COMPARATIVE ANALYSIS OF COMMUNITY SOLAR PROJECTS BETWEEN THAILAND AND JAPAN

Mr. Masataka Yamashita

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Arts in Environment, Development and Sustainability
Inter-Department of Environment,Development and Sustainability
Graduate School
Chulalongkorn University
Academic Year 2018

การวิเคราะห์เปรียบเทียบโครงการพลังงานแสงอาทิตย์ระดับชุมชนระหว่างประเทศไทย และญี่ปุ่

น

นายมาซะทากะ ยามะชิตะ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาศิลปศาสตรมหาบัณฑิต

สาขาวิชาสิ่งแวดล้อม การพัฒนา และความยั่งยืน สหสาขาวิชาสิ่งแวดล้อม

การพัฒนาและความยั่งยืน

บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2561

Thesis Title	COMPARATIVE ANALYSIS OF COMMUNITY SOLAR PROJECTS BETWEEN THAILAND AND JAPAN
By	Mr. Masataka Yamashita
Field of Study	Environment, Development and Sustainability
Thesis Advisor	Associate Professor DAWAN WIWATTANADATE, Ph.D.

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Arts

.... Dean of the Graduate School
(Associate Professor THUMNOON NHUJAK, Ph.D.)

THESIS COMMITTEE

.... Chairman
(Associate Professor VITHAYA KULSOMBOON, Ph.D.)

.... Thesis Advisor
(Associate Professor DAWAN WIWATTANADATE, Ph.D.)

.... Examiner
(Suthirat Kittipongvises, Ph.D.)

มาซะทากะ ยามะชิตะ :
การวิเคราะห์เปรียบเทียบโครงการพลังงานแสงอาทิตย์ระดับชุมชนระหว่างประเทศไทย และญี่ปุ่น. (COMPARATIVE ANALYSIS OF COMMUNITY SOLAR PROJECTS BETWEEN THAILAND AND JAPAN) อ.ที่ปรึกษาหลัก : รศ. ดร.ดาวัลย์ วิวรรธนะเดช

พลังงานแสงอาทิตย์ระดับชุมชน เป็นรูปแบบใหม่ของธุรกิจพลังงานแสงอาทิตย์ทั่วโลก โดยที่รูปแบบการดำเนินธุรกิจของแต่ละประเทศอาจแตกต่างกันไป ปัจจัยที่เป็นเอกลักษณ์ของแต่ละประเทศ ได้แก่ รูปแบบการสนับสนุนจากรัฐบาล คุณลักษณะเฉพาะของชุมชน การจัดสรรผลประโยชน์จากโครงการสู่ชุมชน เป็นต้น วัตถุประสงค์ของงานวิจัยนี้ คือ การเปรียบเทียบผลประโยชน์ทางการเงินของโครงการพลังงานแสงอาทิตย์ระดับชุมชนของประเทศไทยกับญี่ปุ่น เพื่อนำไปสู่ข้อเสนอแนะเชิงนโยบายสำหรับการพัฒนาโครงการพลังงานแสงอาทิตย์ระดับชุมชนต่อไปในอนาคต โดยทำการสัมภาษณ์เชิงลึกผู้ประกอบการโครงการพลังงานแสงอาทิตย์ระดับชุมชนจากโครงการตัวอย่างที่คัดเลือกเป็นกรณีศึกษา ซึ่งประกอบด้วย โครงการในจังหวัดชลบุรีกับประจวบคีรีขันธ์ในประเทศไทย และโครงการในจังหวัดคิตะคิวชูกับอาวาจิในประเทศญี่ปุ่น แล้วนำข้อมูลที่ได้มาทำการวิเคราะห์ดัชนีทางเศรษฐศาสตร์ของโครงการ อาทิ มูลค่าปัจจุบันสุทธิ (Net present value, NPV) และต้นทุนเฉลี่ยตลอดอายุโครงการ (Levelized cost of energy, LCOE) เป็นต้น โดยใช้โปรแกรม System Advisor Model (SAM) ผลการศึกษาพบว่าโครงการของไทยมีต้นทุนโครงการประมาณ 1 ใน 3 ของโครงการในญี่ปุ่น ทั้งนี้เนื่องจากความแตกต่างของเทคโนโลยีระบบพลังงานแสงอาทิตย์ที่ใช้ และค่าแรงงานที่ต่างกันมาก ผลการวิเคราะห์ดัชนีทางเศรษฐศาสตร์ของโครงการนำไปสู่ข้อเสนอแนะเชิงนโยบายสำหรับประเทศญี่ปุ่นเนื่องจากเงินลงทุนโครงการสูงและประสิทธิภาพระบบสูง แนะนำให้ขยายอายุโครงการ ขณะที่โครงการในประเทศไทย แนะนำให้พิจารณาทั้งอายุโครงการและ มาตรการส่งเสริมการรับซื้อไฟฟ้าจากพลังงานหมุนเวียน (Feed-in Tariff, FiT) อย่างรอบคอบและเหมาะสม

สาขาวิชา	สิ่งแวดล้อม การพัฒนา และความยั่งยืน	ลายมือชื่อนิสิต ....
ปีการศึกษา	2561	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

5987554020 : MAJOR ENVIRONMENT, DEVELOPMENT AND SUSTAINABILITY

KEYWORD: Community solar, business model, Policy recommendation, Financial analysis

Masataka Yamashita : COMPARATIVE ANALYSIS OF COMMUNITY SOLAR PROJECTS BETWEEN THAILAND AND JAPAN. Advisor: Assoc. Prof. DAWAN WIWATTANADATE, Ph.D.

Community-solar (CS) has appeared as a new solar PV ownership model in the word, in which the business model of CS should vary depending on each country's context. Various unique factors of each country such as the design of the government's support, characteristics of the community, and business custom may have an impact on how community members benefit from CS projects. The objective of this research is to compare the implemented CS projects in Thailand and Japan and to provide policy recommendation on CS for both countries based on comparison for contribution to further development of CS. The selected case study in this research was conducted in the CS projects at Chon Buri and Prachuap Khiri Khan in Thailand and Kitakyushu and Awaji in Japan. Here, I performed comparative analysis on business models and financial parameters on the current existing two CS projects each in Thailand and Japan considering own energy situation. Also, interviews with the CS projects relevant people were conducted. The economic indicators of CS projects were evaluated by the System Advisor Model, which can calculate net present value, levelized cost of energy (LCOE) and so on. From the data collected through the interviews, it is clarified that the investments in Thailand's CS projects are only about one-third of the investments in Japanese CS projects. The main reasons are the difference in the labor cost, the price of the instruments. As the results of analyses, policy recommendations to both Japanese and Thailand government were made. For the Japanese government, the extension of project lifetime is suggested. Regarding Thailand, FiT price and lifetime should be determined carefully.

Field of Study:	Environment, Development and Sustainability	Student's Signature ....
Academic Year:	2018	Advisor's Signature ....

ACKNOWLEDGEMENTS

First, the author would like to express his sincere acknowledgment to both Chulalongkorn University and Kyoto University for academic fund supporting during his studying at Chulalongkorn University under the double degree program between the two universities.

The author would like to express his deepest gratitude to Assoc. Prof. Dr. Dawan Wiwattanadate, his thesis advisor, for valuable advice and constructive criticism throughout the study. Sincere thank is also expressed to Dr. Sopitsuda Tongsopit, his former thesis advisor. Without her initiation and guidance, this thesis would not have been possible. His greatest appreciation is conveying to Prof. Keiichi N. Ishihara, his thesis co-advisor, for comprehensive supports and highly effective discussions.

Sincere appreciation goes to the thesis committee, Assoc. Prof. Dr. Vithaya Kulsomboon, Dr. Suthirat Kittipongvises, and Dr. Chatchawan Chaichana, for guiding research direction and kind supports.

Advice and comments given by Yosuke Toyota, head researcher of Kiko Network (Japanese environmental NGO) and Seiichi Ogata, Associate Professor of Kyoto University have been a great help for selection of Japanese case studies and set criteria.

Million thanks are express to Mr. Nakae Shinya, general secretary of Kitakyushu City Harbor Airport, for very useful information, kind cooperation for data collection.

Warm regard is conveying to Mr. Hisai Tomohisa, project general manager of Awaji Island Kuniumi Association, for technical and financial data collection support.

The author is particularly grateful for the assistance given by Ms. Unchisa Natalia, Thai Solar PV Association for data collection to solar developers in Thailand.

The author owes his deepest gratitude to Ms. Sirikul Thirasubtrakul for giving time for making warm comments and valuable information on Chon Buri Community-solar Project, and sincere gratitude expressed to Ms. Monsikar Areesawangvong, corporate finance manager of Thai Solar Energy, for giving me the experience from the Community-solar Project at Prachuap Khiri Khan.

Dr. Takaya Ogawa, an assistant professor of Kyoto University, has been tolerant and supportive to the author and giving constructive comments and warming encouragements.

Finally, the author would like to thank his family and friends, both in Thailand and Japan. Without their encouragement and support, this thesis would not have been materialized.

Masataka Yamashita

TABLE OF CONTENTS

Page

CHAPTER 1
INTRODUCTION

1.1 Background

The expected role of renewable energy is becoming more and more important day by day. In the Sustainable Development Goals (SDGs), especially in the Goal 7, the renewable energy is regarding as the most essential technologies for the reorient development towards a more sustainable direction, becoming the center of climate change solutions.

Thinking globally, alternative usage of renewable energy would lead to the protection of the world environment because renewable energy can help reduce the emissions of greenhouse gases from the burning of fossil fuels. Also, most of the countries have limited fossil fuel resources and face with the energy security problems such as rising costs of imported fossil fuels. Therefore, governments have been focusing on and supporting the development of renewable energy to enhance energy security by increasing energy self-sufficiency.

Thinking locally, alternative energy has the potential to create employment, increase economic activities in rural areas, electrify the un-electrified area and secure the production of energy in an emergency. Firstly, the installation of renewable energy requires various activities such as equipment manufacturing, construction and setting, operation and maintenance; therefore, it creates new employment in local areas. Secondary, rural areas tend to have more renewable energy potential such as rich sunlight irradiation, steady wind, rivers with a big drop, geothermal heat. By utilizing the regional potential, renewable energy business can be useful to activate rural areas. Generally, a vast space is necessary for renewable energy generation, and landowners often offer their land. In this case, the involvement of local people makes the project management easier. Thirdly, renewable energy, especially solar energy, is suited for electrification of the area without connection with the utility grid. In the case of the area apart from the utility grid, it is more cost-effective to install photovoltaic (PV) system than to extend the power lines of the utilities. Finally, most of the renewable energy is connected with electrical grids so that electricity can be generated continuously even if the electricity supply from the main grid stops in case of an emergency such as disasters.

To sum up, renewable energy has good potential and reasons to be expected. Especially, solar energy has gathered attention as promising renewable energy in the future and the amount of global installed capacity of PV has increased from 26 megawatts (MW) direct current (dc) in 2000 to at least 303 gigawatts (GW) in 2016 (IEA PVPS, 2016). This shows that solar PV is regarding as a cost-competitive source for increasing electricity generation and for providing energy access through government policies continue to drive solar PV markets in most locations. In addition, unprecedented price reduction, particularly for modules, allows solar PV to ensure the competitiveness with traditional power sources. (REN21, 2017)

Solar energy has several characteristics that make it distinguished from other types of renewable energy. First, solar systems can be set at anywhere sunlight is reached. Though the condition of the sunlight differs from place to place, the deviation of the energy source is less, compared with other renewable energy. Second, it is easy to use PV systems for a long time (over 20 years) and, what is more, to do maintenance and operation because of the simple structure of the solar PV systems. Finally, we can design freely depending on the budgets and needs of the investors or installers. In other words, we can design the whole system based on the purpose of the investors without the limitation from the solar PV system itself.

In this research, the author focuses on community-solar projects in both Japan and Thailand. There are some community-solar projects in both countries, but the number of academic publications relating community-solar projects is limited. The model of community-solar varies with the country's context. Various factors unique to each country such as the design of the government's support, community characteristics, and business models may have an impact on how community members benefit from community-solar projects. Therefore, it is worth doing comparative financial analysis on the current existing community-solar projects of both countries under individual context for contribution to further development of community-solar.

1.2 Definition of Community-solar in This Research

Community-solar is a new solar PV ownership model appearing in the world these days. It allows broad customers to access solar energy, that is, it can provide an opportunity to people who are interested in renewable energy and want to own solar PV by themselves, but giving up for some reasons. The community-solar has great potential to grow further; however, there are many problems need to be investigated. The penetration of community-solar has been a challenging issue.

In May 2011, World Wind Energy Association (WWEA) defined "Community Power" as a project if at least two of the following three criteria are satisfied:

- *"A local individual or a group of local stakeholders, whether they are farmers, cooperatives, independent power producers, financial institutions, municipalities, schools, and so on, own immediately or eventually, the majority or all of a project."*

- *"The community-based organization made up of local stakeholders has the majority of the voting rights concerning the decisions taken on the project."*

- *"The major part or all of the social and economic benefits are returned to the local community."* (WWEA, 2011)

On the other hand, there is no standard industry definition of community-solar; therefore, two examples of definition are proposed. Coughlin et al. defined a community-solar as "a solar-electric system that, through a voluntary program, provides power and/or financial benefit to, or is owned by multiple community members (Coughlin et al., 2012)." Asmus defined a community-owned solar system as a business model with "the ability of multiple users—often lacking the proper on-site solar resources or fiscal capacity or building ownership rights—to purchase a portion of their electricity from a solar facility located off-site (Asmus, 2008)." Community-solar participants are multi-family unit dwellers, small business owners, and rural residents, as well as traditional single-family property owners. Since all cost is sharing, solar communities make it easier for low- to middle-income residents to participate in renewable energy resources. They are also ideal for properties where the panel installation is not possible (Coughlin et al., 2012).

However, these definitions are not suitable for the actual situation of solar projects in either Thailand or Japan. In this research, a community-solar project is defining as "a project which is organized by a municipality or a national company with the cooperation of local people and is aiming at a regional contribution." While community-solar is called "community shared solar," "community-solar" or "shared solar" in the publications, we will refer to "community-solar" here.

1.3 Context of Community Renewable Energy in Europe

In order to understand the context of community-solar all over the world, the development history of the community renewable energy (CRE) was introducing in this section.

The development of CRE mainly began in Denmark. There had been the technical background of wind power in Denmark in 1950s by two inventors, Poul la Cour and Johannes Juul. After the 1973 oil crisis, the development of the wind power technology happened by local citizens and farmers for coping with a lacking source of domestic energy source and searching alternatives to the nuclear power (Krohn, 2002). The citizens and farmers had been using the windmill for mill and water drawing in the agricultural use. They asked agricultural machinery manufacturer to make wind power generator and voluntarily started to build small-scale wind power generators in various locations. There was a large-scale wind project where local universities, private manufacturers, and a research laboratory cooperated openly (Toke, 2011). At that time, the development of nuclear power was discussing by Denmark government and that movement was a kind of expression of their opposition feeling to nuclear power. They tried to contribute increasing the energy security even though their cooperation was unpaid.

