

Catalyzing Solar Photovoltaics Diffusion?

An assessment of the Energy Service Companies (ESCO) Business
Model in Taiwan

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“The lord will be called Wonderful Counselor, Mighty God, Everlasting Father, Prince of Peace. He is my strength and my shield, in him my heart trusts, and I am helped.”

(Isaiah 9:6; Psalm 28:7)

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Chan Yi-Chieh

Abstract

The central role of solar photovoltaics (PV) energy to facilitate transition of energy systems leads to the global diffusion of solar PV systems. Despite increasing deployment, the adoption of solar PV systems still faces numerous barriers. The existence of a business model can contribute to the removal of barriers, and further catalyze solar PV development. This study carries out an assessment to explore the function of the PV-Energy Service Company (ESCO) model in overcoming barriers to solar PV diffusion in Taiwan. A combined methodology of literature review and in-depth interviews is used to examine the barriers, and the operationalization of the ESCO model. The study finds that in Taiwan, barriers to solar PV diffusion involve social, financial, and legal-administrative aspects. Following the designs of the PV-ESCO model, ESCO companies address these barriers in different operational methods and approaches. It implies that the removal of barriers and the diffusion of solar PV installations happen under a synthetic effect of distinct operational ways. Moreover, the change model operationalization stimulates the market of residential-mounted PV installations, and could significantly conduce to the growth of this market segment.

Keywords: Photovoltaics, Barriers, Business Models, ESCO Models, Operationalization

Executive Summary

Problem definition

With the highest technical potential for energy generation, solar photovoltaic (PV) power could contribute significantly to the transition of energy systems and climate change mitigation. PV nowadays receives increased attention, and it is speedily diffusing worldwide. Despite the rapid growth of solar PV installations, the diffusion and deployment of solar PV systems still face numerous sociotechnical, management, policy and economic barriers.

These aspects of barriers were also found to impede a speedy growth of installation in Taiwan, where energy supply needs to be changed from using and importing fossil fuels to developing and utilizing domestic renewable energy sources. In order to conquer these barriers, in 2012 Bureau of Energy in Taiwan introduced a relevant policy scheme to enable the Photovoltaic Energy Service Company (PV-ESCO) model, which since then has been adopted in a large majority of installation projects. The wide adoption of this business model shows its potential to overcome the barriers.

However, so far the operational designs of this model have been more favorable for project sizes with an installed capacity above 100 kW. The adoptability for residential-scale installations is very limited, and hence the market of residential-sized installations in Taiwan remains underdeveloped. Recently, a necessity exists to spur this underdeveloped market, since large-scale installation sites are gradually exhausted. In order to ensure continued growth of solar PV in Taiwan, it is necessary to explore how small and medium-sized enterprises (SMEs) - who are more inclined to target residential-mounted installations as their market niche - can adopt the PV-ESCO model and apply it to residential-sized projects. Given the different level of profitability, the operationalization of the model through SMEs for the residential market requires its customization to the needs of residential customers.

Research questions

The aim of this study is to assess the function of a business model in conquering different barriers to solar PV diffusion. Therefore, the objective of this study is to (1) identify the contextual conditions of barrier formation in Taiwan, (2) explore how operationalization inherent to the PV-ESCO model helps overcoming identified barriers, (3) investigate the transformation of model operationalization that renders the PV-ESCO model more adoptable for small and medium-scale enterprises (SMEs) and residential-scale projects. In order to explore these points, three research questions are defined:

- 1. What are the barriers that impede the diffusion of solar PV systems in Taiwan?**
- 2. How did the PV-ESCO model help to overcome the various barriers (faced by customers) to PV deployment?**
- 3. How could small and medium-sized enterprises (SMEs) adopt the PV-ESCO model and apply it to residential-scale projects?**

Methodology

This thesis deploys qualitative methods. First, the literature review ensures the pertinence of using business model theory as the analytical framework in this study. It also helps defining some key terms such as energy service companies (ESCOs), and synthesizes previous research

that are relevant to the application of business models, as well as barriers to the adoption of the ESCO model. Besides, this study defines the research scope with the literature review. Directions to collect the data in literature are divided into (1) business model theory, (2) business models and sustainability, (3) solar PV business model, (4) concept and operational designs of the ESCO model, (5) barriers to the adoption of the ESCO model, and (6) the application of the ESCO model to renewable energy development.

Regarding the theoretical framework, the analysis of the operationalization of the model follows the business model theory developed by Osterwalder et al. (2005). Under the business model theory, the study reviews the elements of value proposition, target customer, distribution channel, customer relationship, value configuration, core competency, partner network, cost structure and revenue model of each interviewed company that operate the PV-ESCO model.

The in-depth interviews are deployed to explore barriers that customers as well as ESCO companies have faced, and also to analyze different operationalization modes of the PV-ESCO model as actually implemented by large companies and SMEs. This research principally interviewed 7 ESCO companies, all of which are well reputed and provide the optimized model operationalization. Besides, in order to further capture a holistic picture of the whole solar PV industry, the author also interviewed some relevant stakeholders such as governmental representatives, PV component suppliers, a third-party verifier, commercial banks, the solar PV company association, as well as a veteran knowledgeable about the solar PV market in Taiwan.

Findings

First, in Taiwan social, financial, and legal-administrative barriers hinder solar PV investments and installations. Social barriers principally come from people's mistrust and misperception of solar PV energy, which are the results of limited knowledge in society, lack of an information platform, and the destruction brought by the typhoon. In terms of financial barriers, they consist of unprofitability, capital insufficiency and loan inaccessibility. These issues make PV installations unaffordable and unprofitable for people. Regarding legal-administrative barriers, they pose several challenges to solar PV diffusion by prolonging the duration of project accomplishment, reducing the profitability, and limiting the usable installation space.

Second, the different elements of the business model such as the value proposition, distribution channel, customer relation, value configuration, competency, partner network and cost-benefit structure help in overcoming social and economic barriers. The specific mechanisms include (1) guaranteeing PV yields, long-term stable revenues and exempting customers from upfront costs, (2) acquainting a large group of people with accurate information, (3) making loans and collateral conditions more acquirable and favorable to customers, (4) familiarizing particular stakeholders with solar PV industry, (5) spurring ESCO companies to ensure the quality of PV installations, (6) collecting data of electricity data, (7) bridging customers and investors, (8) maintaining the most optimal system operation.

In terms of legal-administrative barriers, the PV-ESCO model smoothens the removal of complex authorization activities for customers and the establishment of a mechanism for loan acquisition. ESCO companies' compulsory responsibility to process the administrative applications facilitates the former. Their voluntary practices that involve undertaking third-party verification, and offering after-sale service, as well as installations with good quality contribute to the later.

Finally, acquiring quantities of projects and accentuating the quality of systems along with service provision are the key direction to change the operationalization of the model. The changes contain (1) laying more emphasis on additional functions and the aesthetical appeal of PV installations when delivering values, (2) more focusing on community-based distribution channel, (3) treating all dwellers as friends and initiating more interactive communication, (4) offering supplementary customized services, and (5) developing knowledgeable and efficient maintenance & repair teams.

Conclusions

Inadequate policy and stipulations in various Acts are the key factor behind many barriers. The lack of a sufficient policy on spreading solar PV energy-related knowledge confines the exchange and dissemination of information, and then negatively influences the social acceptance of solar PV installation. The financial barriers exist also as the result of little prevalence of knowledge, which makes people underestimate the profitability and banks mistrust the solar industry. The formation of legal-administrative barriers also originates from inadequate policy schemes and regulations that comprise cumbersome authorization activities, insufficient mechanisms to facilitate the market, the FiT system, the Electricity Law and the National Land Planning Act.

Moreover, elements inherent to the PV-ESCO model such as the value proposition, distribution channel, value configuration, competency, partner network and cost-benefit structure have greatly helped in overcoming social and economic barriers since 2012. The model also addresses the issue of quality concerns that has existed since 2015 through its partner network. However, the PV-ESCO model helps little to facilitate changes in policy and legislation, although ESCO companies can address some of the barriers more efficiently than private and commercial customers.

Besides, the transformation of the model operationalization to the needs of private customers can stimulate the market of residential-mounted installations. The transformation, nevertheless, comprises changes in the business model elements of value proposition, customer relation, distribution channel, value configuration, and competency.

Another conclusion derived from the findings is that under the same business model, different ESCO companies would have different operationalization. These variations are usually decided according to the financial background of ESCO companies and project sizes they choose to implement. Thus, many barriers are not removed with only one specific type of model operationalization but several operational ways from different companies.

Future research could investigate customer-sided perceptions of the PV-ESCO model. This research is suggested to check the validity of findings in this thesis. Such research could involve the use of both quantitative and qualitative methods.

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Abbreviations

ESCO	Energy Service Company
EPC	Engineering, Procurement and Construction
EUR	Euro
FiT	Feed-in Tariff
GW	Gigawatt
kW	Kilowatt
kWh	Kilowatt Hour
IRR	Internal Rate of Return
MW	Megawatt
PV	Photovoltaic
PV-ESCO	Photovoltaic Energy Service Company
REDA	Renewable Energy Development Act
ROI	Return on Investment
SMEs	Small and Medium-sized Enterprises
SPV	Special Purpose Vehicle
Taipower	Taiwan Power Company
TWD	Taiwanese Dollar

1 Introduction

1.1 Solar Energy—Origin & Development

Due to anthropogenic activities since pre-industrial period, the rapid growth of global atmospheric concentrations of greenhouse gas (GHG) greatly elevates global temperature in 21st century (IPCC, 2007). Most anthropogenic GHG emissions are confirmed to come from the energy services provisioned through burning fossil fuels (IPCC, 2012), and this gives rise to a considerable amount of calls for worldwide sustainable energy transition.

The adoption of renewable energy, as part of options to achieve an energy transition, is receiving an increase in attention. Climate finance pledges to the investment of renewable energy technologies were expanded in 21st Conference of Parties (COP21) (IEA, 2015). This shows the attempt to speed constant innovation and the adoption of technologies based on renewable sources. Among all renewable energy technologies, solar power especially possesses the highest technical potential for energy generation, and can greatly contribute to climate change mitigation (IPCC, 2012). Nowadays, solar photovoltaic (PV) power installation around the world is speedily growing, and the installed capacity skyrockets from 15 GW in 2008 to 177 GW in 2014 (IEA 2014).

Taiwan, ranked as the 24th largest emitter of greenhouse gas (GHG) in the world, and over 97% relying on energy import (CO₂ Information Analysis Center, 2008; Bureau of Energy, 2014; Tseng, 2015), stands in need of the energy transition, which depicts a shift of energy structure from using and importing fossil fuels to developing and utilizing domestic renewable energy sources. In 2000, Bureaus of Energy under Ministry of Economic Affairs established a subsidy scheme for solar PV demonstration project, by which the costs of installation were at least half covered by the government (Chen, 2015). However, this policy instrument did not assist in PV diffusion a lot mainly on account of two factors behind (Chen, 2015). First, the upfront costs were still unaffordable for people, despite the subsidy scheme. Furthermore, solar PV installations at that time were for self-consumption; yet, incentives for self-consumption in Taiwan are negligible owing to the significantly low electricity price. Also, grid-connected technology was just developed, which limited a number of installations. Consequently, from 2000 to 2009, the installed capacity from solar PV energy only reached 9.5 MW (Bureau of Energy, 2014; Chen, 2015).

In order to further incentivize the investment and smoothen solar PV deployment, in 2009 Taiwan has adopted Renewable Energy Development Act (REDA). The adoption attempts to take advantage of abundant solar radiation and decrease high reliance on energy import (Kao, 2010; Bureau of Energy, 2014; Tseng, 2015). Feed-in tariff (FiT) system, stipulated in the Act, works prominently for incentivizing renewable energy development. Technical development for few years made grid-connected technology advanced enough to feed electricity generated from a PV installation in the grid. This system is consequently regarded as the main policy instrument, where renewable energy investors are able to sell electricity to the public monopolist in electricity market, Taiwan Power Company (Taipower), in 20 years with a fixed price double as high as general electricity price (REDA, 2009). With the FiT system, a great majority of installations are not for self-consumption, but for selling the electricity. The Act also shows its objective that 6.5 GW to 10 GW of installed capacity from renewable energy will be achieved with the FiT system.

In order to achieve the objective stipulated in REDA, Bureau of Energy annually establishes the goal for solar PV installation, aiming to increase the cumulative installed solar capacity up to 6200 MW by 2030 (Ministry of Economic Affairs, 2013). Till the end of 2015, the installed

capacity has already been above 800 MW (Wu, 2016), and to achieve this objective by 2030, at least 300 MW of solar PV capacity for each year should be targeted in the future.

1.2 Problem Statement

Barriers to the Diffusion of Solar PV Systems

Worldwide increasing attention on renewable energy development and the rapid growth of solar PV installation show the competency of this industry to compete with conventional energy sources; however global diffusion and adoption of solar PV still face numerous sociotechnical, management, policy and economic barriers (Lettner et al., 2012; Pérez et al. 2013; Emrah & Pranpreya, 2015).

Sociotechnical barriers are in relation to public unawareness, distrust and technical issue. Little knowledge prevalent in society disables people from recognizing solar PV energy and the benefits of this system, further influencing public awareness and social acceptance of the installation (D'Agostino et al., 2011). Also, a growth of skepticism toward the quality of solar PV systems in lots of countries undermines people's willingness to adopt or invest in the systems (Müggenburg et al., 2012; D'Agostino et al., 2011; Emrah & Pranpreya, 2015). Regarding technical issue, it comprises frequency stability, voltage quality, congestion management, amongst others (Barth et al., 2014).

Management barriers come up from ineffective or inappropriate business operations such as neglected after-sale service especially in rural areas. Few incentives exist for companies to warrant system components and provision repairs along with maintenance service, owing to the remoteness of rural areas (Pode, 2013; Emrah & Pranpreya, 2015). Nevertheless, this omission can potentially impair the quality of solar PV systems, and give rise to a growing skepticism toward the quality of installation in the society (Emrah & Pranpreya, 2015).

High initial and repair costs, uncertainties of funding process and sources, as well as long payback period compose economic barriers (Sarzynski et al., 2012; Brudermann et al., 2013; Emrah & Pranpreya, 2015). Costly installation and repair render solar PV energy not economically competitive with conventional energy sources. The uncertainty of funding sources and process even worsen the situation, as people hardly afford the expenses without proper financial supports from governments, commercial banks or even the public. Additionally, long payback period brings investors and commercial banks numerous doubts about the profitability of this system.

In terms of legal-administrative barriers, the failure of institutionalization, bureaucratic issues, and the reduced tariff under FiT system are commonly seen all over the world (Huenteler et al., 2012; Karteris & Papadopoulos, 2013; Emrah & Pranpreya, 2015). Relevant conditions for this industrial development, such as the solar companies' liabilities to attain loan and insurance, have not been institutionalized, and bureaucratic issues in effect constrain the intersectoral coordination and cooperation on solar PV energy development. Also, the reduction of the FiT rate is gradually unable to incentivize the investments, and retards the development.

Barriers were found to hinder the speedy growth of installation in Taiwan as well, even though Renewable Energy Development Act (REDA) was adopted and projected to smoothen solar PV deployment (Wu, 2016). These barriers may further make the annual goal and final objective hard to be achieved on schedule. Yang (2010) points out that the high initial cost per solar PV installation makes people hesitate about investments, and this is one of barriers to solar PV diffusion. However, except for Yang's research, little academic literature

systematically explores and classifies other barriers in Taiwan, and the relevant discussion is underdeveloped.

PV-ESCO Model as a Barriers Conqueror

Conscious that barriers exist and hinder solar PV diffusion, in 2012 Bureau of Energy introduced Photovoltaic Energy Service Company (PV-ESCO) model, which translates the concept application of energy service companies (ESCO) from energy efficiency into solar PV development (Wu, 2016; Cheng, 2016). This model not only structures a business framework for companies and investors to install solar PV systems, but also by the definition of the Department of Commerce in Taiwan, creates a new industry that especially deals with systems, finances, engineering planning, design, manufacture, installation, construction, maintenance, testing, and operation related to new clean energy (Ye et al., 2012).

In Taiwan, five different operational designs under the PV-ESCO model were introduced to conquer barriers; these include (1) installation site-lease model, (2) long-term output guarantee model, (3) energy management model, (4) consultation model, (5) turnkey model (Industrial Technology Research Institute, 2013). The installation site-lease model (the site-lease model)¹ has great resemblance to the full-service ESCO model applied to energy efficiency projects, where ESCO companies are responsible for all tasks, including project design, construction, operation, maintenance & repair, and financing especially. These ESCO companies have rights to use installation sites through contracting with site owners, and principally profit from the FiT revenue. Site owners, on the other hands, attain a fixed percentage of this revenue as rental fee from ESCO companies. Regarding the long-term output guarantee model (the output-guarantee model)², similar to the third party financing ESCO model adopted for energy efficiency projects, it is operated to guarantee that electricity generation will reach an agreed benchmark, which completely enables investors to reap the greatest profits. However, ESCO companies will need to compensate investors according to contracts, as long as the actual amount of electricity generation is less than the benchmark. In this model, ESCO companies take over project design, construction, and maintenance & repair, but are not responsible for financing the projects, although it may help facilitate the financing.

Compared with the site-lease and the output-guarantee model, the following three operational designs are relatively less complicated and adopted. The energy management and the consultation model are barely run by any single company at all. In the energy management model, adopters authorize ESCO companies to take charge of maintenance and repair, but ahead of the authorization, adopters themselves will manage the finance and installation in advance. In the consultation model, ESCO companies will simply offer advice to customers in terms of installation design, construction, and finance. In the turnkey model, ESCO companies will finance and accomplish system installations, and directly sell these installations to potential investors. Table 1 makes these five operational designs more understandable by illustrating each design.

The introduction of the PV-ESCO model exerts significant impacts on solar PV deployment. This model, especially with the operational design of the site lease, has been widely adopted since 2012. It is estimated that in 2012, 48% of total solar PV deployment adopted the PV-ESCO model; in 2013, the adoption grew up to 63%, and in 2014, it even exceeded 80% (Wu,

¹ The following text will use the site-lease model instead to indicate installation site-lease model.

