Sustainable Business Model Dynamics of Distributed Solar PV Projects in China

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Xiaojing Xu

Student number: 5049180

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Graduation committee

Prof. Hanieh Khodaei
Prof. Linda Kamp

TU Delft

Executive Summary

Solar photovoltaics (PV), as one of the renewable energy technologies, has gradually penetrated power systems worldwide. Distributed solar photovoltaics (DSPV) systems characterised by reducing transmission line losses, increasing grid resilience and relaxing requirements for investment have experienced exponential growth over the last decade. China's DSPV power market has witnessed momentous changes since 2012, when a series of policies were introduced. In recent years, China's DSPV industry has been encouraged by national strategies, Photovoltaic Poverty Alleviation Projects (PPAP) and carbon emission 2030 and 2060 targets. DSPV is becoming the main approach to utilizing solar energy in China.

However, there are barriers impeding distributed energy development regarding financial, technological, regulatory, resources and awareness aspects. To overcome obstacles to DSPV development, several scholars emphasized the importance of promoting business model innovation (BMI) in DSPV projects. Before any further design and implementation, a comprehensive understanding of BMI is essential. The fundamental step is to identify the origins of BMI and investigate how DSPV projects enterprises can capture and subsequently respond to changes within and external to their businesses.

This work aims to investigate business model innovation for distributed solar photovoltaic project companies through dynamic sustainable business model frameworks. The main research question is "***How can we develop a dynamic sustainable business model framework to understand business model innovation in distributed solar PV (DSPV) projects in China?"*** The objective is to develop dynamic sustainable business model framework and then apply it to DSPV project companies in China in order to understand business model innovation.

The dynamic business model framework by Kamp et al. (2021) and sustainable business model canvas (SBMC) by Bocken et al. (2018) together contribute to the baseline of the dynamic sustainable business model framework in this research. Referring to Meslin (2019) and Kamp et al. (2021), building a dynamic SBM framework involves three aspects of business models: completeness, interrelationships, and changes over time. These three aspects are based on criteria assessing the degree of dynamics of a business model framework by Khodaei and Ortt (2019). After building the conceptual framework, the framework's performance is measured by case studies of five DSPV project enterprises in China. The framework effectively captured changes in each company's business model over time. The conceptual framework can be further improved by synthesizing the results from the case study.

Through the study, business model innovation at the firm level (DSPV project enterprise) is a dynamic process. Due to environmental and business variables, a company's business model constantly changes in response to external and internal opportunities and threats. These variables are essential for understanding business model innovation. Changes in external factors (e.g., policy and regulation, industrial technology innovation, customer demand, market competition, etc.) and internal factors (e.g., company technology improvement, project O&M management, personnel capability, etc.) could trigger business model innovation. Starting with recognizing opportunities or threats, DSPV enterprises respond to these variables differently depending on company capability and external business environment. Meanwhile, changes within business model elements tend to be coherent and interlinked over time. For an efficient business model innovation, associated business model elements are supposed to be in line with a changed business model element. On the way, these changes can either create or capture value for stakeholders, including customers, society and the environment. The constantly changing process as to BMI is based on a company's flexible operation and management for adapting to the complex and varying environment.

Abbreviation

PV	Solar photovoltaics
DSPV	Distributed solar photovoltaics
BMs	Business models
BMI	Business model innovation
SME	Small and medium-sized enterprises
BMC	Business model canvas
SBMC	Sustainable business model canvas
LSPV	Large-scale PV
PPAP	Photovoltaic Poverty Alleviation Projects
NEA	National Energy Administration
HO	Host-owned business model
TPO	Third-party-owned business model
CS	Community-shared business model
EMS	Solar energy management service model
SBMs	Sustainable business models
O&M	Operation and maintenance
SGCC	State Grid Company of China
NDRC	National Development and Reform Commission
BoS	Balance of system
IEA	International Energy Agency
FiT	Feed-in Tariff
EPC	Engineer, procure, and construct
CEM	Contract energy management model
NGOs	Non-governmental organizations
EOL	End-of-life
VAS	Value added services

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Chapter 1 . Introduction

Solar photovoltaics (PV), as one of the renewable energy technologies, has gradually penetrated power systems worldwide. Due to the distinct merit of PV technology, generating clean energy without greenhouse gas emissions, PV energy generation shows its priority in the transition to sustainable energy systems, slightly behind wind and ahead of hydropower (International Energy Agency, 2021). Distributed solar photovoltaics (DSPV) systems characterised by reducing transmission line losses, increasing grid resilience, eliminating generation costs, and relaxing requirements for investment have experienced exponential growth over the last decade (International Energy Agency, 2021).

In contrast to centralized solar PV systems located away from end-users, distributed solar PV systems generate power at or near where they will be used (United States Environmental Protection Agency, 2021). International Energy Agency (2019) divides distributed PV into three main categories: (1) residential, (2) commercial and industrial (C&I), and (3) off-grid applications. The residential segment refers to rooftop on-grid systems, while commercial and industrial segments refer to rooftop and ground-mounted on-grid systems. According to the report, distributed solar PV capacity is projected to increase by over 250% globally, reaching 530 GW by 2024. Commercial and industrial segments will remain the largest capacity growth rather than residential applications and will increase far more significantly than off-grid DSPV applications.

Unlike the United States, Europe, and Japan that historically apply DSPV systems in residential, commercial, and industrial markets, China's DSPV power market only witnessed momentous changes since 2012 when a series of policies were introduced (Yuan et al., 2014). Despite a comparatively late start, DSPV is becoming the main approach to utilizing solar energy in China (Li et al., 2020). The proportion of cumulative capacity of the DSPV system to the total cumulative PV systems has significantly increased from 13% in 2016 to 31% in 2019 (Wang et al., 2021). However, barriers, such as, insecure rooftop ownerships, difficulty in raising financing, high risks in investment, and uncertainty in return, seriously hinder the development of DSPV power systems in China (Yuan et al., 2014; Zhang, 2016a).

To overcome these barriers towards DSPV development, several scholars emphasized the importance of promoting business model innovation (BMI) in DSPV projects (e.g., Li et al., 2020; Zhang, 2016a; Song, 2021; Frantzis et al., 2008; Li et al., 2018; Horvath and Szabo, 2018). BMI enables researchers to change business models (BMs) to fit local circumstances, giving responses to barriers towards distributed development, and increasing the use of renewable energy (Horvath and Szabo, 2018). However, identifying, designing and implementing new BMs for DSPV projects is not straightforward (Huijben and Verbong, 2013).

Before any further step, a comprehensive understanding of BMI is essential, which requires investigating triggers, processes, implementation, and anchors of BMI (Bucherer et al., 2012). Among research of BMI across different spectrums, the fundamental step is to identify the origins of BMI since triggers of BMI determine further directions of design and implementation (Bucherer et al., 2012). When business journeys stall, companies realize an option that they can renew their BMs to adapt to the changing economic environment and inner company variations (Andreini and Bettinelli, 2017). However, such awareness raises questions about how companies (such as small and medium-sized enterprises or SMEs) can recognize the timing of BMI and how they can capture and subsequently respond to changes within and external to their businesses.

Some of the researchers use business model canvas (BMC) to show companies' BMs (e.g., Osterwalder and Pigneur, 2010). However, this is a static framework representation without revealing BMs changes and is complex in describing changes over time. Researchers require BM frameworks capturing dynamics that allow them to trace the origins of BMI and track effects (Schneider and Spieth, 2013). Furthermore, products and services provided by companies devoted to sustainable technology are commonly endowed with environmental and social values. Conventional BMC that concerns only economic forms of value to satisfy customer needs is insufficient to fit their sustainable solutions (Cardeal et al., 2020). Embedding environmental and societal values on top of the economic value for a broad range of stakeholders, specifically, the environment and society, has grown increasingly in research (e.g., Evans et al., 2017; Geissdoerfer et al., 2016; Bocken, 2015).

Based on these concerns, establishing a dynamic sustainable BM framework can be an approach to understand business model innovation of DSPV project companies and at the same time pursuing sustainability. However, little research is investigating BM innovation through dynamic sustainable BM frameworks, and little study is about the DSPV project companies in China in particular.

This thesis aims to investigate business model innovation for distributed solar photovoltaic project companies through dynamic sustainable BM frameworks. The framework will be developed based on the one established by Kamp et al. (2021), and the sustainable business model canvas (SBMC) by Bocken et al. (2018) is used as a tool. Four criteria to assess dynamic business model frameworks by Khodaei and Ortt (2019) are followed as a guide. Building on the baseline, the framework in this research will focus on DSPV project companies, including unique (sustainable) BMs elements, interrelationships, and changes over time. Meanwhile, the framework in this research will further show internal and external company factors that have impact on BM innovation for DSPV projects. Overall, the objective is to understand BM innovation in DSPV project companies through the dynamic sustainable BM framework. The main research question is: ***How can we develop a dynamic sustainable business model framework to understand business model innovation in distributed solar PV (DSPV) projects in China?***

1.1 Background

1.1.1 Distributed solar photovoltaics energy in China

China's distributed PV (DSPV) industry has already entered a mature market stage with a certain scale (Li et al., 2018). The development of DSPV energy generation in China dates back to 1996 (Zhang, 2016a). Due to lack of governmental supports, the very early experimental programs, *Brightness Program* and *Township Electrification Program*, didn't achieve notable progress in the DSPV market. Until 2009, China ran two subsidy programs, *the Roof Subsidy Program* and *Golden Sun Demonstration Program*, directly stimulating domestic demand and expanding the DSPV market (Zhang, 2016a). While DSPV in China saw impressive progress only since a series of policies were introduced by *China's 12th Five-Year Plan* in 2012 (Zhang, 2016b). DSPV development has been given the same priority as large-scale PV (LSPV) energy generation ever since.

(1) Two national strategies drive DSPV development

Currently, China's DSPV is encouraged by two national strategies. One is the *Rural Revitalization Strategic Plan* (2018-2022) issued by National Development and Reform Commission in 2018 (State Council, 2018). This plan clearly states the utilization of clean energy to maintain the energy demand of rural areas, after which a bunch of renewable energy projects has been launched. Photovoltaic Poverty Alleviation Projects (PPAP) is one of the ten poverty-relief programs linking PV energy and poverty reduction (Liu et al., 2021). The extant PV poverty alleviation projects have three modes: the home-based station, the village-level plant and the plants in suitable locations (Liu et al., 2021). The first model type highly relies on DSPV on rooftops of the poor, by which generated electricity is primarily self-used and then sold the excess to the state grid. The village-level power plant is constructed surrounding the village and is owned by village collectives. The income is shared with all poor involved. These two project models reveal huge potentials for promoting DSPV development.

Another strategy is that China's carbon emission would peak around 2030 and reach carbon natural by 2060 (State Council, 2021). For China to achieve this target, shifting current energy dependence on fossil fuels to renewable energy is a promising approach. Under the circumstances, adopting solar energy, especially DSPV, appears inevitable.

(2) DSPV key applications

There are two key applications of DSPV generation in China: distributed PV power generation demonstration areas and PV poverty alleviation (Yu et al., 2018). Moreover, in Jun 2021, the National Energy Administration (NEA) issued a "*Notice on Actively Developing Distributed Photovoltaics on Rooftops of Entire Counties (District) Pilot Project*" (National Energy Administration, 2021). The notice clarified the total roof area for PV power installation in government buildings (at least 50%), public buildings (at least 40%), industrial and commercial factories (at least 30%) and rooftop of rural residents (at least 20%). Subsequently, in September 2021, the NEA published a list of a total of 676 pilots counties for rooftop DSPV. Seemingly, these pilot projects may create a more active market for DSPV.

(3) DSPV resources

China has abundant and unevenly distributed PV energy resources. As shown in Fig. 1.1.1, areas in the southwest and northwest China, where most larger-scale solar projects are installed, have higher solar radiation than central and eastern regions where more well-developed cities are located. Nevertheless, the power generation potential for distributed PV systems is primarily in eastern and southern China (shown in Fig. 1.1.2), where solar radiation is relatively low and electricity demand is significantly higher. A study by Wang et al. (2021) reflected that increasing power demand calls for DSPV systems without long-distance transmission. Besides, there are more available rooftops to install DSPV systems in less-developed regions of China. Overall, DSPV development in China, driven by national strategies, abundant resources, and increasing demand, sees increasing potential.

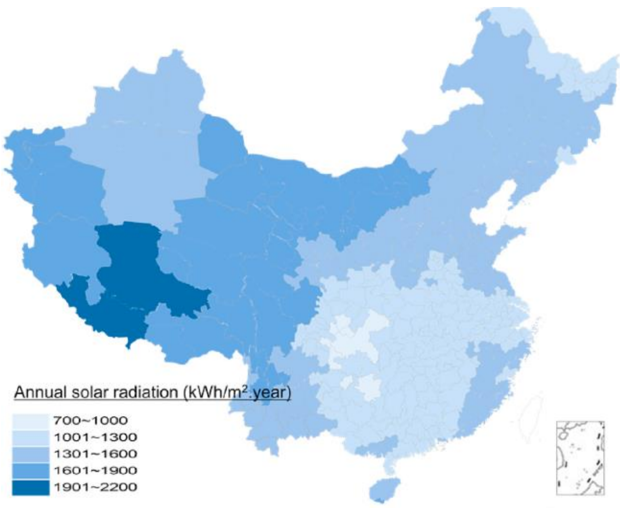

Figure 1.1.1 Annual solar radiation in China (Wang, He & Chen, 2021)

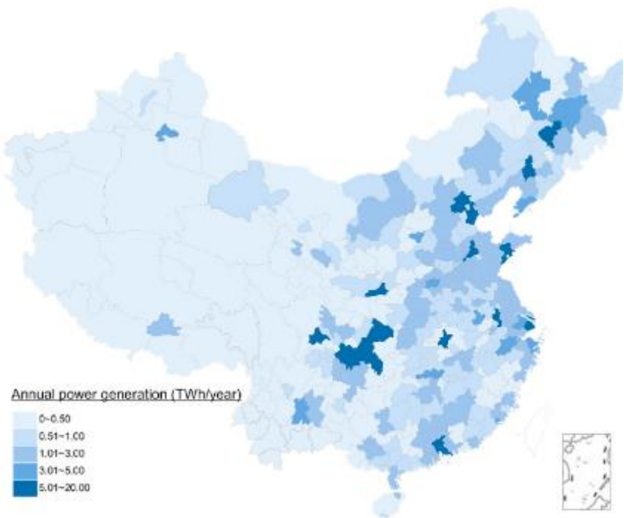

Figure 1.1.2 Power generation by DSPV system at the city level (Wang, He & Chen, 2021)

1.1.2 Business model

Every company has its business model (Teece, 2010). The notion of business model was first introduced in economics in the context of information technology in the 1950s (Fielt, 2013), and it has only risen to prominence until the emergence of internet businesses in the mid-1990 (Horvath and Szabo, 2018). Since the late 1990s, applying the construct of business models to describe firms' business processes and the correlation between these processes has attracted the attention of both practitioners and scholars (Foss and Saebi, 2016). Research from different disciplines has promoted diverse descriptions of business models. Till 2016, despite decades of interdisciplinary research and application, researchers still have not reached a consensus on the definition and compositions of business models due to the vague and obscure concept (Wirtz et al., 2016).

A large and growing body of academic literature has investigated business models. These studies highlighted three research areas: the definition, the frameworks and elements, and the classification (Fielt, 2013). Some researchers with quite a bit of insight into identifying business model themes (e.g., Zott, Amit, & Massa, 2011).

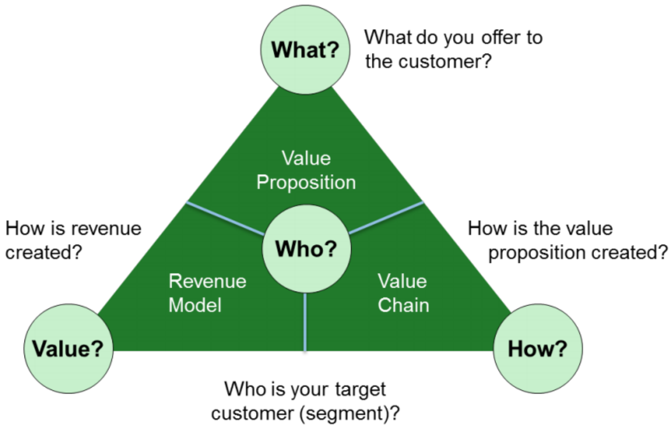

Figure 1.1.3 The St. Gallen business model navigator (Gassmann et al., 2013)

When looking at the definition, one study by Teece (2010) stated that a business model articulates how the enterprise with viable revenue and cost structures creates and then delivers value to customers. Similarly, Osterwalder and Pigneur (2010, p.14) illustrated that "*a business model describes the rationale of how an organization creates, delivers, and captures value*." By their understanding, the concept of 'value' underpins the business model concept. Another study by Gassmann et al. (2013) employed a conceptualization consisting of 4 central dimensions to describe the business model architecture: the Who, the What, the How, and the Value (shown in Fig. 1.1.3). In their view, these four dimensions ask questions associated with customer segments, the value proposition, the value chain, and the revenue model. Notably, the target customer is the central dimension for a business model design. Combining all dimensions, they perceived the business model as a magic unit of analysis describing how a business works. Specifically, a company's business model is constructed out of different business constitutional components.

In summary, although various research streams of business models (BMs), there is still no generally accepted definition of the concept. One research stream believed that the concept of 'value' underpins the business model concept, which tells how a company creates and deliveries values to customers, meanwhile capturing values for itself. To decompose BMs concept, one research area investigates business model frameworks and components.

Business model frameworks and components

Different presentations exist in the literature from different angles when considering the BM frameworks and the main BM components. Some concentrate on connecting technical potential with economic value, and others focus on entrepreneurship. In one well-known research, Osterwalder and Pigneur (2010) proposed a comprehensive representation of the BM framework, namely, the business model canvas (BMC). The BM contains nine components in their illustration, including value propositions, customer segments, customer relationships, channels, key activities, key resources, key partnerships, revenue stream and cost structure (shown in Fig. 1.1.4). Part of the current literature on BMs adopt the BMC as a framework for BMs design or analysis (e.g., Fritscher and Pigneur, 2014; Reis et al., 2021; Khodaei and Ortt, 2019; Kamp et al., 2021). Specifically, some articles utilize BMC to identify business models of DSPV (e.g., Horvath and Szabo, 2018; Cai et al. 2019).

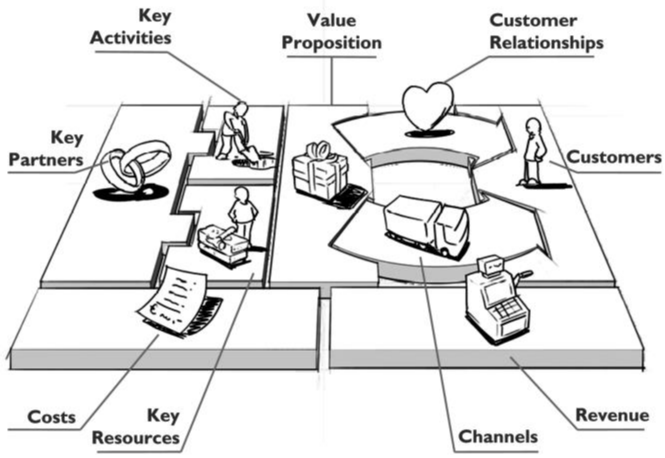

Figure 1.1.4 The business model canvas (Osterwalder and Pigneur, 2010)

However, such a framework with nine blocks can be complex when investigating the interrelationships of BM components over time as changes in BM elements tend to be coherent and interlinked. A visualized or simplified framework could be more helpful in depicting changes in BM over time. Referring to the BM determined by Gassmann et al. (2013), four main elements characterize BMs: value proposition, customer segment, value chain and revenue model (shown in Fig. 1.1.3). To further simplify the framework, Meslin (2019) used a BM framework from Bohnsack et al. (2014) that focuses on three primary elements: the value proposition, the value network, and the revenue and cost model. Deherkar (2020), who follows Meslin (2019), also implemented the same framework to show BMs changes. From these studies, with fewer main components, the framework can be more practical in tracing changes over time.

Combining considerations above, this research requires a framework that not only characterises the well-known nine BM components by Osterwalder and Pigneur (2010) but also allows to simplify and manifest relationships and changes over time when necessary.

1.1.3 Sustainable business model canvas (SBMC)

This research applies the sustainable business model canvas (SBMC) by Bocken et al. (2018) (shown in Fig. 1.1.5), which is one famous framework in literature. A more detailed exploration of this model can be seen in sub-section 5.2.2. Specifically, the SBMC supersedes the BMC for four reasons in this research.

First, it fits more for companies devoted to sustainable technology. Current DSPV BMs are widely focusing on creating economic value solely. However, the products and services they provided commonly are endowed with other attributions. One thing, the scale of sustainable technology is driven by increasing electricity demand and climate change issues. Another thing, the launch of such sustainable technology also serves social purposes, such as engaging in poverty alleviation in developing countries (e.g. Liu at al., 2021). In this context, a company’s value creation logic entails more than just economic value. Environmental and social values attach to it. Thus, a BM with a broad value proposition could be more suitable for companies offering sustainable solutions.

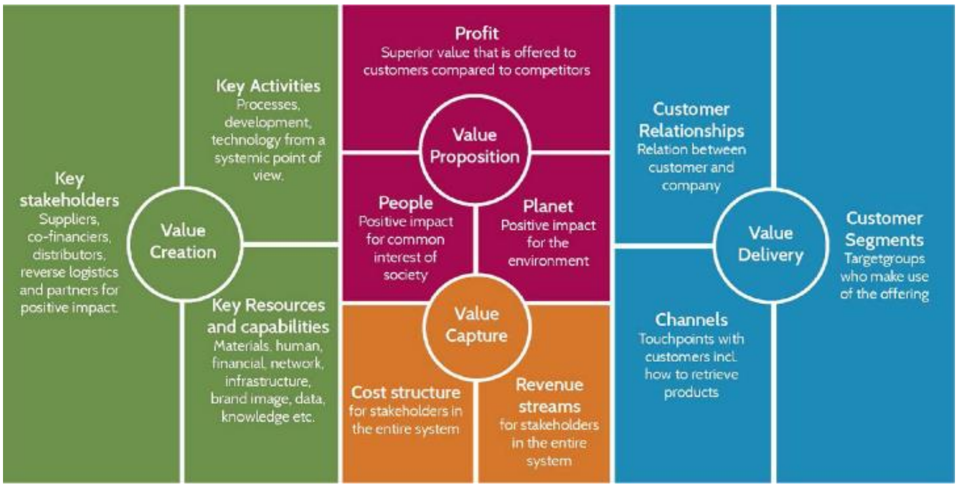

Figure 1.1.5 The sustainable business model canvas (Bocken et al., 2018 developed from Osterwalder and Pigneur, 2010 and Richardson, 2008)

The SBMC entails the most symbolic of sustainable business models concept that incorporates sustainable value and treats the environment and society as core stakeholders (Evans et al., 2017). Thus, it is superior to the conventional economically-oriented BMC for businesses in the field of clean energy.

Second, it keeps the sub-elements structure, which allows to investigate details under each sub-components. Researchers lacks experience using such a comprehensive canvas to describe business models. Before capturing business model dynamics, a general view of a company's business model is necessary. Moreover, this framework adds only two extra value proposition blocks, which simplifies application.

The third point is the four-main-component framework. Because this research aims to develop a dynamic business model framework, four instead of nine or more elements facilitate the investigation of relationships and tracking changes over time. It avoids an overwhelming presentation and is more visually friendly to readers.

Last but not least, this study intends to facilitate understanding BM innovation, especially by investigating the origins of BM innovation. From a broader spectrum, factors triggering BM innovation could relate to environmental and social aspects. For instance, green policies and poverty alleviation. SBMC with certain components integrating all three dimensions can be more helpful for analysing.

In summary, the sustainable business model canvas (SBMC) over BMC in terms of sustainable considerations and simplified structure is more suitable tool for this research. A more detailed explanation of SBMC is in sub-section 5.2.

1.1.4 Business models for DSPV

Categorized by ownership, host-owned (HO), third-party-owned (TPO) and community-shared (CS) business models are standard business models applied in distributed photovoltaic energy markets (Horvath and Szabo, 2018). The host-owned model, also known as host-owned feed-in, customer-sited or ender-user-owned model, means that host-customers own PV systems installed on their property. In third-party-owned models, also known as the solar-city model in the US or solar energy management service (solar EMS) model in China, a system owner (a third-party) finances the system project. The community-shared model, also known as the community solar model in Germany or community-owned model in the UK, has many subscribers connected to the system (Horvath and Szabo, 2018).

Due to the diffusion of consumer-side PV generation in the last two decades, the host-owned business model has been widely adopted in counties like the United States, Germany (Frantzis et al., 2008; Richter 2013a; Strupeit and Palm, 2016), Netherlands (Huijben and Verbong, 2013) and China (Zhang, 2016b). The third-party-owned business model also plays a substantial role in the energy transition as the structural reforms of liberalization across the energy market (Brunekreeft et al., 2016). In contrast, the community-shared business model is a relatively new model with few dedicated studies and is more rooted in the market in the US since its first project in 2006 (Horvath and Szabo, 2018; Strupeit and Palm, 2016; Zhang, 2016b). In comparison, little research investigates the business models of DSPV projects in China. Most studies in China reported existing business models for DSPV projects in China are mainly host-owned and third-party-owned modes (e.g., Cai et al., 2019; Pang et al., 2019; Zhang 2016b).

In summary, although business models can be defined from different perspectives (Pang et al., 2019), this research will categorize BMs from the investor's perspective. BMs are specifically classified based on ownerships of the PV system because focal firms are the study object in this research. Besides, due to little research for the case in China, this research will use the more detailed SBMC to determine DSPV business model components. The simplified four main element framework will be preferable when depicting and tracking changes over time.

1.1.5 Business model innovation in DSPV development

Despite the rapid growth in distributed PV energy generation, obstacles hindering further sustainable transition still need to be overcome. One literature study (Horvath and Szabo, 2018) summarized five main barriers impeding distributed energy development regarding financial, technological, regulatory, resources and awareness aspects (shown in Fig. 1.1.6). Factors underneath each barrier would affect DSPV development to varying degrees.

Main barriers	Elements, main factors
Financial and profitability barriers	• Lack of financial resources • Profitability problems • High initial investment costs • Additional costs • Lack of available loan constructions
Awareness and behavioural barriers	•Lack of knowledge and information •Lack of skilled people •Misinformation about DE benefits •Behavioural barriers and concerns
Regulatory and institutional barriers	•Shortcomings of legal framework •Issues about feed-in-tariffs and taxation •Low electricity price •Unpredictable regulations
Technological barriers	•Grid capacity •Security of supply •System performance risks
Company resource barriers	•Lack of competence •Gaps in the product portfolio •Shortcomings in management and business skills

Figure 1.1.6 Overview of main barriers of distributed energy development (Horvath and Szabo, 2018)

Based on their overview of main barriers and other literature on DSPV BMs, whether current BMs (HO, TPO and CS BMs) can effectively help overcome barriers to DSPV development can then be investigated. However, the result revealed that current BMs of DSPV can only give limited responses to these barriers towards distributed development (shown in Fig. 1.1.7). More stars indicate more possibilities for helping overcome barriers towards distributed development. From Fig. 1.1.7, the TPO business model can partly help while the CS business model shows more opportunities. In contrast, the HO business model sees no possibilities.

Main barriers	Host-owned	Third-party-owned	Community-shared
Financial and profitability barriers		*	**
Awareness and behavioural barriers		*	**
Regulatory and institutional barriers			*
Technological barriers		*	**
Company resource barriers			

Figure 1.1.7 Barrier elimination opportunities (Horvath and Szabo, 2018)

This limited response of current BMs is noticeable when considering China's DSPV development since several barriers are still reported in research despite applying HO and TPO business models. From BM perspectives, if barrier elements in Fig. 1.1.6 can correspond to BMs components, each barrier confronted will reflect specific limitations of current BMs, for instance, limitations stated in the revenue stream, customer segments, and value proposition (shown in Table. 1.1.1).

Table 1.1.1 Barriers reflected in existing BMs towards DSPV development

Barriers reflected in existing BM elements	Literature
Revenue structures	Yu et al., 2018; Zhang, 2016a; Li et al., 2020; Zhang, 2016b
Customer segments	Yu et al., 2018; Li et al., 2020
Value propositions	Yu et al., 2018

First, financial and profitability factors against DSPV development are still observable, which correlate to the revenue model of DSPV BMs. For the host-owned (HO) model in China, the revenue stream of the DSPV owner could be affected by factors such as user consumption capabilities and user creditability (Yu et al., 2018). Although the third-party-owned (TPO) model can release financial barriers against the HO business model, it also has problems obtaining a stable income, which may relate to difficulties in loan financing, high cost of production, long payback period and unstable investment return (Yu et al., 2018; Zhang, 2016a; Li et al., 2020; Zhang, 2016b). As a result, small and middle-sized enterprises (SME) conducting DSPV projects with lower economic competitiveness may not be seen as attractive markets for utilities. These financing risks can also cause unstable cooperative relationships between different actors. Second, barriers against DSPV development reflected in customer segments and the value proposition of BMs are still not overcome (Yu et al., 2018; Li et al., 2020). Due to a lack of awareness of DSPV among society, potential customer segments are unskilled in fast-growing economies like China, and this issue is more evident in rural regions. Customer perception towards DSPV is not as economically favourable as centralized PV stations due to high investment risks (Yuan et al., 2014). Project companies cannot encourage more users to devote themselves to DSPV. Besides, the project's revenue will be affected since it relies on the customer paying electricity fees. Therefore, if DSPV developers are unable to tackle problems relevant to targeted users, both customers and themselves will suffer losses. All in all, although BMs described above have been adopted in DSPV projects, these project companies still need to adapt and renew their BMs over time.