In 1978, owners of the wind power generators set up “the Danish Windmill Owners Association,” and they made demands on the government and utilities to introduce the wind power promoting system. In 1979, the Danish government installed a regulation that the government gave subsidies 30% of the capital cost of wind turbine installation to the developers. Furthermore, in 1984, the government realized the agreement that utilities purchased electricity generated by wind power at a fixed price per kWh. This was the original design of the Feed-in Tariff scheme in the world (Karnøe & Garud, 2012). By these, the wind power economics improved and the owners began to be able to make monetary prospects. As the electricity generation by wind turbines increased, the subsidy percentage for the installation capital declined and finally abolished. However, under the FIT, the project could cover the necessary cost and create benefits to some extent and local people continued to build wind turbines.

In 2015, 42 % of the total electricity generation in Denmark had been produced by wind power and Denmark is the number one country in wind power generation per capita (Norskov & Vittrup, 2016). The appropriate growth policy by the government and the movement by motivated citizens and formers raised the wind power-related industry in Denmark. Citizens own almost 80% of the wind generators in Denmark and there is a law that when a wind generator is built, the local citizens must invest and own more than 20% of the capacity. With the help of this law, local citizens continue to participate in a discussion of planning in the early stage of planning which helped in incorporating the intention of the local citizen. As a result, the opposition movement by local citizens rarely happens and the constructions of more wind generators expanded smoothly.

Germany, a neighbor country of Denmark, is also a country where the introduction of renewable energy is active by citizens and local people. Due to acid rain, almost 33 % of the forests in Germany seriously damaged in the 1980s, mainly caused by sulfur discharged during coal combustion for power generation. This damage strengthened the ecological consciousness of German people and it became a strong driver for renewable energy development. In 1991, the Act on Supplying Electricity from Renewables (Stromeinspeisegesetz, StrEG) enacted as FiT system for renewable energy in Germany. The purchased price changed once a year in proportion to the utilities' electricity selling price to the end-users; however, wind power projects could manage to cover the necessary cost by the act and the installation of wind power advanced rapidly. In 2000, the Renewable Energy Sources Act (EEG) was enacted which was improved and expanded in many aspects from StrEg. Under the EEG, the condition of expansion for all renewable energy was satisfied (Bechberger & Reiche, 2004). At present, renewable energy power plants built in Germany mainly driven by citizens and local people more than developers and industries.

As mentioned above, the renewable energy power creation is active by citizens and farmers in Denmark and Germany because, by the movement, it becomes a mean to a better-off life and creates new industries and employment in the local area. Moreover, the movements have good impacts on whole society such as environmental conservation, industry development and employment creation, improvement of energy self-sufficiency. Therefore the entire society reached a stage of welcoming expansion of renewable energy.

1.4 Current Situation of Thailand's Solar Policy

Power generation capacities of Thailand have continuously been increasing to meet the growing energy demand from both industrial and residential sectors and the source of energy production is mainly fossil fuels such as coal and natural gas. The growth rate of the power supply is less than that of power demand; therefore, Thailand would face an energy security problem with high risks (Chaianong and Pharino, 2015). To deal with this problem, the government of Thailand presented five energy master plans during the year 2015-2036: Power Development Plan (PDP), Energy Efficiency Development Plan (EEDP), Alternative Energy Development Plan (AEDP), Oil Development Plan and Gas Development Plan. The AEDP 2015 focuses on the promotion of energy production with domestic renewable energy resources to strengthen the country's energy security and its target by 2036 is to increase the renewable energy share of total energy production to 30 percent. The position of solar energy is important; therefore, the government set the solar policy and target in order to increase installed capacities of this sector to be achieved 6,000 MW by 2036. There are several solar incentive schemes supporting solar sector and Thailand has one of the most popular programs that many countries adopted: "Feed-in Tariffs (FiT) scheme".

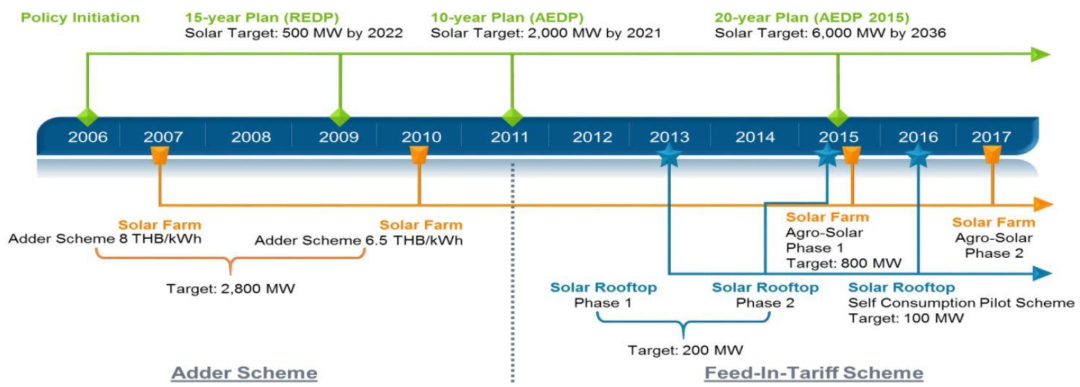

Figure 1.1 Solar PV Policy Timeline of Thailand (GIZ, 2018)

The "solar community programme" announced in 2013; however, did not work functionally. The main objective of the scheme was local value creation and generating new income opportunities for local communities. The programme was designed for implemented by the Thai Village Fund in cooperation with the Provincial Electricity Authority (PEA); however, faced with the problems of financing the project while ensuring the transparency of the scheme. The programme then transformed into "Government and Agricultural Cooperatives Programme (Agro-solar)" and objective of the new programme is to realize "solar farms with up to 5 MW in size in the form of public-private partnerships with the governmental sector or agricultural cooperatives" under the overall target of 800 MW. Each of the governmental agencies and agricultural cooperatives would be responsible for 400MW (GIZ, 2014).

During phase 1 of the programme, there were 67 projects selected and installed 281.32 MW in total and all under agricultural cooperatives. To achieve the program's overall target of 800MW, phase 2 would have a target of 519 MW. 400 MW of which for projects with a government agency and 119 MW for projects with agricultural cooperatives; however, the 400 MW with a government agency, there are issues on complication with public-private partnership and no project have started. (GIZ, 2017).

The quota for governmental agencies are revised to become 100MW. However, only 52.5 MW are subscribed for now.(GIZ, 2018). The capacity of each project under Agro-solar phase 1 was 1-5 MW with value decided by lucky draw.

1.5 Context of Japanese Solar Policy

In 1974, Sunshine project was launched which targeted to develop new energy technology development for dealing with energy and environmental problems. The Oil shock in 1973 was the main reason to start this program. Japan heavily depended on the Middle East for an energy source, petroleum. Therefore, Japan started to seek new stable energy resources. After this project launched, the technology development of solar power was started for lowing cost and raising the efficiency of the modules. The policy for advancing solar energy was also released in 1980 and finished in 1996. That allowed individuals to get finance in low interest for installation of solar PV. Finally, there were 274,000 cases which utilized this policy.

In 1994, "General Outline for Introduction of New Energy" was released which clearly showed the direction of Japanese energy policy to focus on renewable energy for the first time. Because of several efforts, during the second half of the 1990s, Japan had the most installed and manufactured solar PV capacity in the world.

Japan has faced a big problem in energy sources since the Great East Japan's Fukushima Daiichi Nuclear Power Plant Accident with Earthquake and Tsunami in 2011. The Japanese government and electric companies were required to stop the nuclear power plants and purchase fossil fuels to satisfy electricity demand. FiT scheme started in July 2012 and there were two main objectives. The first objective was to create new renewable energy market by ensuring long-term purchase at a fixed price to reduce entry risk. The second objective was to encourage independence of the renewable energy market by cost reduction due to market expansion.

Since the implementation of the FiT scheme in 2012, the installed capacity of renewable energy in Japan has been increasing rapidly and total renewable energy installation capacity became more than double in 3 years. Japanese government presented an outlook where the share of renewable energy would be 22-24 % of total electricity generation in 2030 (METI, 2015) and the FiT scheme is expected to continue to play a critical role for achieving the target. However, the expansion of renewable energy has caused many problems such as the disproportionate introduction of solar energy, the increasing burdens on the public, non-operation of approved facilities under the scheme and restriction of new entries to access power grids by utilities. To deal with these problems, Japan enforced newly revised FiT Act in April 2017, aiming to achieve both the introduction of renewable energy to the fullest and lowing public burdens (METI, 2017).

Regarding community energy in Japan, pioneering projects such as "citizen windmill" and "citizen solar power" has emerged since around 2000. The government policy on energy was nuclear-oriented and the government was not aggressive for expansion of renewable energy for long years. Before 2012, the purposes of the community-solar projects were not making profits but prevention of global warming, improvement of energy self-sufficiency, the creation of local renewable energy expansion system, alternative use of nuclear power and so on. In other words, Japanese citizens had been working on community-solar projects for their purpose even if they had to expend their funds and labors in the projects. (Takeshi et al., 2014)

After the Earthquake and Nuclear Accident in 2011, the public consciousness on renewable energy has grown; in addition, the FiT scheme started in 2012 prepared the political environment. This context activated the movement working on community power all over the country (ISEP, 2016).

Unlike Thailand's solar PV policy, there is no specific policy for supporting community-solar projects in Japan except for the FiT scheme. The capacity of the most community-solar projects is smaller than 50KW; however, a few cases are larger than 1MW.

1.6 The Role of FiT

FiT scheme is a policy designed to increase the investment in renewable energy technologies. FiT has advantages as follows (EPIA, 2008);

- The security of investment is high. The investment from the private sector can be expected.
- The budget of the government is not necessary. The investment from the private sector will increase the investment for public benefit.

- It encourages investment and development of renewable energy technology and the competitiveness of the industry will be developed.

FiT can guarantee payment for certain periods with a relatively high price for renewable energy developers. Under the FiT, renewable energy does not need to compete with nuclear power or fossil fuels regarding price. The purchased price of renewable energy does not affect by the external factors for a relatively long time.

When compared FiT scheme with subsidies from the government, what is most important is that investors can prospect the cash flow through the project life more clearly under FiT. Therefore, the private sector can make a plan of investment to the energy facilities easier. As a result, the installation of renewable energy will increase under FiT.

However, when the FiT price is higher than electricity selling price by utilities, the difference in price will become the burden of electricity consumers. Therefore, the electricity price will rise because of FiT.

1.7 Research Questions

Since information and previous research of community-solar in Japan and Thailand is limited, the research should start from understanding what kind of community-solar model currently exists. Financial analysis for evaluation of community-solar projects feasibility was conducting. Such financial analysis would enable the researchers to understand how community-solar works and identify lessons learned from community-solar projects can be transferred to other countries. This thesis set research questions to build up better understandings of financial analysis of community-solar projects as follows:

- What are the structures and details of business models that the community-solar projects in Japan and Thailand would adopt?
- How do members of the communities in Japan and Thailand benefit from FiT programs and what factors account for the differences?

1.8 Research Objectives

The objectives of the study are:

- To understand and compare how community-solar projects designed in Thailand and Japan.
- To qualitatively analyze the structure and social aspects of community-solar projects.

- To quantitatively analyze the financial metrics of community-solar projects.
- To suggest policy recommendations based on the findings from the analysis.

1.9 Scope of the Study

For the financial comparison, a criterion on choosing the case studies of current working projects in Thailand and Japan is necessary. This research focused on two community-solar projects each in Thailand and Japan and investigated the business models, then compare and analyze the policy and financial indicators. In this research, the focused community-solar projects in Thailand is under Government and Agricultural Cooperative Programme Phase 1, which is the current main support program for community-solar in Thailand released in 2014. It is reported that in phase 1 of it there exist 67 projects (GIZ, 2014) which installed community-solar. Moreover, the focused community-solar projects in Japan are the projects started before the revised FiT program enacted.

CHAPTER 2

Literature Review

2.1 Community-solar Ownership Model in the U.S.

When the motives of people on community-solar projects vary, the community-solar project models vary. There exist many kinds of community-solar business models and they can be broken into mainly four types of community-solar ownership model: Utility-owned model, Third-party owned model, Special purpose entity model, and Non-profit model (Augstine, 2016 and Coughlin et al., 2012).

Utility-owned model is a project which is owned and operated by a utility and open to voluntary ratepayer participation. This model is financed by the utility capital and/or ratepayers' investment. Participation by customers is in the shape of supporting system costs by providing an up-front investment or ongoing payment. In this model, customers will receive payment or bill credit by their contribution and overall electricity generation by the system. This model can make good use of utility's experience in terms of grid network, system adjustment and maintenance. However, in the U.S. context, this model can not take advantage of tax incentives: tax credit allows individuals and businesses to reduce the amount of tax owed. Regarding public and non-profit organizations are exempted from income tax. Therefore this model does not have a tax incentive.

Table 2.1 Comparison of Community-solar Ownership Models

Comparison of shared solar ownership models.

	Utility-owned	Third-party owned	Special purpose entity—utility	Special purpose entity—customers	Non-profit
Description	Utility owns/operates a project that is open to voluntary ratepayer participation and financed through utility capital and/or ratepayer subscriptions	Developer owns/ operates a project that is open to ratepayer participation. Financed through third-party capital, utility capital, and/or ratepayer subscriptions	Utility sets up a separate business enterprise to develop a community solar project or utilizing existing for-profit subsidiary	Individuals join in a business enterprise to develop a community solar project	A charitable nonprofit corporation administers a community solar project on behalf of donors or members
O&M	Utility or third-party	Third-party	Utility or third-party	Third-party	Third-party
Pros	Utility maintains control to adjust the system; can gain first-hand experience; can adjust for optimization of network requirements	Can take advantage of tax incentives; relatively simple for utility to participate	Can take advantage of tax incentives; utility branding; can adjust for optimization of network requirements	Can take advantage of tax incentives	Donors may get tax deduction directly
Cons	Utility exempt from income taxes, so cannot take advantage of federal tax incentives; more work	Lose connectivity with customers; financial/ credit risk associated with third- party; costlier	Complex legal and tax implications	Financial/credit risk associated with third-party; costlier; complex legal and tax implications; requires customer organization	Owner cannot take advantage of tax benefits and utility does not have control
Customer recruitment and billing	Utility	Utility	Utility	Special purpose entity	Non-profit

Table 2.2 Comparison of Community-solar Subscription Models

Comparison of shared solar subscription models.

	Buy panels	Lease panels	Invest in system	Buy energy/capacity
Description	Customers pay an upfront fee for all of the future generation from a panel or a portion of a panel and get bill credits or financial credits	Customers make an upfront or ongoing payments in order to secure energy for a finite term	Customers come together and each pay a percentage of project costs to receive a pro rata share of generation	Customers sign up for a fixed capacity (kW) or generation (kWh) per month, and receive a credit on their bills
Pros	Provides upfront funding for project; long-term benefits for customers; price hedge for customers; possible to pass tax incentives to customers	Provides upfront funding for project; long-term benefits for customers; price hedge for customers; easier to manage end of project	External funding; truly community owned	Affordable and flexible for customers
Cons	Resale issues; securities and tax law scrutiny; long-term commitment by host	Resale issues; lower ROI for customers than purchase	High threshold for participation; long-term commitment by host the site; financial risk to customers	May have lower return for customers; uncertain revenue stream for project owner

Source: Augustine (2016)

On the other hand, special purpose entity-utility model, special purpose entity-customers model third-party owned model are focusing on the taking advantage of tax incentives.