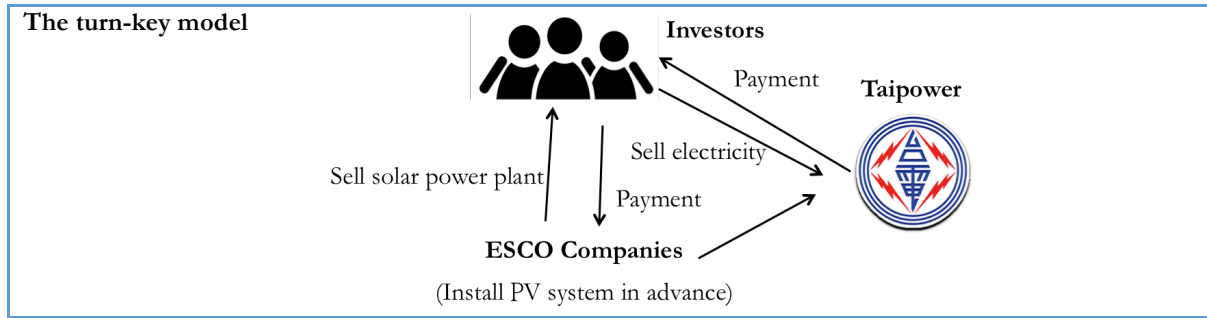
² The following text will use the output-guarantee model instead to indicate long-term output guarantee model.

2015). Most of these adoptions follow the site-lease model, which may tremendously contribute to the diffusion by matching investors and site owners (Wu, 2016).

From the statistics, the PV-ESCO model has shown its core role in solar PV deployment in Taiwan, and may help overcome barriers to solar PV diffusion. Nevertheless, the academic discussion relevant to solar PV energy in Taiwan is completely bare of the study to analyze the factors behind the great contributions of the PV-ESCO model. This leaves a research gap, and inspires the exploration in this research.

Table 1. Illustration of five operational designs under the PV-ESCO model

Operational Design	Illustration
<p>The site-lease model</p>	<p>The diagram illustrates the site-lease model. It features four main entities: Banks (represented by a red dollar sign), Site Owners (represented by a house icon), ESCO Companies, and Taipower (represented by a circular logo with a lightning bolt). The interactions are as follows: Banks offer loans to ESCO Companies. ESCO Companies offer rental and install PV systems for Site Owners. Site Owners provide sites to ESCO Companies. ESCO Companies provide electricity to Taipower. Taipower provides payment to ESCO Companies.</p>
<p>The output-guarantee model</p>	<p>The diagram illustrates the output-guarantee model. It features four main entities: Banks, Site Owners, ESCO Companies, and Taipower. The interactions are: Banks offer loans to ESCO Companies. ESCO Companies install PV systems and guarantee output for Site Owners. Site Owners pay for installation to ESCO Companies. ESCO Companies provide electricity to Taipower. Taipower provides payment to Site Owners.</p>
<p>The energy-management model</p>	<p>The diagram illustrates the energy-management model. It features two main entities: Site Owners (with a note '(have the PV system already)') and ESCO Companies. The interactions are: ESCO Companies provide maintenance and repair services to Site Owners. Site Owners pay for maintenance and repair to ESCO Companies.</p>
<p>The consultation model</p>	<p>The diagram illustrates the consultation model. It features two main entities: Site Owners and ESCO Companies. The interactions are: ESCO Companies offer advice to Site Owners. Site Owners pay for the consultation to ESCO Companies.</p>



Source: Industrial Technology Research Institute, 2013

Necessity to Expand Residential-scale Market Segment

As mentioned above, statistics reveals that the PV-ESCO model may assist in the diffusion of solar PV systems in Taiwan; its market niche, however, is confined to project sizes with installed capacity above 100 kW (industrial-mounted & electrically industrial-mounted solar PV systems). Table 2 categorizes four scales of project size, according to Taiwan Power Company (Taipower). This confinement principally results from the economies of scale (Wu, 2016; Cheng, 2016). Profitability is of importance to ESCO companies adopting the PV-ESCO model, especially with the operational design of the site lease, where these companies also play the role of “investors” by fully financing the installation with their own capital or loans from commercial banks. As investors, ESCO companies seek for profit maximization, which is more attainable by installing (electrically) industrial-mounted solar PV systems³.

Table 2. The category of project size

Installed Capacity	Category
1-20 kW	Residential-mounted solar PV system
20-100 kW	Commercial-mounted solar PV system
100-500 kW	Industrial-mounted solar PV system
>500 kW	Electrically industrial-mounted solar PV system ⁴

Source: Taipower

Since the expenditures of (electrically) industrial-mounted installation on fixed costs, such as human resources, are approximately similar to the costs of commercial and residential-mounted projects, companies would thus prefer to install more capacity that enables them to profit more from the FiT system (Wu, 2016; Cheng, 2016). Additionally, large-sized projects allow companies to lower the initial costs by procuring high quantities of modules (Wu, 2016; Cheng, 2016). All in all, the site-lease model is not pertinently applied to residential-scale projects, which generally have installed capacity within 20 kW. Also due to it, in Taiwan the popularity of residential solar PV systems is little. A statistics confirms this phenomenon, showing that large-sized installations occupy at least 73% of total accomplished installation projects; yet, residential-scale installations only have 4% among all (Lin, 2015). This statistics is visualized in figure 1, which shows the ratio of project size in total accomplished projects from 2010 to 2014.

³ (Electrically) industrial-mounted solar PV installation is regarded as large-sized project in this research.

⁴ Electricity law stipulates that any power plant with installed capacity above 500 kW is regarded as part of utility sector. In order to differentiate from the project having installed capacity from 100 to 500 kW, project with capacity above 500 kW is named electrically industrial-mounted solar PV system.

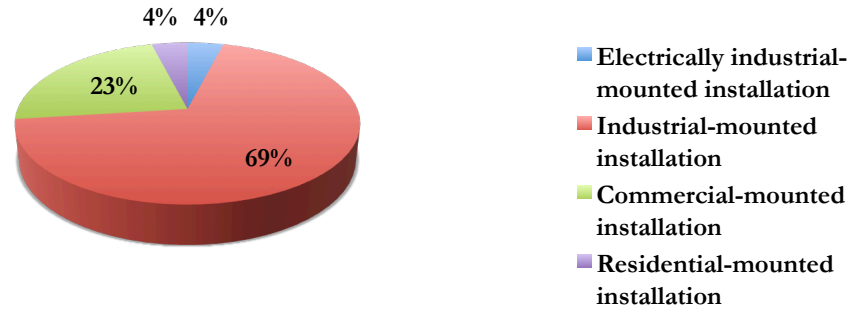


Figure 1. The ratio of project size in total accomplished projects from 2010 to 2014

Source: Lin, 2015

To implement (electrically) industrial-mounted solar PV projects, a prerequisite is investors' financial competency. These large-sized projects require relatively large amount of money that is not exactly affordable for general people, and particularly small and medium-sized enterprises (SMEs) whose paid-up capital do not reach TWD 80 000 000 (EUR 2 160 000)⁵ and employers are less than 200 people (Ministry of Economic Affairs, 2015). Thus, this market is almost occupied by large conglomerate companies whose paid-up capital is absolutely above the capital standard (TWD 80 000 000). These companies are usually capable of accessing to great financial supports either from their parent companies or from commercial banks.

Under conglomerate companies' operation, the PV-ESCO model has exerted positive impacts on the diffusion, and may facilitate a lot of solar PV installations on large-sized rooftops over four years. Recently, large-scale installation sites are gradually exhausted, and a necessity to shift the focus from large-sized installations to residential deployment appears, in order to keep annual goals and ultimate objective achieved on schedule (Wu, 2016). To stimulate this market development, small and medium-sized enterprises' participations in the site-lease model are of particular importance, as most large conglomerate companies have targeted large-sized installation sites as their market niche; residential-type projects, after all, are not profitable enough for these large companies. Furthermore, initial costs of residential-mounted installation are significantly lower, compared with large-scale installations. The expenditures are relatively more affordable for SMEs. However, relatively less upfront cost also brings less profitability. The revenue per residential-sized project has is only a little portion of the total income per large-sized project produces. To maximize the profits, SMEs adopting the site-lease model need to have a business model operation different from conglomerate companies.

Likewise, the academic literature relevant to solar PV energy is deficient in how ESCO companies operate the PV-ESCO model, and how conglomerate companies and SMEs differently operate this model. The operationalization needs to be analyzed in order to stimulate more SMEs to apply the site-lease model to residential-mounted installations, and facilitate the popularity of residential solar PV systems in Taiwan. The expansion of residential-scale market can further make the annual target that at least 300 MW of solar PV capacity should be installed more achievable.

⁵ Taiwanese Dollars (TWD) have been converted to Euros at the rate of TWD 37 = EUR 1 during May 2016 throughout this study using data from Bank of Taiwan.

1.3 Objectives & Questions

The overarching aim of this research is to variegate the academic discussion over business model adopted for solar PV energy, by assessing the function of a business model to overcome barriers to solar PV deployment and diffusion in Taiwan. Thus, the objective of this study is first to identify barriers under the contextual condition in Taiwan; second to explore how operationalization inherent in PV-ESCO model helps overcome identified barriers; third to provide a revised operationalization, which renders the PV-ESCO model also adoptable for small and medium-scale enterprises (SMEs), and can potentially activate the market of residential installation.

Therefore, the three following research questions are being examined:

- 1. What are the barriers that impede the diffusion of solar PV systems in Taiwan?**
- 2. How did the PV-ESCO model help to overcome the various barriers (faced by customers) to PV deployment?**
- 3. How could small and medium-sized enterprises (SMEs) adopt the PV-ESCO model and apply it to residential-scale project?**

1.4 Research Approach

To explore the answers to the three research questions, qualitative research approach is mainly adopted. A combined methodology of literature review and in-depth interviews are utilized to facilitate the author's understanding about not only the contextual background of barriers formation, but also the operationalization of the business model.

In this paper, the research analysis is framed with a business model theory developed by Osterwalder et al. (2005). The business model theory, comprising nine elements that underpin the function of a business model, is utilized to review how ESCO companies do business under the PV-ESCO business model.

Additionally, the literature review shows different operational designs of the ESCO model, barriers to the development and adoption of the ESCO model, and the application of the ESCO concept to renewable energy, especially solar PV energy. This information becomes the basis of argument formation with regard to defining the ESCO concept, scope and barriers in this research.

The in-depth interviews, on the other hands, are used to look into what barriers tht ESCO companies have faced while they partake in the market or carry out solar PV installation projects, and also how the PV-ESCO model is differently operated by large companies and SMEs to overcome these barriers in the reality.

More information on the rationale of methodology selection and data collection is presented in Chapter 3.

1.5 Scope & Limitations

Although five operational designs under the PV-ESCO model were introduced to overcome the barriers to the deployment and diffusion of solar PV systems, considering the aboriginality of the ESCO model and the representativeness, this paper narrows down the research scope by only interviewing ESCO companies who adopt either the site-lease or the output-guarantee model.

More information on the rationale of defining the scope to select interviewees is shown in Chapter 3.

In regards to temporal scope, the PV-ESCO model was introduced to principally deal with barriers faced by customers after 2009 when the Renewable Energy Development Act (REDA) was adopted. Consequently, this study identifies the barriers that exist after the adoption of REDA.

A major limitation of this study consists in the lack of cross-checking attained through customer-sided viewpoints, which potentially leads to lopsided assumptions. Answers to how barriers are overcome come from the author's deduction, which is mostly supported by ESCO companies' experiences and viewpoints. A cross-checking acquired from customers' opinions would better exist to confirm the assumptions in this research. Yet, out of limited time, the thesis excludes customer-sided viewpoints from research scope.

A minor limitation of this paper is language barrier. Chinese and Taiwanese that are used to carry out the interviews in this research pose challenges to the accuracy of semantic delivery and expression in English.

1.6 Target Audience

The intended audience for this thesis encompasses companies interested in the model adoption, ESCO companies, potential investors, as well as legislative and administrative units taking charge of renewable energy development.

The paper provides companies eager to adopt the PV-ESCO model, particularly SMEs, with the insights of how this model is exactly operationalized by well-reputed ESCO companies. This operationalization can further be converted into a benchmark to initiate relevant business. Companies having already implemented PV-ESCO model, on the other hand, are provisioned a reference that facilitates the revision and progression of the business models.

This thesis is also potentially of interest to investors. Through exemplifying how barriers are overcome, this thesis may be able to secure investors' confidences in the investment and installation.

Lastly, legislative and administrative units may comprehend what and where to enhance in terms of REDA and relevant policies by looking at the contextual analysis of barriers that are especially resulted from inadequate policies and legislative stipulations.

1.7 Structure

Chapter one explicitly introduces the topic and the problem that this research attempts to tackle. The research objective & questions, approach, scope & limitations, and target audience are pointed out after problem statement.

Chapter two introduces the analytical framework, defines the research scope and key terms by integrating previous studies relevant to the business model theory, the business model applied to sustainability development, the solar PV business model, the ESCO concept along with the application applied to energy efficiency and renewable energy development.

Chapter three presents the rationale behind the methodological selection, what data was acquired based on which methods, how data was sampled, how interviews were structured, and which ethical considerations are involved.

Chapter four synthesizes the data from the literature review and interviews, and clearly organizes the context of barriers formation in Taiwan, background information of each company, and the morphology of operationalization under different designs and project sizes. Data presented in this chapter answers the first research question.

Chapter five elaborates on the discussion extended from results by clearly presenting the ways that the PV-ESCO model has to help overcome barriers, and the transformation of operationalization from (electrically) industrial-scale installation to residential one. Answers to the second and third research questions are presented in this chapter. Moreover, this chapter provides the directions for future policy revision and legislation amendment.

Lastly, chapter six, based on result and discussion, summarizes the answers to the research questions. Suggestions for future research are proposed here as well.

2. Business Models Theory and ESCO Model

This chapter introduces the analytical framework, defines the research scope and key terms by integrating previous studies relevant to the business model theory, the business model applied to sustainability development, the solar PV business model, the ESCO concept along with the application applied to energy efficiency and renewable energy development.

2.1 Business Models Theories and Applications

Osterwalder et al. (2005) systematically differentiate discussions over business model into three tiers: (1) concept and definition, (2) business model type, (3) application in reality. The first two analyze the elements constitution in a business model and the taxonomy of business model types with different elements. The last one is discussed to illustrate the first two tiers. Academic review of business models theories in this section will be structured with this three-tiered hierarchy.

2.1.1 Concept and Definition

The concept and definition of business models have received substantial attention in academic literatures, and are discussed in various domains such as e-business, strategy, and management (Osterwalder et al., 2005). Fundamental disagreements in the definition and concept, however, trigger a heated debate in relevant academic field. Teece (2010) defines business model as a logic manner to deliver business value, entice customers' purchase and transform their payments into profit. Amit & Zott (2011) emphasize that in addition to being a holistic approach of how firms do business through capturing and delivering values, business models also structure the manner for "value creation". A definition proposed by Osterwalder et al. (2005) comprises all elements in the above-mentioned definitions, suggesting that "to generate revenue streams, a business model logically describes the values offered to several segments of customers, the architecture of the firm, the network of partners for creating, marketing, and delivering values". All in all, designing and adopting a business model assists a company in stabilizing its economic yield, as it helps create the business value, and recognizes the business network as well as the value delivery method.

Although academic literature offers a variety of business models definitions, considering the concept integrity, this study adopts the definition proposed by Osterwalder et al. (2005), who further elaborate on four elements sustaining a business model.

2.1.2 Elements Review

Teece (2010)'s five steps of business model implementation show how a business model is designed. It is guided with the following order: (1) select technologies and features to be embedded in the product and service, (2) determine benefit to the customer from consuming or using the product and service, (3) identify market segments to be targeted, (4) confirm available revenue streams, (5) design mechanisms to capture value (Teece, 2010). Business models elements embedded in this guidance include business value confirmation and delivery (step 1 and 3), payments incentivization (step 2) and the conversion from payments to profits (step 4 and 5). These elements show how a firm communicates with external stakeholders, such as investors and customers, and what the messages should be conveyed in order to incentivize more payments. The deficiency in this model proposal, however, is assessing a firm itself, such as the evaluation for the core competency and the partner network.

Synthesizing more academic discussions over business model elements, Osterwalder et al. (2005), establish a more comprehensive model design, where both external and internal assessments are included. These scholars generalize four pillars, under which nine elements are developed and form the basis of a business model design. Each pillar and element is listed in table 3 and explained below.

Table 3. Elements in business model theory

Pillar	Element	Description
Product & Service	Value Proposition	Delivered values from products and service
	Target Customer	Customers targeted to be offered values
Customer Interface	Distribution Channel	Approaches and means to get in touch with customers
	Relationship	Types of link established with customers
Infrastructure Management	Value Configuration	Activities and resources to support or add the delivered values
	Core Competency	Competencies necessary to execute a business model
	Partner Network	Cooperative network with other companies for a more efficient value provision
Financial Aspects	Cost Structure	Underlying costs to create economic yields
	Revenue Model	Different revenue sources that companies have

Source: Osterwalder et al., 2005

Product and Service

“Value proposition” plays the central role of a business model. This element describes “an overall view of a company’s bundle of products and service” (Osterwalder et al., 2005). More concretely, a firm necessarily searches out a product and service value not only expected or favoured by customers, but also exclusively offered by itself, in order to keep the profitable revenue flows (Afuah & Tucci, 2003). To seek out the value, questioning a firm itself with “What does the customer value?” would be a good starting point (Magretta, 2002; Osterwalder et al., 2005).

Customer Interface

“Target customer” indicates “the segments of customers that a company wants to offer value to” (Osterwalder et al., 2005). This element exists mainly for searching out the right person to be served with the value, and further helps a firm define its market and product scope (Afuah & Tucci, 2003). The question designed for this element is “Who is your customer?” (Magretta, 2002; Osterwalder et al., 2005).

