (local, regional, national subsidies?)

  i. Did you face any difficulties/challenges? What?

  → If no, then continue:
- What do you think could be the benefits of installing solar PV?
- Would you personally be interested in using this system for your home?

  → if yes what are the reasons?
- If you were to consider this system, what would be your biggest concern?

Supports

- Do you think there are enough information available about the benefits and procedures of solar PV in Thailand? Would knowing about the benefits and return of investment be enough to convince you in getting the system?
- Would you consider solar PV system if you know you will be able to sell back excess energy back on grid?
- In your opinion what kind of supports do you think are needed for solar pv?

Appendix B: Residents interview guidelines (Thai)

แนวทางการสัมภาษณ์ – สมาชิกชุมชน

ก่อนที่จะเริ่มขบวนการสัมภาษณ์ อยากจะขอแจ้งข้อมูลและรายละเอียดเกี่ยวกับสิทธิ์ของท่านในการเป็นผู้ให้ข้อมูลนะคะ วิทยานิพนธ์ปริญญาโทนี้เป็นโครงการอิสระและไม่ได้รับการสนับสนุนจากองค์กรใดๆ และแจ้งให้ท่านทราบอีกครั้งว่าการให้ข้อมูลในครั้งนี้ ท่านสามารถเลือกตอบคำถามตามความสมัครใจของท่าน ข้อมูลที่ได้รับจากการสัมภาษณ์ในครั้งนี้จะถูกนำไปใช้สำหรับการวิจัยของวิทยานิพนธ์นี้เท่านั้น และ เจ้าของวิทยานิพนธ์จะเป็นคนเดียวที่สามารถเข้าถึงบันทึกข้อมูลสัมภาษณ์นี้ จะไม่มีการเปิดเผยข้อมูลส่วนตัวของท่านในวิทยานิพนธ์ แต่อาจจะมีอ้างอิงถึงในนามของ “สมาชิกชุมชน” หรือ ภายใต้ ตำแหน่งของท่านในองค์กร

คำถามทั่วไป

- ลักษณะที่อยู่อาศัยของท่าน เช่น บ้าน หรือ ทาวโฮม? เป็นรูปแบบของหมู่บ้าน หรือ บ้านเดี่ยว
- ที่อยู่อาศัยในปัจจุบันของท่านนั้นเป็นลักษะเช่าอยู่อาศัย หรือ ท่านเป็นเจ้าของกรรมสิทธิ์?

การใช้ไฟฟ้า

- ท่านได้รับบริการไฟฟ้า ณ ที่อยู่อาศัยปัจจุบันจากองค์กรใด?
- ค่าไฟโดยเฉลี่ยต่อเดือน ณ ที่อยู่อาศัยปัจจุบันของท่าน อยู่ที่เท่าใด?

พลังงานหมุนเวียน

- ท่านทราบเกี่ยวกับพลังงานหมุนเวียน เช่น พลังงานน้ำ พลังงานแสงอาทิตย์ หรือไม่?
- ท่านมีความคิดเห็นใดเกี่ยวกับหัวข้อนี้?

Solar PV

- ท่านทราบเกี่ยวกับ ระบบผลิตไฟฟ้าพลังงานแสงอาทิตย์ โซล่าเซลล์ หรือไม่ และ มีความคิดเห็นใดเกี่ยวกับหัวข้อนี้?
- ท่านเคยทราบหรือได้ยินเกี่ยวกับโครงการ การให้บริการคำปรึกษาและติดตั้งระบบโซล่าเซลล์ของการไฟฟ้าภูมิภาค เช่น แอพพลิเคชั่น โซล่าฮีโร่ หรือไม่?
- ท่านได้ทำการติดตั้งระบบโซล่าเซลล์ที่บ้านหรือไม่?

  → ถ้ามี

  i. ช่วยกล่าวถึงประสบการณ์ของท่านเกี่ยวกับระบบนี้? เช่น มีค่าใช้จ่ายที่ลดลง หรือ รู้สึกดีที่ได้เป็นส่วนหนึ่งในการผลิตพลังงานสะอาด

  ii. เหตุผลในการตัดสินใจติดตั้งระบบโซล่าเซลล์

  iii. ท่านรู้จักระบบโซล่าเซลล์ได้อย่างไร?

  iv. แรงจูงใจในการติดตั้งระบบโซล่าเซลล์ของท่านคืออะไร?

  ii. ท่านได้รับการช่วยเหลือในแบบของเงินอุดหนุนจากหน่วยงานภาครัฐหรือไม่?

  iii. ท่านได้พบเจอกับปัญหาใดๆ ในระหว่างการติดตั้งหรือไม่? และปัญหาแบบไหน?
- ท่านคิดว่าการติดตั้งระบบโซล่าเซลล์นั้นมีประโยชน์อย่างไร?
- ท่านมีความสนใจในการติดตั้งระบบโซล่าเซลล์ ณ ที่อยู่อาศัยของท่านหรือไม่?