Special purpose entity models are owned by the businesses which try to produce community-solar power. For taking advantage of tax incentives, some organizers of a project choose whether they will structure their project as a business or they will rely on the existing business entities to lead the project. In this model, utilities can also found a separate business enterprise to develop a community-solar project or utilize existing for-profit subsidiary. Third-party-owned models work similarly, but solar systems are owned and operated by solar developers.

Third-party-owned model is a project which is owned by a third-party developer and is open to voluntary ratepayer participation. The system operation and maintenance are done by a third-party. This model is financed through third-party capital, the utility capital and/or ratepayer subscription. In the U.S. context, this model can take advantage of tax incentives. However this model tends to lose connectivity with customers and have financial/ credit risk associated with third-party.

Special purpose entity-utility model is a project which is owned by the utility. In this model, utility founds a business enterprise to develop a community-solar project. This enables to take advantage of tax incentive and the advantages same as Utility-owned model, however, legal process is complex.

Special purpose entity-customers model is a project which is owned by special purpose entity. As mentioned above, individual investors create a business enterprise to develop a community-solar project and the investors can take advantage of tax incentives. However, they have to deal with the complexity of forming and running a business and legal and tax process, therefore investors generally rely on the existing business entities to lead the project. In addition, this model also has financial/ credit risk associated with third-party.

Non-profit model is a project model which is owned by non-profit organization such as schools, churches, municipalities and charitable organizations. Though the donors do not share the benefits of solar installation directly, the motives of donors in this model is lowering energy costs for their favored non-profit organization and demonstrating their environmental leadership. Under this model, a charitable non-profit organization manage a community-solar project and supporters donate for the system then may get tax deduction though projects owner cannot take advantage of tax benefit. Augustine (2016) described each model and relative advantages and disadvantages in Table 1.1 and community-solar subscription model in Table 1.2.

2.2 Previous Research on Community-solar in Thailand and Japan

To the best of my knowledge, the previous research on the community-solar in Thailand and Japan is limited. Tongsopit (2016) analyzed community-solar projects in Thailand and revealed the drivers for the emergence of community-solar and barriers to the success. The driver was a strong local network of neighbors and policy design which distributes solar access and income to a wider population. The barriers were financing even under the FiT program to the candidates. Therefore the announcement of the financing program is essential.

However, these investigated projects were not the projects under Agro-solar phase 1, therefore the project structure and context must be different. Actually, there is a limited number of previous research on community-solar in Japan and Thailand. Therefore, the author found some information on case studies of community-solar or policy contents on the website then reviewed their features and structure.

2.2.1 Shizuoka City, Shizuoka Mirai Energy Company (SYNODOS, 2013)

In this model, a company collects money from investors and installs community-solar at the rooftop of public facilities. Then the company sell electricity to the utility in the FiT price and pay off the principal and rate of return to the investors from the benefits.

Under the support program (the Consigned Operation for Examining the Plans for Community-led Renewable Energy Projects in 2011) by the ministry of the environment, specified nonprofit corporation was developed and Shizuoka Mirai

Energy Company (SMEC) was established. Their purpose is to create and think about local energy with local people through the introducing and spreading renewable energy and environmental education activities. In terms of funding, a local financial institution lent 40 million yen based on the project evaluation without guarantees. They collected 20million yen from citizens and a single unit of capital injection was 50 thousand yen.

At the project planning stage, they looked for the place to install solar panels, however they could not find a place for installing mega solar. Then, they thought deeply on the purpose of this project. They decided to involve citizens as many as possible because they wanted to bring an opportunity for involving in a renewable energy project to citizens. They hoped that citizens would continue to engage in renewable energy projects with this as a starting point, even if the capacity of the solar PV would be small. Then, they chose to utilize the roof of the public facilities. A coordinator from municipal government worked very hard to communicate with relevant departments for utilizing the roof. Finally they could make a contract with Shizuoka City that they could use the roof of public facilities in low price (free, in principle).

In this community-solar business models, SMEC gets to profit from FiT and the dividends are provided to the participants. Though SMEC does not have tax incentive but have a high attitude of contribution to the renewable energy spread, the ownership model of SMEC case may be Third-party owned model.

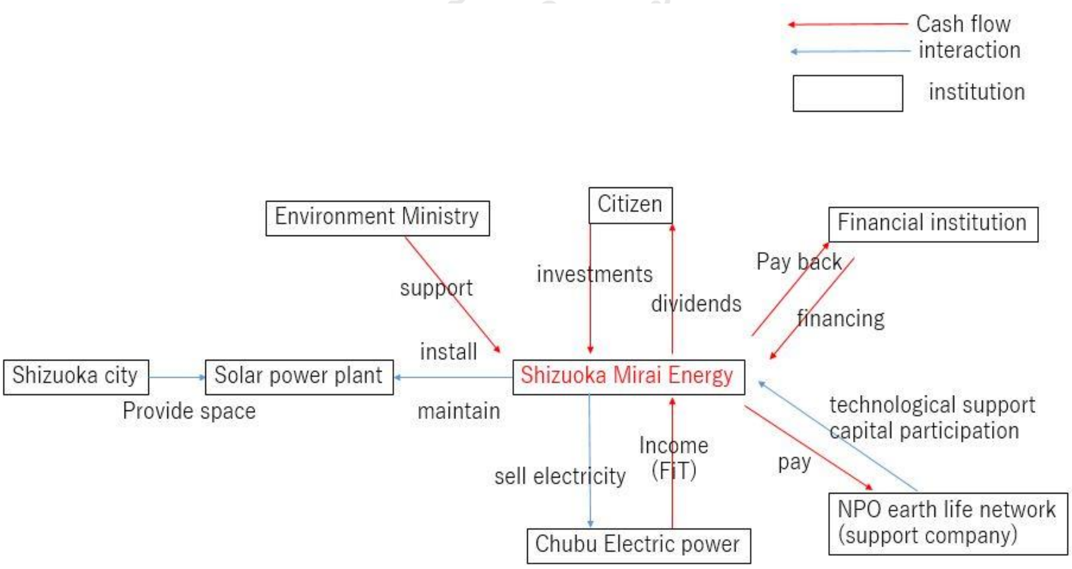

Figure 2.1 Community-solar structure of the Shizuoka Mirai Energy

2.2.2 Tokushima Regional Energy, General Incorporated Association (JREP, 2016)

This association also started from the Consigned Operation for Examining the Plans for Community-led Renewable Energy Projects by the ministry of the environment. This consigned operation finished in 3 years, therefore Tokushima Regional Energy General incorporated Association (TRE) was organized under the instruction of the ministry of the environment to support the renewable energy entrepreneur managers even after it finished.

In this case, TRE mainly does not work as an implementing body. In Tokushima Prefecture, there are several enterprising bodies and TRE plays a role of technical and know-how adviser. An implementing body collects the donation mainly from people in the prefecture and uses the money to install and operate solar power plants. It sells generated electricity to the utility in FiT price and uses the profit to support the local agriculture, forestry and fisheries industry. To the donators, it sends local agricultural and fishery products and this also connects to support local industries.

In this community-solar model, the TRE does not get profit at all and provide all profit to the citizens and local industry, therefore this model seems to suit "Non-profit model."

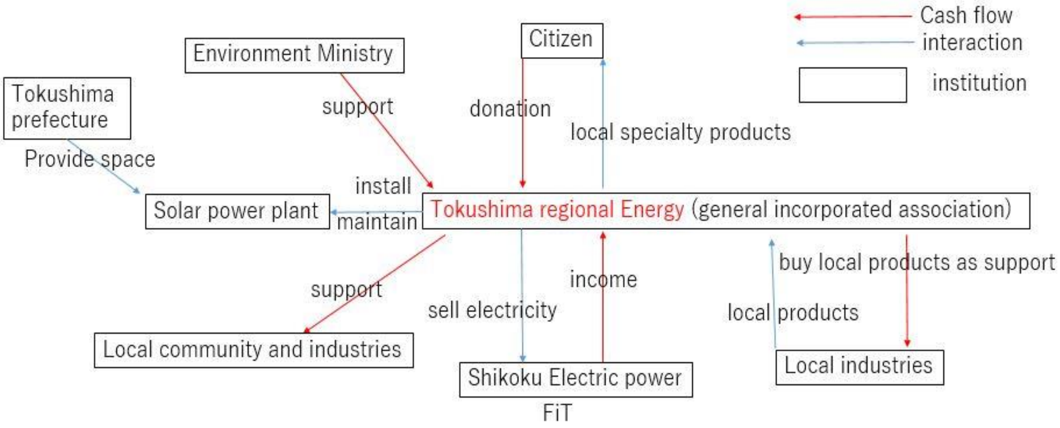

Figure 2.2 Community-solar Structure of Tokushima Regional Energy

2.3 Previous Analytical Studies on Community Energy/Community-solar

Community-solar is relatively a new business model and most of the publications on community-solar are concentrated in the U.S. Research on community-solar is limited both in Thailand and Japan. This research attempts to help fill the scarcity of the research by conducting a comparative analysis of community-solar projects in Japan and Thailand, both of which have rich policy environments on solar PV. To the best of the autthor's knowledge, only one comparative research on community-solar between other countries exists and the contents are the comparative policy analysis between the Netherlands, Germany and Denmark, focusing on the institutional structure and community initiatives for renewable energy (Oteman, 2014). Therefore, the research on the comparative case study of community-solar projects between other countries has not been conducted enough yet. There is enough room to research the key factors to the success of community-solar and feasibility of the community-solar project from comparative analysis.

On the other hand, the comparative research between EU countries on community energy which includes solar, wind, hydropower and biomass have been done extensively. The consciousness on renewable energy of the public is high in EU countries as mentioned in section 1.3 and there are a lot of distributed community energy projects. The differences between community initiatives and organizations have been analyzed from the various framework (Nolden, 2013, Bauwens 2016 and Becker, 2017). Their key findings on the key factors to the success were that the FiT program alone doesn't provide a great opportunity to the stakeholders but the emergence of some social movement or inter-organizational actions can strengthen the ability of local initiative and a network of renewable energy cooperatives.

2.4 The literature on solar PV in Thailand

Regarding with the agro-solar program, the document and publication is really limited as written in section 1.4. Therefore, the previous research on solar PV in Thailand is reviewed in this section.

A research on FiT scheme in Thailand's Alternative Development plan for residential roof top was conducted. In this research, the author suggested three patterns of FiT scheme would provide attractive returns to three level of income groups. (Disorn et al, 2013) There is a case study research on Mae Sariang District for residential solar PV financial feasibility analysis and the result showed the project is financially feasible (Chularat, 2015).

It was researched that cost comparing and benefits of installing solar power system on the roof of the small business building. It compared the cost of installing solar panels on the roof between the transmission of electricity (On grid system) and isolated (Off grid system) by investigating the value in finance and economics at warehouses. It was concluded that the transmission of On grid system have the possibility to invest rather than Off grid system. (Angsana , 2016) There are also researches on the rooftop photovoltaic system for industrial buildings using the financial analysis (Krasae, 2016),

The focus of researches above are on the financial feasibility analysis. These are not relate to Agro-solar projects and it can be said there is a research gap between this research and former studies.

Tongsopit (2016) conducted analysis on community-solar projects in Thailand and revealed the drivers for the emergence of community-solar and barriers to the success. The driver was strong local network of neighbors and policy design which distributes solar access and income to a wider population. The barriers were financing even under the FiT program to the candidates, therefore the announcement of the financing program is important. However, the investigated projects were not the projects under Agro-solar phase 1, therefore the project structure and context must be different.

CHAPTER 3
RESEARCH DESIGN AND METHODOLOGY

3.1 Research Design

The information and previous research of community-solar in Japan and Thailand written in English is really limited, therefore the research started from understanding how CS projects have been working through literature review and semi-structured interview. The financial analysis was then conducted for the evaluation of community-solar projects feasibility. For further development of community-solar, such financial analysis will enable the researchers to understand how community-solar work and what lessons can be learned from CS projects that can be transferred to other countries.

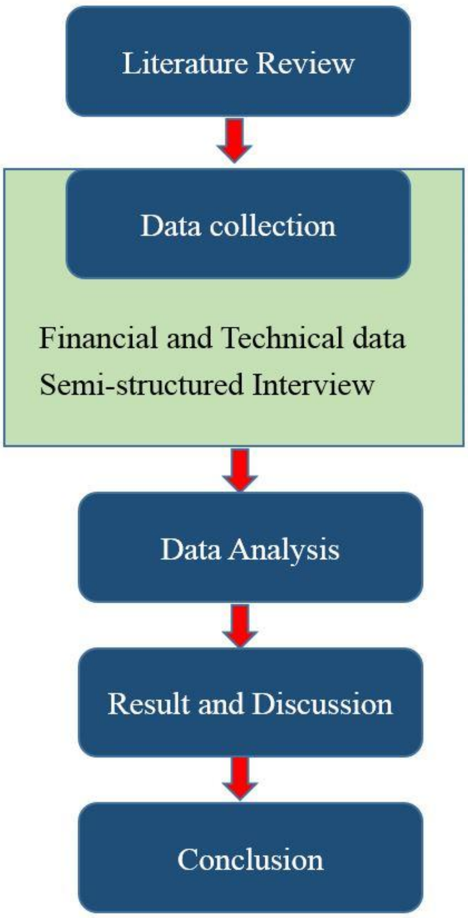

Figure 3.1 Research Design Chart

3.2 Research Methodology

Research methodology for this research contains both quantitative approach (data collection) and qualitative approach (semi-structured interview).

3.2.1 Selection of the Case Studies

Two community-solar projects were chosen from each country. To compare these case studies, a set of criteria is necessary. If the size of solar PV systems and the community-solar designs are totally different, the financial comparison may not have meaning. Criteria of community-solar case study applicants are projects which satisfy the followings:

1) the projects which installed solar PV system between from 1 to 5 MW.
2) the projects which utilize FiT scheme and bring benefits to stakeholders.

As mentioned in section 1.4, the solar PV capacity of the projects under agro-solar projects was from 1 to 5 MW, therefore Japanese case studies were chosen in the same criteria. We selected two projects for Japanese case studies, Kitakyushu Citizens' Solar Power Plant and Awaji Kuniumi Solar Power Plant, denoted J_I and J_{II} respectively in this research. Fig. 3.2 shows the location of the two power plants in southern Japan.

The project location for Thailand was in Chon buri and Prachuap Khiri Khan Province and we denote the two case studies as T_I and T_{II} in this research. Fig. 3.3 shows the location of the two power plants in Thailand. For T_{II}, the financial information could not be obtained. Therefore T_I is only used for financial comparison in Chapter 4.