Another element under this pillar is “distribution channel”, which depicts “the various means of the company to get in touch with its customers” (Osterwalder et al., 2005). Linder & Cantrell (2000) propose that advertising, subscription, consultative selling, promotional pricing and product availability are all inside this coverage.

“Relationship” is the last element, explaining “types of links a company establishes between its different segments of customers and itself” (Osterwalder et al., 2005). The interaction between a firm and customers leads to a relation dynamic, based on which a firm can further decide to maintain a short-term or long-term relation with a particular segment of customer.

Infrastructure Management

“Value configuration” describes “the arrangement of activities and resources to underpin or add the value” (Afuah & Tucci, 2003; Osterwalder et al., 2005). Afuah & Tucci (2003) further propose that adding value requires primary and secondary activities. The former is linked with changing inputs into outputs by the customer interface, and this comprises outbound logistics,

marketing, sales and service. Human resources management, technology development and procurement belong to the later, functioning as a supportive role in primary activities development.

The second element under this pillar is “core competency”, which helps outline “the competency necessary to execute the company’s business model” (Osterwalder et al., 2005). Degree of how value-adding activities and resources are well implemented will lie on the identification of a firm’s competency including its organizational structure, people, systems and environment.

“Partner network”, as the last element in this section, portrays “the network of cooperative agreements with other companies to efficiently offer and commercialize value” (Osterwalder et al., 2005). According to Afuah & Tucci (2003), teaming up facilitates knowledge and resources transfer, and more concrete applications involve alliance, joint venture, and collaborative acquisition.

Financial Aspects

“Cost structure” connects the relationship between revenues and underlying costs to produce these economic yields (Afuah & Tucci, 2003). Determining the cost structure requires the review of how a firm utilizes its cost drivers.

Expressing the way a company makes money, “revenue model” is the last element. A firm can at the same time adopt various methods to create several revenue flows, but prior to the adoption, reviewing the pricing process and revenue sources is the necessary work (Afuah & Tucci, 2003).

2.1.3 Business Models and Sustainability Development

The transformation of business models contributes to the reduction of negative impacts on environment and society (Bocken et al., 2014; Boons & Lüdeke-Freund, 2013). As business models express a logic manner of how a firm does the business, the transformation of a business model also represents the change of customer value, value configuration, core competency, revenue model, those elements enabling a firm to function. In short, re-designing a business model systematically helps re-organize and review each business element. Based on this logic, the starting point to integrate sustainability into business is always changing business models.

Business models designed for sustainable development have been applied in reality; one of the applications is on renewable energy development. A successful business model in fact functions as a strategy to create the value for the application of renewable energy. It can further create situations in which the financial and non-financial barriers to renewable energy diffusion are to some degree overcome (Würtenberger et al., 2012). A business model archetype consisting of value proposition, value creation & delivery, and value capture for renewable energy development has ever been proposed. The proposed value in the model is to reduce environmental impacts, and increase business resilience by addressing limited non-renewable resources and depletion issues (Bocken et al., 2014). Value creation & delivery for renewable energy shows that the introduction of renewable sources and energy renews products and their process; besides, new value networks as well as partnerships with “nature inspired” solutions will be built in this new process (Bocken et al., 2014). Lastly, the value captured in this model would be revenues coming from innovative products and services with the value of the reduced use of non-renewable resources, and reduced emissions (Bocken et al., 2014).

2.1.4 Solar PV Business Models

The above-mentioned business model archetype proposed by Bocken (2014) offers a general idea to establish the value proposition, distribution channel, and cost-benefit structure for renewable energy-related business. However, the operationalization of the archetype may vary when looking at different renewable energy sources, as well as different business models under each source. Solar PV energy, for example, is developed with various business models. Based on financing options, Tongsopit et al. (2016) differentiate these solar PV business models into four categories: the self-financing model, the utility and public financing model, the third-party financing model, and the solar crowding model. Another two famous models, the community shared solar model and the solar service model, are also identified in these scholars' academic literature.

The self-financing model as the first and least complicated one is in which investors shoulder full financial responsibility for installation and maintenance. This model is generally less effective in solar PV diffusion owing to unaffordable upfront costs. The utility and public financing model is operated with stable financial supports from general populace and governments. The property assessed clean energy (PACE) model is the representative of the public funding system. In the PACE model, site owners pay the special property tax at lower interest rate to the municipality in return for having the loan. The installment payments allow owners to profit from solar PV investment first, and afford the special property tax with the revenues. This model design in effect eliminates high up-front costs for energy retrofits, and further lessens investors' economic burdens. Nowadays, several successful cases in the U.S.A. prove its viability (NREL, 2010). Aside from the authority, power utilities could also offer a financial scheme in this model. A few American utilities source finances from banks on behalf of site owners, and build a large-scale solar farm where customers can have a share. The installation and maintenance costs would be directly included in site owners' monthly bills (on-bill financing) (Tongsopit et al., 2016). The operation of this model is generally beneficial to good grid integration and lowering transaction costs (Tongsopit et al., 2016).

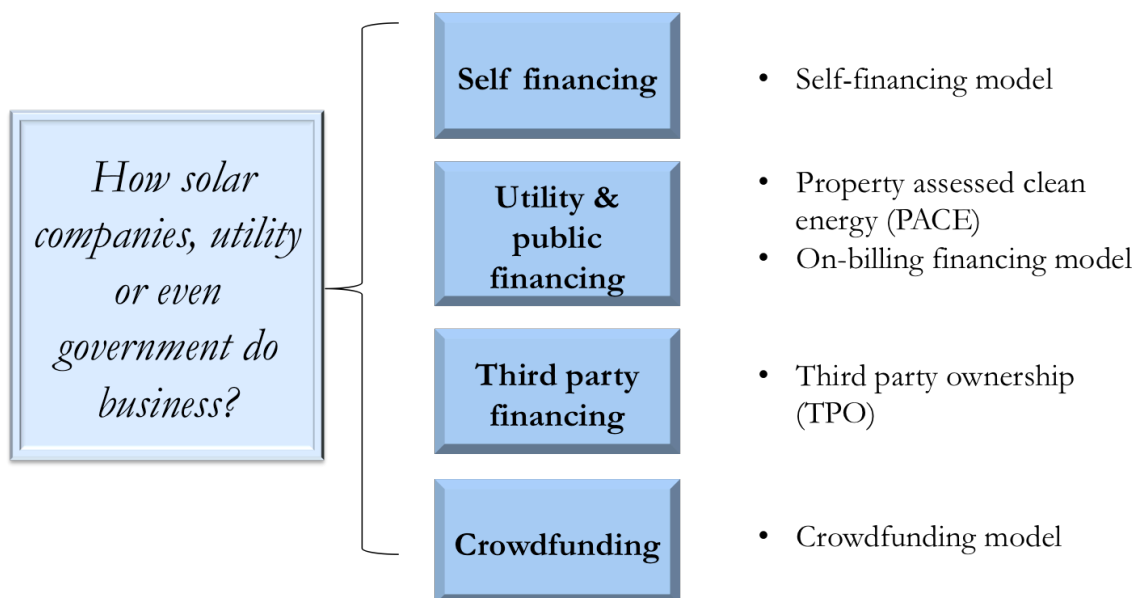
The third model is operated with third party financing, which is usually exemplified by "third-party ownership" (TPO). A third-party company acquires money from private funds which are sometimes provided and managed by large business players such as Google and CitiBank, then building solar PV systems on customers' sites (Tongsopit et al., 2016). Companies usually profit from either leasing the PV system or selling the solar PV-generated electricity to customers. This model also alleviates site owners' financial burdens since the third-party companies take charge of the upfront costs. Solar crowdfunding as the last category is operated in the way that funding received by developer companies (an intermediary role between the public and roof owner) from the general populace is loaned to the roof owners. Similarly, profits from energy retrofits are used to afford the installment payment with interest rate. Developer companies, after receiving money, will further distribute the payment to investors. In this model, investors and donors' generosity out of the strong motivation to support renewable energy development, is the key factor to the success. Nowadays, the wide application of this model around world also proves it as a reliable and scalable business model (Tongsopit, 2015).

The community-shared solar model and the solar service model are additionally categorized in Tongsopit's research. It depicts a collective profit sharing from solar energy generation. An array of solar PV panel supplies the utilities with electricity in exchange of a virtual net energy metering (NEM) for the community. The solar service models, on the other hand, emphasize solar power as a service offered by solar service companies (Tongsopit, 2015). This service ranges over installing, managing and maintaining solar panels (Overholm, 2015). Solar power purchase agreements (SPPA) and the leasing structure usually exemplify the solar service

model (Tongsopit, 2015). Under the former system, solar PPA companies take charge of solar system installation, operation and maintenance, and acquire income through supplying electricity to the site owners. In the solar leasing model, site owners as a lessor acquire revenues from rental fees, and companies as a lessee have rights to run the solar power system. This model allows solar companies to offer a whole package of “service“, which makes the application and installation less troublesome for investors and customers. According to Loock (2012), compared with the best technology and the lowest cost, potential renewable energy investors would prefer to initiate their investment under those business models that propose best “services“ to them. This shows the promising contribution of this service-oriented business model to solar PV diffusion.

The study developed by Tongsopit et al. (2016) actually shows that academic literature presenting “the options of solar PV business model” is quite fruitful. Various choices of the business model have been explored and displayed in the front of solar companies or utilities. However, most literature focuses on how these solar business models work, rather than how they are operated by solar companies and the contextual background of the operation. Strupeit and Palm (2015) adopt business model theory developed by Osterwalder et al. (2005) to study the operationalization of different solar business models in Germany, the U.S.A, and Japan. Compared with Bochen’s study (2014), Strupeit’s and Palm’s research more explicitly points out how solar companies structure their delivered value, target customer, distribution channel, customers relation, value configuration, competency, partner network, and cost & revenue model. This research concludes that the operationalization of a business model archetype vary under different contextual backgrounds and solar PV business models.

Although some operationalization of solar PV business models⁶ has been discussed in Strupeit’s and Palm’s research (2015), numerous solar PV business models are still left to being explored regarding how solar companies operate them. Among all, solar service model is particularly worthy to receive the exploration, as it is potentially more welcomed by investors and customers (Loock, 2012).



⁶ Strupeit and Palm’s research covers the discussion over the operationalization of third-party ownership business model in the U.S.A, cross-selling model business model in Japan, and host-owned feed-in business model in Germany.

Figure 2 Three-tiered hierarchy of solar PV business model based on the taxonomy developed by Tongosopit (2015)

Source: Author, inspired by Osterwalder et al. (2005) and Tongosopit (2015)

2.2 ESCO Model and Its Contextual Environment

The ESCO concept was launched and applied in energy efficiency sector at the beginning of the 1980s in North America (Okay & Akman, 2010). It is defined as “Business that deals with services of oil, electricity market trading, power generation, transportation, electric power transmission, power distribution, water resources, energy conservation, as well as the management of coal, electricity, gas, nuclear, oil, renewable energy, etc.”, according to World Trade Organization (WTO) (Wang et al., 2012). This model concept is differently operationalized in terms of the financial issue (Pätäri & Sinkkonen, 2014), but different operationalization still share fundamental value: service as the priority. This section firstly introduces each variation in the different ways that the ESCO concept is operationalized, secondly deals with barriers and constraints of this model, and lastly discusses the model application under renewable energy development.

2.2.1 Operational Design

Variations in the financial mechanism lead to two different contract models: the shared savings and the guaranteed savings. In the former model, ESCO companies have full financial obligation, but can acquire profits from customers who pay a given share of savings to companies over the contract period (Bertoldi & Rezessy, 2005; Okay & Akman, 2010; Pätäri & Sinkkonen, 2014). In the guaranteed savings model, on the other hand, customers undertake full responsibility to finance the energy retrofit. The role that ESCO companies play is only to assist the retrofit process by providing top-notch techniques, which enable them to guarantee sufficient energy savings that completely cover customers’ annual debt obligations and expenses (Bertoldi & Rezessy, 2005; Okay & Akman, 2010; Pätäri & Sinkkonen, 2014). World Bank (2005), further elaborating on different operational designs, categorizes all designs under ESCO model into eight operational models. The classification is based on distinct financial mechanisms and companies’ responsibilities in the contract.

Full-service ESCO

ESCO companies are responsible for the project design, the implementation and the financial issue, as well as the energy savings verification. They usually profit from an agreed percentage of the real energy savings stipulated in the contract over a fixed period. This is also considered as the “shared savings” approach.

End-use Outsourcing

ESCO companies take charge of the operation and maintenance of the system. They acquire revenues by selling the output to customers at an agreed price. All maintenance costs, including equipment upgrades and repair, fall on companies’ responsibilities. However, the ownership typically belongs to customers.

Third Party Financing

ESCO companies take over the project design and the implementation, but are not responsible for financing projects, although it may help arrange or facilitate the financing. In this model, companies also need to guarantee that the energy savings will be sufficient to cover customers’ annual debt and expenses.

ESCO Variable Term Contract

Approximately similar to the full-service ESCO, this model shows companies' responsibilities extending from the project design to the financing. The difference between two designs is that the contract term can be changed based on actual savings. If the actual savings are less than the expectation, the contract can be extended until companies attain a certain degree of profits that are agreed and stipulated in the contracts. However in the full-service ESCO model, the contract period is basically unchangeable.

Equipment Supplier Credit

Equipment suppliers basically design the project, and have the obligation to ensure that the energy savings performance matches the expectations. The lump-sum payment is usually done either after the accomplishment or over time, and the ownership of the equipment will be transferred to customers afterwards.

Equipment Leasing

This model is approximately similar to the supplier credit model, under which suppliers receive fixed profits from the actual energy savings. However, the difference between these two designs is that suppliers in this model own the equipment until the lease period ends and transfer payments are completed.

Technical Consultant Performance-based Payments

ESCO companies conduct audits and offer assistance in project implementation. The fee paid to companies from customers is agreed by both sides and based on the project performance. This model also includes additional negotiation for lower energy savings and bonuses for higher savings.

Technical Consultant Fixed Payments

ESCO companies conduct audits and design the project. Their roles are either to assist customers on project implementation, or simply offer advice to customers for a fixed lump-sum fee.

2.2.2 Barriers and Constraints

Since the ESCO concept has been differently implemented over 30 years, and now more prevalent in both developed and developing countries, some scholars initiate the academic discussion over the barriers and constraints of this model application. Lee et al. (2003) categorize all barriers into three dimensions: market, institutional and financial barriers. Following the context of ESCO development in Taiwan, Huang's research (2007) additionally adds verification and human resource barriers.

Market Barriers

The ESCO market becomes limited when a society is mostly dominated by small and medium-scale enterprises (SMEs), which usually possess less capital to invest in energy retrofit (Lee et.al, 2003). The limited capital further constrains the size of energy retrofit projects, and hardly incentivizes commercial banks to fund (Lee et.al, 2003). ESCO market development in Taiwan is especially facing this predicament, as around 97.67% of total enterprises are categorized as small and medium scale firms (Ministry of Economics Affairs, 2013). The fact that less energy consumed by SMEs also renders energy retrofit unprofitable (Huang, 2007).

Another market barrier is lack of competition. Academic research points out that fierce competition between companies can inspire companies to cut costs and value their performance (Lee et. al, 2003). This implementation not only potentially brings expenditure

on energy down, but also helps erect reputation. Accordingly, ESCO market development requires a competitive market as the prerequisite for its development.

Institutional Barriers

Since the number of actors involved into energy projects under ESCO model is considerable, new institutional arrangements, and practices may be required to strengthen the integrity of the whole system and actors' participation (Lee et. al, 2003). Moreover, contract establishment between ESCO companies and customers would need legal assurance and enforcement framework. Lack of either institutional or legal establishment can hinder ESCO model from development. In Taiwan, the government is less ambitious to establish legislative and institutional framework for the model. This is very unfavorable to the development of ESCO model (Huang, 2007).

Financial Barriers

Commercial banks usually consider ESCO companies as unreliable customers for two reasons. First, credit history of this industry is not well established owing to the immaturity of this industry. This in effect undermines banks' confidence in this credit relation. Also, long payback time in the energy retrofit projects renders future profits uncertain. These all lead to high collateral requirements, which both ESCO companies and customers usually less agreed on (Lee et. al, 2003).

Verification Barriers

Nowadays, the international society has not reached an unanimous conclusion of how energy efficiency performance should be measured and verified (M&V), as energy efficiency scopes, objects, patterns, methods, costs and benefits vary from projects to projects, and countries to countries. The lack of one authoritative M&V procedure actually makes separate adoption of different versions very problematic (Huang, 2007). Also, the introduced procedures are developed under foreign experiences and context, thus to a certain extent not fitting in with Taiwanese society. However, procedure internalization has not been accomplished, which leads to the barrier to implementation (Huang, 2007).

Human Resources Barriers

In additional to the M&V barrier, Huang (2007) further contends that experts competent to carry out the M&V are greatly insufficient; this basically results from the lack of appropriate trainings and relevant educational mechanisms. Without proper human resources, the M&V mechanism still hardly works even after it has been internalized.

2.2.3 ESCO Application under Renewable Energy Context

Most literature classifies the ESCO model into the business model archetype of "energy efficiency", rather than "renewable energy development". This phenomenon is reflected on some academic discussion led by Hannon et al. (2013) and Bocken et al. (2014). Although the ESCO model and concept were originally developed for energy efficiency projects, more social and political attentions on renewable energy development drive ESCO companies initiating renewable energy service (Ribeiro, 2011).

Renewable Energy Development with ESCO Model

Ribeiro (2011) has ever analyzed the ESCO model applied on renewable energy development in Ontario, Canada, with SWOT analysis. This scholar concludes that the profitability is the biggest constraint of the application. Interviewees in this study frequently mention that long payback period and high upfront cost of renewable energy make the investment possibly

unprofitable. Without the FiT system or a similar piece of legislation in place, renewable energy projects are generally unprofitable for both ESCO companies and site owners. Thus, an incentive FiT system plays the central role in this model development. Additionally, to overcome this challenge, the scholar suggests ESCO companies to develop a flexible model, which enables them to adapt to different incentives in various jurisdictions. This flexibility will basically be built on a wider range of products and services provision as well as multi-skilled employees (Ribeiro, 2011).