In addition to limited responses to barriers to DSPV development, current models show a low degree of adaptability to changes. First, current models do not concern other company and environment factors not involved in the framework, such as execution capabilities, competition, culture, regulation and policy. However, these factors play critical roles in adapting BMs to fit the local circumstances and are worth considering. Second, over time, BMs of the future will be different from today. The existing BMs will no longer effectively respond to barriers to facilitate DSPV development under future conditions. Companies need to change their BMs to survive in the complex and varying business environment.

Furthermore, BMI is closely related to the business strategy in value creation, performance and competitive advantages (Zott, Amit, & Massa, 2011). Some articles exactly explained the importance of BMI in improving firm performance, for instance, profitability, competitive advantage and innovativeness. Aspara et al. (2010) surveyed around 500 firms and found that firms with a higher priority in BMI exhibit higher profitability than others that dismissed this dimension. Johnson et al. (2008) listed five strategic circumstances requiring changes on the business model, in which they stressed the BMI is a response to a shifting base of competition. Schneider and Spieth (2013) discussed three distinct research streams, including prerequisites, elements and process, and effects. The author acknowledged that developing existing BMs is a crucial organizational competence for firms exposed to high uncertainties. Specifically, for companies operating in DSPV energy markets, changing or innovating BMs is recommended by researchers. Brunekreeft et al. (2016) commented that Germany's " big four" incumbents currently confront disruptive challenges and need to rethink their business models for future development. In China, innovating BMs for DSPV is emphasised in the TPO model or contract energy management (CEM) model to maintain stable revenue streams (Li et al., 2020; Zhang, 2016b).

In summary, BMI is required for DSPV development and companies engaged in DSPV development. Although current BMs (HO, TPO, and CS) have been applied to DSPV projects for further diffusion of the technology, existing BMs provide limited responses to overcome barriers to development (Horvath and Szabo, 2018). Besides, without capturing changes within and outside the company over time, these BMs show less ability to adapt to complex and varying environments. Meanwhile, BMI is important to companies engaged in DSPV projects in terms of strategies for long-term development. Therefore, BMI is noteworthy for companies operating in distributed PV energy markets to promote DSPV technology further. However, BM innovation of DSPV companies is not straightforward (Huijben and Verbong, 2013). Researchers need first to understand BMI beforehand.

1.1.6 Business model dynamics and innovation

Instead of analysing BM at a given point in time, one research stream examines BMs from dynamic perspectives. When it comes to BM innovation, this study stream describes it as a dynamic process (Foss and Saebi, 2017), and identifies BM innovation as one type of business model dynamics (Saebi, Lien & Foss, 2017), which indicates that BM innovation can be viewed as a subset of business model dynamics as will be explained below.

1.1.6.1 Business mode dynamics

As shown in Fig. 1.1.8, several concepts in business mode dynamics are often used to refer to changes in BMs (Saebi, Lien & Foss, 2017). These concepts, including BM dynamics, are interchangeably used in some contexts. But, they have their own emphasis on changes of BMs.

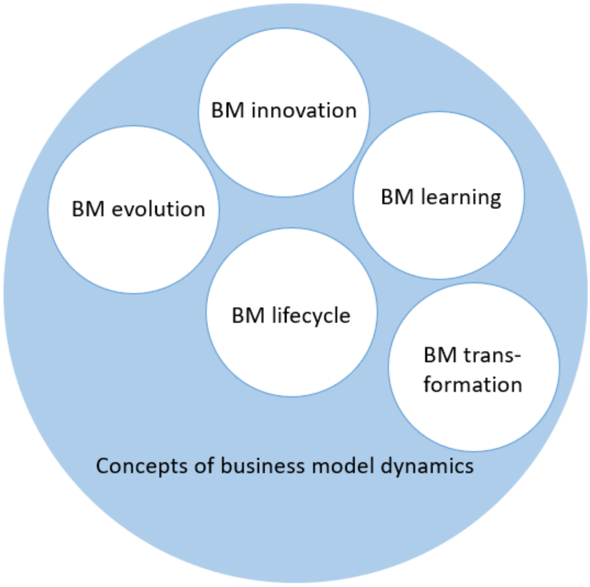

Figure 1.1.8 Concepts of business model dynamics (Saebi, Lien & Foss, 2017)

(1) Business model learning

Instead of simply replicating BMs of pioneers that apply new technologies, some incumbent companies learn from leading competitors and then adjust their existing BMs to similar facsimiles of pioneers' BMs (Teece, 2010). This type of change of BMs is made strategically by companies to remain competitive advantage or minimize damage to their existing businesses due to the technology invasion. Because of years of business activities, the incumbent is superior to the new-tech company or is influential in the industry in many aspects, such as brand equity in the market and a mature value network. The incumbent takes advantage of a new BM by replicating it, simultaneously, integrates the new BM with its existing BM by remaining incumbent cumulated advantages. In this way, the incumbent can develop a new BM with values that the pioneering company cannot provide using the latest technology. An example can be a retail company with its physical stores that adjusts its BMs by learning from a new BM of its competitor who offers online services. BM learning in such context is about changing BMs in responding to threats or opportunities induced by environmental factors, such as market competitors. The concept of learning over replication maintains more characteristics of a company's original BMs.

(2) Business model evolution

Demil and Lecocq (2010, p. 239) define BM evolution as "*a fine-tuning process involving intended and emergent changes both between and within its core components.*" They pointed out that the 'fine-tuning' process correlates sustainability and dynamic consistency of a company. Sustainability is viewed as a company's ability to react to changes due to BM evolution. The dynamic consistency is a firm's capability to change its BM, meanwhile, maintaining its sustainability. Evolution, by their understanding, is a process that a company changes its main BM elements and relationships between elements to develop or place the ability of dynamic consistency to the company.

The change of BMs in concepts of BM evolution is quite similar to the concepts of BM innovation in general. However, BM evolution draws more attention to the management process to reconcile changes and ongoing actions responding to these changes. Differently, the BM innovation turns to be a more strategic decision that focuses on designing changes to a company's BM.

(3) Business model lifecycle

BM lifecycle is another concept showing the dynamics of a BM. Five periods, involving "*specification, refinement, adaptation, revision and reformulation*," compose BM lifecycle (Morris et al., 2005, p. 732). Literally, it is a life cycle of a BM from its relatively informal status to a more dedicated model to direct a company's development. During this process, several activities by the decision made are undertaken to experiment and calibrate the BM. The ultimate goal is to obtain a resilient or sustainable model that can withstand environmental variations such as a downturn in economics. Because it is a cycle process with defined periods, this type of dynamics concentrates on tracking the status of a BM by following the progressive periods. Unlike BM innovation, it does not specify changes in terms of BM elements and the architecture. Besides, although expression of changes of a BM, it calls for new BMs only when major discontinuities occur, such as external changes, which cannot be internally adjusted. In contrast, new BMs are a more general notion in BM innovation. They can be provoked by internal company changes and external environmental changes.

(4) Business model transformation

BM transformation is also a concept describing BM dynamics. In a study by Aspara et al. (2013), it is a change in value creation by the corporation from one time to another time. As this notion is pronounced after a definition given to the 'corporate business model,' the transformation means the corporate BM transformation. Since corporate BM specifies the corporation's business profiles and interlinkages, BM transformation traces changes in the corporation that create value considering business profiles and linkages. In this context, this type of BM dynamics emphasizes changes in answering the 'how' question regarding value creation. Moreover, BM transformation depends more on the assumption of BMs than other dynamic concepts. A specific assumption towards BMs, such as 'corporate,' has its particular focus, and the transformation of such BMs revolves around this concern.

1.1.6.2 Business model innovation

To date, there are few systematic studies of business model innovation (BMI). Instead of systematic studies, some of the literature regards BMI as one theme of the BM (e.g., Zott, Amit, & Massa, 2011; Lambert and Davidson, 2013). According to Foss and Saebi (2017), research in this field revealed an emergent nature of BMI. Academic papers that address BMI are still comparatively less compared to other notions such as business models, dynamic capabilities, and open innovation. Challenged by recent outgrowth and relatively noncumulative study, the BMI's constructs, models, and heuristics have not been clearly articulated to reach a consensus.

In sub-section 1.1.5, the importance of BMI has been briefly explained. BMI is closely related to the business strategy in value creation, performance and competitive advantages (Zott, Amit, & Massa, 2011). Further study could start by looking into what BMI is about.

In one study, Zott et al. (2011) mentioned three themes of the business model, one of which noted BMs as a subject of innovation, which indicates BM itself is a source of innovation. They argued that this subject of innovation complements the traditional innovation subjects such as process, product and organizational innovation. This study shows a close correlation between BMI and BM, and convinced that BM itself allows to be innovated to promote BMI.

From a systematic literature study on BMI, Foss and Saebi (2017) summarised four BMI research streams emphasizing conceptualization, organizational change process, outcome, and consequence. When conceptualizing BMI, the literature documented two dimensions: the degree of novelty and the scope of the BMI. They classify BMI into two novelty degrees that are new to a firm or new to the industry, implying BMI at the firm or industry level. Besides, the scope of BMI is elaborated by three degrees of change in BMs that change in a single element of BM, more than one element, and changes in all BM elements and their interrelation. As described by them (Foss and Saebi 2017, p. 201), BMI can be viewed as an extension of BM and can be defined as "*designed, novel, nontrivial changes to the key elements of a firm's business model and/or the architecture linking these elements*." Based on their research, BMI is about changes in BMs elements and their relationships in various degrees at the firm or industry level.

In summary, from the dynamic perspective, business model innovation is 'a higher-order capability to identify, design and implement new BMs (Mezger, 2014, p. 444).' Factors triggering BM innovation are essential for understanding BMI. Dynamic perspectives on BMs determine the success of BM innovation (Lambert and Davidson, 2013).

1.2 Problem statement

In the last two decades, the rapid growth of large-scale PV (LSPV) plants has curtailed PV generation in China (Wang et al., 2021). More than 70 percent of LSPV projects are in the northwest and southwest regions with abundant solar energy resources, while the more well-developed eastern part has higher electricity demand than the western area. The dependence of electricity demand on long-distance transmission from the west to the east and the lack of grid integration call for solutions. Distributed solar PV (DSPV) generation with few transmission problems and flexible local installation could be a promising technology to stimulate the PV industry and maintain energy demand in the high-load region.

The implementation of DSPV projects has confronted several challenges (as described in sub-section 1.1.5) (Horvath and Szabo, 2018). Promoting BM innovation and developing BMs from dynamic perspectives is needed for companies carrying out DSPV projects. Before implementation new BMs, understanding current DSPV BMs and the origins of BM innovation in DSPV are essential. Investigating through dynamic frameworks is an approach to interpret business model innovation for DSPV project companies towards sustainability. However, building a such framework for DSPV is not straightforward.

First, external factors such as policy and regulation changes, competition, and disruptive technology could pose threats or create opportunities for enterprises (Bucherer et al., 2012). Without capturing vital environmental variables, companies with existing BMs may fail to respond to these externalities effectively and thus could not innovate BMs successful. Meanwhile, internal factors such as company competences, entrepreneurial capability, and growth strategies may affect companies' business model variables in certain circumstance (Khodaei and Ortt, 2019). Researchers without considering internal enterprise factors also cannot adapt BMs towards new ones.

Moreover, investigators may lack knowledge of interrelationships that are critical in changing environment. The interrelationships between different elements of business models, among environmental factors and between environmental factors and business model aspects are worthy of attention (Khodaei and Ortt, 2019). Because the interrelationships help academics comprehend the effects of environment to an enterprise' BMs, and then adjust BMs to fit changing environment.

Additionally, since the interrelationship itself changes over time, researchers paying little attention to the dynamics of these relationships could not maintain sustainable BMs. For example, dismissing or underestimating one element of the BM would induce a series of consequences due to constant interactions between different BM components. Thus, scholars should analyse interrelationships consistently when renewing a company's BMs (Khodaei and Ortt, 2019).

Overall, DSPV projects face challenges in BM innovation due to little attention on the dynamics of BMs. Researchers need to investigate BMs from dynamic perspectives, which helps them understand BM innovation under different conditions. Besides, BM frameworks for DSPV, mostly BMC, are static approaches without describing BM changes. Apart from it, economically-oriented BMC does not involve environmental and social values that are more suitable for sustainable solutions (Cardeal et al., 2020), such as products and services provided by DSPV project companies. Therefore, scholars desire dynamic sustainable BM frameworks to alleviate these problems in conducting DSPV projects.

1.3 Research gap

ScienceDirect, Multidisciplinary Digital Publishing Institute (MDPI) and Wiley Online Library are the main platforms used in this research. Many publications revolve around business models innovation, including books, book chapters, research articles and journal articles. Large quantities of them focus on the application of BM innovation in specific industries and economic entities. Other similar terms such as business model evolution and business model reinvention could also be used to complement research searching as these concepts are interchangeably used in some contexts.

Table 1.3.1 Search results of research topics

Search terms	Number of articles
"business model innovation" and "dynamic sustainable business model"	25,227

“business model innovation,” “dynamic sustainable business model,” and “solar PV”	1621
“business model innovation,” “dynamic sustainable business model,” and “distributed PV”	1,101
“business model innovation,” “dynamic sustainable business model,” “distributed PV,” and “China”	512

When searching “business model innovation” and “dynamic sustainable business model,” the number of publications sharply dropped. Few articles cover both “business model innovation” and “solar photovoltaic” or “distributed photovoltaic.” Likewise, little work on “dynamic sustainable business model” in “distributed photovoltaic.” Besides, there is relatively little research on the "sustainable business model canvas." The results further greatly reduce if adding “China” to foregoing terms. Therefore, there is a research gap in studying business model innovation through dynamic sustainable business models framework in DSPV projects, and more significantly for the case in China (see Table 1.3.1).

1.4 Research objective and scope

This thesis aims to investigate business model innovation (BMI) for distributed solar photovoltaic (DSPV) project companies through dynamic sustainable business model frameworks. The framework will be developed based on the one established by Kamp et al. (2021), and the sustainable business model canvas (SBMC) by Bocken et al. (2018) is the tool. Building on the baseline, the framework in this research will focus on (sustainable) BMs of DSPV projects, including unique BMs elements, interrelationships, and changes over time. Meanwhile, the dynamic sustainable BM framework in this research will further show internal and external company changes that determine business model innovation for DSPV projects. Overall, the objective is to understand business model innovation in DSPV companies through the dynamic sustainable business model framework.

To point out the direction, this research would follow the objectives listed below:

- To investigate current business models for DSPV projects, specifically, BMs applied in China.
- To explore triggers of business model innovation in DSPV projects from internal changes within the enterprise and the external changes to enterprises.
- To investigate important interrelationships between BMs elements should the company consider in business model innovation.
- To develop a dynamic sustainable business model framework to understand business models innovation.
- To apply the dynamic sustainable business model framework to DSPV project companies in China in order to understand business model innovation.

More specifically, when developing the dynamic sustainable business model framework, four criteria assessing dynamic business model frameworks by Khodaei and Ortt (2019) can be followed as a guide. These four criteria are laid out below:

- The dynamic business model framework involves the internal company and external environmental factors.

- The dynamic business model framework can disclose the interrelationship between business model elements, among environmental factors and between environmental factors and business model variables.
- The dynamic business model framework can reveal the interrelationship over time.
- The dynamic business model framework can represent changes in business models framework.

The scope of this thesis is shown in Fig. 1.4.1. This study will focus on on-grid distributed PV systems, including both rooftop and ground-mount systems.

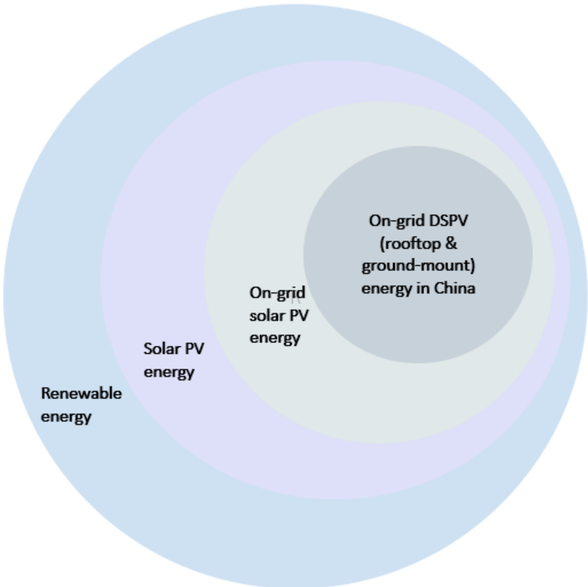

Figure 1.4.1 The scope of the thesis

1.5 Research questions

The main research question is: ***How can we develop a dynamic sustainable business model framework to understand business model innovation in distributed solar PV (DSPV) projects in China?*** Five sub-questions could answer the main question.

1. What are current business models implemented in the DSPV projects, and what are the current business models of DSPV projects in China?

2. What internal changes within and external changes to enterprises may trigger business model innovation in DSPV projects?

3. What important interrelationships between BMs elements and interrelationships over time should the DSPV project company consider in business model innovation?

4. How can we develop a dynamic sustainable business model framework to understand business models innovation in DSPV projects?

5. How can we apply the dynamic sustainable business model framework to DSPV projects in China to understand business model innovation?

1.6 Methodology

1.6.1 Research approach

This exploratory research is mainly based on literature research, interview and case study. Table. 1.6.1 presents the research approach. Each question will be answered through appropriate methods.

Table 1.6.1 The research approach

Research questions	Data collection
Q-1	literature study
Q-2	literature study / Case study / Interview
Q-3	literature study / Case study / Interview
Q-4	Developing the dynamic BM framework
Q-5	Case study / Interview

Sub-Q-1. For Q-1, it will be carried out by literature review. To investigate current BMs for DSPV, this could be conducted by reviewing typical DSPV BMs in countries with increasing DSPV projects going on or countries promoting DSPV successfully. The final part to answer this question focuses on the current DSPV BMs applied in China. One aspect of it should identify elements of DSPV BMs.

Sub-Q-2. Question 2 focuses on understanding BM innovation in terms of identification, and it will be answered by literature study, case study, and interviews. After understanding the definition of business model innovation, it needs to examine the triggers of BM innovation in companies conducting DSPV projects by investigating internal and external changes to DSPV project companies. This can follow the categorization of BM innovation by Bucherer et al. (2012) that distinguishes internal and external factors triggering BMI between opportunity and threat. Apart from the factors obtained from the literature research, more critical triggers to BM innovation in the DSPV projects in China should be concentrated, which can be conducted by the case study. Interviews with selected enterprises can provide additional answers to the above.

Sub-Q-3. Because SBMC is used as the tool, elements and interrelationships should be revised before designing dynamic frameworks. The answer to Q1 provides a more general view of vital BM elements in distributed solar PV energy projects. The study here should concentrate on the interrelationships between business model elements and changes over time. Since more diverse discussions on business model elements and interrelationships are preferable, this question could be answered through literature, case studies, and interviews. Valuable information from the interview with selected enterprises can supplement the investigation. Eventually, all feedbacks and results from the interview, case study and literature review should be synthesized and classified.

Sub-Q-4. After the previous study, this part will provide companies with the dynamic sustainable BM framework. Establishing the dynamic sustainable BM framework is more about synthesizing literature research with practical cases (shown in Fig. 1.6.1). But, at this step, a conceptual framework is desired. The framework can be built on Kamp et al. (2021) dynamic framework and Bocken et al. (2018) SBMC. Four criteria assessing the degree of dynamics by Khodaei and Ortt (2019) can guide the developing process.

Sub-Q-5. After establishing the framework, it is time to apply it to cases in China. The case study offers a detailed description of a company's business models and may help refine the established dynamic sustainable business model framework.

1.6.2 Data collection

literature research. In the literature study, the main subjects would be, business models, sustainable business model canvas, current DSPV business models, business model innovation and dynamic business model frameworks. As this research focuses on DSPV projects, all mentioned subjects revolve around it.

Semi-structured interview. One of the significant benefits of the interview is that respondents from the selected company can provide practical information that may be unknown or unidentified. Open-ended interviews are preferable but with a range of questions prepared beforehand. By open-ended questions, respondents can freely express their perspectives relevant to BMs and BM innovation. After synthesizing answers, the most outstanding environment factors, BM elements and relationships that affect or are vital to DSPV companies can be revealed.

Case study. Apart from leading giants in China's PV industry, most companies engaged in DSPV projects are small companies with little trackable details telling the story of themselves and their responsible projects. This makes the case selection process difficult, considering response-ability and commitment.

1.6.3 Research framework and schedule

Research framework. Figure. 1.6.1 displays the research framework.

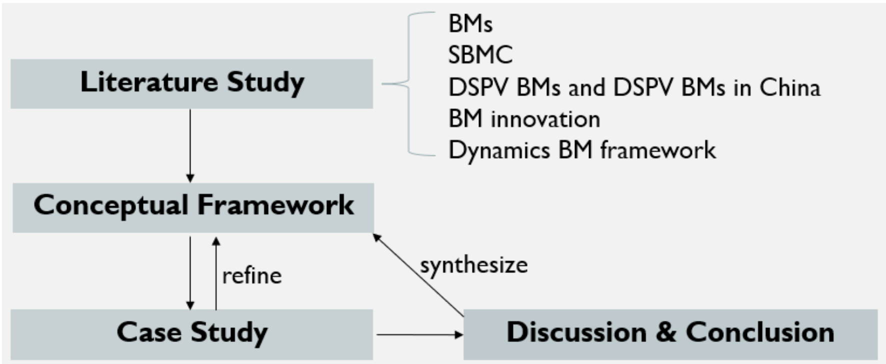

Figure 1.6.1 Research framework

Research schedule. Figure. 1.6.2 shows the research timetable.

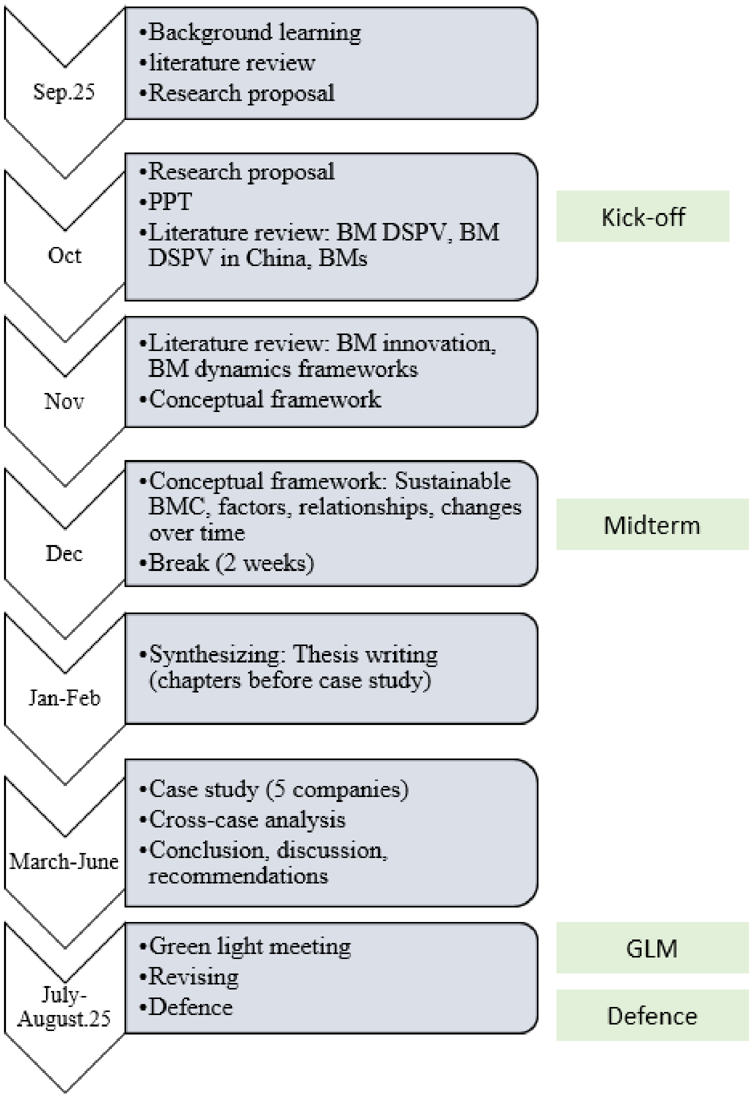

Figure 1.6.2 Research timetable

1.7 Research relevance

(1) Scientific relevance

First, this study fills the academic gap mentioned in sub-section 1.3. The established dynamic framework based on sustainable business model canvas and its practical case study provide not only a reference for research objectives on business model innovation towards sustainability but also increases understanding of business model innovation through the dynamic sustainable business model framework. Besides, by literature review and case study, this thesis offers scholars insights for business models and business model innovation of distributed solar PV projects, especially for projects in China. Future research interested in this topic can refer to this study.

(2) Managerial relevance

Moreover, the results of this study can give recommendations for companies devoted to sustainable technology in today's complex social-economic world. The framework applied helps them understand the adjustment process of their business models better when sustainability becomes a tendency in industry. It also helps them in strategy making and organizational management when facing external and internal threats or opportunities.

(3) Social relevance

By this research, policymakers and environmental-related organizations can better understand the effects of their performance on companies' businesses. It could provoke them to build long and healthy relationships that benefit all. Besides, the feasibility of business models involving sustainable considerations could reduce industry concerns and even direct the technology and business to more sustainable ones. Finally, it also popularises relevant concepts for the public so that people with no background can touch them.

Chapter 2 . Literature review

Before digging into the research, an investigation of China's DSPV backgrounds and a literature review of basic concepts relevant to business models are essential. First of all, distributed solar photovoltaics (DSPV) energy systems in China regarding its definition, policies, and costs are described. Then, the business model (BM) is studied as a fundamental subject since the determination of BMs' main components is one focus task for framework design. Apart from business models, business model innovation (BMI) is another subject that should be learnt beforehand, of which BM innovation for sustainability or innovation towards sustainable business models (SBMs) is a sub-focus to business model innovation.

2.1 Distributed solar photovoltaics (DSPV) energy systems in China

Since China's *12th Five-Year Plan* (State Council, 2013), highlighting distributed renewable energy development, DSPV energy has experienced remarkable growth. According to *Management Measures for Distributed Photovoltaic Power Generation Projects* (National Energy Administration, 2018), distribution solar photovoltaic (DSPV) systems refer to small-scale photovoltaic power generation systems distributed on or near the user side. It mainly includes two types, self-consumption with excess sold to the grid DSPV facilities and self-generation self-consumption DSPV power stations (see Table 2.1.1). The former means that the majority of energy generated by DSPV is for self-use, and excess electricity (less than 50 percent) is connected to the grid at a single point. The total installed capacity should be no more than 6 MW. The latter refers to small-scale DSPV power stations with a total installed capacity of more than 6 MW but not more than 20,000 kW. Technically, DSPV systems can be grid-connected photovoltaic systems and off-grid photovoltaic systems. In some literature, DSPV systems are particularly referred to as grid-connected systems with project sizes smaller than 6 MW (e.g., Zhang, 2016a; Yuan et al., 2014), since most of the current DSPV systems are on-grid applications (International Energy Agency, 2019).

Table 2.1.1 Two main types of DSPV systems in China (National Energy Administration, 2018)

Main types of DSPV generation systems	**Total installed capacity**
Self-consumption with excess sold to the grid DSPV facilities	No more than 6 MW
Self-generation self-consumption DSPV power stations	More than 6 MW but not more than 20,000 kW

In China, the DSPV market still relies highly on policies (Zhao and Zhen, 2019). Primary grid companies, the National Energy Administration (NEA), the National Development and Reform Commission (NDRC), the State Council, local governments are important institutions issuing policies and regulations supporting the DSPV industry development. In 2012, integration regulations from the grid company, State Grid Company of China (SGCC), directed the first grid connection process of DSPV projects (Yuan et al., 2014). Till the end of 2021, the first year of the 14th Five-Year Plan, the grid-connected installed capacity of DSPV reached 107.5 million kW, accounting for around one-third of all grid-connected PV installed capacity in China (National Energy Administration, 2022). According to International Energy Agency

(2019), policies will remain the key growth stimulate for DSPV generation. By 2024, sustainable DSPV systems will continually depend on major tariff and policy frameworks to balance the interests of DSPV system owners, distribution enterprises, and end-users (International Energy Agency, 2019).