  → ถ้าสนใจ ทำไม?
- สิ่งที่ท่านกังวลใจมากที่สุดเมื่อตัดสินใจติดตั้งระบบโซล่าเซลล์

การสนับสนุน

- ท่านคิดว่าข้อมูลที่มีอยู่เกี่ยวกับประโยชน์และขบวนการการติดตั้งระบบโซล่าเซลล์ในประเทศไทยในขณะนี้นั้นเพียงพอหรือไม่?
- ท่านคิดว่าข้อมูลที่ได้รับเกี่ยวกับประโยชน์ และ ระยะเวลาการคืนทุนของระบบโซลล่าเซลล์นั้น เพียงพอที่จะสามารถทำให้ท่านพพิจารณาติดตั้งระบบหรือไม่?
- หากท่านทราบว่าสามารถขายพลังงานไฟฟ้าส่วนเกินคืนให้กับการไฟฟ้าได้ ท่านจะพิจารณาติดตั้งระบบโซลล่าเซลล์หรือไม่?
- ในความเห็นของท่าน ท่านคิดว่าการสนับสนุนแบบใดเป็นสิ่งที่จำเป็น ในการติดตั้งระบบโซล่าเซลล์ในภาคชุมชน

Appendix C: Solar company interview guidelines

Interview Guidelines – Solar company

Prior to conducting the interview, I would like to remind you about how the information from this interview will be used and remind you of your rights as a participant of this study. This is an independent master's thesis project and is not funded by any organization. The participation of this voluntary and each participant has the right to choose what they would like to answer. The information collected from the interviews will only be used for this study and the transcription of this interview will only be accessible by the author. Your personal information such as your name will not be disclosed and only be referred to in the study by your location or your position in the organization.

Introduction/General Questions:
- What is your role at the company? - Can you tell me a little bit about your company? - Do you have operations in other provinces? - What are the general procedures taken when a customer is interested in solar pv installation?
Customers
- Who are your customers? Expats or locals? - Does the company approach them first or do they approach the company, when interested in deploying solar PV? - Roughly how many PVs do you think are on the island? - (If have other operation) or in your opinion how is the island's market in comparison to other markets
Solar PV
- What topic or subject do you discuss with customers to convince them? - What are the drivers for customers to decide to install solar PV? - What do you think are the barriers, stopping people from installing solar pv? Or what are the usual concerns? - Are there difficulty or complexity in the maintenance process?
Process
- What is the time frame for the project? From decision made until the completion of all permits. - Are the paperwork and process usually taken care by the company? - Do customers find the complex paperwork or permit to be unappealing?
Drivers and overcoming barriers
- What do you think could help individuals to overcome the challenges they face with regards to installing solar PV? - How do you see the company's role in that? - What kind of supports do you think are needed to convince you to install solar PV?

Appendix D: PEA interview guidelines

Interview Guidelines – PEA

Prior to conducting the interview, I would like to remind you about how the information from this interview will be used and remind you of your rights as a participant of this study. This is an independent master's thesis project and is not funded by any organization. The participation of this voluntary and each participants have the right to choose what they would like to answer. The information collected from the interviews will only be used for this study and the transcribe of this interview will only be accessible by the author. Your personal information such as your name will not be disclosed and only be referred to in the study by your location or your position in the organization.

Local:

- What are the main energy sources here? (Share of renewables?) How this share has been changing? Why do you think this is?
- Have you experienced an increase interest in renewable energy in the past 5-10 years?
- If yes, What do you think are causing this change?
- Have you experienced an increase in solar PV installation in the province?
- What are the roles of the PEA office, in relation to installation of solar PV?

Management/HQ:

- Share of residential solar in the total energy generated by solar
- What kind of supports can people get from the PEA?
- How important do you deem residential solar to be, in the context of contributing to the national renewable energy commitment?
- What are the plans and goals for solar energy in the next 5-10 years?
  - Are there specific goals for residential solar?
- In your opinion, what do you think are the barriers that stop people from getting solar PV?
- How do you envisage the role of PEA in the future – in the scenario when individuals starting to be interested in solar PV?
- Apart from individual solar PV, is there a possibility to introduce other models?
- In the case, when a group of people approaches PEA for potential community solar PV installation, how would PEA react? Any action plans, strategies exists for that?

Appendix E: Online Survey

Sustainability Practices Committee Questionnaire

Questionnaire about [redacted] awareness on the topic of renewable energy.

This questionnaire consisting of 3 pages will take less than 15 minutes and is prepared as part of the Sustainability Practices Committee (SPC)'s initiatives to introduce sustainable practices to the [redacted] answers from this questionnaire will provide the committee with information regarding current perspectives and levels of awareness which will then be used to guide our committee regarding future projects.

In addition, the information received from this questionnaire will be used in research conducted by a master's student from the Environmental Management and Policy Programme at Lund University, Sweden. This research aims to identify and understand some of the barriers and motivations for residential solar PV installation in the country of Thailand. Throughout this research (fieldwork, analysis, conclusions) your anonymity is protected. No personal information will be used.

Please complete the questionnaire by the 25th of March 2022
Thank you for participating in our questionnaire.

* 1. Prior to answering the questionnaire, this question is to ensure that you have been informed about how and what the information provided will be used for.

◯ I am aware and hereby give my consent.