Despite the challenge, renewable energy business with the ESCO model still has its strengths and opportunities. The familiarity with technical issue, legislative requirement and financial assistance for solar PV installation is the biggest strength that ESCO companies possess (Ribeiro, 2011). Given that the procedure of solar PV installation and investment is complicated and requires different expertise, the whole package service from ESCO companies will more or less make the investors and site owners less burdensome. Moreover, strong suppliers and client relationships are another main strength. The former indicates a stable and profitable supply chain because of large quantities of equipment purchased at lower price, or equipment provision from companies themselves. The later is built because of companies' abilities and willingness to adapt to client needs (Ribeiro, 2011). The last strength is that companies are knowledgeable about the industry and risk management for solar PV development (Ribeiro, 2011). Generally the projects are developed with guaranteed energy savings or energy generation stipulated in long-term contracts, and it is necessary for ESCO companies to manage the risks in order to save or generate more energy. Finally, in terms of opportunities, more social and political attention on renewable energy development and technological improvement play the key roles for future ESCO development (Ribeiro, 2011).

Solar PV Energy Development with ESCO Model

The spirit of ESCO model, service as the priority, has been actually applied to several different solar PV business models that are not directly termed ESCO in reality. In addition to solar leasing and solar power purchase agreements (SPPA) mentioned previously in the solar service model, the third-party ownership (TPO) is also considered to inherit the spirit of the ESCO model. Moreover, the leasing system and the fee-for-service, under the product service system (PSS), are operated with the attribute of the ESCO model.

The third-party ownership, as mentioned previously, is a business model under which companies offer solar rooftop installations as a full service in exchange for customers' long-term payment contracts (Overholm, 2015). This full service, ranging over design, finance, construction, operation, management, and maintenance, adopts the spirit of the ESCO model, and transforms solar installations into a simple service (Overholm, 2015). Customers, on the other hand, sign the Power Purchase Agreement (PPA) with companies and buy the electricity from the on-site PV system at a predetermined rate. Solar PV panels are generally installed on customers' property, but formally owned by TPO companies themselves or their financial partners (Overholm, 2015).

The product service system (PSS), defined as "as a system of products, services, supporting networks and infrastructure that are designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models" (Mont, 2002), also adopts the spirit of the ESCO model. This can be shown when exploring two service models under the PSS concept: the leasing and the fee-for-service model (IEA-PVPS, 2003; Krause & Nordström, 2004; Terrado et al., 2008; Friebe et al., 2013). The leasing system indicated here is different from the aforementioned solar leasing model, and the main difference consists on the role exchange between customers and companies. Companies in this model, also named as service providers, offer system installation on customers' rooftops. These companies take care

of maintenance & repair, and profit from rental fees. Customers, on the other hand, are allowed to use these systems by paying fixed or fluctuated rental fees, depending on how much electricity is used (Friebe et al., 2013). The ownership can be transferred from the companies to customers at the end of the contract period. In other words, customers can own solar PV systems when contracts expire. Shih & Chou (2011) utilize a methodology that estimates people's willingness to pay to explore people's attitude toward this business model. The result supports the claim that leasing instead of purchasing solar power system would be more preferred by people who have concerns about uncertain factors. It is not only because the risks are transferred to companies (Shih & Chou, 2011), but also customers are able to enjoy nearly full service in this model. In the fee-for-service model, it is operated almost in the same way with the leasing model; the only one opposite is that the ownership is never transferred to the customers (Friebe et al., 2013). Thus in comparison with the leasing model, companies are more likely suffering the risks of high maintenance and repair costs when customers do not properly use the system. The fee-for-service model has now been implemented in some developing countries such as Zambia; however the success of this model still lies on the extent of policy intervention, which may render this model more profitable for entrepreneurs (Friebe et al., 2013).

3. Data Collection

This chapter presents the rationale behind the methodological selection, what data was acquired based on which methods, how data was sampled, how interviews were structured, and which ethical considerations are involved.

3.1 Literature Research

Purpose

A literature review is the process and the result to integrate information relevant to research topics. Through literature review, researchers are able to acquire the insights into a particular issue, the basis to develop or adopt an analytical framework, and to define the research scope and key terms. This thesis makes use of the literature review to (1) ensure the pertinence of regarding business model theory as the analytical framework, (2) define some key terms such as energy service companies (ESCOs), (3) identify the previous studies that support the application of business models and barriers to the adoption of the ESCO model, and (4) also define the research scope according to the initial operational designs of the ESCO model.

Method

Literature was retrieved via the on-line database of Lund University Library, Taiwan Nation Central Library search engines, as well as other academic and Internet search engines. The collection is segmented into different categories as below:

1. Business model theory: Literature that defines the concept of business model, elaborates on the elements underpinning the function, and illustrates the operation. This part helps this research identify the most pertinent theoretical framework to be adopted. Interview questions are also formulated based on the business model theory. Figure 3 visualizes how the business model theory serves as theoretical framework in this study.
2. Business models applied to sustainability and solar PV energy development: Literature that draws the relationship between business models and sustainability. Furthermore, some business models utilized to facilitate the diffusion of solar PV energy are reviewed in this section as well. Information in this section shows great contributions of business models to sustainability and renewable energy development, and it further depicts the significance of this research topic.
3. Concepts and operational designs of the ESCO model: Literature that introduces the concept of ESCOs and operational designs derived from this model. This section enables the author to delimit the research scope and key terms.
4. Barriers to the adoption of the ESCO model: Literature that explores the factors that constrain the adoption and development of the ESCO model. This literature assists the author in understanding the prerequisites to stimulate the adoption of the ESCO model.
5. The application of the ESCO model to renewable energy development: Literature that touches upon business models inheriting the spirit of the ESCO model and their applications on renewable energy development, solar PV energy in particular. This section contributes to providing insights into the ESCO model and its strengths.

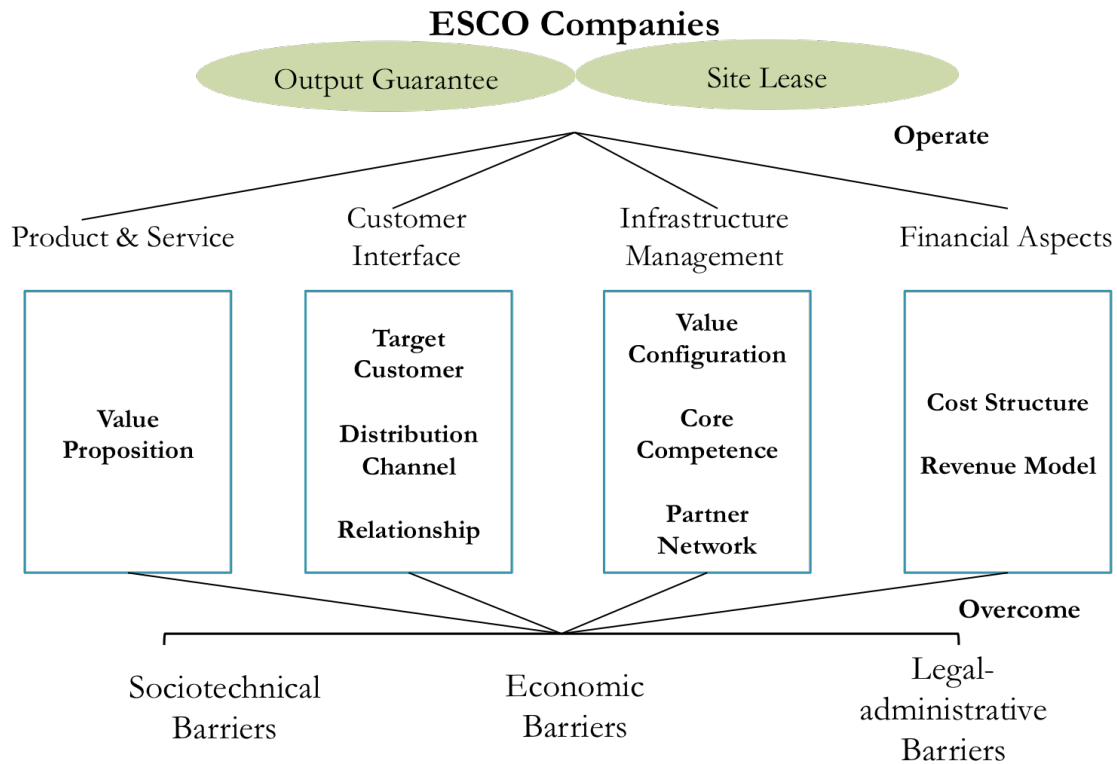


Figure 3. Theoretical framework of this study

Source: Author

3.2 Interviews: In-depth interviews

Purpose

In-depth interviews assist researchers in approaching the answers and truths through narrative, rather than numerical description (Creswell, 2014). This method with relatively loose inquiry structure actually diversifies the answers, by which researchers are further able to explore the deep of the answers and the core of truths.

The author is interested to explore this thesis topic on account of the statistics that shows over 80% of total solar PV deployments adopted the PV-ESCO model and at least 70% of total installation projects adopt the site-lease model. Reasons behind this statistics, and the contributions of this model to solar PV diffusion are more attainable through in-depth interviews. More concretely, the exploration targets the answers to “how this model overcomes the barriers?” and “how do small and medium-sized enterprises adopt this model?”, instead of “how many people or companies feel that the barriers are overcome by this model?”, and “how many SMBs adopt this model?”. These answers can be solely attained through narrative description in in-depth interviews.

Method

All interviews were conducted with some consideration as below:

1. Interview design: ESCO companies, as the informants, are the interviewees in this paper. These companies were firstly questioned about their background information, including industry taxonomy, duration of running business with the PV-ESCO model, projects sizes

and numbers that they have implemented. A set of questions elaborating on the value proposition, customer interface, infrastructure management, and financial aspects came up afterwards. These interviews usually ended up in the questions that explore how the PV-ESCO model helps overcome barriers, and what barriers constrain the diffusion or projects implementation.

Interview questions are all presented in annexes 1.

In order to further capture a holistic picture of the whole solar PV industry, the author also interviewed some relevant stakeholders as listed in table 4. Also, completely showing the stakeholders involved in the solar PV industry, figure 4 visualizes the relationship between different stakeholders and ESCO companies.

Table 4. The list of interviewed stakeholders

Organisation & Position	Introduction and Contribution
Chairman of Solar PV Generation System Association of R.O.C	<ul style="list-style-type: none"> Solar PV Generation System Association is the representative of whole solar PV system industry. This association consists of numerous PV generation system companies that include several ESCO companies. Most numeric data and narrative description that reflect the market situation under the PV-ESCO model was acquired from this interview.
Assistant Director of Skwentex International Corporation	<ul style="list-style-type: none"> Skwentex International Corporation is the solar module and component supplier of three interviewed ESCO companies. The interview brought the author further understanding about whole industrial supply chain.
Research Manager of China Development Financial	<ul style="list-style-type: none"> China Development Financial is one of commercial banks that offer loans on solar PV installation project. The interview helped the author recognize the system and prerequisites to ask for loans on installation project, as well as the relationship between ESCO companies and commercial banks.
Director of Million Rooftop PVs Promotion Office, Bureau of Energy, Ministry of Economic Affairs	<ul style="list-style-type: none"> Rooftop PVs Promotion Office is an official department under Bureau of Energy. It specially deals with the works relevant to solar PV system and market. The interview offered a lot of numeric data and narrative description that show the market situation under the PV-ESCO model.
Manager of PV technology Division in Industrial Technology Research Institute	<ul style="list-style-type: none"> PV technology Division in Industrial Technology Research Institute is a quasi-governmental unit working on PV-related researches and third-party verification. The interview assisted the author in understanding current market situation, the operation of third-party verification and policy deficiency. This information contributes a lot especially to argument formation for policy recommendation.
Project Manager of PINO Technologies Co., LTD.	<ul style="list-style-type: none"> PINO Technologies Co., LTD is one of solar PV system companies in Taiwan. The project manager of this company is an acknowledged veteran of implementing solar PV projects and collecting solar PV-related information in this industry. These hands-on experiences qualify her as one of stakeholders who comprehensively understand solar PV market. The interview helped the author identify well-reputed companies as major interviewees. Also, a lot of narrative descriptions that show the market situation under the PV-ESCO model were offered in the interview.

Source: Author

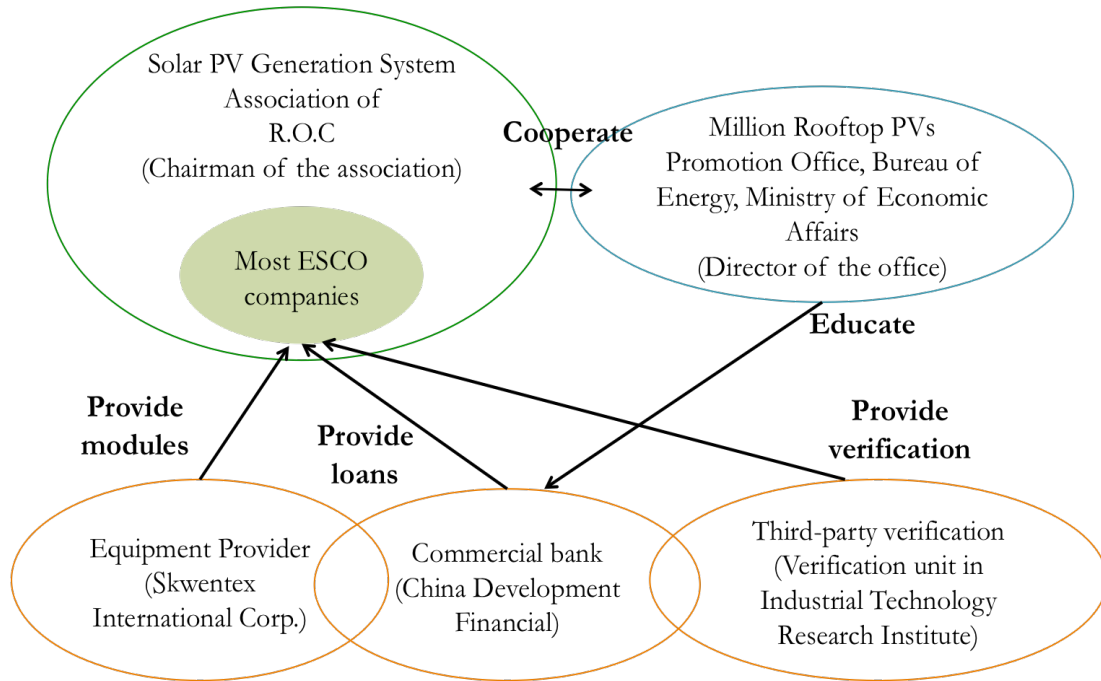


Figure 4. Relationship between stakeholders

Source: Author

Questions to these stakeholders were tailored depending on their roles and function in solar PV industry. However, all the interviewees, likewise, were asked about their own opinions on the barriers that retard the diffusion and installation. Thus, answers to the first research question, “What are the barriers that block the diffusion of solar PV systems in Taiwan?”, originates from both literature review and in-depth interviews.

2. Sampling: The ESCO model has firstly been applied in the energy efficiency sector. The operational designs of the PV-ESCO model that are similar to the operational designs of the ESCO model for energy efficiency projects are abler to inherit the essence and the aboriginality of the ESCO model. The site-lease and the output-guarantee model are more similar to the initial designs for the ESCO model for energy efficiency projects, and possess the aboriginality of the ESCO model. Thus, this study targets interviewees from ESCO companies who adopt either the site-lease or the output-guarantee model.

Additionally, in Taiwan the site-lease model is the most representative one among all operational designs. Statistics shows that at least 70% of total installation projects adopt the site-lease model⁷ (Lin, 2015; Cheng, 2016). The adoption of the site-lease models on large-scale projects is especially striking; around 80% of projects with the installed capacity above 100 kW are processed under the site-lease model (Cheng, 2016). These numbers indeed demonstrate the typicality of this model, as well as the necessity to explore its influence upon overcoming the barriers.

⁷ According to the Chairman of Solar PV Generation System Association of R.O.C., over 80% of projects with the installed capacity above 100 kW adopt the site-lease model, and 50% of projects with average installed capacity around 50 kW are processed under the site-lease model. Projects with the installed capacity above 100 kW account for 73% of total installation projects; yet, projects with the installed capacity ranging from 10kW to 100 kW have 23% market share. After data synthesis, the percentage of projects adopting the site-lease model in all installation projects can be calculated.

ESCO companies were sampled according to the total number of companies adopting either the site-lease or the output generation model. As mentioned previously, around 30 ESCO companies adopt the site-lease model, and less than 10 companies operate the output-guarantee model (Wu, 2016; Cheng, 2016). The ratio of the former to the latter is approximately 3:1. In accordance with the ratio, the author principally interviewed 7 ESCO companies in total, comprising 5 companies operating the site-lease model and 2 enterprises adopting the output-guarantee model.

These companies were also selected based on a set of criteria as below: (1) sustainability of model operation: these companies have operated the PV-ESCO model for several years, and until this year, they are still implementing projects under this model, (2) typicality: part of these companies also apply the PV-ESCO model to residential-scale project, and are typical of SMEs who implement projects under this model; (3) reputation: these companies are well reputed in terms of implementing the PV-ESCO model and solar PV installation projects. The first criteria was set because this thesis attempts to have a long-term assessment of the PV-ESCO model, thus excluding companies who have already disconnected this model operation after conducting few projects. The second criteria exists for exploring the answers to the third research question, “How do small and medium-sized enterprises adopt the PV-ESCO model and apply it to the residential-scale project?”. Lastly, this research intends to offer the best operationalization of the PV-ESCO model, which can solely be acquired through interviewing reputable companies.

3. Interviews Rounds: Basically interviews were carried out in one round with face-to-face communication, and all the data were acquired in the first round. However, in order to further clarify the acquired information, a second round of interviews was conducted through electronic communication for only two particular ESCO companies who offered ambiguous information in the first round.
4. Ethical considerations: Confidentiality is of particular importance in the methodology of the in-depth interview. Considering that some ESCO companies have expressed their unwillingness to be named, this research instead uses a number of codes to refer to these companies in the whole paper.