Fig 3.2 The Location of Case Studies in Japan

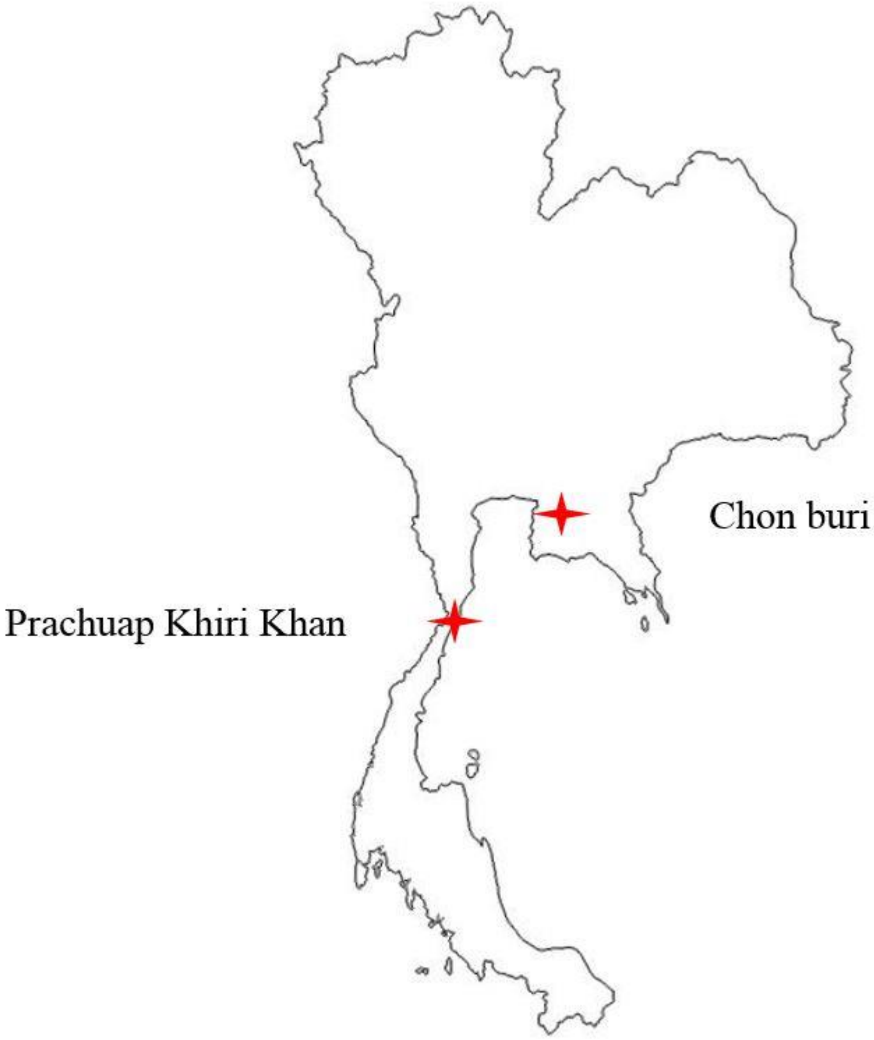

Fig 3.3 The Location of Case Studies in Thailand

3.2.2 Semi-Structured Interviews and Financial and Technical Data Collection

Interviews

Semi-structured interviews were employed to collect qualitative data. The qualitative data was used for the analysis of the financial model of community-solar and making policy recommendations. The interviewee was stakeholders of the community-solar program, mainly project developers.

3.2.3 System Advisor Model (SAM)

SAM, developed by the National Renewable Energy Laboratory (NREL), is “a computer model that calculates the performance and financial metrics of renewable energy systems (NREL, 2014)." SAM can be used for modeling different kinds of renewable energy projects such as solar, wind, biomass, geothermal, and so on. SAM allows us to design a PV system through the life and review the predictions of indicators both technical and financial. The data required for SAM calculation in solar PV projects are weather data, technical data, for example, the performance values of the module and inverter and, weather data including sunlight irradiation. Therefore, it is possible to estimate the impacts on economics by changing various parameters. There are many previous works, in which SAM is utilized to impact predictions of regulation and policy implementation and feasibility estimation of renewable energy technology introduction as a country-level case study. SAM is suitable for this research because it can sufficiently reflect conditions of the country to the estimation as mentioned above. Weather data for SAM calculation is retrieved from a website managed by NREL (Energy Plus, n.d.).

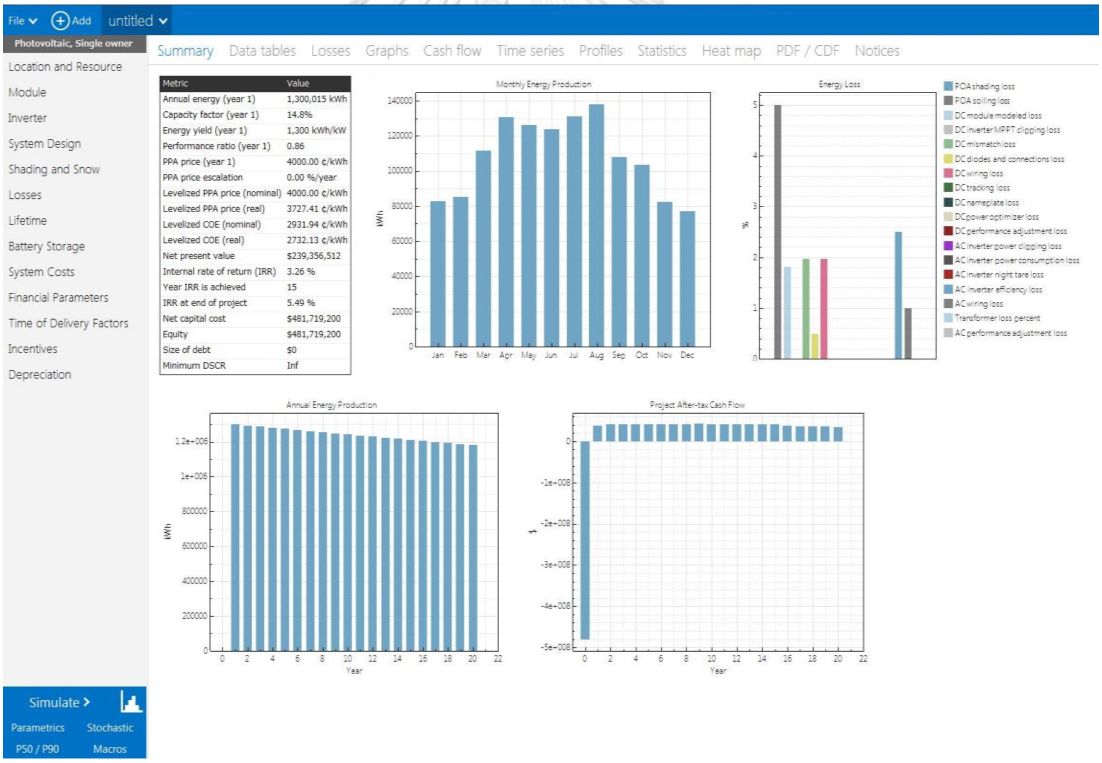

Figure 3.4 The Screen of SAM Calculation Results

3.2.4. Using the System Advisor Model to Analyze the Feasibility of the Projects

The focus of this section is on the comparison of the economic feasibility of community-solar projects in Thailand and Japan. Using SAM, the feasibility was quantified using financial indicators, including payback period, net present value, and levelized cost of energy and so on...

The levelized cost of energy (LCOE) is the value of cost of installing, financing and operating the system per unit of energy over the project life. Therefore, LCOE represents the total project costs and enables different technologies to be compared even if the scales of the operation and operating lifetime are different. LCOE is recommended and used for ranking alternatives because LCOE can draw an appropriate ordering of the alternatives.

The equation below shows the formula of LCOE calculation in SAM;

$$\text{Levelized Cost of Energy (LCOE)} = \frac{\sum_{t=1}^{n} \frac{Ct}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where:

Et = electricity generation in year *t*;

n = lifetime of the CS project;

r = real discount rate

Ct =the annual project costs in year *t* include costs as follows;

Equipment and labor costs, construction period financing costs, project development and financing fees, and sales tax. Operating expenses, including for operation and maintenance, insurance payments, and property taxes. Corporate tax liability.

The formula below shows the relation between real discount rate and nominal discount rate:

$r_{nominal} = [(1+\text{inflation rate})*(1+r_{real})]-1$

SAM calculates both a real and nominal levelized cost values. The real levelized cost is a constant dollar, inflation-adjusted value. The nominal LCOE is a current dollar value. The choice of real or nominal LCOE depends on the analysis. Real (constant) dollars may be appropriate for long-term analyses to account for many years of inflation over the project life, while nominal (current) dollars may be more appropriate for short-term analyses. In this research, the real discount rate and inflation values of both Thailand and Japan are referred and use them as assumption values for SAM calculation (Trading economics, n.d.) (Central Intelligence Agency, n.d.).

Chapter 4
RESULTS AND DISCUSSIONS

All of the results are summarized and discussed in this chapter. Starting from the introduction of policy condition, the business model of two case study in Thailand and Japan, followed by the collected data for SAM calculation and calculation results. Finally, the policy recommendation was discussed based on the calculation, interviews and analysis. The answers of the semi-structured interview to community-solar project developers are in the APPENDIX.

4.1 Policy comparison of Thailand and Japan

The information on FiT policy for case study projects is summarized in table 4.1. At first, the Japanese FiT price in 2012 is high and almost twice of that of Thailand, though the FiT price in Japan has been decreasing as shown in section 4.12. This difference severely affects the financial analysis and business model of both countries.

Regarding the FiT period, Thailand is five years longer than Japan. This can ensure the benefit to the agricultural cooperative and support company for a long time. Also, this affects the financial values of the projects.

Regarding the total project capacity and target of the policy, it was limited for Thailand strictly. For applying FiT, candidates must be a team of an agricultural cooperative and support company as written in section 1.4. Regarding Japan, the total amount is not limited, and it is opened to any corporations or individuals. Before FiT released, the individuals installed solar PV mainly, however, after FiT released, the rather big legal entities started to install solar PV because it is expected to get a huge benefit.

In terms of the examination method of Thailand, after document checking process, the candidates were selected and the amount of capacity was allocated by a lucky draw system. Therefore, it was not guaranteed for the project developers that they would start project at the beginning. On the other hand, in Japan, the developers submit the document to the government and are accepted if the project fits the guideline. Therefore, they are almost guaranteed to be able to start the projects at the beginning stage. It may be one reason why Japanese community solar projects have a variety of business model. In 2017, the FiT act in Japan was revised and the checking process became strictly for dealing with problems as written in section 1.5.

Table 4.1 Comparison of the FiT for Community Solar in Japan and Thailand

	Thailand	Japan
FiT price (USD)	0.1641 (for Agro-solar phase 1)	0.3508 (in 2012)
FiT period	25 years	20 years
Total project capacity	Limited (400MW)	Unlimited
Target	A team of cooperative and support company	Corporations or individuals
Examination method	Document check and lucky draw by government	Document check by government

4.2 The Business Model of Community Solar Projects under the Agro-solar Phase 1

Through the semi-structured interviews with those who are involved in the projects under the Agro solar phase 1, the outlook of the projects becomes clear. The business model structure of T_{II} and projects developed by other two companies were almost the same. Therefore, the business model is the most common under Agro-solar phase 1 as shown in Fig 4.1. The agricultural cooperative works as just a project owner and power purchase agreement (PPA) license holder. PPA license holder can sell the generated electricity to the utilities in the fixed FiT rate for 25 years. The agricultural cooperative does not play a crucial role through the project and does not need to invest money for the project or maintain solar PV system. They can have project supporters which are companies registered in Thailand. The support company works as a project developer, investor, and PPA holder while managing the whole process of the project. On the PPA contract, the name of cooperative and support company is written, in other words, it is not until the cooperative and support company become a team that the team can apply for PPA license. Through the first screening and lucky draw system by the Energy Regulatory Commission (ERC), 67 teams could become PPA license holders out of 167 applicants. The projects under Agro-solar are allocated 1 to 5 MW of PPA as the result of the lucky draw. There is a rule that a company can not get PPA license more than 50 MW, that is, some companies achieved several projects under Agro-solar.

Table 4.2 Basic Information of Developers of Agro-solar

Company Name	Blue Solar	APP Solar (Consulting company) (T_I Project)	Thai Solar Energy (T_{II} Project)	Name in Confidential
Number of Projects	2	.1	1	5
Project location	Pathum Thani, Samut Sakhon.	Chon Buri	Bang Saphan	confidential

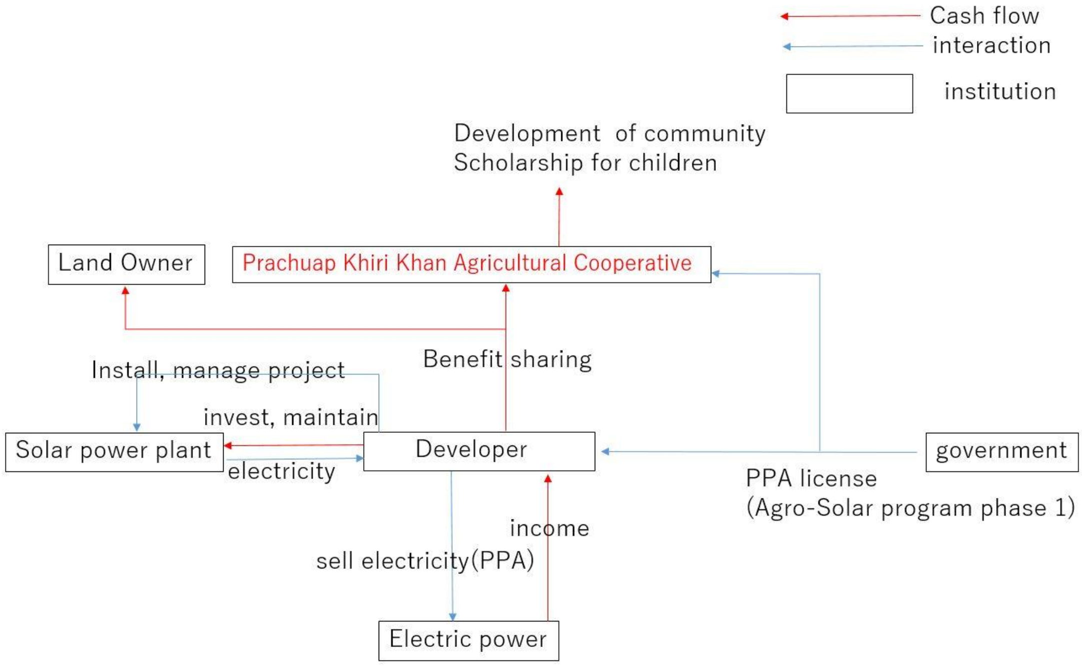

Figure 4.1 The Basic Business Model of Projects under Agro-solar (T_{II})

The developer sells the electricity to the utility in the fixed rate through PPA; then they gain benefit and shares benefit to the agricultural cooperative and the landowner who is a member of the cooperative. The sharing ratio or amount to the cooperative was decided at the beginning stage based on the discussion. The agricultural cooperative can use the money for development of the community, for example, purchasing the instrument for agriculture, preparing the scholarship for children in the community and cannot gain money as a private profit or sharing profit to the community members.

The projects under Agro-solar phase 1 have good impacts on those who are involved. The program is very helpful for the country economy in terms of investment and energy security. It is beneficial to the families of the agro-coop members that are normally low-middle income people. They can have a feeling through the projects that they have a positive contribution to the environment because they produce energy without releasing emission to the climate.