◯ I do not wish to participate in this questionnaire (please specify)

Next

Sustainability Practices Committee Questionnaire

* 1. Contact Information

◯ I would like to remain anonymous

◯ Email Address

* 2. **Do you agree with the following statements?**

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I believe that there are needs for changes in everybody's lifestyles, to sustain the world for the future generation.	◯	◯	◯	◯	◯
I recycle at home*.	◯	◯	◯	◯	◯
I buy local and seasonal produce, if I can from ecological / organic sources.	◯	◯	◯	◯	◯
I am aware of the environmental impact of fossil fuels we use in our energy systems.	◯	◯	◯	◯	◯
I know how approximately much energy my house* consumes.	◯	◯	◯	◯	◯
I am aware that rain water can be stored and used.	◯	◯	◯	◯	◯

* By home/house, your permanent residence is meant, other than Santikhiri

* 3. **What is the status of your [redacted]**

◯ Full time residency

◯ Holiday home

◯ Rental

◯ Other (please specify)

* 4. **If you were to improve or renovate your home, would you consider taking sustainable measures?**

◯ Yes

◯ No

If yes, what would these measures be?

Prev Next

Sustainability Practices Committee Questionnaire

Renewable Energy

* 1. **Do you know what renewable energy is?**

- ◯ Yes
- ◯ No

If yes, what types of renewable energy generation have you heard of?

* 2. **Which of the below energy sources do you consider renewable?**

- ☐ Hydro Power
- ☐ Solar
- ☐ Wind
- ☐ Natural Gas
- ☐ Geothermal
- ☐ Coal
- ☐ Nuclear
- ☐ Biofuel
- ☐ Burning waste to generate electricity in a combined heat and power plant.

* 3. **What would best motivate you to turn to renewable energy?**
Please rank the following factors. Give 1 to the factor that would most motivate you, and 3 to the one that would least motivate you to turn to renewable energy. In case only one or two of the listed factors would motivate you, please select N/A box on the factor that does not motivate you.

	Energy security on a national level	☐ N/A
	Safe and stable accessibility to energy at home (no black outs, no energy shortage)	☐ N/A
	Cost savings	☐ N/A
	Reducing my environmental impact	☐ N/A
	To be a forerunner and to serve as role model for others to adopt renewable energy	☐ N/A

* 4. **Have you heard of solar PV systems such as solar rooftop for electricity generation?**

◯ Yes

◯ No

* 5. **What do you think are the benefits of installing solar PV systems?**

* 6. **Have you considered installing solar PV systems at home*?**

◯ Yes *(Please continue to Q7)*

◯ No *(Please continue to Q8)*

7. **Why have you considered the installation?**

8. **Why have you NOT considered the installation?**

* 9. **Which of the following would best motivate you to install solar PV systems at home?**
(Ranking range from 1 as the best motivating factor to 7 as the factor that does not motivate at all)

- More information on how I can benefit from solar PV installations
- Subsidies from the state/regions
- An expert calculation that shows my cost savings on both short and long-term
- The assurance of stable supply of electricity
- Keeping up with my neighbours' advanced technology
- Reduce my environmental impact
- Utilising the existing and free source of energy

* 10. Are there other motivations that you have, which have not been listed in Question 9?

◯ Yes

◯ No

If Yes (please specify)

* 11. **Do you agree with the following statements?**

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I think my home's design is not appropriate for solar PV systems.	◯	◯	◯	◯	◯
I think that having solar panels in my home would affect the aesthetic of my estate.	◯	◯	◯	◯	◯
I don't think I have enough information to make the decision.	◯	◯	◯	◯	◯
I do not see why I should make an extra investment, as there is already existing electricity supply.	◯	◯	◯	◯	◯
I have not experienced electricity shortages or other difficulties related to the electricity system at home.	◯	◯	◯	◯	◯
I believe that there are too many documents and procedures that must be involved.	◯	◯	◯	◯	◯

Prev Next

* 1. **Are you aware of the capacity of the electricity supply at** [redacted]

◯ Yes

◯ No

* 2. **Do you agree with the following statements?**

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I think that using renewable energy for the common area consumption is good.	◯	◯	◯	◯	◯
I can imagine considering to support a decision to use some of my annual payment as investment in renewable electricity for the common area.	◯	◯	◯	◯	◯
I am satisfied with the current electricity supply at my estate in Santikhiri.	◯	◯	◯	◯	◯
I do not feel the needs to reduce my current electricity bill.	◯	◯	◯	◯	◯
I feel that the current electricity supply is stable and there are no needs for changes.	◯	◯	◯	◯	◯
I think there are more important sustainable practices to focus on	◯	◯	◯	◯	◯
I think that water management is a more crucial issue on Santikhiri than energy supply	◯	◯	◯	◯	◯
I think that waste management is more crucial issue on Santikhiri than energy supply.	◯	◯	◯	◯	◯

3. I would be willing to talk about this topic more with the researcher and can be contacted via the email provided.

◯ Yes (please provide contact information)

◯ No

Please provide contact information

4. If you feel like there are additional discussion points please indicate here. Any comments are welcome!

Thank you for your time.

Prev Done