4. Results

This chapter synthesizes the data from the literature review and interviews, and clearly organizes the context of barriers formation in Taiwan, background information of each company, and the morphology of operationalization under different designs and project sizes. Data presented in this chapter answers the first research question.

4.1 Barriers to solar PV diffusion

To accelerate the diffusion, the Renewable Energy Development Act (REDA) was adopted and projected to conduce to the acceleration by incentivizing investments. However, the inadequate stipulations in related Acts, compounded with insufficient policy schemes, have led to a constant emergence of different barriers. These involve social, economic and legal-administrative aspects.

4.1.1 Social Barriers

Social barriers encompass the dearth of knowledge, an information platform and general skepticism toward the quality of PV system installations. The major social barrier is formed as the result of very limited knowledge of national energy supply, solar PV energy, and the FiT system in society. The chairman of the Solar PV Generation System Association of R.O.C (2016) ascribed this inaccessibility of knowledge and information to a significant deficiency of policy support.

A report surveying public perception of energy supply in Taiwan shows that only 18% of interviewees know that nearly 100% of energy supply comes from the imports; 83% of interviewees falsely recognize the duration of electricity generation from solar PV energy per day, and a large majority of this group of people are not familiar with the cost of solar PV energy (Bureau of Energy, 2014). Moreover, the general populace can barely access to information on solar PV construction and maintenance, as well as the FiT system (Atomic Energy Council, 2014). This data in effect reveals that the general populace are unconscious of (a) the significance of energy diversification, (b) the basic knowledge of solar PV system, (c) the cost and benefit to install a solar PV system, and (d) the policy instrument that has already existed to incentivize investments in solar PV energy.

First, the unawareness of energy diversification disables people from recognizing the necessity to deploy solar PV system. Furthermore, skeptical attitudes toward solar PV energy appear because of insufficient understanding about the technology (Atomic energy Council, 2014). The obscure perception of the cost and benefit to install solar PV systems and the policy instrument even makes people underestimate the profitability. These all pose a significant challenge to diffusion that is achievable only through many efforts to popularize the information and educate people (Emrah & Pranpreya, 2015).

Another social barrier is the lack of a platform to connect investors with roof owners. Generally, a solar PV project necessitates two major prerequisites: money and proper rooftop or land for installation. Investors usually have the capital and interest to invest into solar PV energy but do not own proper sites for installation. Roof owners, on the other hand, own the proper sites but possess little money to invest. Bureau of Energy considered that the existence of a platform would better stimulate this combination, and help speed the deployment (Wu, 2016). Thus, a dearth of the platform also forms the impediment to the speedy diffusion.

The other social barrier is mistrust of installation quality. This barrier exists to hamper the diffusion since 2015 when Typhoon Soudelor slammed into Taiwan, and destroyed over 4 500 solar PV panels (Apple daily, 2015). Electricity generation from 4 500 solar PV panels can

basically suffice over 1855 households per day⁸. The big destruction has made solar PV energy and the quality of installations considerably questioned. Two interviewed companies confirm this point by offering their hands-on experiences to approach customers after the destruction. Both companies received a lot of doubts and inquiries about the quality during the communications with customers; without proper explanations and quality assurance, customers basically would not favor the investment and installation, according to one of companies.

4.1.2 Economic Barriers

Economic barriers involve the issue of profitability, capital insufficiency and loan acquisition. First, during the past few years since the adoption of the Renewable Energy Development Act and the FiT system, the average electricity price only experienced a slight increase, from TWD 2.60 (EUR 0.07) in 2009 to TWD 3.07 (EUR 0.08) in 2014 per kilowatt-hours (Taipower, 2015). This ranks Taiwan as the fourth country with the lowest electricity price in the world (IEA, 2012). The results of the low electricity price include an established energy consumption pattern and high dependence on this range of price (Karl, 2011). Even though people have solar PV installations, these renewable systems are not for self-consumption but for revenues from the FiT system. It is more profitable to sell the electricity than to use it, as the FiT rate is double as high as general electricity price. Thus, without a solar PV system, people still can use electricity at a significantly lower price. This further renders solar PV installation not exactly necessary for people. It is even unprofitable and economically uncompetitive compared with conventional energy sources (Karl, 2011).

The second economic barrier is a high capital requirement for solar PV installation, which is recognized as the largest factor hampering the diffusion (Yang, 2010). Generally, the cost of installation per kilowatt is approximately TWD 30 000 (EUR 810) to TWD 50 000 (EUR 1350). With the cost estimation, a solar PV system installation with 10 kW will cost TWD 300 000 (EUR 8100) to TWD 500 000 (EUR 13510). The maximum cost per kilowatt is tantamount to the average monthly income per person in Taiwan (National Statistics R.O.C., 2015), and only 40-50% of households, who possess disposable income above TWD 800 000 (EUR 21600) per year (Directorate-General of Budget, Accounting and Statistics, 2015), are abler to afford it in Taiwan. Despite having subsidies from some specific municipalities, the majority of people are still unable to afford the initial cost (Pai, 2016).

Finally, the last economic barrier is loan acquisition. Like the financial barriers to ESCO model development mentioned in the literature review, the application of the ESCO model on solar PV development also experiences the difficulty of loan acquisition. Commercial banks show very little willingness to loan money on solar PV projects because the history credit of solar PV industry is not well established. Banks thus are not familiar with the industry and perceive solar PV projects as risky investments (Tseng, 2014). This unfamiliarity and perception furthermore come from limited understanding about solar PV energy and the industry (Tseng, 2014). Without sufficient understanding, banks easily associate solar PV projects with long payback period that renders future profits uncertain. Moreover, the destruction resulted from Typhoon Soudelor further impairs banks and insurers' confidence in this industry. To banks, the devastation has caused serious delays of loan repayments; to insurers, the claim payment for the destruction amounting to 10 billions has inflicted great

⁸ The duration of electricity generation from solar PV energy in Taiwan per day is 3 to 4 hours. Consequently, 1 solar PV panel, which is approximately equal to 1 kW of installed capacity, can generally produces 3 to 4 kWh of electricity per day. 4500 solar PV panels can produce around 18000 kWh per day. According to Taipower, monthly electricity consumption per household is 291 kWh, daily consumption per household is thus 9.7 kWh. With this estimation, 18000 kWh of electricity generation can sustain daily consumption of over 1855 households (18000/9.7=1855).

losses (ChinaTimes, 2015; Huang, 2015). Thus, these two actors have either refused to offer loans on solar PV projects, or increased the collateral conditions and insurance premium after Typhoon Soudelor (Ministry of Economic Affairs, 2015). Unless the borrowers possess strong capital bases and credible collateral for the loans, the feasibility to acquire loans and insurance claims is undermined (Pai, 2016). Without these financial mechanisms, installing solar PV systems have become more unlikely.

4.1.3 Legal-administrative Barriers

Legal-administrative barriers mainly originate from the inadequacy of policy schemes and stipulations in several Acts. Deficiencies in relevant policy schemes include inefficient administrative processes, the absence of systematic mechanisms to facilitate loan acquisition, and the reduction of the FiT rate. Acts creating legal barriers to the diffusion contain the Electricity Law and the National Land Planning Act.

First, cumbersome authorization activities for installing a solar PV system significantly prolong the duration of project accomplishment. An installation project must be processed under the following procedures: (a) solar PV system companies deliver the applications, (b) Taipower assesses the possibility of grid connection, (c) Bureau of Energy authorizes the constructions, (d) investors contract with Taipower, (e) solar PV system companies routinely report construction progress, and register PV system components, and (f) Taipower completes the grid connection (Million Rooftop PVs Promotion office, 2016). Figure 6 illustrates the procedures and shows the complication. Bureau of Energy claims that only 2 to 3 months are required for running procedures (a), (b), and (c) (Chu, 2015); however most interviewed companies' hands-on experiences show that the duration is usually over half a year, irrespective of the the project size is (Cheng, 2016). The deficiency of human resources results in this significant delay. In Taipower, one person undertakes one authorization activity; each activity, however, involves numerous tasks (Pai, 2016). Tasks in procedure (b), for instance, contain the review of all applications and system designs, on-site inspection, documents processing, etc. In order to efficiently implement them, more employees are needed. In procedure (c) and (e), Bureau of Energy outsources the bulk of works to a relevant office at the Taiwan Research Institute, where high turnover rate of staff causes numerous gaps to implement tasks and delays processing. This in effect discourages people's motivation to invest and hinders the diffusion, as the total time needed to complete an installation usually exceeds one year (Pai, 2016).

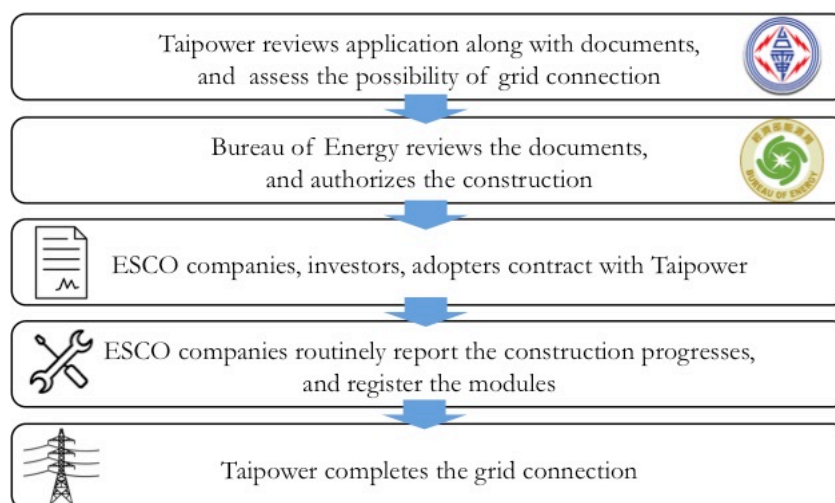


Figure 5. Authorization activities for installing a solar PV system

Source: Million Rooftop PVs Promotion office, 2016

The second legal-administrative barrier is the absence of a standard mechanism to facilitate loan acquisition by regulating the quality of installation and systems. This barrier resembles one of hindrances to ESCO model development mentioned in the literature review, which is a lack of institutional establishment that potentially blurs the liability of ESCO companies and damages the relationships between different stakeholders. In solar PV industry, collateral conditions for loan and insurance claim should also be systematically institutionalized via relevant policy schemes. These conditions necessitate including quality certification (Pai, 2016). As mentioned previously, banks show little willingness to loan on solar PV projects. Such a mechanism can yet secure the bank and insurers' confidence in this industry and increase the accessibility of loan and insurance claim, by explicitly regulating ESCO companies' liabilities to acquire loans, inclusive of quality assurance and certification. Without the mechanism, mutual trusts between these stakeholders are hardly established, which will further influence the provisions of financial supports.

Additionally, the Solar PV Generation System Association ascribes one of legal-administrative barrier formation to the rapid drop of the FiT rate (Ministry of Economic Affairs, 2015). The FiT rate goes down around TWD 1 per kWh every year, and the price in 2015 even approached to the half of the price in 2010. The history of the FiT rate in table 5 shows the trend. Bureau of Energy proclaimed that the declining FiT rate results from the decreasing cost of solar PV panel production and equipment, yet the general costs for an installation does not in effect go down owing to the increase of insurance premium and interest rate for loan after Typhoon Soudelor (Ministry of Economic Affairs, 2015). These increasing expenses are excluded from the considerations to rate establishment, and the drop of the rate undermines the profitability, further discouraging people from investment.

Table 5 Annual FiT rate (Unit: Taiwanese Dollar, TWD)

Category	Installed Capacity	2010 (TWD/kWh)	2011 (TWD/kWh)	2012 (TWD/kWh)	2013 (TWD/kWh)	2014 (TWD/kWh)	2015 (TWD/kWh)	2016 (TWD/kWh)
Roof	1-20 kW	11.18	10.3	9.35	8.27	7.16	6.72	6.18
	20-100 kW	12.9	9.17	8.45	7.43	6.41	5.68	4.97
	100-500 kW	12.9	8.82	8.03	7.02	6.04	5.29	4.58
	>500 kW	11.11	7.97	7.27	6.19	5.23	5.11	4.48
Ground	> 1 kW	11.11	7.32	6.82	5.81	4.92	4.82	4.48

Source: Taipower

Another obstruction created by the Electricity law is the limitation in project size. Projects with installed capacity above 500 kW can contribute more significantly to total power generation in comparison with residential-scale projects. Nevertheless, in Taiwan the percentage of market share occupied by projects larger than 499 kW of installed capacity is only 4% in all installation projects (Lin, 2015). This result is ascribed to the Electricity law stipulating that projects with the installed capacity above 499 kW require additional application for electric industry license. The application is considerably time-consuming, as likewise being processed under cumbersome procedures, according to two interviewed companies who have implemented several of these large-sized projects. Another two interviewed companies also considered this limitation as the greatest hindrance they faced to develop large-scale solar PV deployment.

Another law-related barrier is strict regulations on land use control. The National Land Planning Act delimits the usage of farmland. The uses of the land other than agriculture are not allowed. The restriction causes that abandoned farmland or farmland no longer favorable to agricultural cultivation cannot be further converted into the use for ground-mounted solar PV deployment, and now is left unused. This accounts for a significant underdevelopment of ground-mounted solar PV diffusion in Taiwan, and also the phenomenon that roof-mounted solar PV is more preferentially promoted and deployed (Wu, 2016). Figure 6 gives a quick capture of all barriers mentioned in this section.

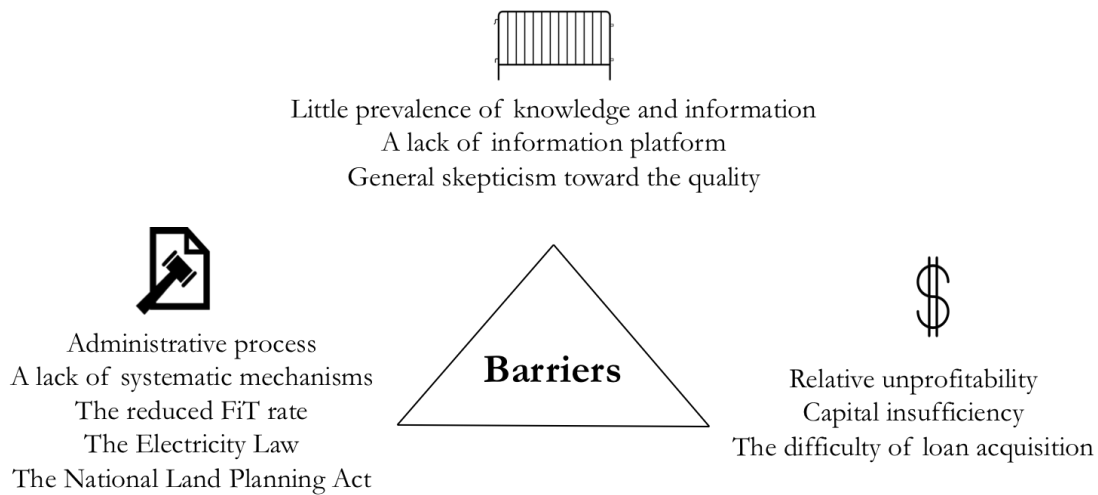


Figure 6. Barriers to solar PV diffusion in Taiwan

Source: Author

4.2 The operationalization of the PV-ESCO model

In this section, background information of interviewed companies and the operationalization of the PV-ESCO model are presented. Background information comprises industry taxonomy, duration of running the PV-ESCO model, projects sizes and numbers that these companies have implemented and public reputation. Secondly, the operationalization shows how companies operate the PV-ESCO model following the morphology of the business model theory.

4.2.1 Long-term output guarantee model

In the output-guarantee model, ESCO companies take charge of all tasks except for funding the projects. Customers, on the other hand, invest their own capital in the projects and make use of solar PV systems for electricity transaction, rather than self-consumption. Compensation will be offered to customers for the failure of achieving a contractual agreed benchmark. In order to discover how this operational design is practically operated, company A and B, who implement this model design, were interviewed. Their background information is presented in table 6.

First, company A is an engineering, procurement and construction (EPC) corporation, and recognized as the most typical, longest-standing and established solar PV system company (Cheng, 2016; Pan, 2016). Aside from running an EPC business, it also devotes itself to developing and selling various solar energy-related products such as solar panels and junction boxes for PV systems. This company initiated the business with this model operation in 2010;

until the beginning of 2016, this company has implemented 120 to 150 projects. Most projects were of industrial-mounted size, but at least 5 projects were of electrically industrial-mounted size. Taking economies of scale into consideration, this company basically rejects to carry out projects with installed capacity smaller than industrial-mounted size.

In terms of company B, its business encompasses EPC and the sale of self-developed monitoring systems for electricity generation. Company B was granted Top Solar System Award⁹ in 2014 (Bureau of Energy, 2014), and is very experienced in solar PV installation and data collection of PV yields in different geographical zones of Taiwan. This company has so far carried out over 117 projects, some of which were residential-scale type.

Table 6. Background information of company A & B

Company	Taxonomy	Duration of Running PV-ESCO model	Project Number and Size	Additional Notes
A	EPC & Solar PV-related product seller	Since 2010	120-150 projects with the majority implemented under industrial-mounted scale	Reject projects with installed capacity smaller than industrial-mounted scale
B	EPC & Solar PV-related product seller	Inaccessible	Over 117 projects with some implemented under residential-mounted scale	None

Source: Author

The customer value propositions placed in this model design consist of quality assurance, higher return on investment (ROI) and internal rate of return (IRR) that are achieved under the means of the system warranty and the output guarantee. The system warranty offered by company A provides limited warranty that features cost-free system maintenance and repair in the first five years, and the paid service in the following 15 years. It basically shows ESCO companies' commitments to take care of the systems for 20 years. The output guarantee, as mentioned previously, promises a benchmark of generation performance, and leads to compensations if performance goes worse than the benchmark. These guarantees firstly ensure the quality of systems by offering top-notch modules and good after-sales service to keep the optimal systems operation. The optimal operation further stabilizes the provision of high yields, and creates higher return on investment (ROI) and internal rate of return (IRR) for customers despite greater expenses. The IRR in a 20-year-long project with installed capacity around 500 kW can even reach 16.5%, according to company A's calculation offered to customers. This rate is much higher than the IRR of depositing money in banks¹⁰, and shows the worthiness of investing in solar PV systems.