4.3 Problems happened in Agro-solar phase 1

The general process of Agro-solar phase 1 starts with the developers visiting many cooperatives in rural areas to make a PPA contract as seen in Fig. 4.2. At first, they educated cooperatives about the Agro-solar projects because rural people usually do not have enough knowledge of solar PV and related policy and regulations. The cooperative then makes a discussion whether join or not. After that, they decide whose land will be used, who will be the manager of the project. Through the selection by ERC, the related process and EPC was started, and finished it before the commercial operation date (COD).

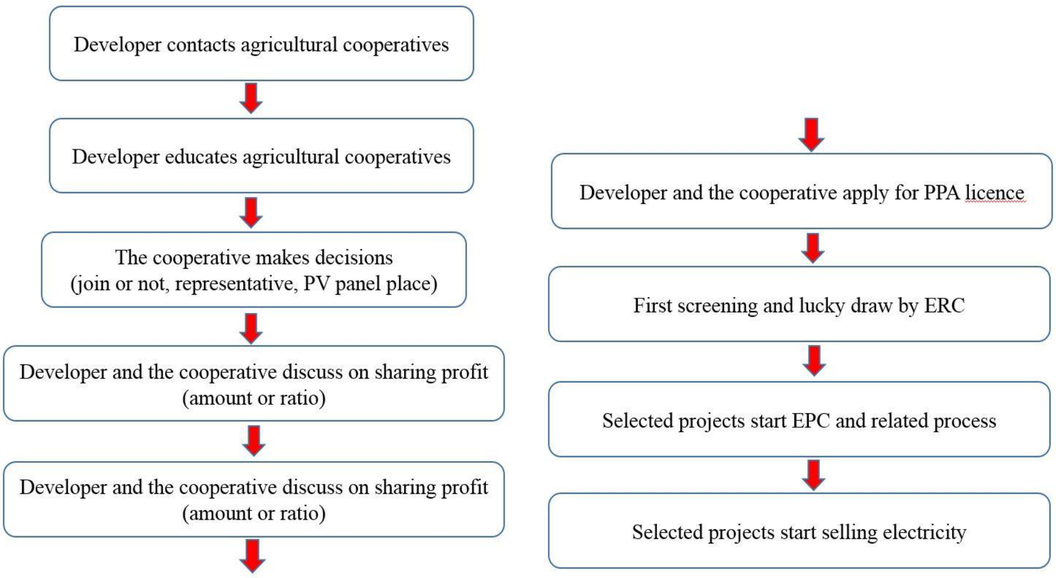

Figure 4.2 The General Process of Agro-solar Phase 1

Developers have tried to get PPA license as much as possible with agricultural cooperatives. However, some of them just focused on the profit from reselling PPA license to other developers and some of them were reluctant to manage the projects because the projects are allocated one to five MW of PPA license by random selection.

Although there is a regulation that the investor name in PPA contract should not be changed at least three years, they did not respect the regulations on PPA contract and tried to find a way of slipping through the net of the regulations. They tried to sell the PPA license to other investors in as high as possible price and this process took several months. Finally, most of the projects developed by them could not finish the process and EPC before coming COD. In some cases, developers tried to change the sharing benefit lower and landowners tried to change the land fee higher than they offered after the selection process.

The T_I project was the victim of selling PPA license. The cooperative asked a solar PV EPC and consulting company to be a consultant for the Agro-solar project in the early stage. The company helps the cooperative in many ways, with managing project. They chose a candidate investor though many developers and investors contacted the cooperative for making a PPA contract. The investor offered good deals, for example, high profit sharing fixed amount, tour for abroad, donation for a local school, if they won the lucky draw. After the lucky draw, the cooperative and the developer could achieve only one MW (maximum is five MW). The developer then sold the license to other company. The business model of T_I is shown in Fig 4.3.

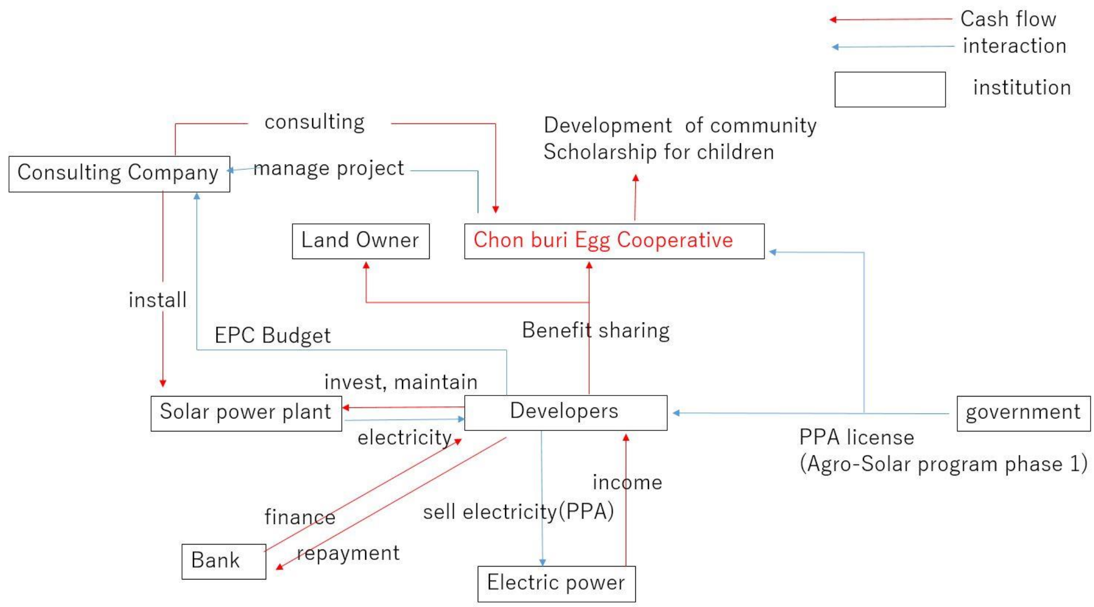

Figure 4.3 The Business Model of T_I Project

4.4 The business model of Awaji Kuniumi Power Plant (J_I)

Awaji Island in Hyogo prefecture locates in the inland sea of Japan. The installation of renewable energy is an expressly active area in Japan. The energy self-sufficiency of Awaji Island was 29.7 % in 2016 and 100% energy self-sufficiency is the target until 2050. This value is more than three times of Japanese national energy self-sufficiency in 2016, 8.3 %.

The objective of the J_I project was the creation of renewable energy with local citizen's participation, and the business model is shown in Fig. 4.4. The active body is Awaji Island Kuniumi Association (AIKA) which is a general incorporated foundation established to do business on the development of Awaji Island. The Hyogo Prefecture issued "Awaji environmental future Island bonds" worth 400 million yen with interest 0.3 % per year and the repayment terms of 5 years. It lent money to AIKA and AIKA have been managing the fund for the construction of solar power plant and managing the project. Because AIKA does not focus on making a profit but contribute to the local area, they purchased Japanese high-quality modules and inverters, developed an undeveloped land, and ask maintenance for local firms. They are still paying back money to Hyogo prefecture. After paying back finished, they plan to utilize the profit for regional contribution, however concrete plan has not been decided yet.

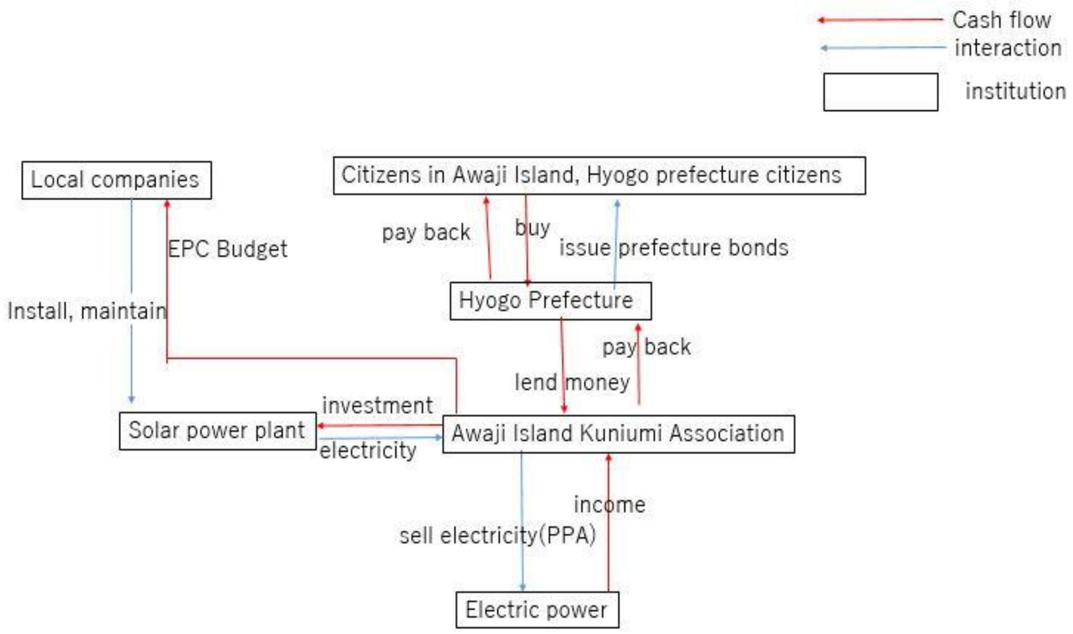

Figure 4.4 The Business Model of J_I Project

4.5 The Business Model of Kitakyushu Citizens' Solar Power Plant (J_{II})

The active body of the J_{II} project is Kitakyushu city with the objective of being "the World Environmental Friendly Capital City." Kitakyushu city had been famous as a polluted city during the 1960s because of the industry development after World War II. In 1971, Kitakyushu city enacted "a pollution control ordinance." The citizens, industries, and government then started to cooperate to deal with the pollutions. The environment recovered dramatically and Kitakyushu city was designated as an "environmental model city" by the Japanese government.

Kitakyushu city citizens send requests to make a solar power plant for creating a symbol of Kitakyushu city as an environmental future city, and Kitakyushu city started a project in 2013. In this project, Kitakyushu city asked donation from citizens and at the same time issued "citizen public subscription bonds" for collecting money for construction of a power plant.

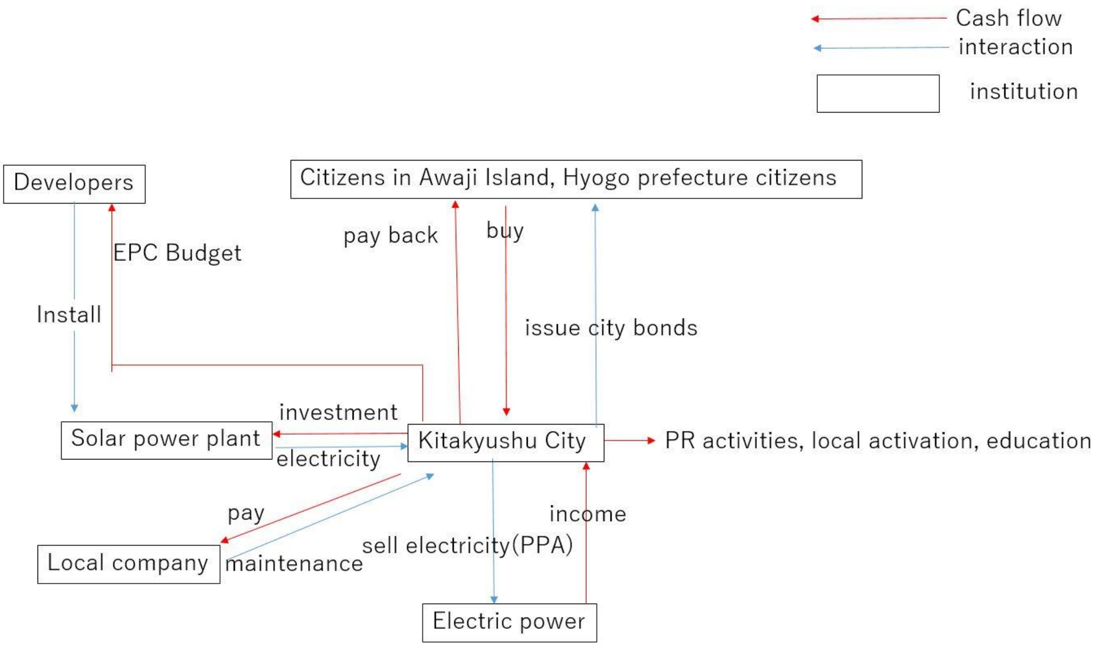

Figure 4.5 The business model of J_{II} project

4.6 Business model comparison

Japanese case study projects are initiated by municipalities. Not all but some of the Japanese municipalities has high consciousness on renewable energy and environmental issues. Kitakyushu city has a history of overcoming the pollutions and Awaji Island has a target to achieve 100% energy self-sufficiency by renewable energy as written in section 4.4 and 4.5. However, it seems that municipalities in Thailand have low passion for the renewable energy project. As written in section 1.4, the governmental agencies are allocated 400 MW in Agro-solar projects, however it is reported only 52.5 MW have started. On the contrary, Agro-solar projects by the agricultural cooperatives with the solar developers are highly competitive as written in section 4.2 and 4.3. The private sector plays an critical role in moving community-solar projects forward so that they can get the benefit for 25 years by selling electricity.

Regarding the contribution to the local area, the agricultural cooperative members in Thailand are normally low or middle-income group people and they are welcome to the profit sharing for the development of cooperative. The cooperative people are not allowed to receive or use the money individually, therefore they decide how to use the money, for example, to prepare the scholarship for children, purchase the agricultural chemicals and instruments. On the other hand, Japanese projects do not focus on helping people but on raising awareness of local people on renewable energy and environmental problems.

For the solar PV modules, projects in Thailand purchased Chinese modules because Chinese modules are cheaper than Japanese modules. The projects in Thailand are managed by the companies as shown in section 4.2, therefore they put a priority on goods performance per cost. It is a natural way of thinking to minimize the cost of the project for companies and this may result in the big difference to the total project budget as shown in section 4.8. For Japanese projects, since the budget is fixed after collecting money from citizens, they havea no incentive to cut the cost. Therefore, they purchased Japanese high quality and expensive modules and inverters within their budget.

Table 4.3 The Business Model Comparison between Thailand and Japan

	J_I	J_{II}	T_I	T_{II}
Key decision factor	100% renewable energy target	50 years anniversary of city government	Agro-solar phase 1	Agro-solar phase 1
Project owner	AIKA	Kitakyushu city	Cooperative and developer	Cooperative and developer
Capacity	1 MW	1.5 MW	1 MW	1 MW
Source of budget	Citizen bonds (citizens in Awaji)	Citizen bonds (citizens in Awaji)	Developer and financial institution	Developer
Regional contribution method	To be decided (Investor can get small interests)	Holding events and prepare subsidies	Cooperative has a choice (develop community, prepare scholarship for children)	Cooperative has a choice (develop community, prepare scholarship for children)
PV module maker	Japanese	Japanese	Chinese	Chinese
Inverter maker	Japanese	Japanese	Japanese	Chinese

4.7 The social analysis of Thailand case study

In this section, the characteristics of CS projects in Thailand and Japan are analyzed based on the interviews.