Aside from policies, the rapid decline in costs has been another vital factor in deploying DSPV generation (International Energy Agency, 2019). Costs of a DSPV system come from three main aspects, including investment cost, cost of operation and maintenance (O&M), and financial expense (Zhao and Zhen, 2019). Investment cost consists of PV module costs, the balance of system (BoS) costs by all other system components, and soft costs relevant to system design, land, construction, management and labour. Additional financing investment and costs after system operation are counted in financial expense. The latest renewable data shows that the investment costs for commercial and industrial (C&I) and residential DSPV systems have fallen from around 4800 USD/kW and 6700 USD/kW to about 1000 USD/kW in China (International Energy Agency, 2019). Approximately 70% of overall system cost reductions in China are attributed to the decrease in PV module costs (International Energy Agency, 2019). BoS costs are central to the cost variation of DSPV systems, and China has some of the lowest DSPV investment costs globally due to the optimised BoS costs (International Energy Agency, 2019).

Overall, policies and a decline in costs have played important roles in China's DSPV development in the last decades. Table 2.1.2 and Table 2.1.3 lay out relevant policies targeting investment cost for DSPV systems and consumption and sale of electricity produced by DSPV systems, respectively.

Table 2.1.2 Policies targeting investment cost for DSPV systems

Policies targeting investment costs	**Explanations by IEA** (International Energy Agency, 2019 p.73)	**China**
Grants and rebates	A fixed subsidy, usually with a one-time payment.	• No subsides for industrial and commercial DSPV projects since 2021 (Development and Reform Commission, 2021b) • No subsides for new household DSPV projects since 2022 (Development and Reform Commission, 2021a) • Subsidy by local governments
Tax credits	Amounts that taxpayers can subtract from taxes, usually based on a percentage of total solar PV system investments.	• None (Federal Investment Tax Credit in the United States, International Energy Agency, 2019)
Accelerated depreciation	PV owners can receive higher tax benefits by depreciating assets more quickly, usually in the first or second year.	• Accelerated depreciation / deduction of fixed asset costs since 2014 (State Taxation Administration, 2019)
Tax exemptions	Sales tax or value-added tax (VAT) reduction or exemption from the PV system price.	• Refunding 50% of VAT on PV power generation products from 2013 to December 31, 2020 (State Council, 2017)

Table 2.1.3 Policies targeting consumption and sale of electricity produced by DSPV systems

Policies targeting consumption and sale	**Explanations by IEA (International Energy Agency, 2019, p.73-74)**	**China**
Buy-all, sell-all	All PV generation is deemed to be sold to the utility, usually at a fixed price.	• Feed-in Tariff (FiT) since *Renewable Energy Law* 2006 (State Council, 2005) • FiT for DSPV projects from September 2013 (the term is in principle 20 years) (National Development and Reform Commission, 2013) • Grid parity for new DSPV projects since 2021 (Development and Reform Commission, 2021a) (I&C DSPV since 2021; household DSPV since 2022)
Net metering	A PV owner receives an energy credit for any excess generation exported to the network during a specific time period. This energy credit can be deducted from network electricity consumed on future bills at another time.	• None (International Energy Agency, 2019)
Real-time self-consumption	PV owners can generate electricity for self-consumption and sell excess to the network. Energy accounting is done in real time.	• Self-consumption with excess sold to the grid • Self-generation self-consumption (National Energy Administration, 2018)

Supply chain, value chain, ad value network

Upstream material, cell manufacture, and module assembly together with the downstream distributor and installer complete the entire PV product supply chain (see Fig. 2.1.1). EPC stands for the engineer, procure, and construct (Frantzis et al., 2008).

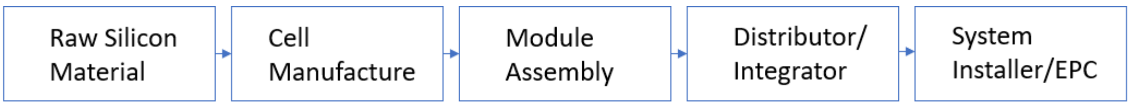

Figure 2.1.1 PV product supply chain (Frantzis et al., 2008)

Beyond supply chain, value chain and value network describe business from a more holistic point of view. Following the value chain, it tells how PV systems are developed and vital activities of PV firms during this process. The primary activities are logistics (e.g., material supply, product transformation, distribution, etc.), marketing, sales, and services (Ricciotti, 2020). Other support activities are associated with technology development (e.g. product and process improvement), human resource management (e.g., recruiting, hiring, training, etc.), and firm infrastructure (e.g., accounting, planning, legal, etc.) (Ricciotti, 2020).

Apart from the value chain, the value network incorporating key participants pictures how a company creates value with the help of its business network (Ricciotti, 2020). Local and state governments, regulators, and utilities play important roles in DSPV projects as they could offer incentives, subsidies, permits and grid connections. Others, project developers, financiers, monitoring providers, operation and maintenance (O&M) providers may also provide indispensable services when necessary. These participants work together to facilitate a project from scratch. In specific cases, one may play multiple roles (Frantzis et al., 2008).

2.2 Business model

Investigation of BMs is prerequisite for this research. This sub-section first studies business model frameworks and determines main BM components. Then, it focus on the popular business model canvas (BMC) by Osterwalder and Pigneur (2010).

2.2.1 Business model frameworks and components

Multiple research streams have emerged, providing perspectives on business models. Table. 2.2.1 summarizes the most prevalent BMs definitions and components. A generally accepted definition of business models is essential to give researchers and practitioners a basic understanding of its abstract concept before designing, implementing, and managing their own BMs. BMs frameworks along with compositions reflect perceptions towards BMs underneath architecture. This sub-section describes the logic behind the determined framework, business model canvas (BMC) and four-main components through literature review.

Table 2.2.1 A selection of BMs definitions and components (incl. articles in Chapter 1)

Author(s)	BM definitions	BM components
Timmers (1998)	"An architecture for the product, service and information flows, including a description of the various business actors and their roles; and A description of the potential benefits for the various business actors; and A description of the sources of revenues." (p.2)	▪ Product/service/information flow architecture ▪ Business actors and roles ▪ Actor benefits ▪ Revenue resources
Chesbrough and Rosenbloom (2002)	"The business model provides a coherent framework that takes technological characteristics and potentials as inputs, and converts them through customers and markets into economic outputs." "The business model is thus conceived as a focusing device that mediates between technology development and economic value creation." (p.522)	▪ Value proposition ▪ Value chain ▪ Cost and profit ▪ Value network
Johnson, Christensen, and Kagermann (2008)	"A business model, from our point of view, consists of four interlocking elements that, taken together, create and deliver value. The most important to get right, by far, is the first. The other elements are the profit formula, the key resources and the key processes." (p.52-53)	▪ Customer value proposition (CVP) ▪ Profit formula (PF) ▪ Key resources (KR) ▪ Key processes (KP)
Richardson (2008)	"A business model is a conceptual framework that helps to link the firm's strategy, or theory of how to compete, to	▪ Value proposition

	its activities, or execution of the strategy." (p.5)	▪ Value creation and delivery system ▪ Value capture
Zott and Amit (2010)	"we conceptualize a firm's BM as a system of interdependent activities that transcends the focal firm and spans its boundaries." (p.216) "the overall objective of a focal firm's BM is to exploit a business opportunity by creating value for the parties involved, i.e., to fulfil customers' needs and create customer surplus while generating a profit for the focal firm and its partners."(p.217)	▪ Activity system content ▪ Activity system structure ▪ Activity system governance
Teece (2010)	"A business model articulates the logic, the data, and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value. In short, it's about the benefit the enterprise will deliver to customers, how it will organize to do so, and how it will capture a portion of the value that it delivers." (p.197)	▪ Value proposition ▪ Customer segment ▪ Cost and revenue model ▪ Value network
Osterwalder and Pigneur (2010)	"A business model describes the rationale of how an organization creates, delivers, and captures value." (p.14)	▪ Customer segments (CS) ▪ Value propositions (VP) ▪ Channels (C) ▪ Customer relationships (CR) ▪ Revenue streams (RS) ▪ Key resources (KR) ▪ Key activities (KA) ▪ Key partnerships (KP) ▪ Cost structure (CS)
Fielt (2013)	"A business model can be defined as the value logic of an organization in terms of how it creates and captures customer value." (p.86)	▪ Customer, ▪ Value proposition, ▪ Organizational architecture ▪ Economics dimensions
Gassmann, Frankenberger, and Csik (2013)	"Business models describe how the magic of a business works based on its individual bits and pieces." (p.1)	▪ Customer segment ▪ Value proposition ▪ Value chain ▪ Revenue model

An early study referred to by many researchers, Timmers (1998), saw a business model as an architecture that shows product, service and information flows. In terms of flow, two descriptions elucidate the architecture. One is related to business actors, including their roles and potential business benefits to them, and another is towards a company's revenue streams.

In addition to these two essentials, the business architecture is identified by the way of determining a company's value chain. A three-step scheme completes the architecture construction process. The first step is to (1) deconstruct the value chain to primary and supportive elements, from inbound logistics to after-sale services and entail procurement, R&D, HR management, etc. The next step is to (2) determine the 'interaction patterns' of actors involved, such as one-to-one and many-to-one, etc. After that is to (3) re-construct the value chain by integrating information across the chain. Through the way, possible BMs architectures are then framed by combining 'interaction patterns' and 'value chain integration.'

This early work pictures basis of business models and directs future investigations on this topic. A business model needs to articulate what interests a company can bring to business actors and what revenue sources are sought along its value chain. That is, business models are supposed to express the value that an organization can create to relevant business participants and the economic value that the enterprise can capture. Besides, BMs architecture by means of value chain reconstruction sees BMs more or less activity systems with information flows.

However, the author believed that a BM only functions as a business description, and it requires following marketing strategies to take actions in practice. In this context, only answers in the What dimension are offered and with a broad view of potential benefit receivers. Business actors are unspecific about targeted customers or markets. Instead, they are participants in a range of relative activities. Additionally, by combining 'interaction patterns' and 'value chain integration,' the author intends to connect the interrelationships of those actors and activities undertaken. However, the framework only enumerates the number of parties rather than narrates the story between them. The description attribute of BMs makes such framework more or less only a general idea.

Subsequent research over the Timmers (1998) study contributed more diverse and fleshed illustrations of BMs frameworks. In a study conducted by Chesbrough and Rosenbloom (2002), BMs mediate between economic and technical domains, mapping from technical inputs onto economic outputs (shown in Fig. 2.2.1). Specifically, a successful business model 'develops a heuristic logic connecting technical potential with the realization of economic value. (p. 529)'

First of all, this kind of interpretation indicates that technology itself has no single intrinsic value. Rather, values are accrued by developing technology in different business processes that tell what value a company will offer its buyers through products and services. Thus, value is specific to value proposition (VP), or the products and services provided to targeted customers in a market. Apart from decrypting value to customer value proposition, a description of value network linking suppliers and customers and an estimation of cost and profit are added to tell a coherent business story beyond defining value chain structure like in Timmers (1998).

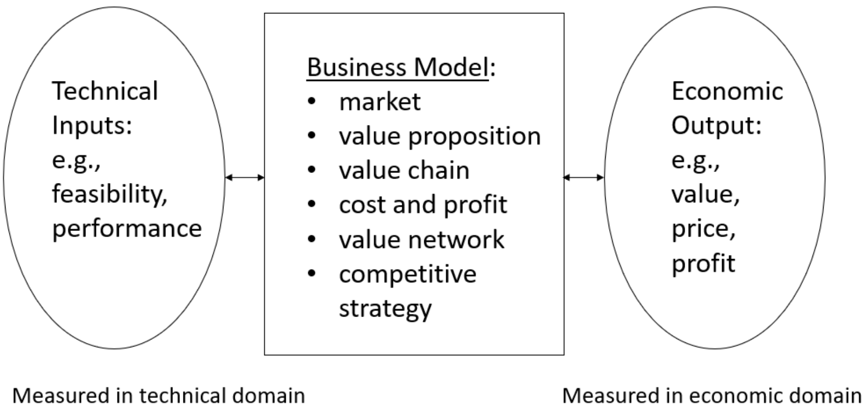

Figure 2.2.1 The mediation of the business model (Chesbrough and Rosenbloom, 2002)

From the above, the Chesbrough and Rosenbloom (2002) framework demonstrates the necessity of BMs to articulate value offered to customers and present value appropriated for a company itself through business. This consolidates BMs to answer the What dimension regarding value propositions and the How dimension towards value capture. More importantly, it highlights another two attributes of BMs, value creation and value delivery, with the help of identifying the value chain and value network.

Like Timmers (1998), Chesbrough and Rosenbloom (2002) held the need for a value chain structure for value creation. This is also emphasized by Gassmann et al. (2013) as to how the value proposition is created. They related it to processes, activities, resources, capabilities and their orchestration in the value chain. Meanwhile, Chesbrough and Rosenbloom (2002) also stressed the effects of the position of the firm within the value network on value creation and delivery. By their understanding, this positioning affects how a company links suppliers and connects with customers.

Value chain and value network are more holistic and systemic views containing more than one stage (e.g., activities from upstream procurement to after-sale services) and more than one type of actor role (e.g., regulator, utility, developer, users, and financier, etc.). Despite value chain and value network, investigations that flesh out BMs elements underneath value creation and delivery could be conducted to disclose BMs frameworks further.

Another study by Johnson et al. (2008) helps such exploration. Two elements, key resources (KR) and key processes (KP), are particularly remarked. In their identification, value creation takes both customer and company perspectives. It details how a company creates value for customers and for itself. The latter is described by profile formula (PF) relevant to cost and revenue, that is value capture. Based on this interpretation, the key resources (KR) then define the resources, channels, and partnerships required to deliver the customer value proposition (CVP). Among them, resources could be people, equipment, information, and brand etc. The key processes (KP) then define managerial and operational processes that can deliver value for the company. It needs to emphasize that the value for a company by the author is the value which can successfully scale the business. Thus, key processes not only embody activities undertaken in business as usual (e.g., training, manufacturing and selling, etc.) but also involve a company's rules, metrics and norms that further reveal the detail as to value delivery (e.g., investment requirements, credit terms, supplier terms and opportunity size).

This study again acknowledges recurring BM elements, including customer segments, value proposition, cost and revenue. Furthermore, it contributes to clearer value creation and delivery de-composition. These components could be resources (e.g., physical, intellectual, and human resources), channels to reach customers, partnerships, business activities, and company norms and goals.

Such exploration was also done from another perspective. As discussed above for the Timmers (1998) framework, BMs architecture based on the value chain is more like an activity system with information flows. A study by Zott and Amit (2010) supported such interpretations. They conceptualized the BM as an activity system performed by the focal company and third parties (e.g., suppliers, customers, partners, etc.). Moreover, they suggested three design elements, the "content, structure, and governance," shaping the system's architecture. Among them, the 'content' refers to a selection of activities. Activities are "the engagement of human, physical and/or capital resources of any party to the business model to serve a specific purpose toward the fulfilment of the overall objective (p. 217)." An activity system is then "a set of interdependent organizational activities." Thus, a selection of activities implies the selection of resources of any party to perform a business purposefully. While more than one BM variable underneath such a selection. It relates to what resources (physical, human and finical resources) are required for the business, what suppliers and partners need to approach for acquiring resources or other objectives, such as cost reduction and risk and uncertainty reduction, and what activities the company decides to conduct. Combining them all tells how the company creates value.

Up to now, a picture of the business model framework is unfolded. From the above study, the concept of 'value' underpins the business model concept. The business model can be defined as a logic demonstrating how an organization creates and delivers value propositions to its targeted customers and captures value for itself along with business is done.

Osterwalder and Pigneur (2010) confirmed such kind of understanding of BMs with a business model canvas (BMC) including nine elements. Teece (2010) and Fielt (2013) reported a similar interpretation that BM as the "*design or architecture of the value creation, delivery, and capture mechanisms*" of a firm (Teece, 2010, p.172). Furthermore, for value creation, delivery and capture, there are a set of elements underneath them jointly to tell the business operation. These elements are customers, channels, resources, activities, partners, costs and revenues, and other relevant components that make the business work. Business model canvas by Osterwalder and Pigneur (2010) considers them all.

In a further study, Short et al.'s (2014) framework groups nine blocks of the BMC into three main elements (as shown in Fig. 2.2.2). This updated framework is also reorganized around the concept of value. The recurring theme, 'value,' in business models is used by Richardson (2008) to establish a framework with three major components: the value proposition, the value creation and delivery system, and the value capture. Because Richardson's (2008) framework is formed from the strategic point of view that aims to gain competitive advantages, elements are grouped, reflecting more strategic thinking. Short et al. (2014) followed Richardson's (2008) framework. Thus, unlike other frameworks, the value proposition is broader in conception in this context, with two dimensions: the What and the Who, to tell not only products and services offered but also the target customer.

Value Proposition	Value Creation & Delivery Systems	Value Capture Mechanisms
1) Product/service offerings 2) Customer segments, and 3) Customer relationships *(What value is provided and to whom)*	4) Activities, 5) Resources, 6) Partnerships and suppliers, 7) Distribution channels. *(How value is provided)*	8) Cost structure, 9) Revenue streams *(How the company makes money from providing value)*

Figure 2.2.2 A business model framework (Short et al., 2014 developed based on Osterwalder et al, 2005 and Richardson, 2008)

Accordingly, this research identifies the main BMs components based on interpretations of BMs described above. They could be the value proposition, value creation, value delivery, and value capture. Indeed, this type of identification of main BMs components stems from Richardson (2008) and is supported by Short et al. (2014) and Bocken et al. (2014). For value creation, delivery and capture, there are a set of elements underneath them jointly to tell the business operation.

2.2.2 Business model canvas (BMC)

The business model canvas (BMC) can be grouped according to main BM compositions based on the above study. This sub-section first illustrates the BMC and then incorporates it with four main elements. Before looking at BMC and incorporating four-main-element, a deep dig into BMC is essential. The BMC by Osterwalder and Pigneur (2010) is a popular framework (shown in Fig. 2.2.3). The nine elements are elucidated one by one here.

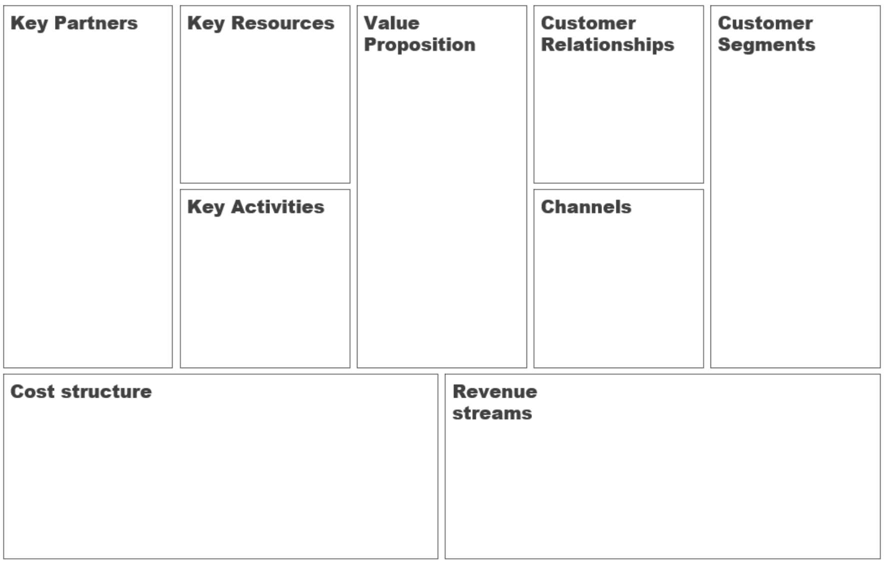

Figure 2.2.3 Business model canvas (BMC) (Osterwalder and Pigneur, 2010)

Customer segments (CS). Customer segments block labels certain groups of people or organizations a company is determined to reach. One customer segment could be classified into sub-segments for sharing common needs or having common customer profiles. As for such way, the company must decide which exact segments to serve. On the one hand, customers could broadly share similar needs or face a problem, such as BMs for mass markets. On the other hand, specialized segments have their specific customer requirements, for instance, BMs for a niche market. The enterprise can enjoy a strong tie to meet specific customer needs only after customer segments are distinct.

Value propositions (VP). Value propositions block expresses products and services a company offers to a specific customer segment or answers the question of what value is created for customers. Through products and services, customer needs are satisfied, or customer problems are resolved. Each value proposition can involve many products and services for catering to a specific customer segment. The value created by products and services could be a price reduction, efficient service, technology innovation, or customer experience, etc.

Customer relationships (CR). Customer relationships block details the relationships developed between the enterprise and a customer segment. It closely relates to customer experience. Driven by different purposes, a company establishes different types of relationships with its customer. From business set-up to its stable stage, these purposes may change from customer acquisition to customer retention or promotion. These relationships could co-exist in the relationship with a customer group. Relationships could be mutual, which indicates companies benefit from them in turn. Examples of this block could be personal assistance during or after sales, personal online profiles, and online or offline user communities.

Channels (CH). Channels block tells how an enterprise communicates with its customer segments to deliver value propositions. Channels servers more than a bridge between a company and its customer segments. Five phases comprise channels phase including awareness, evaluation, purchase, delivery, and after-sales (Osterwalder and Pigneur, 2010). Each channel could cover some of these phases. It is pointed out here that how a company delivers value propositions to a customer segment is only one out of five phases. Channels also have other functions. For instance, raising customer awareness, helping customers to evaluate value propositions, approaches allowing customers to purchase, offering after-sale services (Osterwalder and Pigneur, 2010). Examples of channels could be sales force, web sales, retail stores, and wholesalers, etc.

Key partners (KP). Key partners block describes suppliers and participants and their partnerships involved in a business model. Partners of a company could be non-competitors of business alliances, organizations of joint ventures, suppliers, etc. The company ties its partnerships out for several purposes. It could be aims of the economy of scale, risk alleviation, resource acquisition, etc.

Key resources (KR). Key resources block represents the most significant assets a company needs in a business model. Depending on business types, important resources could differ from one company to another. Generally, four types of resources are physical, human, intellectual, and financial (Osterwalder and Pigneur, 2010). Physical resources could be any physical assets essential to a business, such as manufacturing facilities, distribution networks, online-sale systems, etc. Human resources could be sales forces, scientists, management assistants, etc. Intellectual resources relate to brands, patents, customer databases, and partnerships, etc. Last but not least, financial resources may be needed by enterprises when they borrow money from banks or markets.

Key activities (KA). Key activities block expresses essential activities an enterprise conducts in a business model. Similar to key resources, different business types may stimulate different activities. A business could involve a range of actives, for example, from upstream production design and manufacturing to providing problem-solving solutions and to network-related activities. This block, as well as the key resources block, should be from a multi-angle point of view. That is, key activities (or key resources) that a company needs for offering value propositions, opening up channels, building or maintaining customer relationships, and generating revenues.

Cost structure (C$). Cost structure block tells all costs attached to a business model. Costs are engaged in a business model of creating and delivering value and generating revenues. Cost-driven and value-driven are two types of cost structures(Osterwalder and Pigneur, 2010). Cost-driven BMs are adopted by companies aiming to minimize cost structures, for instance, no-frills airlines. Value-driven BMs are implemented by enterprises focusing on value creation, such as companies pursuing a higher degree of customer experience. Costs could be fixed costs coming from salaries, manufacturing, and rent, or variable, associated with a company's production volume.

Revenue streams (RS). Revenue streams block describes money generated from customer segments. Two types of revenue streams could be involved in BMs. One is transaction revenue of one-time payments, and another is recurring revenue as to ongoing payments. The latter is more often seen from subscription fees, after-sales services, pay for use, leasing, etc. The former usually occurs by selling ownership rights. Companies aiming to generate revenue streams as much as possible need to understand what value a customer segment is genuinely willing to pay for.

Business model canvas and four main components

After looking at BMC in detail, the BMC is now combined with the interpretation of BMs that a concept underpinned by value, and its framework can be constructed accordingly by four main elements (the value proposition, value creation, value delivery, and value capture) as discussed in sub-section 2.2.1. Figure. 2.2.4 shows sub-elements underneath the four main components.

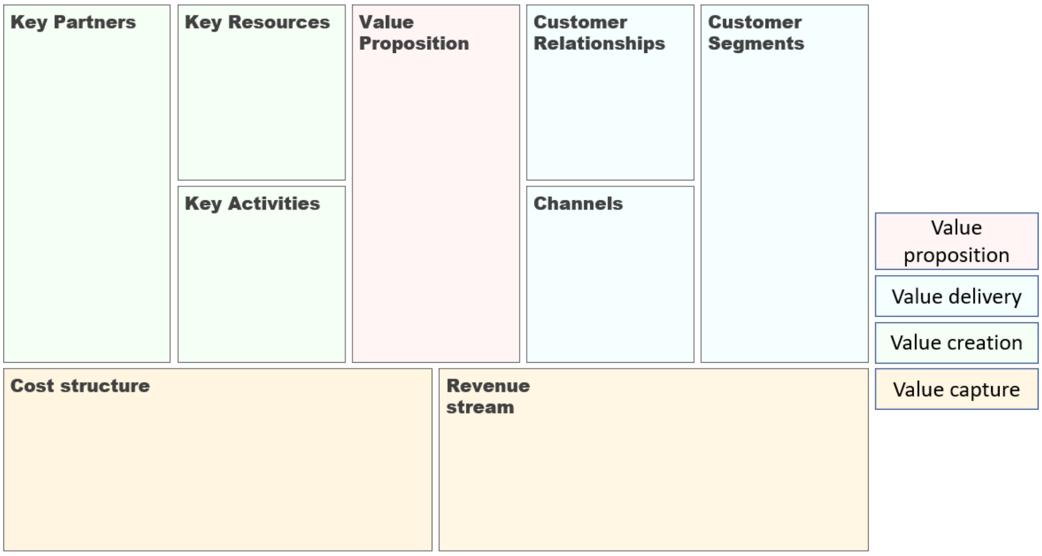

Figure 2.2.4 The business model canvas (BMC) with four maim components (adapted from Osterwalder and Pigneur, 2010; Short et al., 2014)

Value proposition. Value proposition, a separate element, expresses products and services a company offers to a specific customer segment or answers what value is created for customers.

Value creation. Value creation refers to activities, resources, and partnerships required for a company to offer products and services. It answers the question of how the business creates value.

Value delivery. Value delivery combines customer segments, customer relationships, and channels to tell how a company reaches and communicates with its customer segments for customers to access products and services.

Value capture. Value capture includes cost structure and revenue streams to reveal how the business makes money through creating and delivering value to its customer segments.

2.3 Business model innovation

Beyond business model, knowing business model innovation (BMI) is another essential prerequisite to this research. This sub-section first articulates the concept of business model innovation and its effects reflected in the value proposition, value creation, delivery, and capture. An elaboration of the sustainable business model (SBM) follows it.

2.3.1 Business model innovation

Business model innovation (BMI) is a different type of innovation from product innovation. Instead, it complements process, product, and organizational innovation (Zott et al., 2011). As some researchers pinpointed, traditional innovations may not always offer competitive advantages without BM innovation (Zott and Amit, 2012). In other words, BM innovation is a greater source of competitive advantage than new products or services (Bashir and Verma, 2017). It affects the organization more broadly and more often (Bucherer et al., 2012). Table 2.3.1 lays out definitions of business mode innovation in literature.

Mezger (2014) reported a routine for enterprises to engage BM innovation, from identifying opportunities to designing new BMs that address the opportunities and later implementing these new BMs. The starting point, opportunity identification, implies a capability to recognize changes in technology, especially by their competitors, and most importantly, underlying opportunities or threats of these changes. Before further implementation, companies design their new BMs to seize such opportunities or address the threats. Following these three dimensions, firms can engage in BMI systematically.

Similarly, Bucherer et al. (2012) mentioned four phases for BMs design. It begins with a shorter phase of analysis of existing BMs. Then, phases of design and implement new BMs and a final stage about control. As for control, the author indicates continuous monitoring of internal company and external environmental changes. Combining Mezger (2014) and Bucherer et al. (2012), BMI is seemingly iterative and starts with recognizing changes. These changes could be internal and external opportunities or threats. However, BMI is more than a frame of process.