With regard to target customers, installations under this model are capital-intensive because of first class module acquisition; yet this model is designed that projects are completely funded by customers themselves. This implies that adopters need finances sufficient to cover higher

⁹ Tops Solar System Award issued by Bureau of Energy is the highest honor and recognition for solar companies in Taiwan.

¹⁰ According to Taiwan Rate.com, interest rate for yearly savings in most banks is 1.1%, with which the IRR of depositing money in banks is usually less than 1.0%.

upfront costs. Therefore, only middle to high incomes groups are the target customers. However, for (electrically) industrial-mounted scale projects that usually require stable financing sources, target customers are commercial firms, who are interested in PV adoption and collaboratively establish special purpose vehicle (SPV) to systematically manage their finances. This group of firms, according to company A, would ceaselessly continue the investments and turn into loyal customers.

To approach target customers, companies greatly make use of geographical relations and neighborhood ties that more feasibly associate companies with local customers. This is evidently shown at company B, who implemented the majority of projects located in the counties where company B has an office. Channel partners and existing links are another means less significant in terms of getting in touch with customers. For example, company A particularly has built partnership with architects, estate agencies and original customers that serves as links to explore new clients. The systematized door-to-door visits also assist to explore new customers. Proper rooftops are identified with Google Earth ahead of the visits. This helps companies narrow down the scope to search for customers.

In terms of customer relation, a passive relation management is built on the contracts that include output guarantee, maintenance, and system monitoring. It indicates that ESCO companies basically will not do anything other than the tasks stipulated in contracts for customers, and the relation will cease when contracts expire. ESCO companies in the output-guarantee model, however, are more inclined to have an active or interactive relations management, in order to turn first-time customers into loyal clients and further make use of their network. Therefore, ESCO companies would preferably manage this active or interactive relation by helping customers to explore proper rooftops, offering advisory support on loan and insurance, or even directly coordinating these requests with commercial banks and insurers. With these additional interactions, duration of relation between ESCO companies and customers in this model usually exceeds 20 years.

The arrangement of activities that support delivered value involves after-sale service, remote monitoring systems, and the procurement of top-notch modules and components. After-sale service that companies take over contains every part of PV systems, inverters and solar panels in particular. To minimize the impacts, both interviewed companies would timely take care of the problems after receiving fault reports; the longest duration of restoration will not be more than three days. This timely repair and maintenance significantly requires the assistance of remote monitoring systems, by which the hourly data of power generation is reported and stored. The hourly reports enable ESCO companies to actively detect problems and provide timely solutions. In such a manner, systems will always operate under the most optimal conditions, and bring the greatest earnings. According to company B, with monitoring systems, it has not yet experienced any failure of benchmark achievement. Besides, cautious procurement of modules and components is indispensable to underpin the delivered values. Aside from the quality of module, companies also necessarily think over suppliers' commitments to provide after-sale service for these products. Some equipment, inverters for example, cannot receive proper repair in a dearth of original manufacturers' assistances (Pan, 2016). Suppliers' expertise is usually needed to identify and fix these problems, thus companies necessarily consider the willingness of suppliers to help out during the procurement. In addition, companies should have enough modules in stock for timely replacement. These all are for shortening the duration of system malfunction.

To sustain EPC business, basic competency encompasses system design, equipment procurement, and construction. Nevertheless, for companies who operate the output-guarantee model design, well-documented data is essential to the operation. Company B

claimed that solely companies having a very integral database that records power generation in different regions are capable of adopting this model design. The benchmark of electricity generation varies from region to region, and county to county. Giving customers the benchmark that suits local conditions requires a supportive database to help judge and calculate electricity generation. This forms another reason why hourly reports from remote monitoring system are necessary as well. Teams strong in the acquisition of roof projects and maintenance & repair are vital to sustain this model design as well. The site developer team exists for approaching potential customers and assisting professional investors. Owing to an absence of the platform to connect investors with site owners, these ESCO companies that are generally more experienced than investors in site exploration, would need to take this responsibility. As to the maintenance & repair teams, their importance lies on its central role to support the optimization of system operation.

Regarding the partner network, maintaining partnership with banks and insurers outweighs other relation with other stakeholders. Active or interactive relationship maintenance involves the assistance provided by ESCO companies in negotiating the collateral conditions for loans and insurer claims. Good partnerships with banks and insurers facilitate these two stakeholders' willingness to offer professional investors less strict collateral conditions. In order to be creditable partners, ESCO companies' reputation and commitment to electricity generation play the central role. Both company A and B are the veterans of this industry, and well reputed for providing quality installation and service. Thus, for banks and insurers, companies A and B are trustworthy enough to accept their suggestions and coordination. Additional partnerships with suppliers, architects, and even estate agencies—although being not the most significant network to be managed—are still necessarily established for providing first class modules along with after-sale service and approaching more customers.

From the customers' perspective, the cost structure under this model design consists of construction costs, loan interest, insurance fees, and expenses on maintenance & repair after the warranty period. Ranging from TWD 50 000 (EUR 1351) to TWD 80 000 (EUR 2161) per kW, expenditures of ESCO model installation are usually higher than general installations. However, this model still possesses high ROI and IRR due to the greatest revenues from the FiT system. Consequently, as long as customers have the financial capability to afford the initial costs, high profitability follows in the wake of installations. The operationalization of company A and B is organized in table 7.

Table 7. Morphology of the long-term output guarantee model

Elements	Operationalization
Customer value	<ul style="list-style-type: none"> • System warranty • Power generation guarantee • Quality assurance • Higher return on investment (ROI) and internal rate of return (IRR)
Target customer	<ul style="list-style-type: none"> • People having large estate • Professional investors • Special purpose vehicle (SPV)
Distribution channel	<ul style="list-style-type: none"> • Geographical relationships • Existing links with loyal customers • Channel partners • Systemized door-to-door visit with the assistance of Google Earth
Customer relation	<ul style="list-style-type: none"> • Passive long-term relation: contracts

	<ul style="list-style-type: none"> • Active long-term relation: partnership development
Value configuration	<ul style="list-style-type: none"> • After-sale service • Top-notch equipment and module • Remote monitoring system
Core competency	<ul style="list-style-type: none"> • A package of service for general PV installation: system design, equipment procurement, construction • Well-documented database • Developer team • Maintenance & repair team
Partner network	<ul style="list-style-type: none"> • Core: <ul style="list-style-type: none"> ■ Banks and insurers • Sided: <ul style="list-style-type: none"> ■ Suppliers ■ Architects ■ Estate agencies
Cost structure (customer perspective)	<ul style="list-style-type: none"> • Construction costs • Loan interest • Insurance fees • Expenditures on maintenance & repair during the following 15 years
Revenue model (customer perspective)	<ul style="list-style-type: none"> • FiT system

Source: Author

4.1.2 The site-lease model applied to (electrically) industrial-mounted projects

The installation site-lease model (the site-lease model)¹¹ is characterized by providing a full package of service, inclusive of project design, construction, operation, maintenance & repair, and financing especially. This model enables ESCO companies to use roofs or land, own and operate PV systems over the contractual agreed period, and acquire revenue from the FiT system. In such a design, the ownership of solar PV systems and FiT revenues belong to companies, who play a synthetic role of EPCs and investors under this model.

In this section, to examine the operationalization of the site-lease model, all companies were interviewed following their role of being an investor, rather than an engineering, procurement and construction (EPC) corporation. Thus, customers indicated here are not adopters who afford the upfront costs by themselves, but roof owners and landlords who rent out installation sites. To explore the operationalization of the site-lease model on (electrically) industrial-mounted projects, company C, D and E were interviewed. Their background information is presented in table 8.

First, company C is a subdivision under a large conglomerate, whose business primarily focuses on the sale of plastic-related products. The subdivision is financially independent from the conglomerate, and the solar PV business has contributed only a minor portion of earnings in comparison with the conglomerate's other revenue. However, the company has endeavored to manage its PV business for a long time. It holds fast to offering the first-rate solar PV systems and installation service, which indeed helps gain great recognitions from a third-party

¹¹ The following text will use the site-lease model instead to indicate the installation site-lease model.

verifier (Chan, 2016). Also, together with company B, it was granted Top Solar System Award in 2014 (Bureau of Energy, 2014). Large-sized projects are principally the market niche of this company. So far, at least 250 projects have been accomplished, with the most implemented under industrial-mounted scale. The company itself owns two electrically industrial-mounted solar power plants, one of which is the largest one in Taiwan.

Company D started business with optoelectronic products, which nowadays still account for a great percentage of its total earnings. In 2008 this company initiated its solar PV business, devoting itself to the research and development for solar PV panels, as well as EPC business. In 2015, it was the winner of Top Solar System Award (Bureau of Energy, 2015), and is likewise well reputed in the solar PV industry. So far, the total capacity of all projects accomplished by the company has been up to 34.7 MW. In 2016 the company projects to have 20 MW more installed capacity. It also owns an electrically industrial-mounted solar power plant that is the biggest roof mounted project in Taiwan.

Company E is affiliated to a conglomerate whose primary business is selling silver and aluminum paste. The major business of this affiliated company includes the sale of solar PV panels and operating EPC. Finance necessary to run these businesses comes completely from the conglomerate. This company has managed solar PV business over 7 years, thus being well reputed on offering good quality (Pai, 2016). Until the end of 2015, the total capacity of all accomplished projects has been up to 5 MW; a project with 1.5 MW of installed capacity will be completed in 2016. Taking the economies of scale into account, company E now does not accept projects with installed capacity less than 300 kW.

Table 8. Background information of company C, D & E

Company	Taxonomy	Duration of Running PV-ESCO model	Project Number and Size	Additional Notes
C	Main: plastic-related products seller Sided: EPC	From 2010	At least 250 projects with the majority implemented under industrial-mounted scale	Own two electrically industrial-mounted solar power plants and principally target to implement these large-sized projects
D	Main: optoelectronic products seller Sided: EPC & solar PV panels seller	From 2008	Total capacity of all accomplished projects accomplished has been up to 34.7 MW	Own one electrically industrial-mounted solar power plants
E	EPC & solar PV panels seller	From 2009	Total capacity of all accomplished projects has been up to 5 MW	Reject projects with installed capacity less than 300 kW

Source: Author

Values proposed to customers in this model design are composed of stable rental incomes, no upfront cost, environmental-friendly corporate image, thermal insulation, strong commitment to maintenance & repair, and quality assurance. First, stable rental incomes and no upfront cost are especially vital. This combination creates an economically feasible business with low

risks for customers, as the additional revenues come without paying any cost for installations and maintenance & repair. The co-benefit of solar PV installations, environmental-friendly corporate image and thermal insulation¹² are secondarily important. These two values potentially bring customers indirect economic benefits such as reduced expenses on electricity consumption, which can also attract customers' interests, according to company E. Furthermore, in order to seek for benefit maximization from FiT revenues, companies would pursue the greatest power generation yields. These can be attainable only under optimized system operation with premium modules and constant maintenance & repair. Based on this reason, company would be strongly committed to taking care of the systems for 20 years. The strong commitments to a certain extent are important to customers. Fixed percentage of FiT revenues distributed to customers is stipulated in the contracts; therefore, rental incomes are long-term and based on the monthly generation yield. In cases where the PV system exceeds projected yields, customers can also receive more revenues from rental fees.

In terms of target customers, as mentioned previously, the site-lease model design works more suitably on (electrically) industrial-mounted projects. Consequently, people having large-sized rooftops and land are target customers. This particular group involves farmhouse owners, factory owners, governmental agencies, public schools and landowners. From interviewed companies' hands-on experiences, strong commitment, quality assurance, stable rental incomes and no upfront cost are the values necessarily delivered to all types of customers. However, company E also differently emphasized values when communicating with different groups of customers. Values to factory owners, for example, are additionally focused on the contributions to establishing good corporate image and bringing heat insulation. Stable rental incomes, on the other hand, are of particular importance to farmhouse owners, governmental agencies, and public schools, who possessing fixed incomes and are relatively not wealthy.

The above-mentioned values are channeled via word-of-mouth communication, door-to-door visits and channel partners such as engineers. Company C and D regarded customers' word-of-mouth communication as their major approach to get in touch with new roof owners and landlords. Active customer exploration is less important for these two companies, since the established reputation for quality assurance has helped attract customers. For company E, door-to-door visit and channel partners' assistance are the main strategies to search for more customers. Unlike the systematized door-to-door visits mentioned previously, the way adopted here is a random picking of roof owners and landlords. However, in some cases, it is architects, construction engineers, and suppliers, who keep partnerships with ESCO companies, bridge these ESCO companies and customers.

Relations with customers are formalized by contracts covering lease stipulation, maintenance & repair, and system monitoring. The relation maintenance in this model is not as interactive as the relevant management in the output-guarantee model. From customers' side, they completely authorize ESCO companies to operate the systems with companies' own manners, and less care about the provision of after-sale service. From the ESCO companies' side, they unilaterally take over all processes, including financing. Compared with the guarantee model, this decreases the opportunities to interact with customers. Despite little interaction, in order to uphold established reputation, the interviewed companies still search for passive but good relationship maintenance by providing quality system installations.

¹² The average temperature in Taiwan during summer period reaches nearly 30 Celsius degree, based on the statistics of Central Weather Bureau. According to the director of Million Rooftop PVs Promotion Office, solar PV panel is proved to have better effect of insulation than corrugated sheet iron, which is usually used for roof pavement on buildings and factories in Taiwan. Better effect of insulation in effect conduce to energy efficiency in a building, and can help decrease the expense on electricity consumption.

In order to accentuate the values, company C and D arrange demonstration site tours, where people can acquaint themselves with renewable energy, solar PV energy and the operation of premium systems. These tours are open to the general populace, and can function as an education opportunity. The biggest solar power plant managed by company C, for example, serves as a model installation, and greatly conduces to reputation establishment and customer attraction. Another activity underpinning the value of quality assurance is relevant to third-party verification. Company C, for instance, authorizes Industrial Technology Research Institute, a quasi-governmental research unit, to ensure the quality. A series of verification processes include documents review, on-site inspection and equipment test, assure safety, quality and operation of systems (Chan, 2016). In terms of supporting the value of strong commitment, after-sale service and remote monitoring systems for electricity generation are offered. Under this model design, companies more actively carry out maintenance & repair, since the maximization of profits requires the optimal system operation. Thus, company D and E routinely dispatch maintenance & repair teams to manually wash PV panels and inspect systems.

Similar to the output-guarantee model, system design, equipment procurement, and construction are the basic competencies to keep the business of a solar PV system company. However, adopting the site-lease model especially requires strong financial resources to cover all costs for installing and running the systems. Usually, a combined support from parent companies and banks stabilize these resources. Additionally, all interviewed companies under this model possess integrated maintenance & repair teams, which is an essential asset competency for optimized system operation.

Relationships with banks are prioritized for partner network management when operating the site lease model. Upfront cost per industrial-mounted project requires exceeds TWD 3 000 000 (EUR 81 080). Without financial support from banks, ESCO companies are usually unable to sustain the operation of this model. This relationship is maintained via quality assurance and company reputation, with which banks' intrinsic disbelief in solar PV projects has been slightly eliminated. Third-party verification for installation procedure and PV systems, according to company C, significantly helps in this part as well. Another key partner for companies are insurers. As more capital is invested, insuring PV systems becomes more necessary in order to reduce risks. Similarly, companies need to keep this relationship through guaranteeing the quality of systems and installations. Company D shows the way to this maintenance. Based on a strong commitment to provide top-notch solar PV systems, several insurers show their willingness to collaboratively establish a special purpose vehicle (SPV) with company B. This SPV assists in fund and insurance provision, further stabilizing company B's financial balancing sheet. Other partners of ESCO companies in this model are suppliers and engineers, who assist not only in bridging ESCO companies and customers, but also in repairing PV systems.

As to the cost and revenue, the largest attribute of this model consists in a complete project financing that is included in ESCO companies' service. Customers can completely enjoy free-of-charge installation and long-term income by renting out roofs and land. As to the profit, revenues basically come from rental fees, and vary depending on the agreed percentage of FiT income stipulated in the contracts. The operationalization of company C, D and E is organized in table 9.

Table 9. Morphology of the lease model applied to (electrically) industrial-mounted projects

Element	Operationalization
Customer value	<ul style="list-style-type: none"> • Primary:

	<ul style="list-style-type: none"> ■ Long-term rental income based on yield ■ No upfront cost • Secondary: <ul style="list-style-type: none"> ■ Environmental-friendly corporate image ■ Thermal insulation • Tertiary: <ul style="list-style-type: none"> ■ Strong commitment to maintenance & repair ■ Quality assurance
Target customer	<ul style="list-style-type: none"> • Farmhouse owners • Factory owners • Governmental agencies • Public schools • Landlords
Distribution channel	<ul style="list-style-type: none"> • Word-of-mouth communication • Random door-to-door visit • Channel partners
Customer relation	<ul style="list-style-type: none"> • Passive long-term relation: contracts
Value configuration	<ul style="list-style-type: none"> • Demonstration site tours • Third-party verification • After-sale service • Remote monitoring system
Core competency	<ul style="list-style-type: none"> • A package of service for general PV installation: system design, equipment procurement, construction • Finance • Maintenance & repair team
Partner network	<ul style="list-style-type: none"> • Core: <ul style="list-style-type: none"> ■ Banks and insurers • Sided: <ul style="list-style-type: none"> ■ Engineers ■ Suppliers ■ Third party verifier
Cost structure (customer perspective)	<ul style="list-style-type: none"> • None
Revenue model (customer perspective)	<ul style="list-style-type: none"> • Long-term rental income based on yield

Source: Author

4.1.3 The site-lease model applied to residential-mounted projects

The model design in this section completely resembles the site-lease model applied to (electrically) industrial-mounted projects. Accordingly, all interviewed companies play the role of an investor, rather than an EPC. Also, customers referred here are site owners who rent out installation sites. Company F and G, belonging to small and medium-sized enterprises (SMEs), were interviewed to explore the operationalization in this section. Their background information is presented in table 10.