4.7.1 The social aspects of Agro-solar projects in Thailand

The developers and cooperatives are satisfied with the Agro-solar project itself because they can get stable income. However, there are problems such as written in section 4.3. The main dissatisfied points and requests of developers are as follows;

- The selling of PPA license and changing benefit sharing ratio should not happen. The honesty to each other is really important.
- No more lucky-draw-system. The evaluation system of the developer should be prepared.

From these opinions, the author proposes that Agro-solar projects should prepare a developer evaluation system which checks the project performing and the project planning ability of the developer. Based on the evaluation result, the amount of PPA should be allocated to the projects and the companies which submit the insufficient documents and plans should be unaccepted. Furthermore, the government should make a strict rule that developers must not sell the license to others.

The selling license of FiT also happened in Japan. Therefore the Japanese government revised the developer checking system as written in section 4.1. The added points of checking in revised FiT is organized maintenance system, the report on the cost of building a power plant, operating power plant and the prospect of generating electricity, and the abolition plan of solar PV instruments after finished projects. These points can be transferred to Thailand CS projects checking system.

4.7.2 The Social Aspects of Japanese Community-solar Projects

They utilized local citizen bonds to collect project investment and they could succeed to collect money. It proves that Japanese people have the high environmental consciousness. It is maybe because both of the projects started after the Fukushima Nuclear Power Plant Accident. Especially for J_{II}, there were movements from citizens to make a public solar power plant in Kitakyushu city. It may come from the consciousness on anti-nuclear power of citizens which is especially high in Kitakyushu city and the history that citizens, government and the industries in Kitakyushu city overcame the pollution as shown in 4.5.

Both municipalities also utilize their plants as the place of environmental education, and people including students can go easily to see the place. They often hold the events involving local people, and this can strengthen the citizen's consciousness to renewable energy.

From the Japanese case study, it revealed that Japanese municipalities try to strengthen environmental consciousness and citizens have it highly. Therefore, it can be said the effort by the municipalities can bring a good result regarding renewable energy.

4.8 The financial analysis for SAM

The collected or estimated data for calculation by SAM are shown in from Table 4.1 to Table 4.4, and the values in grayscale color are assumption values. All prices are exchanged into US dollars (USD), and fractions are omitted. Project lifetime is the period of a FiT scheme set by the government. The collected data on T_{II} was not sufficient. The financial data collection in Thailand was really difficult because all developers want to keep their financial information to be confidential.

4.8.1 Basic data for SAM calculation

As mention in section 3.3, the inflation rate and real discount rate is used estimation value. In Thailand, there is no property tax system. J_{II} project is owned by Kyushu city. Therefore the project is exempted from property tax and corporation tax. According to Table 4.1, despite being T_I, T_{II} and J_I almost same size, Thailand's CS projects are invested only about one-third of Japanese CS projects. This seems to be mainly derived from the difference in the construction cost, the price of the module and the inverter. Because J_I and J_{II} projects are owned by non-commercial purposes entities, local contribution takes precedence over seeking profits.

Table 4.4 Basic Data for SAM Calculation

Parameters	T_I	J_I	J_{II}
Capacity (MW)	1	1	1.5
Life time (year)	25	20	20
Inflation rate (%)	1.5	0.7	0.7
Real discount rate (%)	1.5	0.3	0.3
Property tax rate (%/ year)	0	1.4	0
Corporation tax rate (%/year)	20	15.9	0
Total installed cost (USD)	1304000	4193000	4165000

4.8.2 Direct Cost for SAM Calculation

$J_1$and J_{II} purchased domestically produced high-quality modules and inverters for the contribution to Japan. J_I developed the undeveloped land for installation of the solar farm, executed undergrounding construction of wires and planted olive trees with consideration of outlook, and constructed barriers for animals, therefore, the labor cost becomes very high. The reason why the initial land cost of T_I being expensive is because they paid contract money to the cooperative and the owner of the land. The value of “others” got from the calculation as follows:

(Others) = (total direct cost) - (module + inverter + other equipment + installation labor)

Table 4.5 Direct Costs for SAM Calculation

Parameters	T_I	J_I	J_{II}
Module (USD)	417000	903000	1482000
Inverter (USD)	115000	263000	394000
Other equipment (USD)	130000	29000	877000
Installation labor (USD)	289000	2975000	1068000
Others (USD)	90000	2000	292000
Total direct cost (USD)	1041000	4172000	4113000

4.8.3 Indirect Costs for SAM Analysis

The initial land cost of T_I is what they paid as contract money to the cooperative and the owner of the land. T_{II} grid connection fee may be count in the installation labor in Table 4.5. In terms of indirect cost, J_1 and J_{II} is lower than T_I, different from other collected results.

Table 4.6 Indirect Cost for SAM Calculation

Parameters	T_I	J_I	J_{II}
Total indirect cost (USD)	260000	53000	53000
Land cost (initial) (USD)	144000	0	0
land preperlation & transmission (USD)	72000	53000	0
grid connection (USD)	43000	0	53000

4.8.4 Annual Operating Cost for SAM Analysis

For J_I case, Hyogo prefecture lends land for PV module installation to them for free. O&M cost for J_I and J_{II} is almost three times of T_I value. This may reflect the labor cost difference between Japan and Thailand. The land cost for T_I consists of the profit sharing to the agricultural cooperatives (15700 USD) and the landowner (9300 USD). As a characteristic of T_I, the whole project costs (except total indirect cost) are smaller than J_I and J_{II}. This may be mainly why the goods price in Japan is relatively higher than that of Thailand and T_I project is working to make profits as much as possible.

Table 4.7 Operating Annual Costs for SAM Calculation

Parameters	T_I	J_I	J_{II}
Operating annual cost (USD) / year	39000	43000	77000
Land cost (annual) (USD) / year	25000	0	23000
O&M (USD)/year	14000	43000	53000

4.9 SAM Calculation Results

The SAM calculation results are shown in Table 4.8. For all CS projects, the values of LCOE are lower than the FiT price. Therefore, it seems all projects are profitable. When we focus on the NPV, J_{II} has especially high value. This may be mainly because of the difference of the project capacity size, tax exemption as seen in table 4.4. When we focus on IRR values, we can see J_I has a small value and T_1 has good value. It seems that these values reflect the way of using money well. As we can see in section 4.8, T_I saved costs in many ways, on the other hand, J_I used 71 % of the total cost in the labor cost. When we focus on the LCOE nominal, the value of T_I and J_{II} is almost half of the FiT price.

Table 4.8 Output of the Performance and Financial Indicators

Output	T_I	J_I	J_{II}
Annual energy (year 1) (kWh)	1475000	1300000	1866000
Capacity factor (%)	16.9	14.8	12.8
Internal rate of return (IRR) (%)	16.1	3.26	9.77
LCOE (nominal) (USD/kWh)	0.0881	0.2571	0.1841
LCOE (real) (USD/kWh)	0.0739	0.2396	0.1717
FiT price (USD/kWh)	0.1641	0.3508	0.3508
Net present value (NPV)	1927000	2099000	5127000

4.10 The Sensitivities Analysis of the LCOE nominal

The nominal LCOE sensitivity to the financial parameters was investigated for T_I, J_I and J_{II} by checking the change ratio of LCOE nominal when the parameters in Table 4.4 to 4.8 is increased by 5% as seen in table 4.9. When the sensitivity of X is plus, X is the factor which makes LCOE increase and when the sensitivity of X is minus, X is the factor which makes LCOE decrease.

First, the purchase period in FiT, which is a project lifetime, for J_I and J_{II} is the first influential factor on the LCOE nominal. Therefore, the expansion of FiT period is recommended for Japanese policy, though this may be difficult realistically.

Second, the labor cost for J_I is a characteristic influential factor. Their purpose for the project is the regional contribution as written in section 4.8.2, however the labor cost is too high especially. They might overestimate the project budget at the planning stage and spend the whole remaining budget to the labor cost. If so, estimation of the budget should be done carefully or they should ask a specialist to estimate because they issued bonds for collecting project money from citizens. Anyway, they should try to decrease the labor cost for sustainable development for community-solar projects. The high investment cost becomes a barrier for newcomers who have an idea to establish a community-solar project. However, the sensitivity of J_{II} is also higher than that of T_{II}. Therefore, it is required some effort to decrease the labor cost for Japanese projects.

Table 4.9 The Sensitivity of the Nominal LCOE Parameters (%)

T_I parameter order	T_I sensitivity	J_I parameter order	J_I sensitivity	J_{II} parameter order	J_{II} sensitivity
FiT price	1.858	Life time	-2.608	Life time	-2.637
Operating annual cost	1.421	Labor cost	2.525	Operating annual cost	1.313
corporation tax	1.057	FiT price	1.092	Module	1.298
life time	-0.716	Module	0.785	Labor cost	0.945
Inflation rate	0.561	Operating annual cost	0.625	Other equipment	0.776
Module	0.548	Corporation tax	0.494	Inverter	0.349
Labor cost	0.381	Inflation	0.307	Inflation	0.333
Total indirect cost	0.341	Inverter	0.254	Real discount rate	0.106
Real discount rate	0.318	Real discount	0.136	Total indirect cost	0.046
Other equipment	0.171	Total indirect cost	0.077	FiT price	0
Inverter	0.154	Other equipment	0.057	Corporation tax	0

Third, the reason why FiT price becomes an influential factor to LCOE is that the revenue from the selling electricity becomes taxable of corporation tax in SAM calculation (see section 3.3) when FiT price increase 5%, LCOE increase 1.85 %. When we utilize the following calculation, we could confirm that when FiT price increases, benefit / kWh increases as seen in table 4.10.

Benefit / kWh = (FiT price) - (LCOE)

Therefore, they do not need to decrease the FiT price despite the result of the sensitivity analysis because the overall benefit is still increasing. The value of T_I financial factors is relatively small. Corporate tax and lifetime are decided by the government. Therefore, the political decision has a significant impact on the LCOE nominal.

Finally, the influence of the module price is relatively small for all cases, therefore, it seems that the approach by the government is more critical than the decreasing price of the module through market competition for further expansion of CS.

Table 4.10 The Effect of Increase in FiT to the Benefit per kWh

Change % of FiT price	FiT Price (Baht/kWh)	Increase in LCOE (baht / kWh)	Benefit/ kWh (Baht)
1	0.1657	0.0003	0.1654
2	0.1674	0.0007	0.1667
3	0.1690	0.0010	0.1680
5	0.1723	0.0016	0.1707
10	0.1805	0.0033	0.1772

4.11 Feasibility of Future community solar projects in Japan and Thailand

The FiT price was 0.351 USD/kWh in 2012 when FiT scheme started in Japan. However, the FiT price in 2018 decreased to 0.158 USD/kWh. As shown in Figure 4.6, the FiT price in Japan has been decreasing since it started.

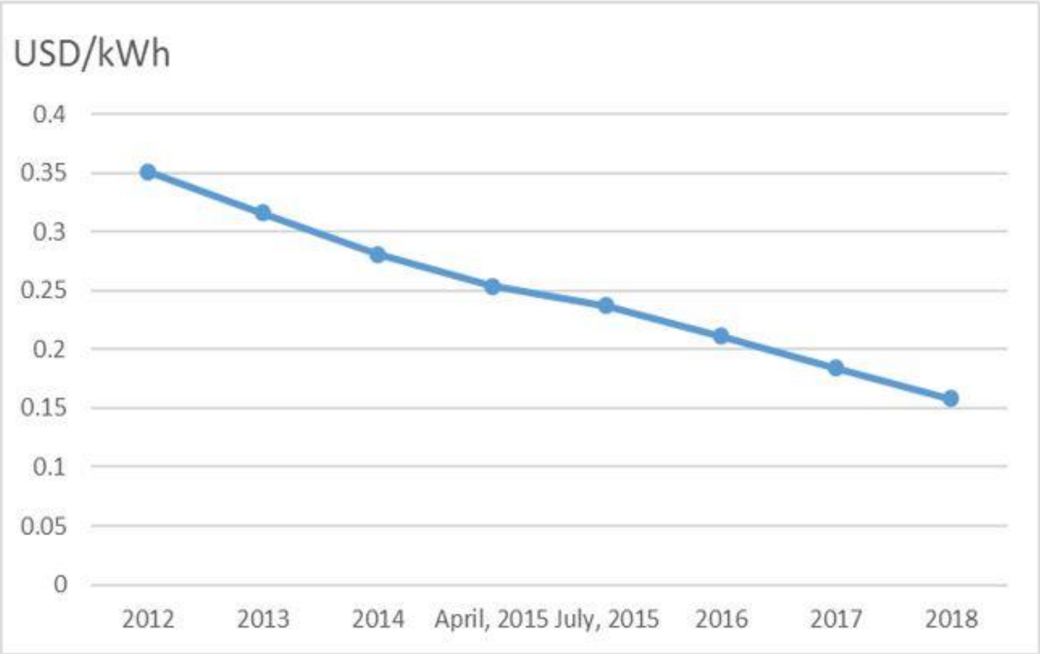

Figure 4.6 Japanese FiT Price Transition

As shown in table 4.8, the nominal and real LCOE for J_I and J_{II} are higher than current FiT price. In other words, J_I and J_{II} were not profitable projects if they sold electricity with the FiT price in 2018. However, when we focus on the LCOE sensitivity factors as shown in table 4.9, it is necessary to increase project lifetime and decrease labor cost and module price. However, they focused on regional contribution and invested to the local industry by purchasing modules and inverters locally. The business model of J_I and J_{II} projects seems no longer applicable to the current FiT condition. Therefore, the efforts on project cost reduction are required for developers of the new community-solar projects to manage the projects feasible and sustainable, for example, buying imported modules at a low price as projects in Thailand did.

Regarding T_I case, the FiT price in Agro-solar phase 1 is 0.1641 USD/kWh and in phase 2 is 0.1194 USD/kWh. Therefore, the LCOE of T_I is lower than the current FiT price and it can be said the CS projects in Thailand under Agro-solar program are still feasible as shown in table 4.8.

It is said the FiT will be no longer necessary shortly because the FiT selling price will be lower than buying price from the utilities. Therefore, it is better to consume the generated electricity than to sell to the grid. The business models of community-solar must be totally changed at that time but that is the contents for future researchers.

4.12 Policy Recommendations

From the policy analysis on community-solar projects as shown in section 4.1, the initiative of governmental agencies and the education to cooperative members by the developers seems lacked, compared with a Japanese case study. The target of the policy in Agro-solar program is only the team of agricultural cooperative and support company, or governmental agencies and support company. However, the governmental agencies in Thailand lack positive attitude on the Agro-solar project, whereas private sector and agricultural cooperative in Thailand are willing to join the project. However, developers from the private sector mainly focus on making a profit and not focus on education to the cooperative members as shown in section 4.3. On the contrary, Japanese municipalities and citizens have high consciousness of renewable energy as shown in section 4.7.2. It suggests that the efforts on environmental education by the municipalities have an impact on citizens' environmental consciousness.