Table 2.3.1 Business model innovation

Author	Definition

Giesen et al. (2010)	Three types of business model innovation: revenue model innovation, industry model innovation, and enterprise model innovation.
Amit and Zott (2012)	BMI can occur in a number of ways: adopting new activities (activity content system), new ways of linking activities (activity-system structure), and new ways of governing activities (activity-system governance) (p. 44)
Bucherer et al. (2012)	"We define business model innovation as a process that deliberately changes the core elements of a firm and its business logic." (p. 184)
Mezger, F., (2014)	BMI can be defined as "a higher order capability to identify, design, and implement new business models." (p. 444)
Foss and Saebi (2017)	BMI as "designed, novel, nontrivial changes to the key elements of a firm's business model and/or the architecture linking these elements." (p. 201)

Literature review on business models concludes the BM as the "*design or architecture of the value creation, delivery, and capture mechanisms*" of a firm (Teece, 2010, p.172). Foss and Saebi (2017) confirmed this definition of BMs and conducted a systematic study of BMI based on it. When conceptualizing BMI, the literature documented two dimensions: the degree of novelty and the scope of the BMI. They classify BMI into two novelty degrees that are new to a firm or the industry, implying BMI at the firm or industry level. Besides, the scope of BMI is elaborated by three degrees of change in BMs that change in a single element of BM, more than one element, and changes in all BM elements and the architecture. Subsequently, two types of BMI at the firm level are distinguished based on the scope of BMI (see Table. 2.3.2). First, evolutional BMI describes voluntary changes in individual (modular) BM elements that often naturally occur. Second, adaptive BMI represents the adaptation of BM architecture in response to external environment changes. Since this thesis research investigates BMs and BM innovation from companies' perspectives, the novelty degree is specific to new to the firm. From their study, BMI is about changes in BMs elements or/and the architecture at the firm level. Likewise, Bucherer et al. (2012) described BM innovation as a constantly changing process of core elements and their interrelationships and thus the business logic.

Table 2.3.2 Business model innovation typology (Foss and Saebi, 2017)

	Scope	
Novelty (new to firm)	**Modular**	**Architectural**
	Evolutional BMI	Adaptive BMI

There is similar research on BMI associated with changes in elements and architecture towards value creation and capture. In the early study, Zott and Amit (2010) defined BMs as an activity system performed by a focal firm and third parties to determine how a business is conducted. They characterized three elements of a company's activity system, "content, structure and governance," shaping the system's architecture. These three elements are highly interdependent to create value. Later on, Amit and Zott (2012) reported three ways BMI can occur, by adding “content,” or linking “structure,” or changing “governance” of the system. More specifically, these three methods refer to selecting novel activities to be undertaken, or linking activities in novel ways, or changing parties that perform activities. On the way, these changes can either create or capture value to stakeholders.

Besides, they then suggested six questions for managers to follow concerning BMI (shown in Fig. 2.3.1). For a company trying to innovate its BMs, it needs first explicit of customer value propositions of new BMs. Then, it considers BMs content, structure, and governance innovation, like questions 2, 3 and 4, to live up to the value propositions. To perform one new selected activity often requires a range of supporting activities. After that, subsequent decisions need to be made for creating and capturing value to stakeholders and the firm itself, like questions 5 and 6. From all, BMI is to integrate novel changes within a firm’s BMs in terms of activities, links of activities and participants of activities to address predetermined customer value propositions. Changes in any type alter the BM architecture and consequently affect how the company creates and captures value.

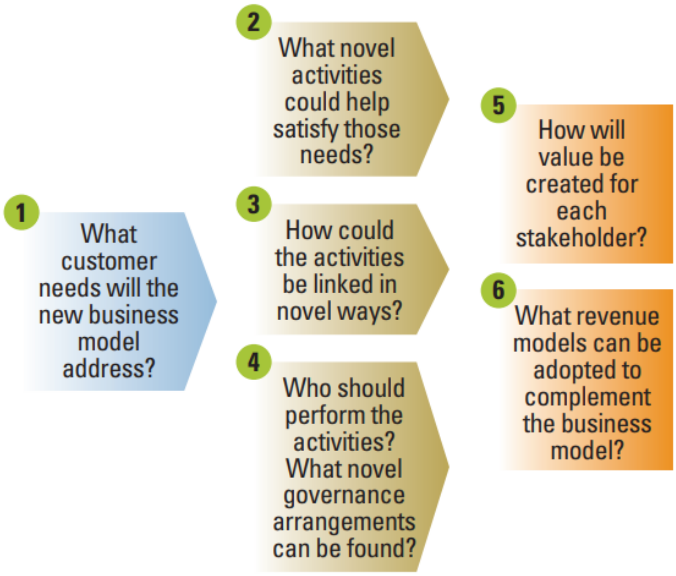

Figure 2.3.1 Six questions about business model innovation (Amit and Zott, 2012)

Giesen et al. (2010) also published an article regarding innovating BMs but drew attention to what factors determine a successful BMI. They formed a “Three A’s” model to characterise successful BMI (see Fig. 2.3.2). First of all, they differentiated three types of BM innovation: industry model innovation, revenue model innovation, and enterprise model innovation. Industry model innovation occurs in the case of unprecedented industry transformation, such as during economic downturns and periods of extensive industry change. Revenue model innovation refers to changes in value proposition and pricing model under new customer preferences. The last one, enterprise model innovation, is often provoked during economic turmoil. Therefore, to their understandings, BM innovation is a way to pursue new opportunities or respond to environmental threats. Similar to the first dimension of BMI capability by Mezger (2014) and the last design phase of Bucherer et al. (2012).

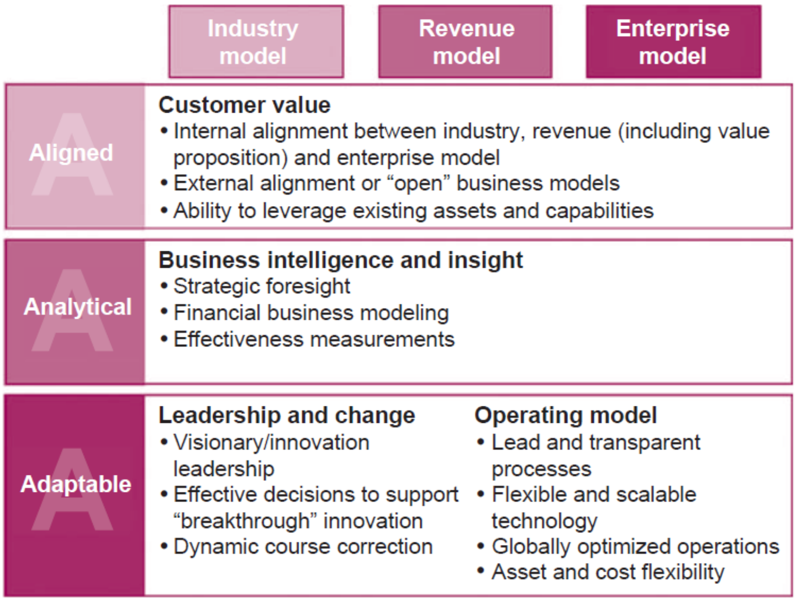

Figure 2.3.2 Three A's model for business model innovation (Giesen et al., 2010)

Furthermore, Giesen et al. (2010) featured aligned, analytical, and adaptable BM innovation. For a company, the alignment of BM innovation starts with aligning customer value proposition to the way of value capture and value delivery. Then, the company needs to orchestrate business participants, including customers, partners and suppliers, or in authors' words, open collaboration and partnerships. Finally, BMI alignment requires leverage of core capabilities and assets of the company, for instance, unique technologies, processes, or talents. For aligned BMI, customer value proposition is built under the consistency of all three aspects. Value propositions are supposed to in line with value creation highlighting partnerships and key resources, value capture and value delivery.

Additionally, analytical BMI demonstrates an acute understanding of new products and services a company delivers to its (new) customers through a different (new) delivery mechanism. This needs strategic foresight regarding value propositions, customer segments, and value delivery components. To guarantee a profitable and workable BM, it also needs analysis of financial impacts for prioritizing company actions and a constant measurement for rapid course correction to stay in sync with business decisions.

The final one is adaptable BMI. BMs adaptability is vital for enterprises to manage uncertainties in the fast-changing business environment. To encompass adaptability in BMs, innovative leadership in addition to a flexible operation model making effective decisions out of a culture of innovation and an entrepreneurial mindset and helping dynamic course correction is essential. A flexible operation model asks for end-to-end visibility of a company's operation process, flexible underlying infrastructures (including technology), and assets and costs flexibility for faster responses. Adaptability demonstrates an effective combination of a company's flexible management and operation abilities under complex and varying environments from dynamic perspectives. In a later paper, Lambert and Davidson (2013) acknowledged the Giesen et al. (2010) model. The three essentials, alignment, strategic analysis and adaptability, feature successful BM innovation. For enterprises, innovating BMs entails a systemic design and continuous updates.

In summary, business model innovation is a constantly changing process of BM elements or/and the architecture at the firm level in response to external and internal opportunity and threats. This process shapes the architecture of a firm's value creation, delivery, and capture mechanisms. BM innovation requires a systematic consideration in terms of the alignment of value mechanisms, strategic analysis, and adaptability.

2.3.2 Sustainable business model

The pressure for businesses to address sustainability concerns is building up due to climate issues worldwide. The 'sustainability' objective becomes a business jargon. This leads companies to pursue more sustainability-oriented business models and view them as one approach for sustainability (Evans et al., 2017). As a result, business model innovation for sustainability or innovation towards sustainable business models (SBMs) has seen a recent surge in academic research (Molina-Castillo et al., 2021).

By emphasizing environmental and social value on top of economic value, research on sustainable business models (SBMs) is gradually increased. The definition of a SBM varies between authors. By literature review on this topic, Geissdoerfer et al. (2018) found commonalities in defining SBM that the SBM is seen as a modification of the conventional BM, aiming at achieving sustainability or integrating sustainability considerations into business mechanisms. The way that they engage sustainability concerns is by '*creating sustainable value, incorporating pro-active multi-stakeholder management, and holding a long-term perspective* (p.405).'

Based on their findings, the SBM brings additional elements building on the conventional business model concept. Thus, the SBM can be viewed as a subset of the business model concept (as shown in Fig. 2.3.3). Another notion, circular business models (CBM), is also a subcategory of business models but is for circular economy solutions (Geissdoerfer et al., 2018). The SBM and CBM share most characteristics, but CBM has additional attributes: close, slow, intensify, dematerialise and narrow resources loops.

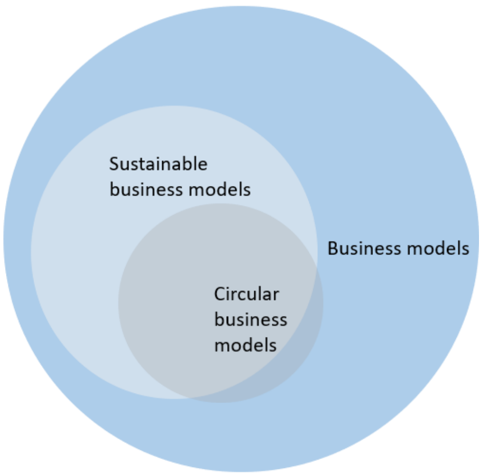

Figure 2.3.3 Business model concepts (Geissdoerfer et al., 2018)

As elaborated before, no matter how researchers characterise BMs, the concept of 'value' underpins the business model concept that value propositions provided by companies and the way they do business through creating, delivering and capturing values. However, unlike the conventional BM only realizes customer value, a sustainable BM is supposed to '*create, deliver,* *capture and exchange sustainable value for, and in collaboration with, a broad range of stakeholders*' (Geissdoerfer et al., 2016, p. 1219).

The sustainable value indicates a more holistic view of value integrating economic (customer), environmental, and social goals (Evans et al., 2017). Figure 2.3.4 illustrates the sustainable value and its three value forms. From it, the SBM is not only with a lens of economic value but also environmental and social values. For a company adopting the SBM, its value proposition now should entail three aspects: the customer, the environment, and society. Beyond suiting customer needs, providing positive impacts for or benefits to the environment and society incorporates into the company's value creation logic.

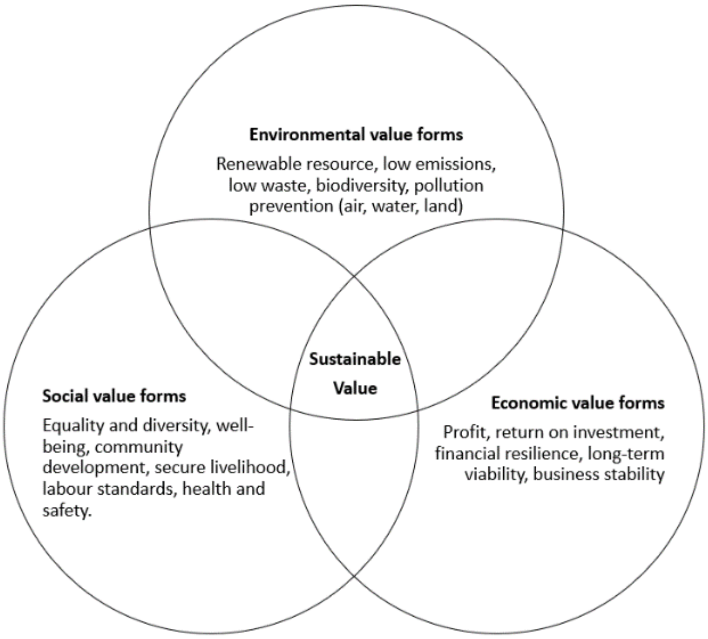

Figure 2.3.4 Sustainable value (Evans et al., 2017)

As such, the SBM needs to consider a broader range of stakeholders, specifically, society and the environment, than just customers and shareholders (Bocken et al., 2013). This consideration of wider stakeholder segments can be achieved by internalizing of harms and benefits to society and the environment alongside business is done (Bocken et al., 2015). By doing this, the value creation and delivery systems and the value capture mechanisms are enriched. Thus, interactions and relationships between BM components add. The triggers of BM innovation could be more diverse.

2.4 Chapter summary

This chapter contains literature reviews of distributed solar PV (DSPV) energy systems in China and two essential concepts: business models (BMs) and business model innovation (BMI). Sub-section 2.1, distributed solar photovoltaics (DSPV) energy systems, looks at DSPV energy systems in China in terms of the definition, policies, and costs. China's DSPV mainly includes two types, self-consumption with excess sold to the grid DSPV facilities and self-generation self-consumption DSPV power stations. Policies and a rapid decline in costs have been vital factors in deploying China's DSPV generation in the last decades.

Sub-section 2.2, Business models (BMs), describes the logic behind the determined BMs framework. Business model concepts are studied, and the results revealed that the concept of 'value' underpins BMs concept. BMs can be viewed as a logic demonstrating how an organization creates and delivers value propositions to its targeted customers and captures value for itself along with business is done. Accordingly, this research identifies four main BMs components based on such interpretations of BMs. They could be the value proposition, value creation, value delivery, and value capture. This type of identification of main BMs components stems from Richardson (2008) and is adapted by Short et al. (2014) and Bocken et al. (2014). The famous business model canvas (BMC) by Osterwalder and Pigneur (2010) is elaborated in sub-section 2.2.2 and is regrouped accordingly to have the four main BM elements. Such a canvas is the base of the sustainable business model canvas (SBMC) by Bocken et al. (2018) that will be discussed later in Section 5.

Sub-section 2.3, Business model innovation, gives the understanding of business model innovation, a constantly changing process of BM elements or/and the architecture at the firm level in response to external and internal opportunity and threats. Such a process shapes the architecture of a firm's value creation, delivery, and capture mechanisms. Besides, business model innovation towards sustainability or innovation towards sustainable business models (SBMs) is studied. The sustainable business model brings additional elements building on the conventional business model concept. A sustainable BM is supposed to create, deliver, capture and exchange sustainable value for, and in collaboration with, a broad range of stakeholders, specifically, society and the environment (Geissdoerfer et al., 2016; Bocken et al., 2013). The sustainable value covers economic, social and environmental values rather than customer value solely.

Chapter 3 . Current business models for distributed solar PV projects

This chapter answers sub-question one "***What are current business models implemented in the DSPV projects, and what are the current business models of DSPV projects in China?***" Based on the literature review, DSPV business models can be defined from different perspectives. One study by Pang et al. (2019) classified DSPV business models from consumption or investors' perspectives. The former focuses on the energy-using of consumption, while the latter focuses on identifying ownership of the system and cost and revenue to the company. Other literature directly pays attention to three main BMs: host-owned BMs, third-party-owned BMs, and community-shared BMs. These models are classified according to the ownership of DSPV systems.

The United States, the Netherlands, Germany, and China are some countries that research digs in. DSPV BMs differ among countries due to dissimilar contextual conditions. Companies adjust their BMs to local policies and electricity markets and adapt to fit social circumstances like increasing migration rates and building sector development. Environmental aspects, such as solar radiation, landscape, and public awareness of renewable energy, also affect their decisions. In China, host-owned and their-party-owned BMs are the main DSPV BMs (Zhang, 2016b; Cai et al., 2019; Pang et al., 2019; Li et al., 2020; Franco and Groesser, 2021). This chapter articulates the three main DSPV BMs in literature one by one and the two main models in China.

3.1 Host-owned (HO) business model

Host-owned (HO) business models, the most widespread PV BMs, have been applied in many countries (Horvath and Szabo, 2018). Although researchers named it differently, including customer-owned BMs, host-owned feed-in BMs, end-user owner BMs, or customer-sited BMs (as shown in Table 3.1.1), the underlying logic regarding ownership is the same. This study uses the term "host-owned (HO) business models."

Table 3.1.1 Host-owned business models

Business model	Allonym	Countries in literature study
Host-owned (HO) BMs	Customer-owned/Host-owned feed-in/ End-user owner/Customer-sited	United States (Frantzis et al., 2008; Zhang, 2016b); Germany (Strupeit and Plam, 2016); Netherlands (Huijben and Verbong, 2013); China (Zhang, 2016b; Cai et al., 2019; Pang et al., 2019)

In host-owned BMs, PV systems are owned by the host, who is the owner of the property on which PV systems are installed (Zhang, 2016b). Based on the literature study, HO BMs can be further differentiated depending on whether the power produced is primarily consumed by the host, or fully accessing to the utility grid, or utterly used by the host. The last two subdivisions occur when all power generated is sold to the utility grid and when the host consumes the entire electricity generated, respectively. Whereas in the first subdivision model, electricity generated is first used by the host. The surplus energy is fed into the grid and reimbursed by utilities according to energy-supply policies, such as feed-in-tariff (FiT) scheme (e.g., Renewable Energy Sources Act in Germany) or net-metering policy (e.g., in the US) (International Energy Agency, 2019). As this study focuses on on-grid distributed PV systems, the complete host consumed model without connection to the utility grid is out of the research. But this type of model is still covered in discussion due to its characterization of host-owned models. Figure 3.1.1 is an overview of HO BMs.

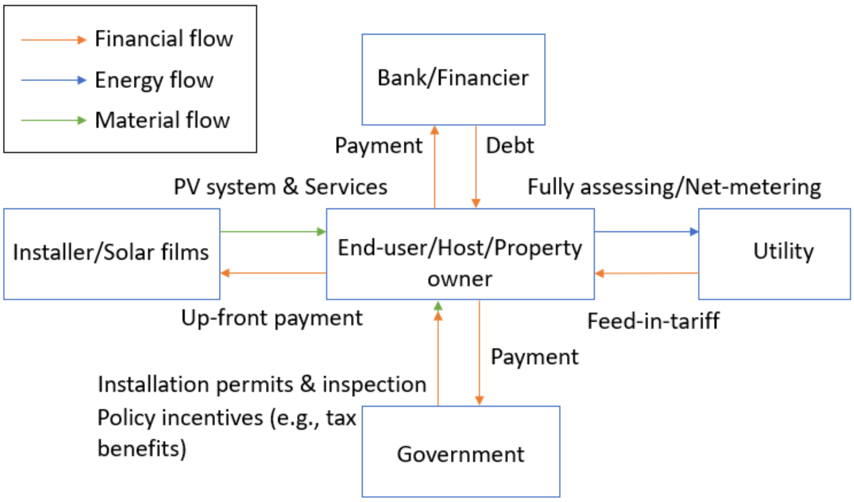

Figure 3.1.1 Host-owned BMs (based upon Franco and Groesser, 2021 and Strupeit and Plam, 2016)

The HO BMs can benefit customers in several ways. The first one is the pre-fixed packages offered by solar firms. The package contains converters, inverters, cables, batteries, PV panels, and other electrical elements constructing the PV system. Because solar firms usually complete installation, customers do not need to build the PV system from scratch on their own. In HO BMs, non-pre-fixed packages allowing customized systems to fit specific customer needs are also available in some companies (Horvath and Szabo, 2018).

Another benefit is the reduction in energy bills. Since customers can produce and use their energy, the dependence upon utility grids is reduced. Moreover, customers can take advantage of other supporting policies resulting from the spread of renewable energy. In addition to the FiT, customers could also enjoy tax benefits (Zhang, 2016b), such as solar investment tax credit (ITC) (e.g., Federal Solar ITC in the US) and accelerated depreciation deductions (e.g., Modified Accelerated Cost Recovery System (MACRS) in the US), and benefit from extra state-level financial support programs that reduce investment risks meanwhile increase incentives.

However, customers may suffer high up-front costs and long-term payback periods in HO BMs. The host customers are also investors, which necessitates paying up-front investment costs. Such up-front costs put strains on customers getting financial capabilities. Customers who can access supporting policies or/and financing sources are more likely to gain credits from government programs and banks. Hosts having less financial capabilities are blocked in this very first step. The high up-front costs and lack of financing sources lead to long payback periods to investors, which in turn decreases the demand for renewable energy (Horvath and Szabo, 2018). In addition to financial criteria, a suitable rooftop or land condition, a sufficient area with proper solar panel orientation and without shading, is required.

Due to the notable requirement towards customers, customer segments are narrowed. High and regular-income households (Reis et al., 2021; Huijben and Verbong, 2013) and SMEs (Horvath and Szabo, 2018; Reis et al., 2021; Franco and Groesser, 2021; Huijben and Verbong, 2013; Strupeit and Plam, 2016) dominate the host-owned business. Furthermore, members of households could be characterised according to market segmentation. A technology adoption life cycle (Meade and Rabelo, 2004) describes market diffusion from early to the mainstream market (see Appendix A). Customers in a market are classified according to the technology adoption life cycle. The early market comprises innovators and early adopters who characterise part of customer segments in HO BMs. From it, the innovators and early adopters in HO BMs could be households with financial fluidity enabling them to invest in the DSPV system, or households with social considerations aiming to reduce energy independence of large utilities or promote technology, or environmentally conscious households. Thus, customer segments could be more specific to homeowners, PV engineers, environmentalists, collective PV initiative volunteers and organizations (e.g., in Netherlands, Huijben and Verbong, 2013) etc.

Apart from customer-side, companies in HO BMs undertake several activities to carry on the business. Most of the companies provide turn-key solutions from upstream system design, permits arrangement, and component procurement, to downstream system installation, and if available, performance monitoring and operation and maintenance (O&M). Besides, some companies also sell PV panels to their customers, take care of price bargaining, and offer insurance services (Huijben and Verbong, 2013). Under such circumstances, companies in HO BMs seek stable partnerships with producers and wholesales of system components. They also need to build prolonged relationships with utilities for accessing grids and banks for acquiring financing services.

Companies make money in HO BMs primally through system installation. Other revenue could come from charging after-sale services such as O&M. Revenue sources will be enriched if companies sell PV panels. Moreover, some companies also earn money through additional energy consulting services (Strupeit and Plam, 2016). This type of service is not only a revenue source but also an opportunity to establish long-term relationships with their customers. One way to accomplish this is by building direct personal channels. It could be sales representatives visiting customers to evaluate site conditions and gather customer preferences, or others. Another way could be by online contact forms on companies' websites. To open up channels for raising awareness about companies' products and services, solar walks in Germany (Karakaya et al., 2016) allowing visits to reference buildings with PV systems instilled could be options. Costs for companies in this model could be fixed costs, including sales costs and salaries, and variable costs covering inventory-holding costs, warehousing costs, and insurance.

Host-owned (HO) business model canvas

Table 3.1.2 Host-owned business model canvas (adapted from Horvath and Szabo, 2018; Cai et al., 2019; Reis et al., 2021)

Main elements	Sub-elements	Label	
Value proposition (VP)	Customer	CVP	• (Non) Pre-fixed packages • Reduced energy bills • Tax benefits (e.g. investment tax credit (ITC), accelerated depreciation deduction, etc.) • Benefit from feed-in tariffs (FiT) • Independence from utilities

			• Reduced investment risk • Government incentives (e.g., subsides)
Value delivery (VD)	Customer segments	CS	• SMEs • Households (incl., homeowners, PV engineers, environmentalists) • Initiatives in NL (e.g. organizations, volunteers) • Farmers
	Customer relationships	CR	• Direct interactions, personal relationships • Online contact forms
	Channels	CH	• Company website • Sales representatives • Different personal channels (e.g., solar walks, housing fairs, etc.) • Conference marketing • Ground promotions
Value creation (VCR)	Key partners	KP	• Producers of system components • Wholesalers of system components • Utilities • Banks
	Key activities	KA	• Turn-key solutions • Sales of PV panels • After-sales services • Customer support services
	Key resources	KR	• Technical knowledge • Human capital (e.g. expert staff) • Close knowledge of consumers • Close knowledge of local markets • Visibility of the company • Brand image and reputation
Value capture (VCA)	Cost structure	C$	• Sales costs • Wages • Stock costs • Inventory holding • Warehousing costs • Insurance
	Revenue stream	RS	• PV system installation • Sales of PV panels • After-sale services (e.g., M&O) • Energy consulting services

Host-owned (HO) business model in China

In China, host-owned business models share similar characterizations to the above. Differences yet exist under the context of the Chinese energy market, policies, and society. Households, including farmers with available roof or land areas, are one major customer segment (Cai et al., 2019). Indeed, due to the high up-front costs, government subsidies are crucial for household DSPV in China. However, as China pursues grid parity, subsidies have continued to fall recently. According to National Development and Reform Commission, the subsidy for household distributed photovoltaics power generation, included in the scale of financial subsidies of 2020, was adjusted to CNY 0.08/kWh (National Development and Reform Commission, 2020). This subsidy was further cut to CNY 0.03/kWh for household DSPV projects that are included in the scale of financial subsidies of 2021. From 2022, the central government will no longer subsidize new household DSPV projects (National Development and Reform Commission, 2021a). Although some local governments still offer financial supports, such a transition may hesitate investors as they lose one source of income.

For companies in host-owned BMs, a closer relationship with their customers is required. Conference marketing, advertising, ground promotions, housing fairs are additional channels for solar companies approaching their customers (Cai et al., 2019). On the one hand, companies need to win customers' trust to deliver products and services. On the other hand, transaction costs could be reduced, for DSPV featuring miniaturization and decentralization. In addition to customer relationships, stable partnerships with grid companies, local governments, communities, financial institutions are important in business activities. Customer subsidies, policy supports and incentives for DSPV power from local governments play an important role in companies promoting their products and services. Successful PV system installations and connections to grids need close ties with local banks, financiers, and grid companies. Besides, technologies, experts, staffs, sales celebrities, brand images are vital resources to companies. As internet transactions through live-broadcasting platforms gradually ingrain into customer consumption habits, sales celebrities could be a new way of promotion or resource to DSPV companies in China.

3.2 Third-party-owned (TPO) business model

Third-party-owned (TPO) business models first emerged in the United States in 2005 (Strupeit and Plam, 2016). After almost two decades of development, it now spreads rapidly in countries such as the Netherlands, Germany, and China. Despite variations under different countries' contextual conditions, the underlying logic of TPO BMs is similar. In this study, the term "third-party-owned" BMs is used instead of other allonyms, including third-party ownership BMs, third party PV BMs, third-part financing model, SolarCity model, and solar energy management service model (see Table 3.2.1).

Table 3.2.1 Third-party-owned business model

Business model	Allonym	Countries in literature study
Third-party-owned (TPO) BMs	Third-party ownership/Third party PV/Third-parties/Third-party financing/SolarCity model/Solar energy management service (solar EMS) model / Contract energy management model (CEM)	US (Frantzis et al., 2008; Zhang, 2016b; Strupeit and Plam, 2016); NL(Huijben and Verbong, 2013); Germany (Brunekreeft et al., 2016); China (Zhang, 2016b; Cai et al., 2019; Pang et al., 2019)

Unlike host-owned BMs, TPO BMs are born with a superior feature, eliminating high up-front costs, since third-party finances such business models. DSPV system is installed on customer properties or premises, and the ownership of the PV system belongs to the third-party financier. Solar service firms, also project developers, provide a full-service solution from early-stage site inspection, arrangement of financing and insurance, securing building permits, negotiation with utilities, to the later system installation and O&M (Strupeit and Plam, 2016; Zhang, 2016b; Reis et al., 2021; Franco and Groesser, 2021). Electricity generated by DSPV is sold back to customers according to different financing models, either power purchase agreement (PPA) or leasing. Under the long-term PPA model, customers consume the electricity from the DSPV system and pay solar firms a predetermined energy bill over 15-20 years. The developer, in turn, receives a combination of revenues, including electricity sales and government tax incentives and subsidies. At the end of the contract, customers can either buy the system or remove it or renew a new agreement (Horvath and Szabo, 2018). Under the leasing model, customers buy electricity and pay the system developer fixed monthly rental payments, regardless of energy production (Franco and Groesser, 2021). Figure 3.2.1 shows the material, finical, and energy flows in TPO BMs.