Company F has operated solar PV business for several years but simultaneously has additional business in heat insulation and energy efficiency. This company offers the installations and systems certified by TÜV Rheinland, a global testing, certification, and training provider. Until

2016, this company has carried out 15 projects, all of which were residential-scale type. The accumulated capacity from all projects has reached to 150 kW.

Regarding company G, its business involves EPC and the sale of self-developed monitoring systems for electricity generation. It now also executes the business of second-hand cars transaction. Solar PV business was initiated in 2013; currently the company has accumulated 3 years of experience in installation as well as data collection. It is also well famed for implementing building-integrated PV (BIPV) system projects (Pai, 2016). So far, the company has implemented over 125 projects, around 80 of which were residential-scale type. The cumulative capacity has been up to 10MW, and in 2016 the company targets to accomplish 10 to 20 MW of installed capacity.

Table 10. Background information of company F & G

Company	Taxonomy	Duration of Running PV-ESCO model	Project Number and Size	Additional Notes
F	EPC & Energy efficiency service provider	Inaccessible	15 projects, with all are residential-scale type	Only focus on residential-scale type project
G	Main: EPC & Solar PV-related product seller Sided: Second-hand cars transaction	From 2013	125 projects, around 80 of which are residential-scale type	Accept all sizes of installation project

Source: Author

Value propositions for residential-mounted projects are characterized by quality assurance, no upfront cost, stable rental income, additional functions such as sunshade, rain canopy, as well as thermal insulation, and aesthetical appealing and differentiation from other buildings. In the site-lease model, quality assurance, no upfront cost and stable rental income are certainly conveyed irrespective of project size. However, according to company F, compared with these three values, additional functions and aesthetical appealing are more favored by residential customers in this market. Sunshade, rain canopy, and thermal insulation, for customers, practically conduce to enhancing the function of residential buildings, which further contribute to better residential quality. The function of sunshade and thermal insulation especially captures customers' attentions, due to longer and longer duration of scorching hotness. Another addition to delivered values is aesthetical differentiation from other buildings. Solar PV panels are much more aesthetically appealing than corrugated sheet iron roof that is typically and commonly seen in Taiwan. In the interview, company F several times emphasized how this ornamental function evoked customers' interests.

Target clients in residential-scale projects comprise general dwellers with rooftops suitable for installation and residents in a community. The suitability of rooftops is a prerequisite condition to select customers. Roofs on residential buildings are mostly dominated by corrugated sheet iron pavement, which possesses weak structural to underpin the construction of solar PV systems. This would make ESCO companies narrow down the scope to pick customers. Additionally, targeting the installation on a residential building situated in a community is vital as well. Two interviewed companies all experienced a spillover effect that results from the existence of a model demonstration and strong word-of-mouth communication in a community. As long as companies are capable of capturing one customer in a community, others will actively show their interests in the wake of the first installation.

For company G, it prioritizes the ease to get along with customers when searching for target clients. This company sticks to regarding customers as good neighbors, thus would prefer to target residents with mild temperament. On the other hand, for company F, who dedicates itself to managing residential-scale projects, owners with large building roofs and land are basically excluded from the target clients on account of its preference and capability to implement small-sized projects.

As to distribution channels, both word-of-mouth communication and community management are the main channels. A close attachment to a community is usually managed through active interactions with not only roof owners but also their neighbors. These people have strong competency spreading the information, and can greatly assist in publicizing product and service values. However, company F also mentioned that developing this bond would not be easy; it usually requires an internal connection such as geographical relation that helps bridge psychological distance between companies and local people. Therefore, company F particularly hires a local to manage and expand the bond.

Regarding customer relation, similar to the site-lease model adopted for large-scale projects, 20-year-long relations with customers are tied by contracts that include lease stipulation, maintenance & repair, and system monitoring. Considering the influential role that residents play in advertising communication, aside from passive relationship management built on contracts, companies also take the initiative to provide customers with other customized services that strengthen the functionality and value of residential buildings. Company F, for example, additionally helps construct carports with broken solar PV panels and coat the buildings with heat-resistant materials. Company G, on the other hand, pays more efforts to communicate with dwellers and their neighbors, attempting to expand this target group by catering to their tastes and needs. Another means to strengthen this relationship is through quality provision. It is more necessary for ESCO companies to provide premium systems that satisfy customers enough to bring strong word-of-mouth communication.

Values proposed to habitants are sustained by activities such as after-sale service, third-party verification, remote monitoring systems for electricity generation, construction reinforcement for the whole building design, and shade simulation. Company F pointed out the necessity to have the third-party verification in order to eliminate customers' concerns about the instability of the whole construction; these concerns were in effect derived from the destruction in Typhoon Soudelor. In order to ensure the quality and optimize the system operation, company G chooses to install remote monitoring systems that are not commonly included in most residential installations. Moreover, as installation sites are dwelling places, the security is highly considered. Construction reinforcement adopted by company G strengthens the structural support under the roof, and shade simulation tells the optimal design for installations. These are all for bringing habitants the safest and most customized system installations.

Basic competency here also contains system design, equipment procurement as well as construction, and financial competency is also the central of running the site lease model irrespective of project size. Categorized as small and medium-sized enterprises, both company F and G rely on financial support from banks more than their own capital. Hence, companies need to maintain their abilities and qualifications to ask for loans. Furthermore, profit that residential-scale projects have is much less than the earning that (electrically) industrial-mounted projects produce. In order to suffice for all expenditures, both companies have other businesses such as energy efficiency services, sales of solar PV-related products, and second-hand cars; these, from company F's perspective, are very required to bolster the site-lease model business. Besides, less profits also turns maintenance & repair teams into the central to

companies' competency. Company F points out that it also seeks for the optimization of system operation in order to profit as much as possible. This requires knowledgeable and efficient maintenance & repair teams that are equipped with abundant technical expertise dealing with different types of issue.

As to the partner network, due to great reliance on banks' support, good relationship maintenance with this group outweighs partnerships with other stakeholders. For these two companies, after-sale service and quality assurance are the threshold to open bankers' minds, yet building a truly mutual trust lies on the provision of third-party verification, construction reinforcement, established reputation and PV demonstration projects. Besides, suppliers and third party verifiers need to be incorporated into the network, given their roles to strengthen ESCO companies' quality assurance and after-sale service.

Lastly, the cost and revenue model is identical to the site-lease model applied to large-scale projects, where customers receive monthly rental fees but are not responsible for the payments of deployment and system operation. The operationalization of company F and G is organized in table 11.

Table 11. Morphology of the lease model applied to residential-mounted projects

Element	Operationalization
Customer value	<ul style="list-style-type: none"> • Primary: <ul style="list-style-type: none"> ■ Additional function as sunshade and rain canopy ■ Aesthetical appealing and differentiation from other building ■ Thermal insulation • Second: <ul style="list-style-type: none"> ■ Strong commitment to maintenance & repair ■ Quality assurance ■ Long-term rental income based on yield ■ No upfront cost
Target customer	<ul style="list-style-type: none"> • Dwellers with proper roofs • Residents in a community
Distribution channel	<ul style="list-style-type: none"> • Word of mouth communication • Community management • Regional relationships
Customer relation	<ul style="list-style-type: none"> • Passive long-term relation: contracts • Active long-term relation: partnership development
Value configuration	<ul style="list-style-type: none"> • After-sale service • Third-party verification • Remote monitoring system • Shade simulation • Construction reinforcement for the whole house design
Core competency	<ul style="list-style-type: none"> • A package of service for general PV installation: system design, equipment procurement, construction • Other auxiliary business • Maintenance & repair team
Partner network	<ul style="list-style-type: none"> • Core: <ul style="list-style-type: none"> ■ Banks

	<ul style="list-style-type: none">• Sided:<ul style="list-style-type: none">■ Suppliers■ Third party verifier
Cost structure (customer perspective)	<ul style="list-style-type: none">• None
Revenue model (customer perspective)	<ul style="list-style-type: none">• Long-term rental income based on yield

Source: Author

5 Discussion

This chapter elaborates on the discussion extended from results by clearly presenting the ways that how the PV-ESCO model may help overcome barriers, and the transformative operationalization from (electrically) industrial-scale installation to residential installation. Answers to the second and third research questions are presented in this chapter. Moreover, this chapter provides the directions for future policy revision and legislation amendment.

5.1 The role of the PV-ESCO model in overcoming barriers

With a large percentage of projects adopting the PV-ESCO model, this model shows its way to help overcome different aspects of barriers. This section explores which aspects of barrier are conquered, and how they are overcome. Table 12, placed in the end of this section, summarizes the exploration.

5.1.1 Social Aspects

The PV-ESCO model addresses social barriers jointly formed by limited knowledge, the absence of information platforms and quality concerns through its internal elements, which include distribution channels, value configuration, partner network, and competency.

Distribution channels

As suggested by the Chairman of Solar PV Generation System Association of R.O.C (2016), the PV-ESCO model was introduced to render solar PV deployments and relevant information speedily widespread. This is fulfilled through distribution channels, which accelerates the prevalence of knowledge and information. This study finds that these channels expand the opportunities to completely familiarize a large group of people with solar PV energy and FiT system. First, door-to-door visits, especially being implemented under random picking, involves a larger group of people to be notified of this knowledge and information. Part of interviewed ESCO companies pointed out that ahead of the visits, other solar companies had already visited all farmhouse owners, which made this group of people very acquainted with this information. Besides, door-to-door visits also prevent people from receiving false and scattered information. This active communication thoroughly delivers a package of correct knowledge and information to customers.

Word-of-mouth communication is another channel facilitating the spread of accurate knowledge and information. This thesis discovers that as a spillover effect of information dispersion would rapidly occur when one installation was accomplished, some interviewed ESCO companies considered every project as educational opportunities to pass accurate information on to more people. The effect is usually formed through word-of-mouth communication, and offers the general populace the access to more correct information. Gillingham's and Bollinger's academic study (2012) confirms this point. One of the conclusions in the research is that peer effects caused from word-of-mouth communication transfer the accurate information and can decrease the uncertainty in the expected value of installations (Gillingham & Bollinger 2012). From the literature and data, the effect of word-of-mouth communication to overcome the barrier of information immobility and inaccuracy has been theoretically and practically reflected.

Value configuration

In the PV-ESCO model, value configuration also positively influences the spread of information through internal activities. The author's finding shows that demonstration site tours, as a vital activity, service as opportunities to educate people. Tours, where visitors are

informed of the importance of renewable energy development, the basic knowledge of solar PV systems, and the FiT system, are basically open to all people. Hence, a lot of people are accessible to a package of accurate knowledge with this direct guidance in solar power plants.

Another finding reveals that the setup of remote monitoring systems for electricity generation, as a necessary activity to bolster the operation of the PV-ESCO model, significantly helps collect the data of PV yields in different geographical zones of Taiwan. Several interviewed companies considered that government paid few efforts on collecting data of solar power generation. The insufficiency of data collection, although is not serious enough to form a barrier, still requires to be fixed up. Hourly report and storage of electricity generation in different regions and counties can keep replenishing the database, and speed up the collection.

Moreover, value configuration in the PV-ESCO model makes customers less doubtful about the quality of installations and systems. In this model, ESCO companies need to commit themselves to managing a 20-year-long relation with customers, during this period after-sale services are constantly offered, and remote monitoring systems hourly detect the problems and report the power generation. This careful monitoring exists owing to the pledge of benchmark achievement and the ambition to attain the greatest yields, which all force companies to cautiously take care of systems during the contract period. Out of this factor, companies prefer to install the systems with top-notch modules as well as components.

Partner network

Managing partner networks in the output-guarantee model brings positive impact on spreading knowledge and information as well. The research discovers that good partnerships with banks and insurers are built on the delivery of information. In order to help negotiate, ESCO companies need to manage the partnerships by making these stakeholders recognize them as trustworthy partners. The right knowledge of solar PV energy, as well as how to recognize the quality of systems is ceaselessly passed on to these stakeholders. This information can acquaint the stakeholders with the industry and ESCO companies, further consolidating stakeholders' trust in ESCO companies. Thus, with ESCO companies' coordination between customers, banks and insurers, more information is distributed to these key stakeholders in the industry.

In the site-lease model, partner network management motivates companies to offer PV installations with good quality. As mentioned previously, developing mutual trust with banks and insurers is of particular importance to ESCO companies who operate the site-lease model. However, trust has gone down after typhoon Soudelor; therefore, ESCO companies are motivated to keep these relationships by focusing on the quality of products or acquiring third-party verification.

Competency

The output-guarantee model is capable of tackling the barrier of a missing information platform that connects the investors and site owners. Developer teams fill up the gap by searching rooftops and land suitable for installation. Their cumulative experience as well as systematized methods successfully assists in approaching site owners, and finding proper installation sites for investors. Through the coordination initiated by these teams, more owners and investors are matched up, and more deployment comes up afterwards.

Besides, efficient maintenance & repair teams exert positive impacts on removing the skepticism toward the quality of PV installations. Timely restoration along with routine

maintenance provided by ESCO companies completely ensures good operation of PV installations over 20 years.

5.1.2 Economic Aspects

Economic barriers exist because of relative unprofitability, capital insufficiency and loan inaccessibility. These are dealt with values proposition, cost-benefit structure and customer relation and partner network that are inherent in the PV-ESCO model.

Value proposition & Cost-benefit structure

First, values in the output-guarantee model bring customers the security to invest into solar PV installations. These values compose a long-term mechanism that guarantee the PV yields, customers' revenues and good operation of PV systems. Stipulated in the contracts, this mechanism in effect renders investments not only much less risky but also certainly profitable.

Besides, this study finds that values and cost-benefit structure proposed in the site-lease model also address the issue of profitability. These values bring customers co-benefits of installations and long-term stable rental incomes, but exempt them from paying upfront costs. The exemption, in both (electrically) industrial and residential-scale projects, is particularly appealing to customer groups who are interested in the deployment but have little capital to cover the expenses on installations.

Customer relation

In the PV-ESCO model, managing customer relation conduces to solving the issue of capital insufficiency. ESCO companies voluntarily provide assistance in the negotiation of collateral requirements for loan, in order to keep close relationships with customers. With the coordination, loans are more acquirable for customers, and to a certain extent alleviate their financial stress. One of interviewed ESCO companies claimed that their customers' had not experienced any failure to acquire loans under its coordination. This implies that ESCO companies in effect exert great impacts on loan acquisition, and the coordination can be the key to customer relationship management.

Aside from the coordination on loan acquisition, companies also help customers bargain with insurers. Likewise, lower insurance fees are also negotiable and acquirable due to ESCO companies' coordination. The attainment of lower insurance fees would further decrease the upfront costs, and renders the installations more affordable for customers.

Partner network

Partner networks managed by ESCO companies deal with the difficulty of loan acquisition. ESCO companies, especially operating the site-lease model, necessarily build mutual trust with banks by providing after-sale service, quality assurance, third-party verification, construction reinforcement, and showcasing PV demonstration projects. The established trust would further facilitate banks' willingness to offer loan on solar PV projects. Furthermore, ESCO companies usually have a certain level of financial background and reputation that characterizes them as more trustworthy borrowers for banks. The powerful financial background would make banks more inclined to approve loan requests from ESCO companies than from individual adopters.

5.1.3 Legal-administrative Aspects

Legal-administrative barriers consist of inefficient administrative processes, the absence of systematic mechanisms, reduced FiT rate and strict laws regulating the electric power industry and land use. The PV-ESCO model helps very little in changing these processes, policies and legislations, but facilitates to tackle some of barriers more efficiently than other models can do.

In regard to administrative process, all solar companies are basically obligated to process this complex administrative application for customers. This process is applicable to all projects with no exception to PV-ESCO projects, and human resources for processing the grid connection assessment and installation authorization are not expanded when more ESCO projects are coming (Pai, 2016; Cheng, 2016). However, the compulsory responsibility undertaken by solar companies more or less helps tackle this barrier formed by complex authorization activities, from customers' viewpoint. As the literature review suggests, solar companies' familiarity with administrative and legislative requirement makes the installation less burdensome for customers (Ribeiro, 2011).

The PV-ESCO model barely conquers barriers originated from the reduction of the FiT rate, strict stipulations in the Electricity Law and the National Land Planning Act. These regulations and calculations are either codified or institutionalized in the laws and policies, and do not vary or create any exceptional interpretation for the PV-ESCO model. Hence, the changes can only be attained through policy and law amendments.

Despite few contributions to overcoming most legal-administrative barriers, the PV-ESCO model exerts a positive impact on building the systematic mechanisms to facilitate loan acquisition. Due to the relationship maintenance with banks and insurers, ESCO companies voluntarily undertake third-party verification, and offer after-sale service, as well as installations with good quality. One of interviewees expects that these voluntary provisions would gradually form unspoken rules, and lay the foundation for the mechanism establishment in the future. The practice, also, is worthy to be referred when government plans to institutionalize the mechanism.

Table 12. Barriers overcome by the PV-ESCO model

Aspect	Barriers	Elements	Operationalization
Social	Limited Prevalence of Knowledge & Information	Distribution channel Value configuration Partner network	<ul style="list-style-type: none"> Door-to-door visits, word-of-mouth communication, community management Demonstration site tours, remote monitoring systems Coordination on loan and insurance
	The Absence of Information Platform	Competency	<ul style="list-style-type: none"> Developer team
	Quality Concerns	Value configuration Competency Partner network	<ul style="list-style-type: none"> After-sale service, remote monitoring systems Efficient maintenance & repair team Relationship maintenance with banks, insurers and

			customers
Economic	Relative Unprofitability & Capital Insufficiency	Value proposition Customer relation Cost & revenue structure	<ul style="list-style-type: none"> Free-of-charge installation, stable rental income Coordination on loan and insurance
	Loan Inaccessibility	Partner network	<ul style="list-style-type: none"> Relationship maintenance with banks and insurers
Legal-administrative	Administrative Process	X	X
	Reduced FiT rate and Strict Laws	X	X
	The Absence of Systematic Mechanisms	Partner network	<ul style="list-style-type: none"> Relationship maintenance with banks and insurers

Source: Author

5.2 The PV-ESCO Model Adjusted for Residential-scale Projects

The PV-ESCO model has been mostly applied to large-scale projects and industrial-mounted installations. Nevertheless, large-scale installation sites are gradually becoming exhausted (Wu, 2016). This implies a necessity to stimulate residential-scale market by encouraging small and medium-scale enterprises' (SMEs) participation, in order to achieve the target that at least 300 MW of solar PV capacity should be installed every year.