Therefore, it is proposed that the Thai government should hold a workshop on renewable energy with the local municipalities to enhance the environmental consciousness of the governmental agencies and to establish information exchanging network on agro-solar projects. To the solar developers who join in Agro-solar program, it should be an obligation that they hold educational events on renewable energy periodically near the project location to the local people.

From the business model comparison in section 4.6 and feasibility analysis for the current FiT situation in 4.11, it is clear that Japanese municipalities have not enough consciousness on project cost reduction. Their business model is no longer feasible at the current condition, therefore the efforts to project cost reduction is required for developers of the new community-solar projects to manage the projects feasible and sustainable. The author proposes that Japanese municipalities should ask the specialists or consultants in the private sector to correct the project budget at the beginning stage of the project. The bonds should be issued later the correction.

From the financial analysis by SAM in section 4.10, policy recommendations to Japan and Thailand are proposed. For the Japanese government, the extension of a project lifetime (FiT purchased period) and making a policy that encourages to decrease the labor cost for solar PV installation is recommended. In terms of Thailand, all CS projects in Thailand is under the control of the Thailand government and current policy works well from the financial viewpoint. The setting of FiT price and lifetime has the most significant impact on LCOE nominal. Therefore, these values need to be determined carefully by the government.

CHAPTER 5
CONCLUSION

In this research, the author illustrated the business model and the social context of case study projects in Thailand and Japan. In Thailand, the community-solar projects are under “Government and Agricultural Cooperatives Programme (Agro-solar)” by Thailand government. The agricultural cooperative members obtain benefit from the Agro-solar and they use the money for the development of cooperative and scholarship for children. For a Japanese case study, they issued bonds for local people and citizens then purchased and gained interests. Their main object is the regional contribution; therefore, the profit will be used for regional development or regional support.

For the financial analysis of this research, the calculation in System Advisor Model (SAM) was used. The data required for SAM calculation are financial data, technical data, and weather data. Financial data and technical data were collected through the interview. Technical data refers to performance values of the module and inverter. The levelized cost of energy (LCOE) is the value of the cost of installing, financing and operating the system per unit of energy over the project life. LCOE calculated by SAM is the main focused financial indicator in this comparative research. From the data collected in the interviews, Investments in Thailand's CS projects is only about one-third of the investments in Japanese CS projects. This is mainly because of the difference in the labor cost, the price of the module, and the inverter. Because two projects in Japan are owned by non-commercial purposes entities, local contribution takes precedence over seeking profits.

From the policy analysis on community-solar projects, it is proposed that Thai government should hold a workshop on renewable energy with the local municipalities to enhance the environmental consciousness of the governmental agencies and to establish information exchanging network on agro-solar projects. To the solar developers who join in Agro-solar program, it should be an obligation that they hold educational events on renewable energy periodically near the project location to the local people.

From the business model comparison, it is proposed that Japanese municipalities should ask the specialists or consultants in the private sector to correct the project budget at the beginning stage of the project.

From the financial analysis by SAM, for the Japanese government, the extension of FiT purchased period and making a policy that encourages to decrease the labor cost for solar PV installation is recommended. Regarding Thailand, all CS projects in Thailand is under the control of the Thailand government and current policy works well from the financial viewpoints. The setting of FiT price and lifetime has the most significant impact on LCOE nominal. Therefore, these values need to be determined carefully by the government.

LIMITATION OF THE STUDY

In this research, only two projects were selected for a case study for each country. In Thailand, it is reported that there are 67 projects under Agro-solar phase 1 as shown in section 1.4. By the cooperation of Thai Solar PV Association (TPVA), contact information of 8 projects were obtained. In the beginning, the author asked them to reply questionnaire, however only four of them replied regardless following up by a phone call and email many times. The author then conducted the interview about their financial and technical information. However, two of them refused to tell the information because the information on the Agro-solar project is so crucial that they strongly wanted the data to be confidential. Fortunately, one agreed to give full and 1 gave partial financial and technical information to the author. Therefore, the two cases were used for financial analysis in this research. However, it should be noted that these four projects showed a cooperative attitude for sharing knowledge and experience except financial and technical information.

After the data collection in Thailand, it is known that the capacity of the 2 case studies in Thailand is 1 MW. It was crucial that the capacity of a case study in Japan was around the same capacity for the comparative analysis. Through interviews with the specialists in Japanese community solar projects, the author learned that there are many community solar projects in Japan. However, most of their capacity is smaller than 50 kW. Fortunately, three projects have capacities bigger than 1MW and these were the candidates for data collection and interview. One of them was very cooperative to interview and the project owner was interested in this research. However, they signed a confidentiality contract with financial institutions on the information disclose and they could not give financial information. The other two projects were willing to support data collection and gave complete information. These two were used for the Japan case study.

Due to the limitations, only two projects for each country were selected for a case study. Therefore, they can not be the representatives for all projects. They are just example projects in each country.

REFERENCES

Asmus, P. (2008). Exploring new models of solar energy development. *The electricity journal, 21(3)*, 61-70.

Augustine, P., & McGavisk, E. . (2016). The next big thing in renewable energy: Shared solar. *The electricity journal, 29(4)*, 36-42.

Aznar, A. Y., Zinaman, O. R., & McCall, J. D. (2018). Informing Mexico's Distributed Generation Policy with System Advisor Model (SAM) Analysis (No. NREL/TP-7A40-71038). . (National Renewable Energy Laboratory (NREL), Golden, CO..).

Bauwens, T., Gotchev, B., & Holstenkamp, L. . (2016). What drives the development of community energy in Europe? The case of wind power cooperatives. *Energy Research & Social Science, 13*, 136-147.

Bechberger, M., & Reiche, D. . (2004). Renewable energy policy in Germany: pioneering and exemplary regulations. . *Natural gas, 3(21.7),36.*

Becker, S., Kunze, C., & Vancea, M. . (2017). Community energy and social entrepreneurship: Addressing purpose, organisation and embeddedness of renewable energy projects. . *Journal of Cleaner Production, 147*, 25-36.

Blair, N., Dobos, A. P., Freeman, J., Neises, T., Wagner, M., Ferguson, T., ... & Janzou, S. . (2014). System advisor model, sam 2014.1. 14: General description (No. NREL/TP-6A20-61019). In.

Chaianong, A., & Pharino, C. (2015). Outlook and challenges for promoting solar photovoltaic rooftops in Thailand. *Renewable and Sustainable Energy Reviews, 48*, 356-372.

Chularat, C. (2015). *Solar PV Rooftop Financial Feasibility Study : A Case of Households in Mae Sariang District, Mae Hongson Province.* (ph.D), Kasetsart university, Thailand.

CIA. (n.d.). THE WORLD FACTBOOK. . Retrieved from https://www.cia.gov/library/publications/the-world-factbook/fields/2207.html

Coughlin, J., Grove, J., Irvine, L., Jacobs, J. F., Phillips, S. J., Sawyer, A., & Wiedman, J. . (2012). A Guide to Community Shared Solar: Utility, Private, and Nonprofit Project Development. .

DEDE. (2015). *The Renewable and Alternative Energy Development Plan (AEDP 2015- 2036).* Thailand

Disorn, C., Sopitsuda, T., Naebboon, H. . (2013). APPROPRIATE FINANCIAL MEASURES FOR THE SUPPORT OF RESIDENTIAL ROOFTOP SOLAR SYSTEMS IN THAILAND. . (Energy Technology and Management Program, Graduate School, Chulalongkorn University).

Economics., T. (n.d.). Trading Economics. Retrieved from https://tradingeconomics.com/

EnergyPlus. (n.d.). Weather Data. . Retrieved from https://energyplus.net/weather

EPIA. (2008). Supporting Solar Photovoltaic Electricity. An Argument for Feed-in Tariffs. (European Photovoltaic Industry Association).

ERC. (2017). *ERC's info page on government and solar agricultural co-op projects*. Thailand Retrieved from http://www.erc.or.th/ERCWeb2/Front/News/NewsDetail.aspx?rid=23719&CatId=1&&muid=36

GIZ. (2014). *Military regime pushes solar with new policies in Thailand. Project Development Programme (PDP) South-East Asia.* Retrieved from Thailand: http://www.erneuerbare-energien.de/EEE/Redaktion/DE/DENA/Downloads/2014_09_03_thailand.pdf?__blob=publicationFile&v=1

GIZ. (2017). *Thailand Solar PV Policy Update 01/2017*. Retrieved from Thailand:

GIZ. (2018). *Thailand Solar PV Policy paper 1/2018*. Retrieved from Thailand:

JREP. (2016). Community happy solar from Tokushima. Retrieved from http://www.jrep.or.jp/547

Karnøe, P., & Garud, R. . (2012). Path creation: Co-creation of heterogeneous resources in the emergence of the Danish wind turbine cluster. *European Planning Studies, 20(5)*, 733-752.

Krasae, A. K., P (2016). *Cost-Benefit Analysis of the Rooftop Photovoltaic System Project for Industrial Buildings*. Ramkhamhaeng university, Thailand.

Krohn, S. (2002). Danish wind turbines: an industrial success story. (the Danish Wind Industry Association).

METI. (2015). *Long-term Energy Supply and Demand Outlook.* Japan Retrieved from http://www.meti.go.jp/press/2015/07/20150716004/20150716004_2.pdf

METI. (2017). *JAPANESE INDUSTRY AND POLICY NEWS May 2017*. Japan Retrieved from http://cdnsite.eu-japan.eu/sites/default/files/publications/docs/japanese_industry_and_policy_news_may_2017.pdf

Mey, F., & Diesendorf, M. (2018). Who owns an energy transition? Strategic action fields and community wind energy in Denmark. *Energy research & social science, 35*, 108-117.

Navarro, J. P. J., López, J. M. C., & Connolly, D. . (2017). The effect of feed-in-tariff supporting schemes on the viability of a district heating and cooling production system.

Nolden, C. (2013). Governing community energy—Feed-in tariffs and the development of community wind energy schemes in the United Kingdom and Germany. *Energy Policy,* *63*, 543-552.

Norskov, J., Vittrup, C (2016). New record-breaking year for Danish wind power. . (2016). New record-breaking year for Danish wind power. .

Nowak, S. (2015). Trends 2016 in Photovoltaic Applications: Survey Report of Selected IEA Countries between 1992 and 2015.

Oteman, M., Wiering, M., & Helderman, J. K. (2014). The institutional space of community initiatives for renewable energy: a comparative case study of the Netherlands, Germany and Denmark. . *Energy, sustainability and society, 4(1)*, 11.

PlanèteÉnergies. (2014). The History of energy in Germany. Retrieved from https://www.planete-energies.com/en

REN21. (2017). *Renewables 2017 Global Status Report (Paris: REN21 Secretariat).* Retrieved from Paris: http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf

Short, W., Packey, D. J., & Holt, T. (1995). . . (1995). A manual for the economic evaluation of energy efficiency and renewable energy technologies (No. NREL/TP--462-5173). (National Renewable Energy Lab., Golden, CO).

Shota, H. (2013). Creation of local renewable energy. Retrieved from https://synodos.jp/fukkou/4683

Takeshi, W., Yosuke, T., Kenrou, T., & Shingo, I. (2014). *市民・地域共同発電所のつくり方:皆が主役の自然エネルギー普及* Kyoto: Kamogawa Publisher.

Taylor, M., Ralon, P., & Ilas, A. . (2016). *The power to change: solar and wind cost reduction potential to 2025.* Retrieved from

Toke, D. (2011). Ecological modernisation, social movements and renewable energy. . *Environmental Politics, 20(1)*, 60-77.

Tongsopit, S., Moungchareon, S., Aksornkij, A., & Potisat, T. . (2016). Business models and financing options for a rapid scale-up of rooftop solar power systems in Thailand. . *Energy Policy, 95*, 447-457.

WWEA. (2011). WWEA defines Community Power. Retrieved from http://www.wwindea.org/communitypowerdefinition/

APPENDIX

APPENDIX: Table of answers of the semi-structured interview questions to Agro-solar project managers

Company Name	Blue Solar	APP Solar (Consulting company) (T_I Project)	Thai Solar Energy (T_{II} Project)	Name in Confidential
Q.1 Experience from project	The program is very useful for the country economy in terms of investment and energy security. It is beneficial to the families of the agro-coop members that are normally low-middle income people. These projects also have a positive contribution to the environment as they produce energy without releasing emission to the climate.	This is a good program to develop the solar farm and bring benefit to agriculture. However, there were some problems. Investors reduced the benefit to the cooperative. Landowner changed the cost of land rental for the project.	No comment	No comment
Q1.1 Positive experiences in agro-solar program.	As a project is owned by the agri-coop with support from the private sector, many conditions have been reduced (for example; exempt of bank guarantee for both bid bond and	Investor, cooperative and landowner will get the benefit for 25 years. People around the solar farm are happy with the farm because it creates a job for cleaning and	Government and private sector cooperate and it brought benefit to the local people.	The guaranteed benefit from selling electricity for 25 years to both coops and their company.

	PPA bond) in order to make the project easier to be developed. After the selection process by ERC finished, the project sponsors would not be competitors for each other anymore. Many companies that were sponsors for Agro-solar program shared knowledge and solution for problems to others and became friends.	brings benefit to cooperatives.		
Q1.2 Problems, barriers on the projects	Blue Solar faced serious problem during the land purchasing due to one of the 3 co-owners had difficult conditions. The PPA under Agro-solar program has a legal issue so that some financial institutions are not comfortable. The selection process and PPA issuance were delayed. This resulted in a delay of	At the negotiation process, representative of investors offered many benefits to the cooperative. However, after the lucky draw process, some investors tried to sell the license of PPA to another investor for getting money. Originally, in the regulator's rules, it cannot be possible to change the	There were problems on delaying in electricity extension process and finding land for PV module construction. The selection process is not good enough. Lucky draw system cannot reflect the efforts or conditions of companies. Therefore, some evaluation system for PPA applicants is required.	It took much time and money for a selection of the project place, furthermore for the education of the cooperative. The cooperatives had almost no knowledge on solar PV and related policy on the Agro-solar project.

	project financial closure.	investor and cooperative in the contract. Then, some investors change to benefit that they used to offer.		
Q3 Company role in the project	The developer of the 2 projects	Consultant of the Chonburi Egg Cooperative and EPC of the project	Project developer and project manager (including O&M)	Project developer and project manager for 5 projects (including O&M)
Q4 Financial institution for the project	Bangkok Bank supports 2 projects.	In the beginning, the investor uses cash for investment. After COD, Investor asks a loan from the bank.	No	No
Q5 Total project cost	Confidential	45MB	53 MB	Confidential
Q6 Support company	Co-investor in Samut Sakhon	No support from any supplier and bank at the beginning due to it is only 1 MW.	1 company, technological support	No
Q7 Cooperate company or institutions	Blue Solar have a technical advisor and legal advisor for the projects. Technical advisor helps them to ensure technical feasibility of the projects and legal advisor help them review EPC contracts between	Investor company	No	No

	Blue solar company and contractors.			
Q8 Profit sharing	Blue Solar shares revenue portion of 5-15% to the agri-coop monthly. The rates depended on negotiation between investors and the agri-coop and based on the acceptable financial return of the project.	Their solar farm generates income more than 8 MB/ year. The benefit shared with Egg cooperative and landowner. Total is 850,000 baht/year.	Bang Saphan cooperative obtain benefit from Thai solar energy in some ratio of profit based on the negotiation.	Profit sharing depends on the result of negotiation among cooperatives. Some cooperatives get a fixed amount of money and some cooperatives get profit based on the certain ratio of money.
Q9 Advantage of business model	Revenue sharing in the long term would keep cooperation between Blue Solar and the agri-coop together. The agri-coop could potentially help, support and solve problems in the future time that we may have conflicts with the local community.	Transparency of the project is good for all partners. Coop does not need any commission or under counter money. The investor just needs to pay investment cost, no commission fee for coop and consultant.	Investment has a low risk to this project and investors can obtain the expected return.	Long-term revenue is ensured by the selling electricity.
Q10 Cooperative benefit	The agri-coop that cooperate with Blue solar receive both -First-time reward after the project passed the ERC selection process.	In Q.8	In Q.8.	In Q.8

	-Monthly revenue sharing.			
Q11 Disadvantage of business model	In some project, Blue Solar provided too high revenue sharing ratio and bought an expensive big piece of land. That results in the financial return of the project. Moreover, their projects were supported by corporate finance that needed many collaterals and has higher interest rate than project finance.	Many investors focused on benefit more than solar farm quality. In some case, investor tried to sell the PPA license to gain money, without starting construction and permit process. That is why many solar farms could not be in time for COD.	The allocated amount for their project was only 1MW. Because some investors were just focusing on selling PPA license and got more licenses than them, they felt this situation was very unfair and lucky draw system should be changed.	From the viewpoints of the project developer, there is no need that cooperatives participate in the solar farm projects. The education to cooperatives takes time and effort. In addition, many developers visit the same cooperative, and then, some company starts to pay under counter money to cooperative to win the selection by cooperatives.