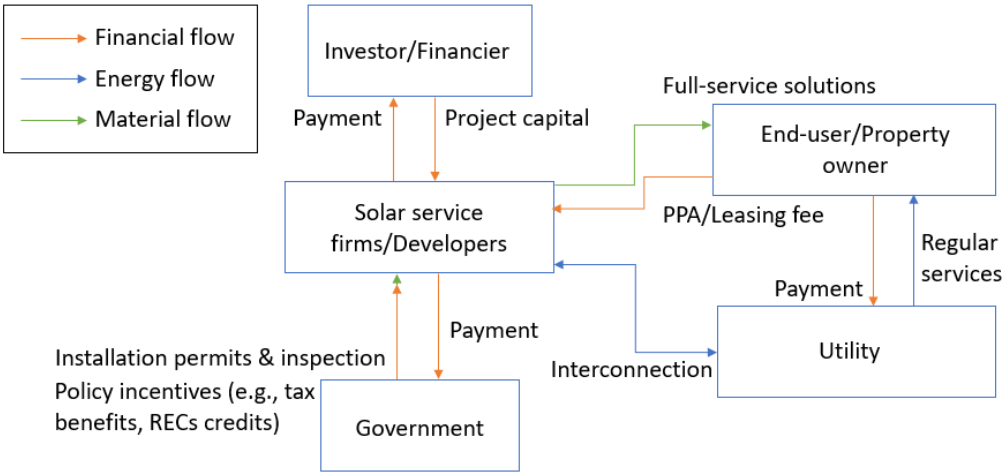

Figure 3.2.1 Third-party-owned BMs (based upon Franco and Groesser, 2021 and Strupeit and Plam, 2016)

As can be seen in the above illustration, customers in TPO BMs can benefit not just from the elimination of upfront costs but from predictable energy payments, electricity bill savings, and transaction costs reduction. Transaction costs could be relevant to negotiations with financiers (e.g., banks and investors), utilities (e.g., accessing permits and connections) and insurance companies. Moreover, system performance risks shift from customers to solar firms due to full-service solutions. Solar firms are burdened with any potential cost and uncertainty associated with O&M, solar radiation variations, technical performance, etc. In TPO BMs, customers could also install the systems themselves (Huijben and Verbong, 2013).

Because of the benefits described above, customer segments in TPO BMs widen. Households who cannot afford system upfront costs can now acquire energy from DSPV systems. These customers usually also desire decreased electricity bills, and they are conscious of environmental protections. Industrial and commercial companies, communities, farmers, and public organizations are other customer segments (Horvath and Szabo, 2018). Besides, investors who enjoy the PV system ownership while getting government subsidies and PPA or leasing payments are potential customers as well.

Due to the long-term contracts, either PPA or leasing, companies in TPO BMs develop a stable relationship with their customers. They communicate with customers through personal contacts and online forms. Channels to touch on personal connections could be sales representatives, industry conferences and exhibitions, active media advertising, etc. Company websites could also be informative and useful for presenting products and services and connecting with customers.

Partnerships are critical for companies in TPO BMs. Firstly, companies need to acquire project funds from financial institutions and other investors. ITC and accelerated depreciation breaks are not directly beneficial to most solar firms because of low-income tax to offset (Strupeit and Plam, 2016). To take advantage of tax incentives, solar firms need to seek potential tax equity investors who are large and profitable corporations and willing to pay equity capital in exchange for preferred tax credits from eligible PV projects (Kollins et al., 2009). Secondly, due to the full-service solutions, solar service firms may need partners like producers and wholesalers of PV components, consultants, insurance companies, installers, law firms and O&M companies. Thirdly, a tie with local government authorities for subsidies and permissions. Last but not least, relations with utilities for successful connections to grids.

For PV companies, customer payments for PPA and leasing contracts contribute to most revenue. In addition to tax benefits, such as investment tax credit (ITC) and accelerated depreciation, local government subsidies and incentives are sources of income. Likewise, solar incentives offered by some municipalities and local utilities could be earnings as well (Strupeit and Plam, 2016). Furthermore, regional policies may drive another type of revenue. For instance, revenue through sales of Renewable Energy Certificates (RECs) to companies in some states of the US to meet renewable portfolio standards (RPS) (Kollins et al., 2009). Costs incurred in all activities and to mobilize their key business resources. Important resources in TPO BMs is the management software and well-skilled employees as solar firms undertake complex tasks.

Third-party-owned business model canvas

Table 3.2.2 Third-party-owned business model canvas (adapted from Horvath and Szabo, 2018; Cai et al., 2019; Reis et al., 2021)

Main elements	Sub-elements	Label	
Value proposition (VP)	Customer	CVP	• No up-front costs • Reduced energy bills • Predictable cost of electricity • Eliminating high transaction cost • Removal of tasks (e.g., O&M) • Shifting system performance risks • Possibility of installing the system individually
Value delivery (VD)	Customer segments	CS	• Households • Farmers • Communities • Industrial and commercial companies (incl. industrial parks) • Public organizations (incl. schools, hospitals, etc.) • Institutional and private investors
	Customer relationships	CR	• Long-term relationships • Personal contacts • Online contact forms
	Channels	CH	• Sales representatives • Conferences and events (e.g. exhibitions) • Online and printed marketing tools • Active media relations • Company website
	Key partners	KP	•Banks • Large corporations

Value creation (VCR)			• Utilities • Producers and wholesalers of PV components • Consultants • Law firms • Insurance companies • Installation and O&M companies
	Key activities	KA	• Provide lease or PPA • Providing turn-key solutions • Sale of Renewable Energy Certificates • Taking permits • Arranging interconnections with utilities • Acquiring incentives and tax breaks • Marketing activities
	Key resources	KR	• Existing customer base • Project management software • Well-trained employees
Value capture (VCA)	Cost structure	C$	• Acquiring investors • PPA and lease management costs • Construction, installations, O&M costs • Sales costs • Marketing costs • Stock and warehousing costs
	Revenue stream	RS	• Power Purchase Agreements (PPA) payments • Solar lease payments • Government subsidies and incentives • Incentives offered by municipalities and local utilities • Tax benefits (incl. renewable energy investment tax credit, and accelerated depreciation) • Sales of Renewable Energy Certificates (RECs) • Development, monitoring and other service fees • Excess power sold to the grid

Third-party-owned BMs in China

TPO BMs in China are adjusted and given various names (see Table. 3.2.3). Despite variations, the ownership of PV system belongs to the third party who often also plays roles as a solar service provider or developer, operating DSPV systems. Systems are installed at customers' properties with or without rental charges. For power grid enterprise charging electricity fee model (PGECEF) and roof rental model, investors rent customers' roofs, which results in a cost to companies. Customers pay electricity fees to enterprises according to contracts signed between them. The agreement could be similar to PPA or leasing (e.g., in solar EMS model and CEM model), or it could be based on the electricity price of the catalogue (e.g., in PGECEF).

Table 3.2.3 Third-party owned (TPO) BMs in China

Business model	Allonym in literature study
Third-party owned BMs	Third-party owned BMs (Pang et al., 2019) / Solar energy management service model (solar EMS model) (Zhang, 2016b) / Contract energy management model (CEM model) (Li et al., 2020) / Energy Management Contract (EMC) (Cai et al., 2019) / Power grid enterprise charging electricity fee model (PGECEF) (Li et al.,

	2020) / Solar shared saving model (Pang et al., 2019) / Roof rental model (Pang et al., 2019)

Moreover, researchers highlighted connections between enterprise and utilities. The surplus power of the DSPV system could be transmitted and sold to utility grids, which adds to revenue streams (Pang et al., 2019; Zhang, 2016b; Li et al., 2020). This differentiates roof rental models from others as full power from DSPV is sold to the utility grid based on FiT in roof rental models (Pang et al., 2019). In this situation, customers are only roof renters.

Apart from that, the leading customer segments in TPO BMs in China are industrial and commercial enterprises (Cai et al., 2019). The announcement from National Development and Reform Commission that the central government will no longer subsidize new industrial and commercial DSPV projects from 2021 (National Development and Reform Commission, 2021b) indicates a change to companies' revenue streams. Besides, due to *Distributed Photovoltaics on Rooftops of Entire Counties (District) Pilot Project*, hospitals, schools, and public buildings could be large potential segments in the future (State Council, 2018; Cai et al., 2019).

3.3 Community-shared (CS) business model

Community-shared (CS) model, also known as community solar model, community-owned model or shared solar model, is a growing BMs but is still new in DSPV (see Table 3.3.1). This research uses 'community-shared' BMs for consistency.

Table 3.3.1 Community-shared (CS) business model

Business model	Allonym	Countries in literature study
Community-shared (CS)	Community solar/Community-owned model/Shared solar/Energy community BMs	US (Augustine, 2015; Augustine and McGavisk, 2016; Zhang, 2016b; Horvath and Szabo, 2018); NL (Huijben and Verbong, 2013)

Unlike HO and TPO BMs, CS BMs can be administered or sponsored by utilities, solar project developers, or non-profit organizations (Horvath and Szabo, 2018). Multiple customers access to energy systems without PV systems installed on their sites. They purchase energy from a PV park, farm, or garden through virtual net-metering. Virtual net-metering means multiple subscribers can receive credits for a share of energy generated by PV systems that are not physically connected to their properties and premises (Augustine, 2015). That is, companies in countries or communities that are in the absence of such policies need to pay energy taxes over electricity (Huijben and Verbong, 2013).

In CS BMs, customers subscribe to PV projects with different subscription options, either by purchasing or leasing panels, by investing in systems, or just by buying energy or capacity. In return, they receive credits on energy bills for paying upfront fees through purchasing panels. In the case of customer investment, they finance the project and thereby buy an equity stake. From the ownership perspective, the CS BMs could be underneath HO BMs or TPO BMs.

CS BMs enlarge customer segments to those that previously cannot enjoy DSPV systems because of several obstacles. They may not own the property (e.g., renters), not have insufficient and suitable spaces for installation, and are not willing to bear risks and uncertainties in system performance. With contract subscriptions, usually 5 to 20 years (Horvath and Szabo, 2018), customers now have a low-risk long-term energy access option. Meanwhile, they can benefit from reduced energy bills due to virtual net-metering. Subscriptions could be sold with customers' properties or separately in case of property selling, adding flexibility to customers. Besides, subscribers could be businesses, commercial companies, institutional consumers (e.g., local governments, universities, the military, etc.), and non-profit organizations. Volunteers, driven by environmental protection and opening up local PV markets, also could be one customer segment (Huijben and Verbong, 2013). Figure 3.3.1 shows the CS BMs.

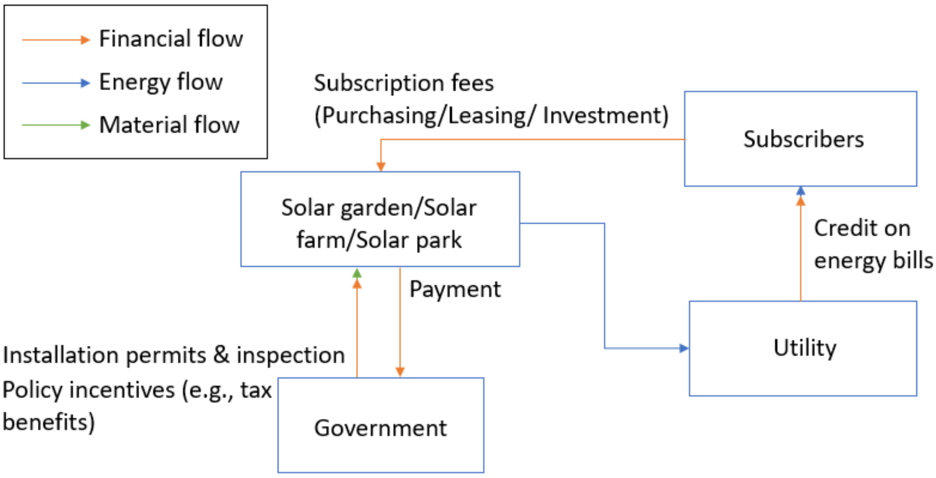

Figure 3.3.1 Community-shared (CS) business model (based upon Franco and Groesser, 2021; Augustine and McGavisk, 2016)

Due to the early phase of CS BMs, companies approach their customers and sponsors through conferences, educational programs, and community events more than other common channels like sales representatives and company websites (Reis et al., 2021). If subscribers are customers of the utility, the utility company needs subcontractors such as construction companies, producers and wholesalers of PV components. To take advantage of tax benefits, the utility may need to connect with a third-party solar developer with access to tax equity since the utility tend not to have tax liabilities. Furthermore, generated electricity must be synchronized with utilities' billing systems for virtual net-metering (Horvath and Szabo, 2018). Companies (utilities or service providers) require software monitoring systems to manage the real-time energy flow, highlighting the need for IT infrastructures and management teams. Subsequently, these induce subscriber management costs. Costs are also incurred if the community does not fund upfront investments. Additionally, O&M costs count a significant part.

Community-shared business model canvas

Table 3.3.2 Community-shared business model canvas (adapted from Horvath and Szabo, 2018; Reis et al., 2021)

Main elements	Sub-elements	Label	

Value proposition (VP)	Customer	CVP	• Use of green energy without hosting the PV system (no ownership and site problems) • Reduced electricity bill • Decreased financial barriers and costs • Flexibility
Value delivery (VD)	Customer segments	CS	•Residential customers •Businesses • Commercial companies • Non-profit organizations (e.g. religious organizations) • Institutional consumers (e.g. local government, universities, military, etc.) • Environmentally driven volunteers
	Customer relationships	CR	•Personal contacts •Online contact forms
	Channels	CH	•Conferences •Educational programmes •House parties, community events •Websites •Sales representatives
Value creation (VCR)	Key partners	KP	• Utilities • Subcontractors (e.g. construction company) • Producers and wholesalers • Technical know-how providers (e.g. engineers, lawyers, accountants, etc.)
	Key activities	KA	• Subscriber management • Program management (incl. customer protection, data reporting, regulatory compliance) • Installation (sometimes not) • System O&M
	Key resources	KR	• Existing customer base • IT infrastructure • Workforce (incl. sales representatives)
Value capture (VCA)	Cost structure	C$	• Initial infrastructure development • O&M • Labour and IT costs • Energy taxes (if no net-metering policy)
	Revenue stream	RS	• Sale of solar bonds • Upfront payments • State incentives • Tax incentives (incl. ITC and accelerated depreciation)

3.4 Chapter summary

This chapter elaborates three main BMs of distributed solar PV projects in current literature and two primary model types in China. These three types of BMs, host-owned (HO), third-party-owned (TPO) and community-shared (CS) BMs, are classified by the ownerships of DSPV systems. The former two are the leading models in China.

Overall, every business model shares similar operating principles across countries, including the United States, Netherlands, Germany, and China, but has subtle differences when the environmental contextual conditions change.

In host-owned (HO) BMs, DSPV systems are owned by the host, who is the owner of the property on which DSPV systems are installed. Due to the high up-front costs and the long-term payback period, relationships with financiers (banks) and local governments, impacting financial flows in HO BMs, narrow the range of customer segments. PV enterprises make money in HO BMs primally through system installation. Because of the grid parity stated by the central government in 2021, newly DSPV project investors (hosts) in China may hesitate to enter the market, affecting customer segments.

Third-party owned (TPO) BMs, financed by a third party, eliminate high up-front costs in HO BMs. Financing models, such as power purchase agreement (PPA) or leasing, connect the solar service firm and end-users, building a long-term relationship between them. In this model, financial institutions and other investors are critical to solar firms as they need to acquire project funds. The ownership of the DSPV system belongs to the third-party financier. In China, similar agreements to PPA and leasing could be signed between customers and solar firms, or payment according to the electricity price of the catalogue. Industrial and commercial enterprises are the leading customer segments in TPO BMs in China.

Community-shared (CS) BMs allow multiple customers access to energy systems through virtual net-meeting. CS BMs can be administered or sponsored by utilities, solar project developers, or non-profit organizations. The customer segments could expand to those that previously could not enjoy DSPV systems because of several obstacles. However, China has not engaged in such business models in the literature.

Chapter 4 . Business model innovation triggers and drivers

This chapter partly answers sub-question two "***What internal changes within and external changes to enterprises may trigger business model innovation in DSPV projects?"*** The sub-section 2.3 has already revealed BM innovation as a process responding to changes but does not disclose what these changes possibly are other than technology. Literature on this theme focuses either on antecedents of BMI or BMI drivers or triggers or by simply asking when a new business model is needed or what elements lead to BMI. Such kind of study contributes to the completeness of dynamic business model framework (Wirtz et al., 2016; Khodaei and Ortt, 2019; Kamp et al., 2021), which is unfolded in Chapter 5.

Scholars tend to classify these factors into external or internal triggers and drivers according to their attributes to enterprises, in relation to changes in the external environment or changes within the company. Table 4.1 collects and lists these factors reported by Giesen et al. (2010), Andreini and Bettinelli (2017) and Saebi et al. (2017). These factors can be categorised by several major factors, documenting in bold. The external triggers could be related to major changes in technology and behavioural developments, changes in economic, competitive, social and environmental environments, and changes associated with business operation. The internal triggers could be changes in product and services, revenue and cost mechanism, resource allocation and organizational management.

Table 4.1 Business model innovation triggers and drivers (adapted from Giesen et al., 2010; Andreini and Bettinelli, 2017; Saebi et al., 2017)

Types of tiggers and drivers	Factors
External	• **Major changes in business/economic/industry environment** - Increasing globalization of the business environment - Economic recession - New business models by new market entrants - Industry transformation • **Technological and behavioural developments** - New information and communication technologies (ICTs) (e.g. Web 2.0, digitization) - New disruptive technology (e.g. a new global positioning technology) - A brand-new technology (e.g. Apple player) - A tested technology (e.g. military technologies in the commercial space) • **Changes in the competitive environment** - New propositions introduced by competitors - Heightened competition resulting from liberalization - The need to fend off low-end disrupters - The need to response to "good enough" low-end entrants • **Changes in social and environmental environment** - The need for sustainability (e.g. sustainable construction, sustainable development, etc.) - Changes to regulatory environment (either by industry or geography) - Cultural context (e.g. the issue of internationalization; operating in new national contexts) • **Changes in business** - Shifts in value chain (e.g. value migration along the value chain) - Changes in partnerships (e.g. new partners; changing demands of stakeholders (e.g. manufacturers)) - Changes in customer preferences

	- Changes in customer segments
Internal	• **Products or services innovation** • **Declining or negative growth relative to the industry** • **Modification in revenue/cost models** - Utilization of new resources - Developing a new source of revenues - Externalising a value chain activity - Setting new financial arrangements • **Changes in resources availability** (e.g. a lack of financial resources; the need for leveraging right skills and capabilities) • **Changes in marketing channels** • **Changes to internal strategic** (e.g. corporate strategy) • **Changes in organizational characteristics** - Reengineering an organizational process - Changes in organizational capabilities - Changes in executives' cognitive processes

Among the articles, after describing 11 cases of company BMI, Bucherer et al. (2012) suggested further distinguishing internal and external factors between opportunity and threat. Subsequently, they listed four origins of BMI: internal opportunity, internal threat, external opportunity, and external threat (shown in Table. 4.2). The threat implies that the company is forced to innovate their BMs, while the opportunity is when BMI is triggered to capture opportunities for companies. As the author pointed out, whether it is an opportunity or a threat to companies could be relative to their different development stages. An opportunity to a new venture could be a threat faced by an established firm (an incumbent). Therefore, opportunities or threats should be considered in the company context. Meslin (2019) also classified the internal & external factors regarding the focal firm by opportunities or threats, by which the author developed the completeness of the dynamic business model framework.

Table 4.2 Origins of BMI (adapted from Bucherer et al., 2012; Meslin, 2019)

	Opportunity	**Threat**
External	• Changes in key technologies • Changes in public perception of the products • Environmental targets / pacts / pledges • More frequently-occurring natural disasters • Promoting efficiency after a mature Industry chain • Changes in customer preferences • New customer segmentations • Supportive financial system	• Competitions induced by price erosion • Lack of social acceptance • Policy and regulatory requirements • Changes in customer needs • Changes in competitive landscape • Industry over-capacity • Constraining financial system
Internal	• New product solutions • New service systems • New technological infrastructure • New process innovation	• Investments in new capabilities • The outsourcing of certain activities (splitting up a part of the business) • Requiring new value propositions after hype • Anticipating a breakup of the value chain • Increasing costs • The erosion of margins

In summary, the internal changes within and external changes to enterprises that may trigger business model innovation have been explored in this chapter. To answer the research sub-question two, these triggers and drivers need to be specific to DSPV projects. Since the triggers and drivers summarised in Table 4.1 are obtained from the literature that holds a holistic point of view towards business model innovation in a broader industry field, which demonstrates that possible changes provoking business mode innovation in DSPV projects could be covered in such an overview. Additionally, according to Bucherer et al. (2012), whether an internal or external factor is identified as an opportunity or a threat should be considered in the company context. Table 5.3.3 in Section 5 that developing the conceptual sustainable business model framework lists examples of such identification to DSPV projects by literature review. In the conceptual framework, the case study results by Bucherer et al. (2012) can be a reference, as the opportunity or threat can be identified in addition to the origin of factors. The factors in Table 4.1 only reveal their origin. After the case study chapter, some of the factors in selected DSPV project companies might be more outstanding than others, or other new triggers may emerge.

Chapter 5 . Dynamic sustainable business model frameworks

After literature review and knowing of some main current DSPV business models, the research can now unfold how to build the dynamic sustainable business model framework. The entire chapter partly offers the answer to sub-question four, "***How can we develop a dynamic sustainable business model framework to understand business models innovation in DSPV companies?"*** This goes from investigating dynamic business model frameworks (refer sub-section 5.1) to looking at sustainable business model frameworks (refer sub-section 5.2) and to ultimately establish the dynamic sustainable business model framework (refer sub-section 5.3) that follows three procedures documented by Meslin (2019). Sub-section 5.3.1 partly answers the sub-question two, "***What internal changes within and external changes to enterprises may trigger business model innovation in DSPV projects?"*** The factors affecting sustainable business model elements are investigated. Sub-section 5.3.2 and 5.3.3 partly provide answers to sub-question three, "***What important interrelationships between BMs elements and interrelationships over time should the DSPV project company consider in business model innovation?***" By partly answering, it is because a final version of the framework will be synthesized after the case study. Similarly, business model innovation tiggers, interrelationships and changes over time will be finalized after the actual case analysis.

5.1 Dynamic business model frameworks

To begin with, this research looks at the 'dynamic' business model frameworks. According to elaboration on BM innovation in terms of definition and approaches facilitating it (refer Chapter 2.3) and origins and drivers (refer Chapter 4), it is clear that a more dynamic view of BMs will help scholars and also companies better understand when to introduce BMI and what factor may trigger BMI. Besides, the limitation of the current static business model canvas (BMC) described in sub-sections 1.1.2 and 1.2.3 encourages dynamic frameworks not only characterizing BMs but also capturing changes. Looking at both sides of the coin, a dynamic business model framework based on BMC can be a tool to depict changes in BMs and help understand BMI on the way. The question now is how researchers can build business model dynamics frameworks. There are several dynamic BM frameworks reported in the literature.

5.1.1 The Meslin (2019) framework

Meslin (2019) reported a dynamic business model framework following previous research by Khodaei and Ortt (2019), in which they explained a dynamic business model framework is the BM framework capturing changes within a company and external environmental aspects. In a later study, Kamp et al. (2021) further developed Meslin's (2019) framework and proposed six considerations for building such a framework (refer sub-section 5.1.4).

Khodaei and Ortt (2019) identified four criteria assessing the degree of dynamics of a business model framework which guided Meslin's (2019) framework. These four criteria are (1) completeness, (2) interrelationship, (3) interrelationship over time, and (4) framework changes (shown in Fig. 5.1.1). The four criteria highlight the way to develop extant static BMC frameworks towards dynamic ones. (1) First, the dynamic BMs framework needs to capture internal company and external environmental factors. (2) Second, the framework requires containing the interrelationships between different elements of BMs, among environmental factors, and between environmental aspects and BM aspects. (3) Third, the framework should involve the dynamics of interrelationships that change over time. (4) Finally, the framework needs to highlight changes under different conditions. Meslin (2019) and Kamp et al. (2021) combined the last two criteria to ‘changes over time,’ as they together describe changes affecting BM over time. Therefore, three aspects of business models capture the dynamics for a BM: completeness, interrelationships, and changes over time.

Criteria	Degrees in Which Criteria Can Be Met
1. Completeness	a. Complete in internal company environment variables b. Complete in external company environment variables c. Complete in business model variables
2. Interrelationships	a. No interrelationships distinguished b. Relationships assumed but not specified c. Relationships specified
3. Interrelationships over time	a. No interrelationships over time distinguished b. Relationships over time assumed but not specified c. Relationships over time specified
4. Framework changes	a. No framework changes distinguished b. Framework changes assumed but not specified c. Framework changes specified

Figure 5.1.1 The degree of dynamics in business model frameworks (Khodaei and Ortt, 2019)

Based on the guidance, Meslin (2019) established a business model for off-grid projects in Indonesia. The framework is composed of three main elements, the value proposition (VP), the value network (VN) and the cost and revenue stream (CRS). Concerning completeness, Meslin (2019) captured environmental factors that influence the BM variables. The framework characterized these factors by external (E) or internal (I) origins and threat (T) posed or opportunity (O) provided. Then, the framework met the second criterion by grouping the interrelationships of BM elements based on a systemic study of 14 research papers. There are six groups of interrelationships among the three main BM components. Simultaneously, Meslin (2019) classified interrelationships according to whether they are forced changes (F) or strategic choices (C). The last two criteria are accomplished by representing changes in all directions of interrelationships on a time axis (shown in Fig. 5.1.2).

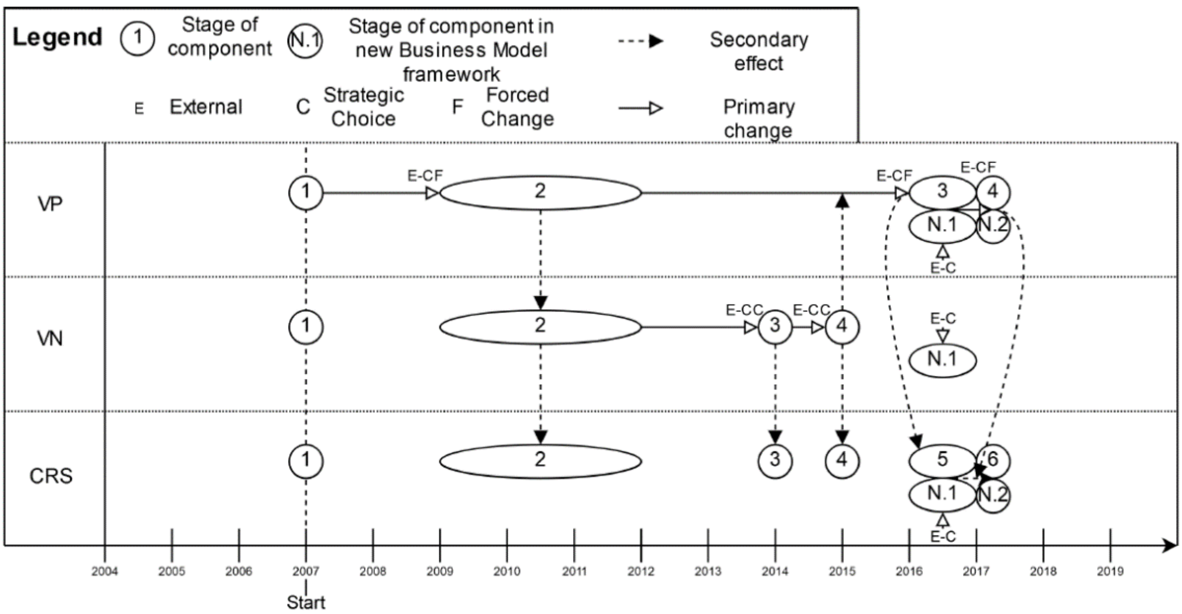

Figure 5.1.2 An example of the dynamic view of business models (Meslin, 2019)

It needs to emphasize that the interrelationships among environmental factors are not presented by Meslin (2019). Meslin (2019) identifies the internal and external factors regarding the focal firm. By this framework, the categorization of origins of changes in BM elements due to external and internal environment variables can be noticed by their types (E/I). The interrelationships between different BM elements can also be seen (F/C). However, there are relationships between the internal company and external environment factors (Khodaei and Ortt, 2019). Omitting interrelationships among environmental factors may be because environmental variables co-evolve (Khodaei and Ortt, 2019). That is, the process of changes, changes in one environmental variable causing changes on other environmental variables, could be relatively synchronous in time. As a result, the researcher could not tell the causality. This process of changes could also be subtle so that there are no major consequences to each other.