The direction to adjust the operationalization for residential-scale projects is characterized by the emphasis on high quantities of projects. Residential-scale projects are not as profitable as (electrically) industrial projects¹³. Compared with millions in TWD per industrial project has, this annual income of residential-scale projects is significantly minute and it is hard striking a balance between cost and revenue from running this business. Therefore, implementing a high number of residential-mounted projects is prerequisite for ESCO-companies in order to be profitable. Adopting the PV-ESCO model to the residential market requires companies to alter different elements of the business model, including value proposition, distributional channel, customer relation, value configuration, and competency. The comparative operationalization between conglomerate companies and SMEs respectively on large-scale and small-scale projects is listed in table 13.

The value proposition is the first element to be changed in the operationalization of the ESCO model for the residential market. It is noteworthy that rental fees that residents annually receive account for 8% of total FiT revenues, which is approximately TWD 6 400 (EUR 170) to TWD 7 200 (EUR 195) for a typical residential system. The amount is in effect not so attractive for customers, according to the interviewed ESCO companies. As a result, the true attractiveness of residential installations consists of additional functions such as sunshade, rain canopy, and thermal insulation, which enhance the function of residential buildings and create better residential quality. Another value, though being less important for customers, is the aesthetical appeal of PV installations that differentiate the dwellings from other buildings and increases the value of these houses. As a result, ESCO companies need to emphasize values that feature additional functions and aesthetical appeal more than financial parameters such as no upfront cost and stable rental income in residential-scale projects.

¹³ According to company F, a project with 10 kW of installed capacity can only bring annual income ranging from TWD 80 000 (EUR 2 162) to TWD 90 000 (EUR 2 432), averagely 8% of which is distributed to roof owners. The actual revenues attained from FiT system is around TWD 73 600 (EUR 1989) to TWD 82 800 (EUR 2237) per year.

Besides, quality assurance is essential to the transformative operationalization as well. This value should not only be delivered, but also be felt by customers. Usually, high quantities of projects are partly attainable through the provision of quality. Interviewed ESCO companies claimed that as long as they bring customers good installations and service with sincerity, customers themselves will spontaneously help the ESCO-company to reach out the next batch of clients. Through this way, companies can effectively obtain a high number of residential projects.

In terms of distributional channels, word-of-mouth communication is of vital importance to all companies adopting the site-lease model. One difference from large-sized projects is that this communication, as operated by small and medium-scale companies, is community-based. A specific community is targeted when companies successfully approach a customer who lives there or nearby, and the active interactions with local people come afterwards. This management is for making use of local residents' strong word-of-mouth communication, which leads to a spillover effect and helps ESCO companies acquire numerous projects. Also, a solar PV installation is more visible in a community owing to its exterior differentiation and more people living there. Some large-sized systems are installed on factories, farmhouses and public buildings located in desolate areas that people barely visit. These large-scale installations are thus unlikely to be detected. Yet, residential installations in a community are absolutely detected by a certain group of people living there, and usually, word-of-mouth communication happens when one particular homebuilding is exteriorly equipped with a solar PV system. This point is also shown in Gillingham's and Bollinger's academic research (2012), which concludes that the visibility of solar PV systems and word-of-mouth communication increase social interactions that give rise to more solar PV adoption, especially at a localized street level. Based on this result, Gillingham's and Bollinger's study further points out the significance of site selection and its potential to be a good marketing strategy.

With regards to customer relation, considering the significant role that all customers play in advertisement, ESCO companies need to manage the relationships with them. Different from large companies, small and medium-sized companies more sincerely treat all dwellers as friends, and they initiate lots of active and interactive communications with customers. Besides, the communications are extended to clients' neighbors and families, who can possibly become the next customers. In contrast, large companies have less pressure to acquire numerous projects through customers; as a result, the communications with customers are more passive and only focused on roof owners and landlords. Another way to maintain the relationship lies on providing other customized services to completely satisfy customers. The assistance in taking care of other parts of housebuilding, which tightly connects the company and customers, is the example of the customized service. This assistance, more concretely, includes constructing carports with broken solar PV panels and coating the buildings with heat-resistant materials.

Regarding the value configuration, offering additional services aside from after-sale service, third-party verification, remote monitoring systems, shows ESCO companies' sincerity to build a long-term and close relationship with customers. One example is construction reinforcement for the whole house design. Services such as after-sale service, third-party verification, and remote monitoring systems are critical to bring customers optimized system operation and good service, and these are adopted by large companies as well. However, in residential projects where the installed sites are living places, ESCO companies need to make safety of installations a priority. The construction reinforcement is to assure that the structure of the whole housebuilding is strong enough to bolster the PV installations.

As to competency, SMEs are required to have knowledgeable and efficient maintenance & repair teams in order to optimize system operation. It is noteworthy that multi-skilled employees play the central role in these teams. Employees in SMEs are much fewer than conglomerate companies. In order to tackle different levels and types of technical issues, ESCO companies prefer to hire multi-skilled and knowledgeable employees who are able to take care of multiple technical problems.

Table 13. The operationalization between conglomerate companies and SMEs respectively on large-scale and small-scale projects

Element	Small-scale project	Large-scale project
Value proposition	<ul style="list-style-type: none"> Emphasizing Additional functions and quality assurance 	<ul style="list-style-type: none"> Emphasizing Free-of-charge installation and stable rental income
Distribution channel	<ul style="list-style-type: none"> Word of mouth communication based on community 	<ul style="list-style-type: none"> Random word of mouth communication
Customer relation	<ul style="list-style-type: none"> Active and interactive communications Communications are expanded to customers' neighbors and families Sincerely regarding customers as friends Customized service provision 	<ul style="list-style-type: none"> Relatively passive communications
Value configuration	<ul style="list-style-type: none"> Construction reinforcement aside from after-sale service, third-party verification, remote monitoring system 	<ul style="list-style-type: none"> Principally after-sale service, third-party verification, remote monitoring system
Competence	<ul style="list-style-type: none"> Multi-skilled employees in maintenance & repair teams 	<ul style="list-style-type: none"> Maintenance & repair teams does not matter as much as the counterpart in SMEs

Source: Author

5.3 Rethinking Policy & Legislation

The PV-ESCO model helps address legal-administrative barriers more efficiently, but does not practically eliminate these barriers. Only changes in policies and legislation could completely remove these barriers. They are recommended and discussed in this section.

First, human resources for administrative processes need to be replenished in both Bureau of Energy and Taipower (Pai, 2016). The procrastination of documents review, as a result of insufficient human resources, happens especially in procedure (a), (b), (c)¹⁴. These procedures are mainly implemented by Bureau of Energy and Taipower. Thus, compared with other governmental agencies, these two units would particularly benefit from an expansion of their human resources. Furthermore, the extent of replenishment can be decided following the growth of project number. Human resource shortage still exists if the replenishment does not correspond to the growth (Pai, 2016). Based on this point of view, Bureau of Energy and Taipower are recommended to re-evaluate the sufficiency of human resources when project numbers are increasing or decreasing.

¹⁴ Procedure (a) is the assessment of application; (b) is the assessment of grid connection; and (c) is construction authorization.

Next, a mechanism to facilitate loan acquisition needs to be institutionalized in the policy relevant to solar PV development. Bureau of Energy, as the major governmental unit taking charge of renewable energy development, is advised taking over the establishment of such a mechanism. It would facilitate the building of mutual trust between banks, insurers and ESCO companies by providing criteria that explicitly show ESCO companies' liabilities to the provision of quality services and installations. In order to build the criteria, the author suggests that Bureau of Energy can firstly investigate what general collateral conditions for loan acquisition on solar PV projects are involved. Direct observations of these stakeholders' negotiations will be conducive to the investigation. Also, Bureau of Energy can establish the criteria by referring to the procedures of third-party verification. This basis for the establishment of criteria could be very convincing, as it would come from third-party verifiers and this possesses a certain degree of impartiality.

Regarding the FiT rate, the decline of the rate is principally owing to the false estimation of upfront costs. The rate is annually established by a group of experts, who do not exactly hold insights into the solar PV market and the industry. These experts basically refer to a formula composed of average installation cost, operating life, maintenance cost, and annual generation capacity, to decide the rate. During this process, stakeholders such as ESCO companies and banks are not allowed to participate in (Tseng, 2015). The lack of stakeholders' participation gives rise to the underestimation of upfront costs, and further impacts the FiT rate. A more democratic approach in decision-making would result in a more transparent process and the FiT rate that reflects actual market developments. Bureau of Energy is suggested to re-define the criteria of selecting experts. These criteria should involve different stakeholders' participation and assess candidates' hands-on experiences to partake in the market.

Lastly, the author also suggests amending the Electricity Act and the National Land Planning Act to create more space for solar PV development. In the Electricity Act, regulations of the utility industry need to be partitioned according to the energy sources. The suggested amendment still can classify power plants generated from renewable sources and with installed capacity above 500 kW as an electricity industry, but exempts these plants from the need to obtain additional applications for a license. In other words, this size of solar power plant can directly be recognized as the electric industry, and exempted from being licensed. In terms of amending the National Land Planning Act, government is recommended to re-define the land use for agricultural activities. Untillable area such as seriously polluted land and land subsidence area should be identified and excluded from the definition of farmland in the National Land Planning Act (Bureau of Energy, 2012). This exclusion will vacate more land to be used for solar installations, and could help to accelerate PV diffusion. However, the conditions to use this land for solar installations should be listed. For example, installations must not worsen soil contamination. Additionally, implementing plans for pollution remediation and installing the systems will concur (Bureau of Energy, 2012). In general, the land should still be detoxified and cleaned even though it is used for non-agricultural activities.

5.4 Methodological Aspects and Limitations

This section discussed some methodological aspects with regards to the sampling of ESCO companies that were interviewed. Since the major purpose of this research is to study good-practices of the PV-ESCO model, this research selected 7 ESCO companies that represent of the best operationalization of the business model. Therefore, the qualitative data in this paper is pertinent to generalizability, in terms of the best model operationalization in Taiwan.

However, regarding the generalizability of model operationalization in the entire solar PV system industry in Taiwan, these samples are not fully representative. In reality, around 30 companies have implemented the PV-ESCO model, and the quality of service that ESCO

companies offer to customers are significantly uneven (Wu, 2016; Cheng, 2016). This actually leads to different levels of barriers removal. For example, the PV-ESCO model is also operated by ill-reputed companies, which install the systems with inferior equipment and modules, in order to lower the upfront costs. Thus, these companies do not really tackle barriers that result from quality concerns (Cheng, 2016). Hence, a certain degree of caution should be taken when it comes to the representativeness of findings for the entire solar PV system industry in Taiwan.

6 Conclusions

Based on the results and the discussion, this chapter summarizes the answers to the research questions. Suggestions for future research are proposed here as well.

6.1 Answers to Research Questions

This study uses a combined methodology of literature review and in-depth interviews to examine (1) barriers to solar PV diffusion, (2) the best operationalization under the PV-ESCO model and (3) the operationalization of a transformed model for residential-mounted projects in Taiwan. These examinations helped in answering the following research questions:

1. **What are the barriers that block the diffusion of solar PV systems in Taiwan?**
2. **How did the PV-ESCO model help to overcome the various barriers (faced by customers) to PV deployment?**
3. **How do small and medium-sized enterprises (SMEs) adopt the PV-ESCO model and apply it to residential-scale projects?**

First, in Taiwan, social, financial, and legal-administrative barriers restrain general populace's willingness to invest in or install solar PV systems. People's mistrust and misperception of solar PV energy form the social barriers. These negative perceptions principally result from little prevalence of solar PV energy-related knowledge in the society, a lack of information platform, and considerable destruction of PV systems after a typhoon. Regarding financial barriers, they include the issue of profitability, capital insufficiency and loan inaccessibility, which all renders PV installations unaffordable and unprofitable for people. Moreover, legal-administrative barriers complicate the installation process, decrease profitability, and limit the space that can be utilized for installations. The effects of this inadequate legislation pose a significant challenge to PV diffusion.

In regard to the second research question, the study concludes that the PV-ESCO model has significantly helped in overcoming social and economic barriers with its value proposition, distribution channel, customer relation, value configuration, competency, partner network and cost-benefit structure. The value proposition and cost-benefit structure create a low-risk environment for investments in solar PV installations by guaranteeing PV yields, long-term stable revenues and exempting customers from upfront costs. The distribution channels contribute significantly in acquainting a large group of people with the most complete and accurate information relevant to solar PV energy. Close customer relations and the partner network make loans for solar PV projects more acquirable, and the collateral conditions of these loans become more favorable to customers. The partner network additionally provides the opportunity to familiarize particular stakeholders with the solar PV industry, and it spurs ESCO companies to ensure the quality of PV installations. Through after-sale service, remote monitoring systems and demonstration site tours, the value configuration aids in multiple aspects of removing barriers, including the issues of insufficient data collection, information immobility, and quality concerns. As to competency, it does not only bridge customers and investors, but also brings customers the most optimal system operation.

In terms of legal-administrative barriers, only amendments of policy and legislation can completely eliminate these barriers. The PV-ESCO model does not exactly change these legal-administrative regulations, but ESCO companies can tackle these barriers more efficiently than commercial and private consumers. This is especially reflected in the removal of complex authorization activities for customers and the facilitation of establishing mechanism for loan acquisition. The former is achieved through ESCO companies' compulsory responsibility to process the administrative applications, which renders the installation less burdensome from

the customers' viewpoint. The latter is built on ESCO companies' voluntary practices that involve undertaking third-party verification, and offering after-sale service, as well as installations with good quality.

Finally, for SMEs who plan to adopt the PV-ESCO model on residential-mounted projects, the business model elements of value proposition, distribution channel, customer relation, value configuration and competency need to be transformed in order to acquire high quantities of projects and accentuate the quality of system along with service provision. Regarding the value proposition, SMEs should lay more emphases on additional functions and aesthetical appeal of PV installations. In order to reach new residential customers, the strategy to channel values should be community-based and able to facilitate more word-of-mouth communication. In terms of customer relations, the sincerity to treat all dwellers as friends and more interactive communication with their neighbors aid a lot in building long-standing relationships. Moreover, supplementary customized services such as construction reinforcement and carports erection do not only underpin the values delivered to customers, but also strengthen customer relationships. Besides, it is required that SMEs have knowledgeable and efficient maintenance & repair teams that consist of multi-skilled employees.

The findings from this research suggest that a business model indeed assists in removing hindrances to solar PV development and potentially facilitates sustainability development through its operationalization. However, the operationalization would vary from company to company, and project size to project size. It is unlikely to generalize a set of standard operationalization modes for a business model. Thus, barriers are overcome under the operationalization compounded of several different operational methods, and solar PV diffusion is catalyzed with a synthetic effect of this operationalization.

6.2 Future Research

Built on this study, it is suggested to further develop and explore two research issues in the future:

First, this study relies to a large degree on data from the hands-on experience of ESCO companies. Future research could investigate customer-sided perceptions of the PV-ESCO model as well in order to cross-check and validate the findings of this thesis. For example, it could be valuable to utilize quantitative methods to survey customer-sided perceptions of the PV-ESCO model as a barrier conqueror. Such a quantitative method could be adequate to explore the correlation between the PV-ESCO model and barriers removal, especially when population¹⁵ is large. However, a qualitative method is also recommended to examine a causal relation between these two variables.

Besides, the development of the PV-ESCO model greatly relies on the promotion and support from relevant policy schemes. The changes in these policy schemes and legislation may influence the effect of this model as well as the model operationalization. A future research is advised focusing on how revisions and amendments in policy and legislation change the operation of the PV-ESCO model, the level of barriers removal and the operationalization brought by ESCO companies.

¹⁵ Customers of ESCO companies are the population of this research.

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Appendix 1.

Interview Questions for ESCO companies

#	Content
1.	Background Information
1.1	Which products and service do you provide?
1.2	Which operational designs under the PV-ESCO model do you adopt?
1.3	How many projects with the PV-ESCO model have you implemented?
1.4	Generally, what is the project size in most projects that you have implemented?
1.5	How long have you operated the PV-ESCO model?
1.6	Until this year, how much is the accumulative capacity from all the projects that you have implemented?
1.7	Why would you like to adopt the PV-ESCO model?
2.	Customer Interface
2.1	Under the PV-ESCO model, who are your target customers? How large are these groups?
2.2	Generally, how do you approach target customers? Do you have a systematic method to approach them?
2.3	Under the PV-ESCO model, is the relationship with customers long-term or short-term? Usually, how long is it?
3.	Customer Value
3.1	When you approach target customers, what values would you usually convey to customers under the PV-ESCO model?
3.2	How do you discourse upon these values? Do you provide any calculation, case study and the comparative analysis of different investments?
4.	Infrastructure Management
4.1	What activities do you emphasize and provide in order to underpin the value proposition?
4.2	What core competency do you need in order to operate the PV-ESCO model?
4.3	Who are your partners in terms of running the PV-ESCO model? Do you have long-term cooperation with specific suppliers, banks and insurers?
4.4	Usually, what are collateral conditions that you need in order to acquire loan and insurance claim? What barriers do you face when communicating with banks and insurers?
5.	Financial Aspects
5.1	From customer's perspective, what are the costs of solar PV installation under the PV-ESCO model?
5.2	From customer's perspective, what are the revenues or savings of solar PV installation under the PV-ESCO model?
6.	General Questions
6.1	What barriers do you or your customers usually face in terms of solar PV installations?

6.2	Do you think the PV-ESCO model helps overcome the barriers to solar PV diffusion, which are faced by customers and ESCO companies? How does this model assist in the removal?
6.3	How do you think of the adoptability of the PV-ESCO model on residential-scale installations?
6.4	Now large installation sites are gradually exhausted, will you prefer to apply the PV-ESCO to residential-sized projects?