Q12 Criteria for choosing community	Blue solar tried to find the agri-coop that has a working area covering their targeted plant location.	They are a consultant of the egg cooperative; therefore, they did not choose.	The cooperative must have available land for the construction site. The land area should not go far from the high-voltage transmission line.	The cooperatives which locate near from the high-voltage transmission line.
Q13 Maintenance of solar PV	Monthly and yearly maintenance plan	Investor manages O&M and check the efficiency every day. Cleaning up every day	Monthly and yearly maintenance plan	Monthly and yearly maintenance plan
Q14 Insurance to cooperative	No	No	Insurance to protect any damage that may cause the loss of income.	No

APPENDIX: Table of answers of the semi-structured interview to Japanese Community-solar project managers

Question	Awaji Island Kuniumi Association (AIKA)(J_{I} case)	Kitakyushu City Citizens' Power Plant (J_{II} case)
Q.1 Experience through the project	1. It took time and effort on project planning based on the frequent discussion with EPC companies and checking project land. 2. It did not take time for collection project budget by selling bonds to individual investors in Awaji Island. The Bonds was 400 million yen but they were sold out within a month by 471 investors. This revealed that Awaji citizens had high consciousness of environmental problems and regional contribution. They are proud of this as people in charge.	The project budget of this project comes from donation and bonds purchase by citizens in Kitakyushu city. This is a municipal mega solar and this business model is unique in Japan. This project is of citizens, for citizens, and by citizens.
Q.2 Good experience	1. The government of Awaji island has a target to achieve 100% energy self-sufficiency from renewable energy. This project is just one of the business in the target, however, many people were interested in and participated in this. 2. No critical problems have occurred to the power plant.	This project was started as a 50 years anniversary of Kitakyushu city governance. In the planning stage, the project was designed to contribute to the lives of citizens sustainably. This project will remind citizens of the 50 year anniversary for decades.
Q.3 Problems	Once, blackout happened near the project place. Next day, they checked the amount of electricity generation by the power plant,	1. The division of roles in the city government was a problem. It was not easy to separate the role on project development and project

	and then noticed the generation became zero. They asked repairing to the contracted maintenance company. After this, the same problem have not happened.	O&M to the different sections of city governance departments. 2. The way of contribution to citizens by revenue from electricity selling was well discussed. Finally, the revenue is distributed as financial resources of each city government department business.
Q.4 Financial investment	Hyogo prefecture issued prefecture bonds of 400 million yen, and then 471 individual investors in Awaji Island purchased. AIKA borrow the money from Hyogo prefecture for the project budget.	500 million yen is from bonds purchased by citizens and 17 million yen is from a donation from citizens.
Q.5 Role of industries	Not industries but citizens participate in the project.	Kitakyushu city faced and overcame environmental pollutions in the past, then become an advanced environmental city. Through the experience, in Kitakyushu city, some citizens is environmentally active and local industries, which has high technologies. There were requests from various civic organizations and representatives of industries that Kitakyushu city should make a solar power plant as a symbol of "an environmental future city" by taking advantage of Kitakyushu city.
Q.6 Involvement of institution	Hyogo prefecture provides project place for free, issuing bonds for the project budget.	Answer in Q.5
Q.7 Local industry profit	Local industry gain profit by O&M of the solar PV power plant.	Local industry gain profit by O&M of the solar PV power plant.
Q.8	At the current stage, the revenue	Review the link below(Japanese):

Revenue usage	from selling electricity is used for paying back to Hyogo prefecture. After finishing paying back, they will start contributing to the local area. However, they have no idea of the concrete plan yet.	http://www.kitaqport.or.jp/jap/outline/about_solar_kangen.html They invest the revenue in various kinds of projects and events, aiming at "maximizing ability of Kitakyushu city, taking advantage of citizens and local ability", "deepening the love to and being proud of hometown, Kitakyushu city", "appealing the good points of Kitakyushu City to inside and outside of the country", "making children to have dreams and hopes."
Q.9 Advantage of business model	Through this project, participants can contribute to reducing CO_2 emission. This is good chance for citizens in Awaji Island to enhance the consciousness on renewable energy.	Since the project started, the current account becomes positive every year. They expect to keep the projects working smoothly.
Q.10 O&M	Regarding O&M, the company in Osaka Prefecture is in charge. Kansai Electricity Safety Inspection Association checks the power plant system periodically. Local associations play roles in the cutting grass and maintenance of project place scenery.	Regarding O&M, they think it is important to keep generating electricity highly for the long-term. Therefore the operation company's skill and experience accumulation are essential. Therefore, they conclude a contract with a local company for 20 years.
Q.11 the frequency of meeting with people involved in the project	Once a year, they report the generation performance of the power plant for investors. They do not hold a meeting with the investors. However, they hold many events dealing with renewable energy expansion to	Twice in a year, they hold a meeting for deciding what the regional contribution projects are invested. The meeting committee consists of the representatives of citizens, such as the association of city commerce and industry, the association of ladies, the association of education.

	citizens in Awaji Island.	
Q.12 Message to the citizens	There must be meaning on raising awareness on renewable energy of citizens in Awaji Island for the prevention of global warming. Awaji Island will continue to work on "sustainability on energy, life, food and agriculture" under "the Plan of Environmental future Awaji Island" for realizing environmental-friendly future Island.	1. The successful construction of citizens' solar power plant reveals that Kitakyushu city has outstanding technologies and the citizens' environmental ability. 2. This project has been a good opportunity for many citizens to recognize that Kitakyushu city is "a future environmental city." Furthermore, solar PV power which is the most symbolic of renewable energy play a role in environmental education place to citizens and also contribute to enhancing citizens' environmental ability. 3. By this project, Kyushu city contributes to enhancing the quality of lives of citizens, for example, planting trees as conservation of nature, executing environmental education tours, and supporting citizen-motivated events and local events through subsidies. Through these events, Kyushu city tries to contribute to enhancing citizens' lives and raising civic pride.
Q.13 Plan	If citizens have a demand, they will respond to it.	They will think out the way of PR of this project to citizens for making it better known.

APPENDIX: Semi-structured Interview Questionnaire (English and Thai)

Questionnaire for solar developers under Government and Agricultural Cooperatives Programme: “Agro-solar”

แบบสอบถามสำหรับผู้พัฒนาโครงการผลิตไฟฟ้าจากพลังงานแสงอาทิตย์

ภายใต้โครงการผลิตไฟฟ้าจากพลังงานแสงอาทิตย์แบบติดตั้งบนพื้นดิน สำหรับหน่วยงานราชการและสหกรณ์ภาคการเกษตร พ.ศ. 2560 (โครงการโซล่าสำหรับหน่วยงานราชการและสหกรณ์ภาคการเกษตร)

Q1. What have been your experiences with the development of solar projects under the Agro-Solar program?

คุณมีความคิดเห็นในภาพรวมอย่างไรบ้างเกี่ยวกับโครงการโซล่าสำหรับหน่วยงานราชการและสหกรณ์ภาคการเกษตร?

Q1.1 What have been your positive experiences with this Agro-solar program? Please list three positive experiences, if any.

ประสบการณ์ทางด้านบวกของการพัฒนาโครงการโซล่าสำหรับหน่วยงานราชการและสหกรณ์การเกษตณมีประเด็นใดบ้าง กรุณากล่าวถึงประสบการณ์ด้านบวกอย่างน้อย 3 ประเด็น (หากมี)

Q1.2 Have you encountered any problems? Please identify at least three top barriers, if any.

คุณประสบปัญหาอุปสรรคในการดำเนินการบ้างหรือไม่? กรุณาอธิบายโดยกล่าวถึงประเด็นปัญหาอุปสรรคที่สำคัญที่สุดอย่างน้อย 3 ประเด็น (หากมีประเด็นปัญหาดังกล่าว)

Q2. How many solar projects do you have under Agro-Solar program? Please provide their location in terms of tambon, amphoe and province?

คุณมีจำนวนโครงการผลิตไฟฟ้าจากพลังงานแสงอาทิตย์กี่โครงการ

ภายใต้โครงการโซล่าสำหรับหน่วยงานราชการและสหกรณ์ภาคการเกษตร? และโครงการเหล่านั้นตั้งอยู่ที่ใด (กรุณาระบุตำบล อำเภอ จังหวัด)?

Q3. What are the type of engagements in solar projects? Are you a developer? Do you manage whole projects or just install and maintain the PV systems?

ขอบเขตในการดำเนินงานของคุณคืออะไร? คุณเป็นผู้พัฒนาโครงการ คุณบริหารจัดการทั้งโครงการ หรือเพียงรับติดตั้งและบำรุงรักษาระบบผลิตไฟฟ้าจากพลังงานแสงอาทิตย์?

Q4. Is there any financial institution for the solar projects? If there is, what is the name? How much money did they finance for the project?

ในปัจจุบันมีสถาบันการเงินที่สนับสนุนโครงการผลิตไฟฟ้าจากพลังงานแสงอาทิตย์หรือไม่? ถ้ามี กรุณาระบุชื่อสถาบันการเงินเหล่านั้น? สถาบันการเงินเหล่านั้นสนับสนุนเงินเป็นจำนวนเท่าใดให้แก่โครงการ?

Q5. What is the total cost of this project?

ต้นทุนของโครงการทั้งหมดมีมูลค่าเท่าใด

Q6. Is there any support company which cooperates in terms of capital participation or technological support?

มีบริษัทที่ให้ความสนับสนุนทั้งในรูปแบบการร่วมลงทุน หรือการสนับสนุนด้านเทคโนโลยีหรือไม่?

Q7. Are there any other institutions or companies which you cooperate for solar projects? If so, how do you work with them?

คุณมีสถาบันหรือบริษัทที่ร่วมพัฒนาโครงการกับคุณหรือไม่? ถ้ามี คุณทำงานร่วมกับพวกเขาอย่างไร?

Q8. How do your solar projects make financial benefit? With whom do you share the profit? How did you decide the profit sharing ratio?

โครงการผลิตไฟฟ้าจากพลังงานแสงอาทิตย์ของคุณสามารถสร้างรายได้อย่างไร? คุณต้องแบ่งปันผลกำไรกับใครบ้าง? คุณมีวิธีพิจารณาอัตราการแบ่งปันผลกำไรอย่างไร?

Q9. What do you think is the advantage of your business model? And why?

คุณคิดว่าอะไรคือข้อดีของรูปแบบธุรกิจของคุณ? และทำไม?

Q10. How does the community that collaborates with you on this project benefit from the project? For example, do they share profit or income? And how?

สหกรณ์การเกษตรที่ร่วมมือกับบริษัทของท่านได้รับประโยชน์จากโครงการในรูปแบบใดบ้าง เช่น การแบ่งสรรกำไร หรือแบ่งรายได้ กรุณาอธิบาย

Q11. What do you think is the disadvantage of your business model? And why?

คุณคิดว่าอะไรคือข้อเสียของรูปแบบธุรกิจของคุณ? และทำไม?

Q12. How did you choose the community to cooperate with you on this project? What are the key criteria for choosing the community (s)?

คุณมีวิธีคัดเลือกและตัดสินใจเลือกหน่วยงานราชการและสหกรณ์ภาคการเกษตรแต่ละแห่ง เพื่อที่จะร่วมพัฒนาโครงการอย่างไร?

Q13. Do you maintain the solar PV systems? If so, how often?

คุณมีการบำรุงรักษาระบบผลิตไฟฟ้าจากพลังงานแสงอาทิตย์หรือไม่? ถ้าใช่ ความถี่ในการบำรุงรักษาคือ?

Q14. Do you provide any insurance to the cooperatives? If so, what kind of insurance is it?

คุณมีการทำประกันให้กับสหกรณ์หรือไม่? ถ้าใช่ คุณทำประกันอะไร?

APPENDIX: Semi-structured Interview Questionnaire (Japanese)

市民太陽光発電所用インタビュー

Q1. 市民太陽光発電プロジェクトを通じてどのような経験をしてきましたか？

Q2.　市民太陽光プロジェクトで特に良かったと思う経験を教えてください。

Q3. プロジェクトにおいてどのような問題が発生しましたか？またそれらにどのように対処しましたか？

Ｑ４．このプロジェクトはどの機関がどれくらいの割合で出資していますか？

Ｑ５．このプロジェクトには企業がどのような役割で参加していますか？

Q6.　このプロジェクトには何らかの機関が関係していますか？それはどのような形ですか？

Q7. このプロジェクトで利益を得ている企業はありますか？それは地元の企業ですか？

Q8.　売電収益はどのように分配されていますか？　市民に還元されているとすればそれはどのような形ですか？

Q9.　このプロジェクトのビジネスモデルをどのようにお考えですか？それはなぜですか？また利点と欠点は何だと思いますか？

Q10.　太陽光パネルの運用、保守はどのように行われていますか？そこに地元の人は関わっていますか？

Q11.　売電が始まった後、どれくらいの頻度でプロジェクトに関わった方々と交流する機会がありますか？

Q12.　このプロジェクトを経て、世間の方々に共有したい思いはありますか？

Q13. 現行の政策の変わってほしいところやこういう制度があればいいなということがあれば教えてください

VITA

NAME	MASATAKA YAMASHITA
DATE OF BIRTH	01 March 1993
PLACE OF BIRTH	Hyogo, Japan
INSTITUTIONS ATTENDED	Kyoto University Chulalongkorn University
HOME ADDRESS	7-29, Shimizu-Cho, Ako City, Hyogo, Japan
PUBLICATION	none
AWARD RECEIVED	none