The Meslin (2019) framework is not entirely applicable to this research in terms of dynamic business model framework. The segmentation of main BM elements does not see key resources and key activities as two separate sub-elements. Instead, the two sub-elements are indirectly accounted for in the VP and VN. In fact, these two elements are essential to the case of DSPV projects, especially cases in China, as described in three types of BMC in Chapter 3.

5.1.2 The Deherkar (2020) framework

Deherkar (2020) developed a frugal business model dynamics framework for the bottom-of-the-pyramid (BOP) market in Africa based on Meslin's (2019) framework. This dynamic business model fosters frugal energy innovations that serve the lower half of the human economic pyramid.

Since this framework is created on Meslin's (2019) framework, it also follows the four criteria defined by Khodaei and Ortt (2019). That is the completeness, the interrelationships, the interrelationship over time, and the framework changes. The significant differences with Meslin's (2019) framework are that Deherkar's (2020) framework is unique to the BOP market and regards frugal innovation concepts, which can be discovered in the unique BM sub-elements and their interrelationships.

Deherkar's (2020) framework consists of two parts (shown in Fig. 5.1.3). The left side building on the business model canvas illustrates the composition and variation of the BM. Similarly, the BM components are grouped into three main ones, VN, VP and CRS. The right side shows the dynamics. Deherkar (2020) also characterized the type of environmental factors affecting BM variables by their origins (external or internal) and the natural property (opportunity or threat). The interrelationships and changes over time can be traced as well.

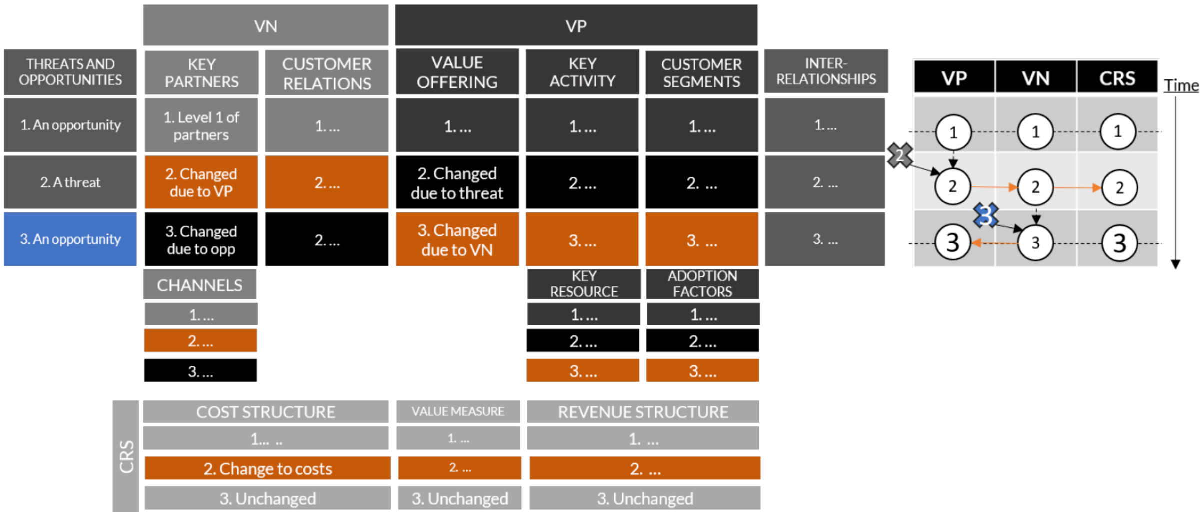

Figure 5.1.3 The frugal business model dynamics framework (Deherkar, 2020)

In contrast to Meslin's (2019) framework, Deherkar's (2020) framework with an additional BMC can straightforwardly tell the story of a business. Any variation on the right side can be referred to a further description on the left side, which is more accessible for researchers to learn or for organizational managers to undertake strategic management. Besides, two blocks, threat and opportunity and interrelationship changes, added to the conventional BMC are conducive for scientists to trace possible origins of BMI.

However, Deherkar's (2020) framework eliminates indicators of whether a BM variation is a strategic choice or forced change. While categorizing the type of change is supportive for scholars to interpret the consistency of BMs and even encourage enterprises to become more proactive, not reactive, to the external environment and internal company changes.

5.1.3 Cosenz & Bivona (2021) framework

Cosenz & Bivona (2021) tailored a dynamic business modelling (DBM) approach for SMEs to develop and innovate their BMs (shown in Fig. 5.1.4). Such an approach blends a revised BMC with the system dynamics (SD) methodology and brings the fit between the inherent attributes of SMEs and BMs.

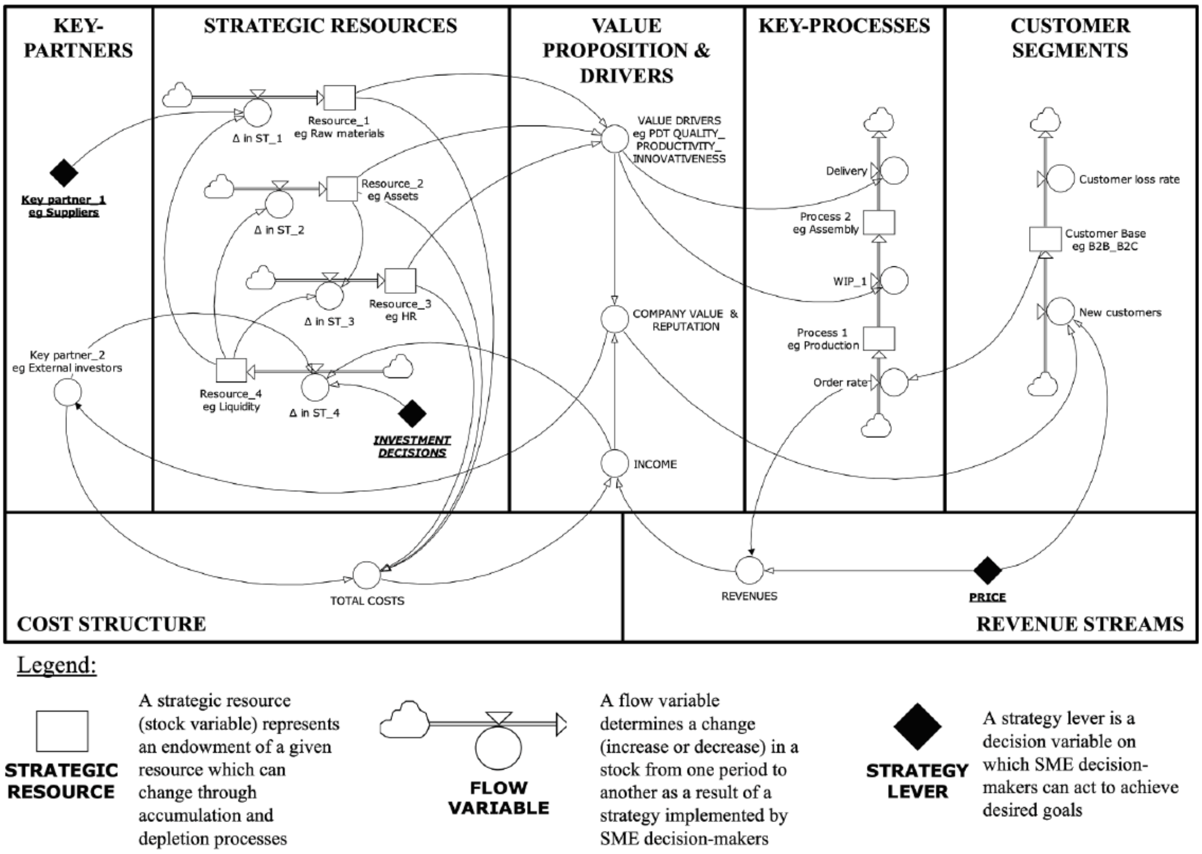

Figure 5.1.4 The dynamic business model framework (Cosenz & Bivona, 2021)

Similar to frameworks outlined previously, this framework also formed on BMC defined by Osterwalder & Pigneur (2010). But, Cosenz & Bivona (2021) modified the BM components, such as strategic resource, value drivers, and key-process, to fit with the inherent attributes of SMEs. In fact, this BM structure is in accordance with the conventional BMC by Osterwalder & Pigneur (2010), but adjusted BM composition for SMEs by taking a resource-based perspective through SME value generation processes. Besides, using SD modelling, Cosenz & Bivona (2021) captured the interrelationships between BM elements and tracked changes over time. They first identified causal feedback loops (seen lines and arrows). Then they simulated the behaviour of the BM using SD-based simulation software after converting BM variables into stock-and-flow diagrams (seen shapes). Moreover, Cosenz & Bivona's (2021) framework identifies main strategy levers (seen shapes filling in black) that decision-makers can make to change companies' business strategies and innovate their BMs.

Although this is a modelling framework, it provides insights for scientists to understand BM innovation with the help of a dynamic BM framework. This framework highlights the relevance of BMs in the SME context. To ensure such appropriateness, recurred inherent SMEs attributes are identified. This identification is a vital prerequisite for determining the main BM elements that are applicable for companies in a specific context, such as an industry, a size and a resource-based process. In addition to capturing interrelationships, causal relationships are connected, forming closed feedback loops to track changes over time, with the same purpose as the second and third criteria by Khodaei and Ortt (2019).

However, it is visually overwhelming to depict changes using BMC since the interrelationships tend to interlink and be complex. Besides, by only looking at the framework (see Fig. 5.1.4), scientists could not tell factors triggered BM innovation are opportunities or threats and could not determine the decision variables (strategy levers) the entrepreneur made to achieve business goals are strategic choices or forced choices. Furthermore, compared with the Meslin (2019) framework, a time axis provides audiences with clearer pictures regarding changes over time.

5.1.4 Kamp et al. (2021) frameworks

Meslin's (2019) dynamic BM framework was later improved by Kamp et al., (2021). Build on Meslin (2019), Kamp et al. (2021) framework remains the original structure but labels and represents design elements differently. Figure 5.1.5 shows the redesigned dynamic business model framework.

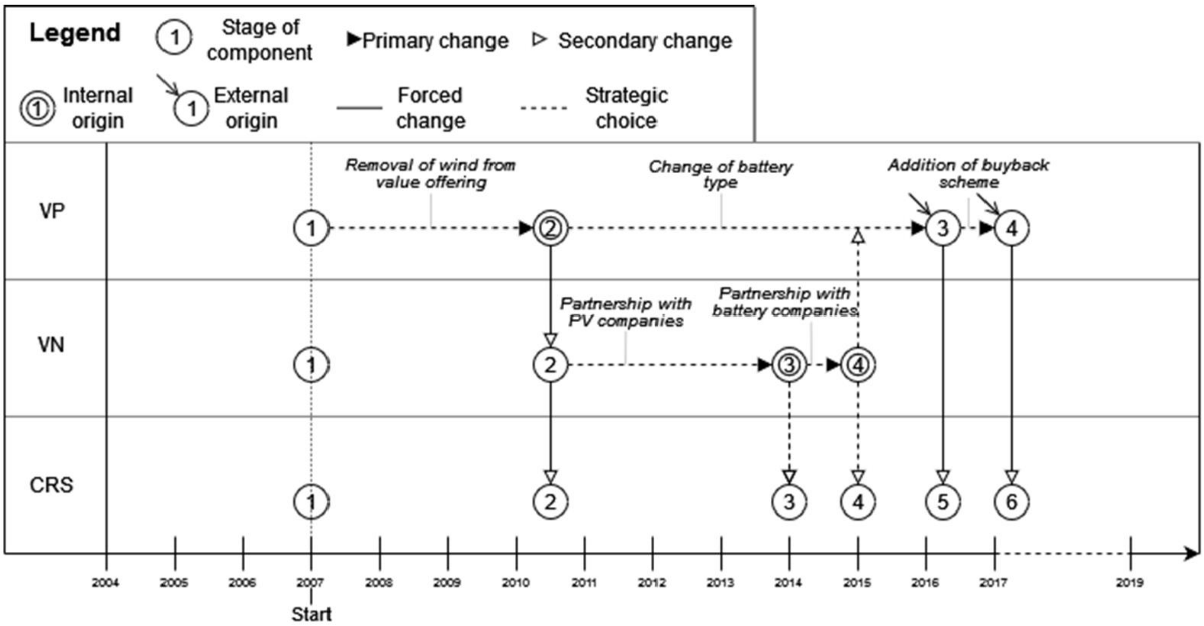

Figure 5.1.5 The dynamic business model framework (a case example of Solar Power Indonesia by Kamp et al., 2021)

Several considerations compile such a framework. First, three main elements (VP, VN, CRS) comprise the framework, which keeps the same as Meslin (2019). Second, the origin of a change is either internal represented by a double-line circle or external shown by a circle with a small arrow attached. Then, an initial change to a particular BM element, called a primary change, is presented by a black-tipped arrow. A follow-up change, named secondary change, is presented by a white-tipped arrow. The sequence of changes that an original change in one BM element tends to lead to changes in another or a subset of other BM elements indicates the need for the BM consistent (Kamp et al., 2021). But, the secondary change would not always necessarily appear and show in the framework if the element already exists. It also does not always necessarily occurs later in time than the primary changes. The authors assume they take place at a single frame in time. Finally, the change can be a forced change (an arrow with a solid line) or a strategic choice (an arrow with a dashed line). Apart from these aspects, every major change of the BM from the start has been pointed in a timeline.

Compared with Meslin (2019), factors that affect BM variables, either external or internal, are visible in the Kamp et al. (2021) framework. These factors are expressed in phrases placed on the lines, whether solid or dashed lines, that are from one element stage to another. For instance, Solar Power Indonesia's business model underwent a change in 2012 owing to an internal factor, removing wind turbines as a product offering, leading to a primary change in the value proposition (VP1 to VP2) which is a strategic choice (see Fig. 5.1.5).

Table 5.1.1 Cause and effect of changes (an example of Solar Power Indonesia's Business Model from Meslin, 2019; Kamp et al., 2021)

N.	Cause	Primary effect	Secondary effect
1	More efficient packaging of PV panels compared to wind turbines	VP 1->2: Change from PV and wind combination to only PV	VN & CRS 1->2: Removal of wind turbine manufacturers from Value Network, and removal of wind turbine associated costs from Cost & Revenue Structure
2	Advantages of partnerships	VN 2->3: Partnership with PV companies	CRS 2->3: Different costs and pricing of PV
3	Advantages of partnerships	VN 3->4: Partnership with battery companies	CRS 3->4: Different costs and pricing of batteries
4	Value Network / technological opportunity	VP 2->3: Change from lead-acid to lead-carbon batteries	CRS 4->5: Different costs and pricing due to new battery
5	Implementation of net metering policy	VP 3->4; VN 4->5; CRS 5->6 (black dotted line): New on-grid Business Model	
6	Customer's fearing PV obsolescence	VP 3->4 (green line): Implementation of buyback scheme for old panels VP 4->5 (black line)	VN 4->5; CRS 5->6 (green line): New company-customer relationship and interactions and new costs and revenues from the buyback scheme VN 5->6; CRS 6->7 (black line)

In addition to the above considerations, the author emphasized other concerns. One aspect, the subsequent changes after a change in one element are needed when BM consistency is necessary. For instance, the change of VN1 to VN2 and CRS1 to CRS2 due to the initial change of VP1 to VP2 in the example of Solar Power Indonesia (see Fig. 5.1.5 and Table. 5.1.1). Besides, subsequent states of one element may have subsequent numbers. In the example of Solar Power Indonesia, the VN2 and CRS2 changes to VP3 and CRS3 in 2014 while VP2 does not change and remain the same stage. This also can be observed in 2017, during which cost and revenue structure (CRS) at the stage CRS6 while other two elements are at VP4 and VN4. Furthermore, the dotted line in the time axis represents an uncertain year in which the event occurs, although the order of the occurrence is nailed. For example, the events take place after year 2017 (see Fig. 5.1.5). Overall, the Kamp et al. (2021) framework makes the entire dynamic business model framework more accessible for this research.

5.1.5 Summary

In summary, sub-section 5.1 illustrated four dynamic business model frameworks reported in the literature. This thesis research decides to develop the dynamic framework based on Kamp et al. (2021).

Although all four dynamic frameworks are available to capture BM dynamics, the Meslin (2019) framework and the follow-up Kamp et al. (2021) framework are more applicable to this study. Using only main BM elements to depict business model changes over time, the framework is more visually friendly to audiences than showing changes over time in BMC.

For scientists, it also simplifies the complexity to identify interrelationships and trace changes. Besides, the origins of BM changes offer insights into triggers of BM innovation to a specific business. Additionally, the sequence of changes combining the attribute of changes (strategic choices or forced choices) tells the story of how a business innovates its BMs in response to external environmental or internal company opportunities and threats.

Asides from these advantages, Kamp et al.'s (2021) framework relabels and represents design elements in the framework and shows factors affecting BM components in phrases, making researchers more accessible to read and follow. Therefore, this research will adopt the dynamic business model framework by Kamp et al. (2021). But, this is only the first step in terms of the dynamic business model framework. The final dynamic sustainable business model framework also needs to incorporate sustainable considerations as well.

5.2 Sustainable business model canvas (SBMC)

A dynamic sustainable business model framework asks for 'sustainable' considerations. This sub-section first investigates four sustainable business model frameworks in literature. Then, it elaborates the sustainable business model canvas (SBMC) by Bocken et al. (2018) used in this research in detail.

5.2.1 Sustainable business model frameworks

Research on this topic proposed several frameworks to present sustainable business models. Based on the interpretation that the SBM is built on the BM concept, the sustainable BM framework can be established on top of the conventional BM framework. Bocken et al. (2015) adapted the BM framework by Short et al. (2014), adding sub-elements that characterise SBMs (shown in Fig. 5.2.1). The first outstanding modification is in the value proposition, which not only satisfies customer needs by products and services but also offers environmental and social benefits. Another prominent adjustment occurs in value capture. Since the environment and society are viewed as core stakeholders in SBMs, the way that companies capture value now takes a holistic perspective, including value capturing for environmental and social stakeholders. Otherwise, as this framework is formed under the BM concept by Richardson (2008), bestowing strategic thinking, the value proposition also embodies customer segments and customer relationships. The company's growth strategy or ethos are also added to the value capture. The technology and product features are additions to value creation and delivery system.

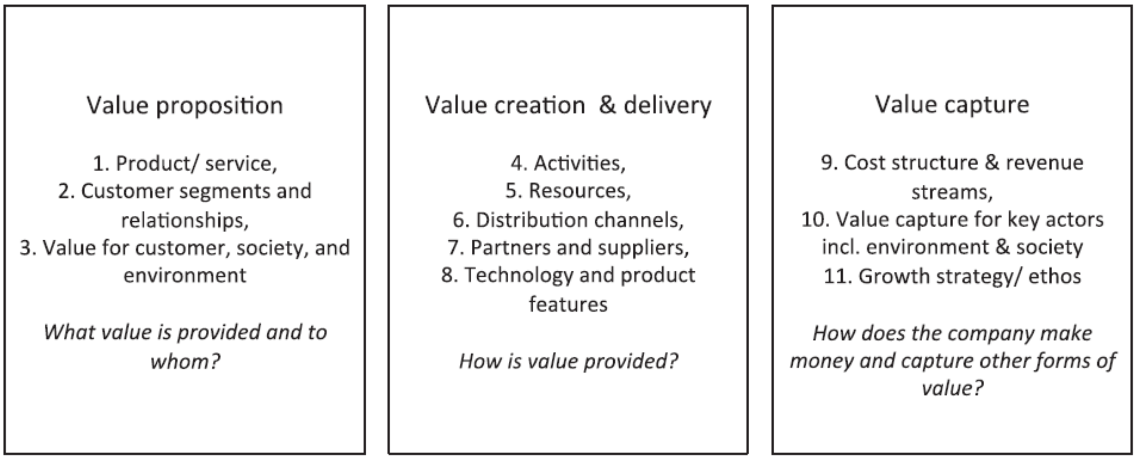

Figure 5.2.1 Sustainable business model framework (Bocken et al., 2015 adapted from Short et al., 2014)

In the following research, Bocken et al. (2018) developed a sustainable business model canvas (SBMC) building on the practical BMC by Osterwalder and Pigneur (2010) (shown in Fig. 5.2.2). Original nine blocks with two new ones compose the model structure. The additional elements, People and Planet, together with element, Profit, complete value proposition of a sustainable BM covering economic, environmental and social angles. Due to multi-stakeholder under the SBM concept, a broader perspective can be imparted to other components, such as key stakeholders, cost structure, and revenue streams, to integrate sustainability concerns further. Besides, the author determined four main components simplifying the framework under the interpretation that the concept of value underpins the BM concept.

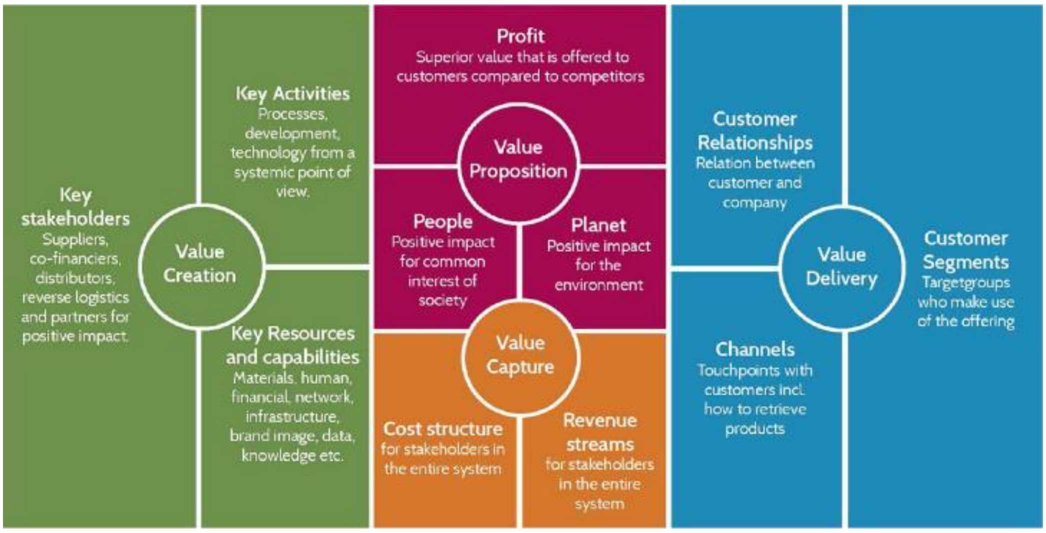

Figure 5.2.2 The sustainable business model canvas (Bocken et al., 2018 developed from Osterwalder and Pigneur, 2010 and Richardson, 2008)

Another approach is suggested by Joyce and Paquin (2016), called triple layered business model canvas (TLBMC), which extends the economically-oriented BMC developed by Osterwalder and Pigneur (2010). Literally, this canvas has three layers: economic, environmental, and social layers. The economic layer remains the same as the BMC by Osterwalder and Pigneur (2010). The environmental canvas layer is based on a life cycle perspective of products and services to reveal environmental impacts. The social canvas layer explores social impacts of an organization from a stakeholder perspective by using a stakeholder management approach. Apart from it, the most significant contribution of this framework is that it supports horizontal and vertical coherence (shown in Fig. 5.2.3). By highlighting the relationships between nine elements of an individual layer, the three layers provide horizontal coherence for capturing economic, environmental and social values. The vertical coherence is created by aligning components across the three layers to integrate a triple bottom line (TBL) perspective.

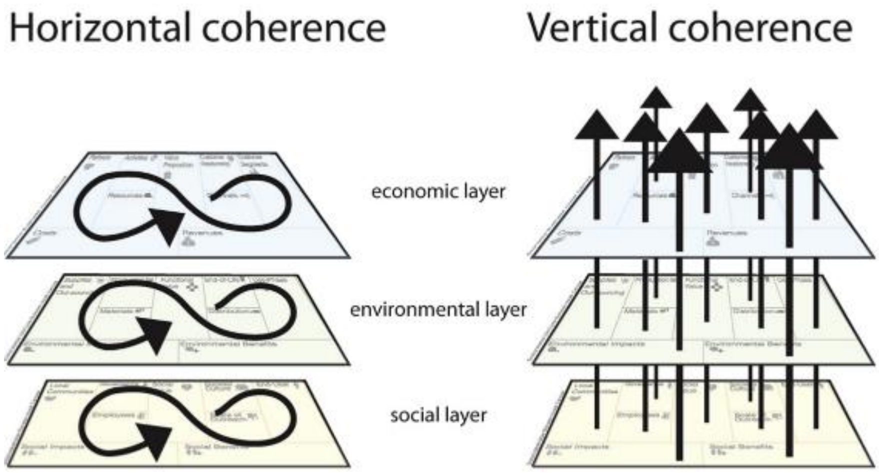

Figure 5.2.3 Triple-layer business model canvas (Joyce and Paquin, 2016)

One recent study by Cardearl et al. (2020) reported a different extension of the Osterwalder and Pigneur (2010) BMC, named business model canvas for sustainability (BMCS). Instead of distinguishing three canvas layers, this framework integrates economic, environmental, and social dimensions in one canvas, and each block has a tripartite view (shown in Fig. 5.2.4). Additionally, unlike the TLBMC that takes customer, life cycle, and stakeholder perspectives, this canvas incorporates sustainability from only the life cycle perspective, eliminating vertical coherence. Moreover, the author reorganized the original elements in BMC and mapped them in new naming blocks. To be more precise, the input-related stakeholders are those relevant to the upstream phase of the organization's activity, such as suppliers and manufacturers. The output-related stakeholders are from customers to actors until the end-life of products or services. Burdens and benefits are negative impacts resulting from and positive impacts generated by the organization, respectively. There are no considerations about cost or revenue in the business.

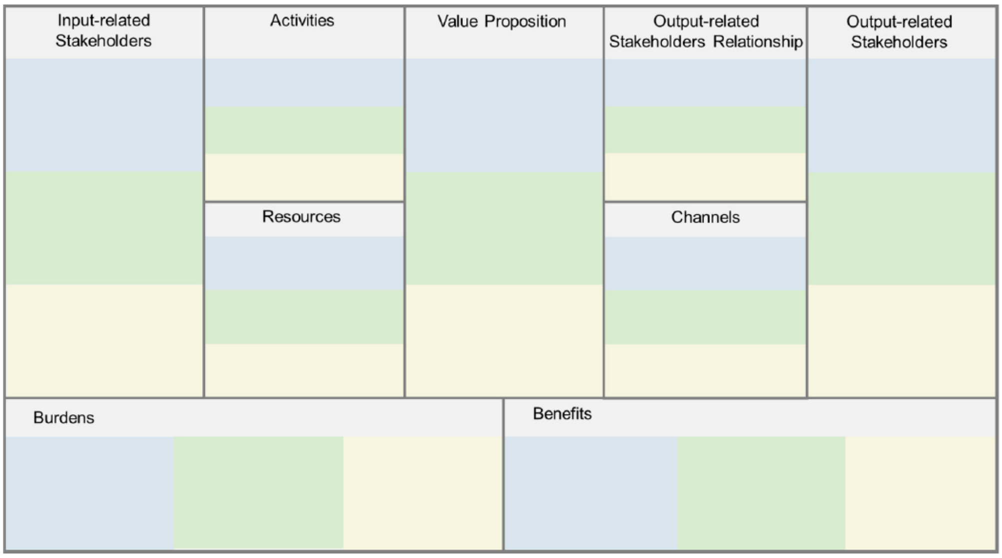

Figure 5.2.4 Business model canvas for sustainability (Cardearl et al., 2020)

Although there are options for sustainable BM frameworks, not all of them are preferable for this research. The TLBMC by Joyce and Paquin (2016) and BMCS by Cardearl et al. (2020) are more complex approaches than others because of additional BM elements out of the three-layer features. Predictably, research applying these frameworks needs more time to collect and analyse data to identify interrelationships and trace BM changes over time. Besides, it could be visually chaotic when presenting all interrelationships and changes in such frameworks. The Bocken et al. (2015) framework and Bocken et al. (2018) framework with main BM components help capture BM dynamics. But, referring back to the investigation of main BM elements in sub-section 2.2 and BM innovation in sub-sub-section 2.3, four instead of three main components are determined for this research, which is in line with SBMC. Moreover, sub-section 1.1.3 also illustrates why the sustainable business model canvas (SBMC) by Bocken et al. (2018) is chosen rather than the conventional economically-oriented BMC. Combined all, this research uses SBMC by Bocken et al. (2018).

5.2.2 Sustainable business model canvas (SBMC) by Bocken et al. (2018)

Since SBMC is determined as the tool for this research, it needs to be learnt. Sub-section 2.3.2 explains the definition of sustainable business modes (SBM) on top of business models (BMs) concepts (e.g., Geissdoerfer et al., 2018; Geissdoerfer et al., 2016; Evans et al., 2017). This sub-section discloses SBMC by Bocken et al. (2018) (shown in Fig. 5.2.5) beyond economically-oriented BMC.

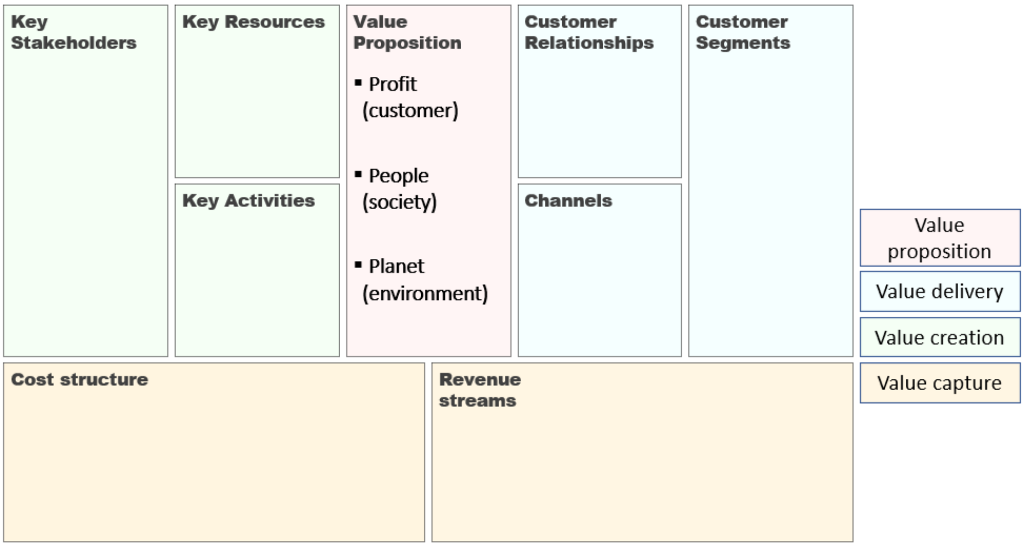

Figure 5.2.5 The sustainable business model canvas (SBMC) (Bocken, 2015 building on Osterwalder and Pigneur, 2010; Bocken et al. 2018)

Value propositions. According to the triple bottom line (TBL) dimensions entailed in sustainable value (mentioned in sub-section 5.2.1), value proposition now has other two pillars on top of customer value propositions (Profit, in short). One is society value propositions (People, in short). It describes what positive impacts the business brings to society. The benefits could be contributions to public health, social safety, community development, equality, secure livelihood, well-being, etc. (Evans et al., 2017). Another is environment value propositions (Planet, in short). It tells what positive impacts the business can create on the environment. This category of value proposition could be payoffs to low emissions, low waste, pollution prevention, etc. (Evans et al., 2017).

Value creation. Key activities (KA) and key resources (KR) blocks mostly remain similar to BMC. This is because one business activity could incorporate more than one value proposition dimension. For instance, a problem-solving solution could meet customer needs and at the same time benefits society or/and the planet. Yet there are specific activities undertaken for creating social or/and environmental value, such as R&D activities for improving production efficiency, using less rare materials, and reducing carbon emissions. When it comes to key resources, physical, human, intellectual, and financial resources differ not much with BMC. Only the material is especially included in the context of ecology. In contrast to the other two sub-elements, key stakeholders (KS) block are more distinct to cover environmental and social motivations. This could be any partner creating or enlarging positive impacts, such as state and local governments, local communities, media, non-governmental organizations (NGOs), universities, etc.

Value delivery. Customer segments (CS) and customer relationships (CR) are not much different from BMC but an expanded view of possible targeted groups of people or organizations that have a higher awareness of environmental protection and social stability. As profitable customers and profit-driven purposes dominate the market, economic customers are the focus. Apart from the five phases expressed in BMC, channels (CH) also consider how a company retrieves its products to fulfil environmental value.

Value capture. Cost structure (C$) and Revenue streams (RS) in this context represent all costs incurred and revenue generated to create and deliver values of all three value propositions. This requires taking a systematic view about the business.

5.3 Conceptual framework

According to sub-section 5.2 and 5.3, the dynamic business model framework by Kamp et al. (2021) and sustainable business model canvas (SBMC) by Bocken et al. (2018) together contribute to the baseline of the dynamic sustainable business model framework in this research. Building on the baseline, the next step is to develop the framework for this study. Referring to Meslin (2019) and Kamp et al. (2021), such a framework involves three aspects of business models: completeness, interrelationships, and changes over time. At the end of this sub-section, the final dynamic sustainable business model framework is presented.

5.3.1 Completeness

To establish a dynamic sustainable business model framework, the first criteria is BM completeness (Khodaei and Ortt 2019). According to the author, it involves both internal enterprise and external environment aspects. Despite using the popular business model canvas (BMC) to capture changes, like Cosenz & Bivona (2021), only changes relevant to BM variables are embodied. The environmental variables affecting BM variables are utterly dismissed. However, BM innovation responds to both changes within the company and changes in the external environment (refer Chapter 4). Thus, developing a dynamic framework to understand BM innovation entails examining the BM completeness.

Meslin (2019) provides an approach by using two forms to cover all aspects to investigate BM completeness. One is a BMC that entails all BM components to a business, and another form lists external and internal factors affecting BM elements. In this research, these two original tools still function but with adaptations.

(1) Sustainable business model canvas for DSPV projects

First, the dynamic sustainable business models framework adopts the sustainable business model canvas (SBMC) by Bocken et al. (2018) instead of the economically-oriented BMC by Osterwalder and Pigneur (2010). In Chapter 3, BMCs to three major types of DSPV business models distinguished by ownerships of PV systems have been built (see Table 3.1.2, Table 3.2.2 and Table 3.3.2). These canvas should be revised to cover sustainable value and regard the environment and society as main stakeholders (see Table. 5.3.1). Additional elements are obtained for a more thorough scan through a broader search of renewable energy technology and PV energy-related articles but revolve around distributed solar PV. In other words, the economically-oriented BMC elements are the same as in the three types of BMCs in Table 3.1.2, Table 3.2.2 or Table 3.3.2, depending on the ownerships of PV systems. Additional elements for SBMC are added to the three types of BMCs. In this study, these additional elements are in dark blue (see Table. 5.3.1). Besides, this research uses three colours to distinguish the three types of value propositions Bocken et al. (2018) declared. The main SBM elements are coloured coordinating with the SBMC.

Value propositions (VP)

Customer value propositions (CVP) are the same as in BMC in section 2.6. In addition to them, companies could provide society value propositions (SVP) and environment value proposition (EVP) through DSPV projects (see Table 5.3.1). Positive impacts on the environment are apparent. The first one is the benefit of climate change mitigation. The burning process of fossil fuels (e.g., coal, oil, and natural gas) for electricity production has increased the concentration of carbon dioxide (CO2), one major greenhouse gas (GHG), since the last century. Greenhouse gas emissions, along with global warming, pose severe threats to ecology, such as extreme weather, biodiversity loss, food scarcity, sea-level rise, etc. Facing these crises, renewable-sourced electricity is regarded as a promising solution for decarbonisation (International Renewable Energy Agency, 2022). It can not only significantly improve air quality benefiting human health but also minimize environmental damages caused by climate change. Besides, PV power generation could mitigate and solve other ecological challenges, including toxic gas emissions, water shortage, and noise pollution, through optimized design, material development, recycling and site selection (Tawalbeh et al., 2021).

Apart from EVP, Society value propositions (SVP) out of DSPV projects could be diverse. The very first social benefit is its role in promoting electrification. For regions, such as Sub-Saharan Africa (SSA), where there is low electricity access, DSPV, together with other renewable energy technologies, could produce positive electrification rates, contributing to sustainable urbanisation and industrialization (Chirambo, 2018). On the way, these regions could reduce their energy vulnerability to climate change and mitigate negative perceptions about their economic growth. Besides, expanding such solar projects has the potential to improve a region's energy security since it reduces the burden of imported fuel from the other areas or countries (Tyagi et al., 2013), becoming more independent in energy supply.

Moreover, there is an inclination in developing countries to link solar PV energy with poverty reduction (Liu et al., 2021). In China, PV Poverty Alleviation Projects, one of the major applications of DSPV in China, has revealed a noticeable poverty reduction effect with a net effect of 31.9 percent (Liu et al., 2021). Furthermore, financing and regulatory frameworks for DSPV projects could be improved (Chirambo, 2018) as the penetration of DSPV to energy supply. To encourage more renewable projects, governments working with grid companies and financial institutions issue energy policies, introduce regulations and offer project incentives, which address financing difficulties and promote industry normalization. Meanwhile, these policies and incentives facilitate business activities, attracting more investments and strengthening regional cooperation. The emerging projects also create new renewable energy sector-related jobs reducing unemployment (Chirambo, 2018). From all, they jointly boost the local economy. Besides, energy use technologies could be upgraded through these projects. Driven by reducing energy consumption in building sectors, PV companies may concentrate more on enhancing PV efficiency to provide more energy-saving solutions.

Value delivery (VD)

When it comes to value delivery (VD), Bocken et al. (2018) highlighted channels for product retrieving to fulfil environmental value. In the PV industry, retrieving products is usually associated with end-of-life (EOL) management (International Renewable Energy Agency, 2016). Since the PV market is still young and a typical lifespan of a PV panel is around 30 to 35 years, there are not many PV systems currently entering the end-of-life stage. However, it can be projected that more and more systems will go to the end of their life in the next few decades. To attain the environmental value propositions (EVP), companies tend to involve waste management of reusing (or repairing), recycling and reducing along their value chains (International Renewable Energy Agency, 2016). Solar PV waste management advisors and decommission (e.g., dismantling, recycling, and disposal) service company or non-profit organization websites could be channels to educate customers and at the same time help PV companies deal with end-of-life PV systems (Chowdhury et al., 2020), ultimately, contributing to the environment.

Value creation (VCA)

There are value creation (VCA) elements focusing on specific resources, activities, and partnerships to achieve environmental and social value propositions. Companies entailing end-of-life services for delivering EVP need to evaluate system operation conditions to identify if PV panels need to be repaired or reused (Ndzibah et al., 2021). Otherwise, companies collect and then recycle these end-of-life products in the case of panels that cannot be fixed (Chowdhury et al., 2020). Such companies may also undertake R&D activities to create value from end life products and train their employees with knowledge and skills for end life product management (International Renewable Energy Agency, 2016). Besides, socially and environmentally friendly system analysis and design in terms of land use, materials use, water usage, noise and visual impacts could be carried out at the beginning of projects for delivering both EVP and SVP (Tawalbeh et al., 2021).

The above activities could be coordinated in all by an EOL management company (International Renewable Energy Agency, 2016) or partly supported by non-profit organizations that offer management advice (Chowdhury et al., 2020). Otherwise, DSPV enterprises may make joint consent with supplier companies for such processes (Ndzibah et al., 2021). In this case, DSPV enterprises need carefully select suppliers and manufacturers capable of collecting and recycling materials. Additionally, the DSPV company may also require connecting with insurance companies to cover costs for the risk of its suppliers disappearing from the market (International Renewable Energy Agency, 2016).

Furthermore, DSPV enterprises need to build relations with other participants regarding the EOL management process. Governments play an important role in developing regulatory frameworks supporting the life cycle management of PV systems. Their directives may affect the costs of retrieving productions, for example, whether it is financed by producers (International Renewable Energy Agency, 2016). Finally, media that raise the public's awareness of climate change and promote the benefits of renewable energy technologies advertise the company's products while facilitating EVP and SPV delivery. Key resources (KR) now include recycled products that could be used to create second values and EOL management-related techniques and infrastructures (Chowdhury et al., 2020).

Value capture (VCP)

Cost structure (C$) now involves all costs incurred for creating and delivering EVP and SVP. One of the primary costs will be collation and recycling costs if suppliers do not finance such costs or if the DSPV company pays the services to an EOL management company. In other cases, cost of collection and recycling maybe covered by market participates (International Renewable Energy Agency, 2016).

Table 5.3.1 Sustainable business model elements for DSPV projects (additional elements in dark blue to BMC in Chapter 3; bule: CVP; yellow: SVP; green: EVP)

Main elements	Sub-elements	Label	Typical examples
Value propositions (VP)	Customer	CVP	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2
	Society	SVP	• Promote electrification • Support sustainable urbanisation and industrialisation • Achieve reasonable energy security • Reduce regional vulnerability to climate change • Mitigate negative perceptions about a region/country's growth • Improve the financing and regulatory frameworks for energy sector • Diversify local economy • Promoted local employment • Poverty alleviation • Health benefits of improved air quality • Advancement in technologies • Awakening community about the climate change
	Environment	EVP	• Climate change mitigation • Use of clean energy • Elimination of fossil fuels • Reduction of greenhouse gas emissions • Prevention of toxic gas emissions • Noise-free • Better quality water • Less waste
Value delivery (VD)	Customer segments	CS	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2
	Customer relationships	CR	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2
	Channels	CH	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2 • Solar PV waste management advisors • Decommission (e.g., dismantling, recycling, and disposal) service company or non-profit organization websites
Value creation (VCA)	Key stakeholders	KS	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2 • State and local governments for regulations of life cycle management • Media for raising public's awareness of climate change • Supplier companies for collecting and recycling • End-of-life management companies • Waste management non-profit organizations • Insurance companies for collecting and recycling
	Key activities	KA	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2 • Socially and environmentally friendly system design • Evaluation of operating conditions • Collection and recycling of EOL products • R&D development for EOL products • Knowledge and skills development for EOL products

			• Developing regulatory frameworks supporting EOL management
	Key resources	KR	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2 • Recycled materials • EOL management techniques and infrastructures
Value capture (VCP)	Cost structure	C$	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2 • Costs in collecting and recycling EOL PV panels
	Revenue stream	RS	• Same as Table 3.1.2 or Table 3.2.2 or Table 3.3.2

(2) Factors affecting SBM elements

Second, external and internal factors that impact SBM elements are investigated. Like Meslin (2019), these factors are identified as opportunities or threats. Business model innovation can be defined as a constantly changing process of BMs elements or/and the architecture at the firm level in response to external and internal opportunities and threats (refer sub-section 2.3.1). Chapter 4 studies the external environmental variables and internal company triggers and drivers of business model innovation. By definition, these triggers and drivers can lead to changes in business model elements, thus, contributing to completeness.

Table 5.3.3 lays out factors affecting BM variables. This table is based on case study results by Bucherer et al. (2012), the investigation by Meslin (2019) and the literature on business models innovation of renewable energy technologies. One thing can be noticed that this table does not build on triggers and drivers that are concluded in Table 4.1 in Chapter 4 because only external or internal origins of factors are indicated by literature in Table 4.1. However, the conceptual framework here requires knowing whether a factor is an opportunity or threat to the DSPV project and the effects of the factor on the business model elements.

Apart from investigating factors, the types of factors are concluded in Table 5.3.2. According to Chapter 4, factors are first classified by external or internal origins. Since more than one factor can affect one business model change in a real case (Kamp et al., 2021), the most important factor is the decisive factor to a primary change in the business model in this research. Besides, the factors are further identified as an opportunity or a threat. Based on Chapter 4, whether a factor causes opportunities or threats to a specific company should be considered in the company context. This research also applies such identification. Only after investigating the company's business and environment situations, including its response or action to the factor affecting business model elements, can the factor be determined as an opportunity or a threat.

Table 5.3.2 Factor types and statements

Types of factors		Statement	Real case representation
External origin	E	Factors in relation to changes in the external environment	The most important factor the decisive one
Internal origin	I	Factors in relation to changes within the company	
Opportunity	O	Factors cause changes to capture opportunities for companies	Considering in the company context
Threat	T	Factors force companies to change to avoid threats	

Table 5.3.3 Factors affecting business model variables (based upon Bucherer et al., 2012 and developed from Meslin, 2019; external opportunity (E.O); external threat (E.T); internal opportunity (I.O); internal threat (I.T);)

Type of factors	Relationships between environmental variables and BM variables		Code
	Effects	**Factors**	
E.O	E.O->CVP/EVP	Environmental targets / pacts / pledges	E1
	E.O->CVP/EVP/SVP/VD	Frequently-occurring natural disasters	E2
	E.O->CVP/VD	Changes in customer preferences or demands (e.g., Cai et al., 2019)	E3
	E.O->CVP/VCA/VCP	Changes in key technologies	E4
	E.O->VCP	Supportive financial system	E5
	E.O->VCA/CVP/EVP/SVP	Social and environmental value creation targets (e.g. EU's Strategic Energy Technology Plan) (Mihailova et al., 2022)	E6
	E.O->VCA	Collaboration in a company's network for competitive innovation and sustainable development (Rossignoli and Lionzo, 2018)	E7
E.T	E.T ->VCP	Competitions	E8
	E.T->CVP	Changes in customer preferences	E9
	E.T->VCP/CVP	Rregulatory requirements (Demil and Lecocq, 2010)	E10
	E.T->VCP	Constraining financial system	E11
	E.T->CVP/VD/VCA	Landscape changes	E12
I.O	I.O->CVP	New product or services (Laukkanen et al., 2019)	I1
	I.O->VCA	New technological infrastructure	I2
	I.O->CVP	Changes in perspectives on distributed PV technologies (Richter, 2013)	I3
	I.O->CVP/EVP/SVP	Changing from a product-oriented to a more service-oriented logic (Tolkamp et al., 2018)	I4
	I.O->VCA	Knowledge and competencies (Rossignoli and Lionzo, 2018)	I5
	I.O->EVP/CVP/SVP	Enhancing enterprises' reputation (Cai et al., 2019)	I6
I.T	I.T->VCP	Increasing costs	I7
	I.T->VCA	Outsourcing of activities	I8
	I.T->VCA	Investments in new capabilities	I9
	I.T->CVP	A breakup of the value chain	I10
	I.T->CVP	Company hype	I11
	I.T->VCP	Revenue erosion and loss of profits (Richter, 2013)	I12

5.3.2 Interrelationships

The second criterion to build a dynamic framework is interrelationships (Khodaei and Ortt 2019). Aside from interrelationships between external environment variables and BM elements, interrelationships are also present between different BM components. BM innovation, by definition, includes the changing process of the architecture of BMs (refer sub-section 2.3.1). The architecture of BMs refers to the relations among value creation, delivery and capture mechanisms that jointly construct the BM logic (refer sub-section 2.2.1). Thus, investigating relationships between BM elements is essential to understand BM innovation.

Meslin (2019) captured these relationships and presented them in a table in which interrelationship between two BM elements is identified according to whether the initial change in the first component and the resulting change in the correlated component are forced changes (F) or strategic decisions (C). Table 5.3.4 provides the interrelationships types and statements in Meslin (2019) by using an example of BM elements A and B.

Table 5.3.4 Interrelationships types and statements (example of BM elements A and B) (adapted from Meslin, 2019)

Relationships	Type	Statement
A->B	CC	A strategic change to the A can lead to a strategic change in the B
	CF	A strategic change to the A can lead to a forced change in the B
	FC	A forced change to the A can lead to a strategic change in the B
	FF	A forced change to the A can lead to a forced change in the B

In the case of SBMC, interrelationships exist between four main BM elements (see Table 5.3.5). These relationships are investigated by searching literature entailing two aspects in all, which circle the scope of research. One part focuses on renewable energy or PV energy, or DSPV energy in specific. The other part mentions sustainable BM elements relevant to at least two of the four main components. For example, 'PV energy' plus 'sustainable business model' and 'value creation and delivery.'

Table 5.3.5 Interrelationships between BM elements (building on Meslin, (2019); relationships cited in Meslin, (2019) in black)

Relationships between BM elements	Type (FF/FC/ CC/CF)	Relationships (examples)
VP & VCA		
VP->VCA	CC	Sustainable products and services offering CVP, EVP, and SVP bring changes in companies' resources and competences (e.g., brand image, reputation, innovation capabilities) (Laukkanen et al., 2019).
	FC/CC	Value propositions (incl. CVP, EVP, SVP) lead to different business activities (e.g., social and environmental projects, environmental-conscious R&D), partnerships (e.g., suppliers for reusing/recycling), and resources (e.g., brands) (Morioka et al., 2016).
VCA->VP	CC	Due to the extensive involvement of participates, companies can improve and use their (renewable) technologies to provide new CVP, simultaneously, offer EVP and SVP (Rossignoli and Lionzo, 2018).
	FC/CC	Campines generate new jobs (SVP) and benefit to the environment (EVP) due to engagement of EOL panel decommissioning activities (Ndzibah et al., 2021).
VP & VD		
VP->VD	FC/CC	By expending new value propositions based on distributed PV technologies, companies start to cover new markets (Richter, 2013).
	CC	Companies offing new VP (incl. CVP, EVP, SVP) target a different type of customer who pursues a sustainable lifestyle or is sensitive to issues of sustainability (Rossignoli and Lionzo, 2018).
VD->VP	FC/CC	Due to service-oriented sustainable value propositions: customer relationships extend beyond the purchase is made (e.g., in design and marketing phases); direct channels (e.g., personal interaction) are

		preferable; online application might be necessary (Tolkamp et al., 2018).
	CC	The reciprocal information flow between users and companies by extended customer relationships contributes to the satisfaction of customer value propositions (Tolkamp et al., 2018).
VP & VCP		
VP->VCP	CC	Companies with objectives other than profit maximization provide sustainable products and services, leading to improvements in companies' resource efficiency that is directly translated into cost reduction (Laukkanen et al., 2019).
	CF	A Value Proposition for which willingness to pay is less will lead to unsustainable Revenues (Preston, 2010).
VCP->VP	FC	Where returns are found to be decreasing, innovation and expansion to new customer segments are viable strategies (Emrah Karakaya & Hidalgo, 2016).
	CF	Different distributions of costs and revenues in the firm and end user will lead to a different value offering for different customer segments (Kulatilaka et al., 2014).
VD & VCA		
VD->VCA	CC	Changes in value delivery towards customers involvement lead to high priority activities (e.g., undertaking pilot projects or research projects, gathering feedback, organizing meeting); and thus new partnerships (e.g., knowledge institutes); additional resources requirements (e.g., software, customer networks) (Tolkamp et al., 2018).
	FC/CC	For company involving product retrieve channels (e.g., for EOL PV panels), they need to extend their partners (e.g., suppliers, research institutions, universities, governments, waste management companies, hazardous materials disposal companies) to promote efficient collaboration towards EOL management (Ndzibah et al., 2021).
VCA->VD	CC	To create sustainable values, the company build a joint relationship with their stakeholders including customers, which alters customer segmentation and relationships. (Mihailova et al., 2022)
	CC	Changes in value delivery towards customers involvement lead to high priority activities (e.g., undertaking pilot projects or research projects, gathering feedback, organizing meeting); and thus new partnerships (e.g., knowledge institutes); additional resources requirements (e.g., software, customer networks) (Tolkamp et al., 2018).
VCP & VCA		
VCA->VCP	CC/FC/ CF/FF	Changes in sustainable value creation can lead to changes in sustainable value capture (Morioka et al., 2016).
VCP->VCA	CC/FC	To reduce the high cost in recycling EOL panels, companies undertake R&D activities related to recycling techniques (Ndzibah et al., 2021).
VD & VCP		
VD->VCP	CC	Companies offing new VP (incl. CVP, EVP, SVP) earn revenue from new customers by different approaches (e.g., up-front installation payment of PV panels) (Rossignoli and Lionzo, 2018).
	CC/FC/ CF/FF	Changes in sustainable value delivery can lead to changes in sustainable value capture (Morioka et al., 2016).
VCP->VD	FC/CC	Finicing models owing to leasing or power purchase agreement (PPA) can lead to long-term customer relationships (e.g. 20 years) (Horváth and Szabó, 2018).

5.3.3 Changes over time

Changes over time refer to the last two criteria, interrelationships over time and framework changes (Khodaei and Ortt, 2019). A company's BM is not static due to interactions between and within BMs core elements (Demil and Lecocq, 2010). Instead, it is dynamic and can be viewed as a single frame from a motion picture. Besides, when the specific context that a BM exists alters, the entire architecture of a BM and the combination of all BM elements need to be adapted. The framework of the BM differs in that case (Fritscher and Pigneur, 2014). Additionally, sub-section 2.3.1 elaborates that BM innovation is a constantly changing process in response to external and internal changes. From all, investigation of BM innovation requires looking at changes over time.

It has been described that this research uses dynamic business model framework by Kamp et al. (2021) as a baseline and adopts the sustainable business model canvas (SBMC) by Bocken et al. (2018) to incorporate sustainable considerations of a business. The framework for this study remains most of these attributions but has a major modification. The three elements used by Kamp et al. (2021) are replaced by four main components: the value proposition (VP), the value creation (VCA), the value delivery (VD) and the value capture (VCP). This is not only in accord with the conclusion obtained from the literature review on business models (refer Chapter 2, sub-section 2.2) but also in line with the four primary elements of the SBMC by Bocken et al. (2018). In addition to adjustment in BM elements, the SBMC by Bocken et al. (2018) applied in investigating BM completeness results in more diverse origins of BM changes and more complex interaction between BM elements (refer sub-section 5.3.1 and 5.3.2), owing to economic, social, and environmental value incorporation.

Sub-section 5.1.4 has already explained in detail how the dynamic BM framework by Kamp et al. (2021) works and several considerations involved to present it. Table 5.3.6 lists the framework composition based upon Kamp et al. (2021). The dynamic sustainable business model framework is given below and illustrated with two examples (see Fig. 5.3.1 and Fig. 5.3.2).

Table 5.3.6 The framework composition (based upon Kamp et al., 2021)

Framework composition	Presentation in the framework
Stage of components	A circle with a number
Internal origin	A double-line circle
External origin	A circle with a small arrow attached
Primary change	A black-tipped arrow
Secondary change	A white-tipped arrow
Forced change	An arrow with a solid line
Strategic choice	An arrow with a dashed line
Opportunity	A white perpendicular cross
Threat	A red cross
Time	A time axis with indicators
Cause of the trigger	Expressed in words
Business model elements	
Customer value proposition	CVP; bule
Environment value proposition	EVP; green
Society value proposition	SVP; yellow
Value creation	VCA
Value delivery	VD

Value capture	VCP

Presentation of the framework: examples

Figure 5.3.1 shows how the framework works when a change in value creation leads to value proposition , value delivery, and value capture changes. The primary change (a black-tipped arrow) in value creation from its initial stage (VCA1->VCA2) is a strategic choice (an arrow with a dashed line) made by the company and is triggered by an internal origin (a circle with a small arrow attached). The change in value creation causes forced changes (an arrow with a solid line) in customer, environment, and society value propositions (CVP1->CVP2, EVP1->EVP2, SVP1->EVP2). These are secondary changes (a white-tipped arrow). The consequences of changes in value creation on the value delivery (VD1->VD2) and value capture (VCP1->VCP2) are the result of the forced change (an arrow with a solid line) for BM consistently.

This process can be exemplified in the context of Green Energy companies, including solar system SMEs (Rossignoli and Lionzo, 2018). The change in value creation (VCA1->VCA2), collaboration with other product or service providers, is because companies lack the necessary knowledge and competencies (see I5 in Table. 5.3.2). Companies view the internal factor as a threat hindering them from achieving greater market share (a red cross). Such cooperation brings about new customer value propositions (e.g., improving energy efficiency) and benefits the environment and society (e.g., utilization of green energy, technology innovation, etc.) (see Table. 5.3.4). These companies then target different types of customers, especially those concerning sustainability issues (see Table. 5.3.4). The costs and revenue are also rearranged by addressing environmental issues and involving new customers (see Table. 5.3.4).

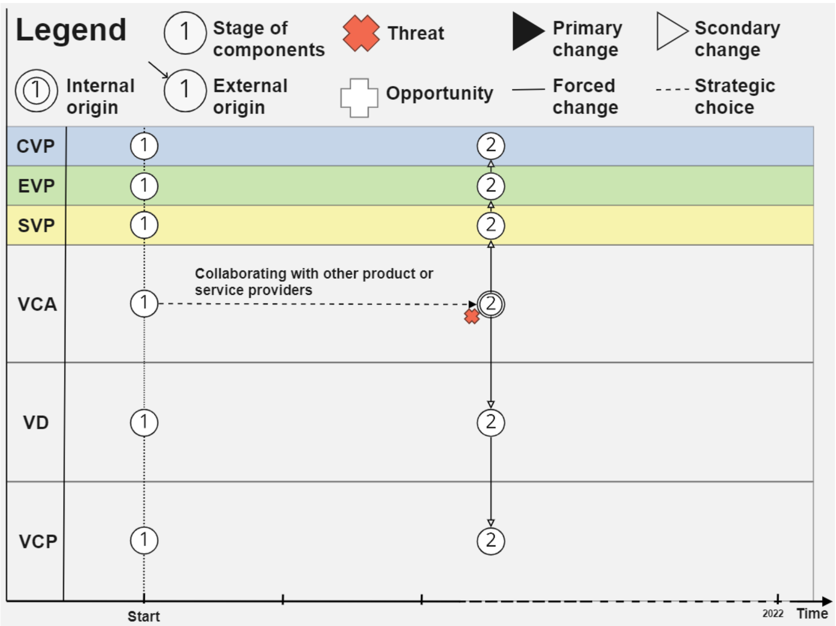

Figure 5.3.1 Dynamic sustainable business model framework (Example 1: strategic choice value creation change with internal origin forcing changes in value propositions, value delivery and value capture)

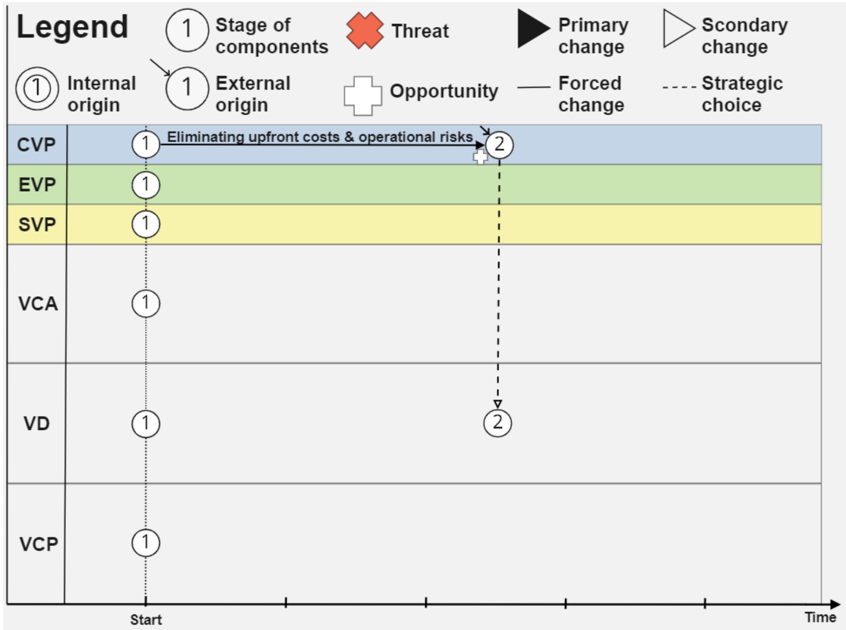

Figure 5.3.2 Dynamic sustainable business model framework (Example 2: forced value proposition changes with external origin leading to a strategic choice in value delivery)

Another example displays a change in customer value propositions leading to changes in value delivery (see Fig. 5.3.2). This can be exemplified in the context of the Energy Management Contract business model in China (Cai et al., 2019). The primary change (a black-tipped arrow) in the customer value proposition is a forced change (an arrow with a solid line). The change in customer value proposition (CVP1->CVP2), eliminating up-front costs and operational risks, is driven by customer preference (see E3 in Table. 5.3.2). This is an external factor (a circle with a small arrow attached) that customers seek solutions with low-risk investment and simple installation and post-installation tasks. This external customer need could be viewed as an opportunity for the company to enlarge its market (a white perpendicular cross). The secondary effect of changes in CVP (a white-tipped arrow) due to the change in customer value propositions is that industrial and commercial enterprises become the main customer segments of DSPV developers (VD1->2). This is a strategic choice (an arrow with a dashed line) of the company to enlarge its DSPV market (see Table. 5.3.4).

In addition to those above, several other aspects needed to be articulated. First, subsequent states of one element may have subsequent numbers. In example 2, the CVP and VD are at stage 2, while SVP, VCA and VCP are still at stage 1. Second, the dotted line in the time axis represents an uncertain year in which the event occurs, although the order of the occurrence is nailed. In example 1, the time the change happened is unknown, while in example 2, the time could be accurately aligned with the timescale on the timeline. Finally, the subsequent changes after a change in one element are needed when BM consistency is necessary. Looking at example 1, the strategic changes in VCA followed by forced changes in VD and VCP due to BM consistency. That is, two types of changes are labelled as the forced change (an arrow with a solid line) in this research. One is the change that is forced upon the company (e.g., CVP1->CVP2, EVP1->EVP2, SVP1->SVP2 in example 1). Another is subsequent changes for BMs consistency (e.g., VD1->VD2 and VCP1->VCP2 in example 1). This distinction also is stated in Kamp et al. (2021).

5.4 Chapter Summary

This chapter discloses how the dynamic sustainable business model framework is established, which gives answers sub-question four, *"**How can we develop a dynamic sustainable business model framework to understand business models innovation in DSPV companies?**"*. It starts with investigating dynamic business model frameworks and sustainable business model frameworks in literature. As a result, the dynamic business model framework by Kamp et al. (2021) and sustainable business model canvas (SBMC) by Bocken et al. (2018) are more applicable to this research.

After choosing the baseline, this study's framework is completed following the conceptual procedure reported by Meslin (2019). This contains three major steps, completeness, interrelationships and changes over time, which stem from four criteria for the dynamic business model framework (Khodaei and Ortt, 2019). When it comes to completeness, it is achieved using an SBMC of DSPV projects (see Table. 5.3.1) and a form listed environmental factors that affect business model variables (see Table. 5.3.3).

At the second step, interrelationships between BM elements are discussed based on literature review and are laid out in Table 5.3.5. This step partly offers the answer to sub-question three, "***What important interrelationships between BMs elements and interrelationships over time should the DSPV project company consider in business model innovation?***" Since SBMC is used, the interrelations between value proposition (VP), value creation (VCA), value delivery (VD) and value capture (VCP) are explored. For DSPV projects to innovate their business model, changes in interrelationships among these BM elements give insights into business model innovation as business model innovation is a constantly changing process of the architecture of BMs. The architecture of BMs refers to the relations among value creation, delivery and capture mechanisms that jointly construct the BM logic. Knowing of how these elements affect each other helps understanding business model innovation in in terms of triggers and their consequences.

Finally, the dynamic sustainable business model framework is established together with the last step that presents BM changes over time. It provides a part of the answer to sub-question three. The framework follows several considerations documented in Kamp et al. (2021) but is adjusted to cover sustainable thinking (see Table. 5.3.5 and Figure. 5.3.1). The next chapter shows how the framework is applied in DSPV project companies.

Chapter 6 . Framework application

Before digging into the cases, Table 6.1 shows steps directing the further study. It consists of three main procedures. The first step is to select possible cases applicable to this research. These cases should align with the scope and focus of this research. Then, the material collection, including project study and interview, is the next step, followed by case study reporting, the last procedure. This chapter partly answers the last research sub-question, "***How can we apply the dynamic sustainable business model framework to DSPV projects in China to understand business model innovation?***" This chapter discloses case selection and material collection, especially interview question design. Case reporting is delivered in Chapter 7.

Table 6.1 Case study steps (based on Rashid et al., 2019)

Main Steps	Focus/Sub-steps
1. Case selection	• Scope and focus of the research
2. Case material collection and Interview	• Interview questions design • Contact participants • Project company study • Interview • Integration of meeting notes and feedback documents
3. Case reporting	• Case description • Dynamic sustainable business model framework of the case • Analysis, discussion and implications • Conclusion

Framework application starts with case selection. Table 6.2 lists possible DSPV project companies for the case study. They are either leading giants in China's PV industry or SMEs committed to DSPV systems for years in China. They conducted DSPV projects that are typical cases on companies' websites and in accord with the thesis scope regarding DSPV installed capacities and on-grid systems. Besides, the projects conducted are representatives of host-own (HO) business models or third-party-own (TPO) business models. One aspect, sustainability, these case companies have the potential to integrate social, environmental and economic pillars in their DSPV business models despite only background searching. Another, these project companies should be engaged in the DSPV business long enough (e.g., at least five years to now) to capture BM dynamics. Ultimately, five out of thirteen project companies will be applicable for the case study because not all companies give responses.

Table 6.2 List of DSPV projects in China

N.	Company	Response-ability (N/Y)
1	Trina Solar	N
2	JINKO POWER	Y
3	Astronergy / CHNT	N
4	SUNREN	N
5	LONGI	N
6	CHINA CLEAN ENERGY	N
7	JASOLAR	N
8	SUNGROW	Y
9	JOLYWOOD	Y

10	Canadian Solar	Y-N
11	NAMKOO	Y
12	Inner	Y
13	Shenzhen Hengtongyuan Environmental Protection Technology Co., Ltd.	N

After case selection, the next step is to collect case materials. As described in Chapter 1, semi-structured interviews can be carried out along with meeting notes and background documents collection. Due to the semi-structured interview, questions would not be asked in a predefined structure, but a list of issues that needed to be discussed is papered (see Table. 6.3). Once participants confirm the interview, background studies can be undertaken through companies, PV organizations and government websites. These types of project material could contribute to parts of the information required to perform the dynamic sustainable business model framework. However, some information gathered in this way may not always be accurate or authoritative, which would be tricky in data analysis. Under this circumstance, any uncertain or unreleased information could be asked in the interview. Besides, interviews complement some undiscovered or unreported issues of DSPV projects.

Table 6.3 Interview questions

Question scope		**Framework related aspects**	
General information	• What are you currently doing at this company? • How long have you been working in this field? • Is the company information correct? • What is your role in DSPV projects? / What position do you hold in the company?		
Value propositions (VP)	• How do DSPV projects benefit society (or people) and the environment? Could you please give some typical examples?	• Completeness	EVP, SVP
	• Has your company ever decided to offer customers additional services or products after the systems are built? If so, what are they, for what reasons, and what were the effects?	• Completeness • Changes over time	CVP
	• Has your company had the inclination to incorporate more sustainable solutions in DSPV projects ever before? If so, when did it happen, what did your company do, for what reasons, and what were the effects?	• Completeness • Relationships • Changes over time	VP & other elements
Value delivery (VD)	• Why does your company service these customers with the project? • What do you know about the user experience of this project? • How do you view your company's user channels? • Do your company offer other options to the customer when the contract is over? (TPO model)	• Completeness	CS, CR, CH
	• Have you changed your target market since? If so, what are they, for what reasons, and what were the effects?	• Relationships • Changes over time	CS & other elements

	• How does your company decide to deal with the PV waste when the system is at the end of life? If so, how you cover the costs?	• Relationships	VD & VCP
Value creation (VCA)	• What are the most important business partners or relationships for DSPV projects going well so far? • Who financed or is currently financing DSPV projects? Are they the main source of financing for the projects or are there other sources? (customers, banks, grants, venture capital) • Who provides other services (e.g., O&M)? Who covers the costs? • Who are DSPV projects suppliers (e.g., system components)? • Are your company also cooperating with NGOs or institutions in DSPV projects (e.g., environmental protection organization, media, waste management / EOL companies, etc.)?	• Completeness • Relationships	KP, KR, KA VCA & VCP VCA & VP
	• How do policies and regulations affect DSPV projects operation (e.g., subsidy declining, gird parity, carbon-neutral target, etc.)?	• Changes over time	KP, KR, KA
Value capture (VCP)	• What are the biggest costs with DSPV projects? • What exactly do customers pay for DSPV projects? (based on HO & TPO models) • What are the payment methods? • How do you cover the additional costs if your company decides to manage the EOL PV?	• Completeness	C$, RS
	• Has any business decision ever affected (add or cut) the costs a lot? If costs are added, how did you respond to it?	• Relationships • Changes over time	C$ & other elements
Business model innovation	• What were the most challenging moments for conducting DSPV projects? What caused these situations? How did your company go through them? What were the effects to the DSPV business? • What were successful strategies your company made smoothing the DSPV projects operation? • What are the biggest lessons you obtained from DSPV business?	• Changes over time	

Chapter 7 . Case study

This chapter partly answers the last sub-question, “***How can we apply the dynamic sustainable business model framework to DSPV project companies in China to understand business model innovation?***” The dynamic sustainable business model frameworks of five DSPV companies are unfolded after project company studies and interviews. Table. 7.1 shows the interview details of the five companies. The integrated results are presented in sub-section 7.1 to 7.5. Besides, sub-section 7.6 provides a cross-case analysis that partly answers sub-questions one, two and three. This subsection discusses important sustainable business model elements for DSPV projects in China, vital internal and external factors affecting business model variables and important interrelationships between sustainable business model elements. Last but not least, improvements for the conceptual framework are described in sub-section 7.7.

Table 7.1 Details of the interview

Company	Participants		Date
SUNGROW	Business manager	15-year experiences in PV field	Monday, 21, March, 2022
JOLYWOOD Minsheng	Head of Sales - APAC	11-year experiences in PV industry	Tuesday, 5, April, 2022
NAMKOO	Sales Engineer	6- year experiences in PV industry	Friday, 22, April, 2022
JINKO POWER	Sales Manager	2-year experiences in PV industry	Monday, 1, May, 2022
INNER	Investment Analyst	11-year experiences in PV industry	Monday, 9, May, 2022

7.1 SUNGROW

Sungrow is one of China’s high-tech enterprises focusing on R&D, production and sales of renewable energy power equipment, such as photovoltaic inverters, and is committed to providing PV power solutions. The company has specialized in the development, investment, construction and operation management of PV power plants after China’s 12th Five-Year Plan launched in 2012. Ever since the 2013s, the company has begun to offer the DSPV solutions, especially rooftop power stations.

The majority of projects undertaken by the company in the early stage of DSPV business development were driven by China’s poverty alleviation projects. Sungrow delivers mostly EPC (Engineering, Procurement and Construction) projects to poverty families, and these projects are mainly under third-party-owned (TPO) business models from the ownership point of view. Sungrow initiates contracts with its customers holding full control of the DSPV projects from early-stage initiation to the final-stage closing. At the end of the contract, Sungrow would either give the system for free or dismantle and recycle it, depending on the customer’s willingness. Giant companies and institutions under State Grid are the actual project owners or financers in the case of most poverty alleviation projects. Apart from these state-holding projects, Sungrow itself also invests in DSPV projects servicing industrial and commercial (I&C) customers. Not only because these types of customers over households have superiority in rooftop conditions in general but also because they have higher annual electricity consumption and higher business integrity about the return. Host-owned (HO) and TPO business models are available for these customers from system ownership perspectives.

Under EPC contracts that the contractor operates and manages the entire project, Sungrow cooperates with suppliers for DSPV system components. Among the supply companies, Infineon, a company dedicated to semiconductor technology, offers a large portion of transistors required for producing inverters that would then be self-supplied by Sungrow in the DSPV projects. PV panels are sourced from international brand companies, such as Trina Solar and JA Solar. Besides, Sungrow also collaborate with sub-contractors and service providers to undertake business activities such as system installations and maintenance, etc.

When it comes to value capture, most of the costs are over DSPV project Construction rather than Engineering and Procurement. The cost paid for system installation under a subcontract makes up a large part. Likewise, Sungrow bears costs incurred in design, purchasing, after-sale services (e.g., O&M) and other activities. If a project functionally and profitably goes well, the electricity bill from customers would contribute to the most revenue stream.

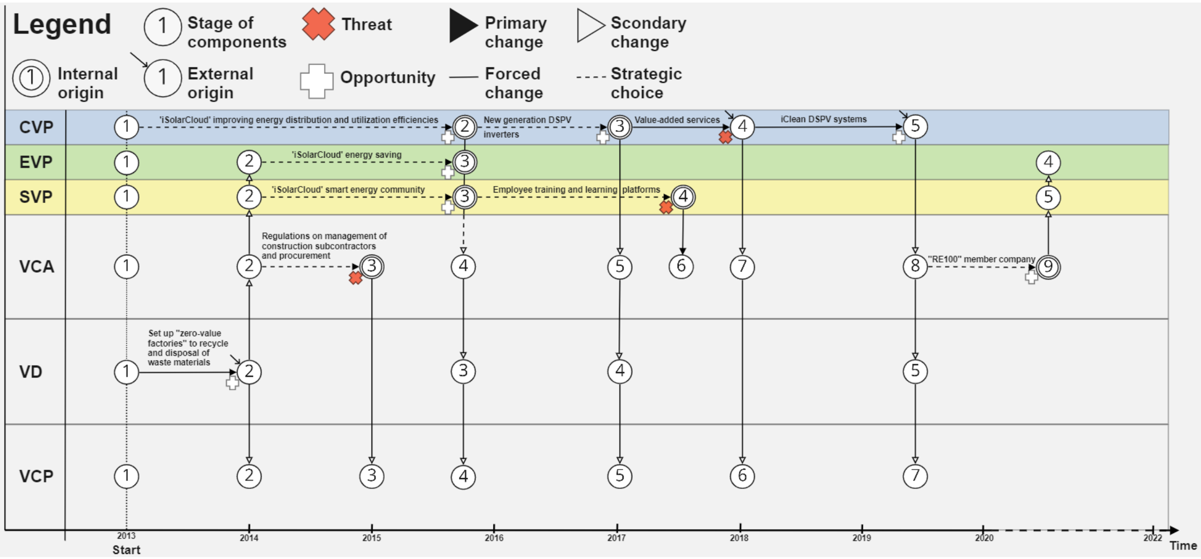

Figure 7.1.1 SUNGROW's dynamic sustainable business model framework

Table 7.1.1 Major changes to sustainable business model of SUNGROW

N.	Year	Origin		Causing	Primary effect	Follow-up effect
1	2014	Implementation of industrial regulations of resource recycling	E.O	Set up "zero-value factories" to recycle and dispose of waste materials	VD 1->2: Adding channels for production waste reuse and disposal	VCP 1->2: Additional costs associated with the disposal of waste material VCA 1->2: Materials companies EVP 1->2: Less waste

						SVP1->2: Promoting local health due to harmful waste disposal
2	2015.6	Unstandardized procurement in EPC projects and high costs in outsourced PV system installation	I.T	Introducing "Regulations on the Management of Construction Subcontracting Procurement Business"	VCA 1->2: Management regulations; High-quality suppliers and subcontractors by bidding; Regularly evaluations of supply chain	VCP 2->3: Cost reduction in construction
3	2015.11	Five-year SUPER development strategy on PV energy	I.O	Releasing "iSolarCloud" for smart PV energy system solutions	CVP 1->2: Improving energy distribution and utilization efficiencies SVP 2->3: Developing users' electricity habits through smart energy community EVP 2->3: Energy saving due to smart energy balance system	VD 2->3: Strengthened customer relationships because of increased user experiences VCA 3->4: Cooperating with internet company VCP 3->4: Costs in system development and improvement
4	2017	Sungrow comprehensively upgraded its business strategy (a system provider with clean power conversion at its core), focusing on Technology Innovation	I.O	Releasing new generation DSPV inverters (SG15/17/20KTL)	CVP 2->3: Increasing power conversion efficiency; Adapting to various rooftop installation environments; Maximizing customer revenue	VD 3->4: Industrial and commercial customers VCA 4->5: Increased proportion of marketing and sales personnel VCP 4->5: Increased selling expenses
5	2017	Increased personnel - requirements for employee capabilities	I.T	Providing employee training and learning platforms	SVP 3->4: Promoting sustainable development of employees	VCA 5->6: More skilled employees; Propagating corporator culture

6	2018	Increased market competition - increasing domestic enterprises	E.T	Offering value-added services	CVP 3->4: Customized services in consulting, planning and design; Additional services in insurance and leasing	VCA 5->6: Working with insurance companies VCP 6->7: Leasing revenues
7	2019.6	Industry technology innovation – the self-cleaning double nozzle patent design	E.O	Releasing iClean DSPV systems	CVP 4->5: Automatic and optimized cleaning; Increased power generation by 8%	VCA 6->7: Different value creation VD 4->5: Different value delivery VCP 6->7: Different value capturing
8	2020-	Tacking climate change as one prioritized subject in sustainable orientation (Sungrow's Social Responsibility Report, 2020)	I.O	One of the RE100 (Renewable Energy) member companies- utilizing renewable electricity in all business activities by 2028	VCA 7->8: Participated in global climate group; Building factory rooftop DSPV systems; Company image	EVP 3->4: Reduction of carbon emission SVP 4->5: Accelerated change towards zero carbon power grids

Overall, Sungrow experienced eight major changes in DSPV business over time (see Figure 7.1.1 and Table 7.1.1). The first primary change occurred in 2014, during which Sungrow set up "zero-value factories" to recycle and dispose of waste materials. The establishment of such factories was mainly a reaction to several policies announced during periods of China's 11th and 12th five-year plans. After the first *Circular Economy Promotion Law* was enforced in 2009, production enterprises are responsible for utilizing recycled materials or harmless disposal according to their technical and economic conditions. For companies entrusting other organizations due to a lack of technology and finance capabilities, these third-party institutions should sign contracts and comply with the relevant laws and administrative regulations to dispose of or reuse the waste. The reuse of waste also involves construction units or qualified operators at the construction stage (State Council, 2008a). Moreover, the *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products* in 2011 specified the liability of relevant parties to recycling and disposal of waste products (State Council, 2008b). During the 12th five-year plan period, *Energy Conservation and Environmental Protection Industry Development* further emphasized research and development of recycling technologies (State Council, 2012). Together with the increasing awareness of environmental protection worldwide, these policies forced Sungrow to consider possible channels to dispose of waste materials (VD1->2), although adding the channel ("zerovale factories") to recycle and dispose of waste brought processing costs. Sungrow saw this as an opportunity (a white perpendicular cross), creating new values through the management of waste. For explanation, this primary change was a forced change (a black-tipped arrow with a solid line) with an external origin (a circle with a small arrow attached).

Because of the change in value delivery, value creation was affected moving to the next stage. Based on the quality and property, some materials could be reused, and some could be sold to other firms, offering financial benefits. The granular material used in support assembly of water surface DSPV system is a typic example of Sungrow's "zero-value factory" that had a recycling rate of around 10.2% in 2018. Other valuable wastes (e.g., metal scraps, cartons, plastic packages, cables of BoS components, etc.) are resold to materials companies for reuse. Working with these companies helped Sungrow turn those waste into its resources (VCA1->2). Besides, value capturing was also impacted (VCP1->2). Sungrow covered costs associated with waste treatment but also obtained an economic paid-off, despite a relatively low return compared to costs. Aside from effects on value creation and capturing, this channel delivered environmental value propositions (EVP1->2) and social benefits (SVP1->2). In addition to mitigation of climate change over clean (solar) energy generation, since then, less waste has been produced through this process, especially electrical and electronic waste. Particularly, dismantling and recycling harmful waste like circuit boards protect the local ecosystem, promoting local health, both human and other living creatures. The secondary changes in value creation, value proposition, and value propositions were forced change showing by a white-tipped arrow.

The second significant change in DSPV projects happened in 2015. This change had an internal origin (a double-line circle) that posed threats (a red cross) to the company. Since Sugrow functioned as an EPC contractor carrying all the liabilities in the DSPV projects, selecting subcontractors and suppliers is vital for them. For one thing, co-operators with lower credibility and qualification in providing products or services could lead to poor project performance. Meanwhile, unstandardized procurement and sub-contraction easily led to integrity issues within the company, damaging the company image. For another, costs incurred in the outsourced installation could go higher than actual prices without competition-oriented selections.

These internal threats encouraged Sungrow to introduce regulations on managing construction subcontracting and procurement, which directly affected the value creation (VCA1->2) of Sungrow's business model. Since then, Sungrow has organized construction bidding to determine sub-contractors for delivering qualified services at reasonable prices. In addition to bidding, Sungrow also decided to regularly evaluate its supply chain partners to not only assess product quality but also help product improvement. This regulation towards subcontractor management effectively reduced costs at the construction stage (VCP2->3). For explanation, the primary change in value creation was a strategic choice, and its subsequent change in value capture was a forced change.

The third major change also appeared in 2015. This change was due to an internal trigger that Sungrow altered its development strategy later this year. The core of the new strategy was to pursue sustainable development in the long-term and concentrate on providing smart PV energy solutions to sustain its competitive advantages. This strategy was made according to its new objective, leading Sungrow to become the most socially responsible enterprise in China's renewable energy industry in the next five years. To achieve its goal in terms of delivering smart PV energy solutions and sustainable development, Sungrow released its first-generation ‘iSolarCould’ system for PV project management.

By launching ‘iSolarCould’, the value propositions of DSPV projects were enriched. First, the customer value proposition was changed (CVP1->2). Energy distribution and utilization efficiencies were improved due to the real-time control. Customers have released the tension in electricity generation as the system intelligently balanced the energy supply and demand based on user data collection and optimization of the entire distribution grid. Excess electricity over the customer demand would be sold to utilities or other local users by Sungrow. Simultaneously, such a system with insight monitoring and remote adjustment effectively saved more energy (EVP2->3), eliminating electricity abandonment and maximizing the value of energy utilization in DSPV projects. Meanwhile, ‘iSolarCould’ created a smart energy community with its customers, benefiting the local society towards sustainability (SVP2->3). Users were available to access the ‘iSolarCould’ platform on PC and mobile sides, by which Sungrow educated customers about energy usage, developing users’ electricity habits. Besides, most end-users of Sungrow’s DSPV projects at that year of the stage are families in poverty alleviation projects. Despite governmental incentives, people’s perspectives towards renewable energy were less positive than traditional energy supply as they suspected the profitability of such projects. The smart community with transparent management gave these end-users a channel to self-check their daily energy usage and electricity fees, along the way, convincing them of the win-win feasibility of tackling climate change through renewable energy.

The above changes in value propositions had subsequent impacts on value delivery (VD2->3) in terms of awareness and purchasing channels. In addition to value delivery, integrating ‘iSolarCould’ project system made the internet company a significant partner to Sungrow, affecting its value creation (VCA2->3) of the business model. Sungrow strategically decided to cooperate with Alibaba Cloud Computing in delivering such a smart system and updated this system annually for more automatic and intelligent operation. Costs associated with ‘iSolarCould’ system development and improvement were involved (VCP3->4).

Only two years into its five-year plan, Sungrow upgraded its business strategy comprehensively in 2017, resulting in the fourth major change to DSPV projects. This change was mainly due to the internal factor. Power generation costs and feed-in tariffs (FiT) in some regions of China are higher than conventional fossil energy. DSPV projects still highly rely on government support. With the industry development, grid-parity could be projected. Because of the high investment in DSPV projects, once the governmental subsidy changes profoundly, such as no subsidies anymore, the revenue stream of the project will be impacted to a certain extent. Facing the risk of policy fluctuations, Sungrow chose to update its development trajectory actively. Instead of largely relying on project investment return, it has turned to be a system provider with clean power conversion at its core. *Technology Innovation* was the heart of this strategy.

Leading by the company strategy, Sungrow released its new generation inverter specifically for DSPV projects, offering additional customer value propositions (CVP2->3). The new generation DSPV inverter could adapt to various rooftop installation environments, especially rooftops in urban districts. It could also improve power conversion efficiency, increasing customer revenue. This technology improvement brought out a change in value delivery

(VD3->4), targeting industrial and commercial (I&C) customer segments out of households, expanding Sungrow's DSPV business. Before it, the early-stage DSPV projects were mainly applied to households in counties that have more available roofs, and the inverters were generally more applicable to large-scale PV projects. With the rapid promotion of DSPV solutions with its inverter innovation, the proportion of marketing and sales personnel, seen as essential resources in value creation (VCA3->4), increased substantially during this year. At the same time, costs arising out of selling expenses (VCP4->5), including sales staff salaries and related office expenses, travel expenses and other expenses, went up. The expenses boosted by 81.14% compared to the figure in 2016.

The fifth change with an internal origin occurred later in 2017. The rapid growth of business this year led to an increase in the number of employees and higher requirements for employee capabilities. At the same time, the turnover rate increased, especially in sales positions. Under this situation, Sungrow introduced training and learning platforms, promoting sustainable development of employees, thus, adding social value propositions (SVP 3->4). To confront a large group of new employees, Sungrow organized "Sunflower Project," training them in generic skills to help them integrate quickly. Sungrow also undertook manager development programs, setting business and human management courses to cultivate senior managers. The company also developed an online self-learning platform, allowing managers to arrange courses for subordinates to learn relevant knowledge and skills as needed. Subsequently, value creation (VCA 5->6) was altered. Sungrow had more skilled employees in marketing, project management and technology. The corporate culture that cultivates employees and focuses on employees' experiences and satisfactions has been propagated to the public, benefiting the company image.

The sixth change was in 2018, provoked by increasing competition in the DSPV market. Attracted by the growth potential of the domestic market, more and more enterprises have been entering the DSPV market. Asides from technology improvement to differentiate Sungrow from its competitors, offering value-added services (VAS) was another way to maintain its advance. This directed customer value propositions to the next stage (CVP3->4). The value-added services provided additional services in insurance and leasing on top of customized services in consulting, planning and design. This resulted in changes in value creation (VCA5->6) and value capturing (VCP5->6). On the customer side, they were no longer required to select insurance companies themself. Rather, Sungrow worked with insurance companies to offer services. Additionally, Sungrow could lease the system equipment to its customers and collect certain rents based on the contract, bringing in a new revenue stream. For explanation, the primary change in customer value propositions and following changes in value creation and value capturing ware forced changes. The change in value capture was due to business model consistency.

The seventh change was in June 2019. This change resulted from an external trigger that was an opportunity from Sungrow's perspective. Encouraged by technology innovation that the industry's first self-cleaning double nozzle patent design, Sungrow launched its 'iClean' DSPV system at the 2019 International Photovoltaic Power Generation and Smart Energy Conference & Exhibition (SNEC). The 'iClean' integrated an automatic intelligent self-cleaning system into the DSPV project by programming fifteen operation procedures, including monitoring, cleaning, measuring, etc. Customer value propositions moved to the next stage (CVP4->5). By artificial intelligent weather assessment and perception of cleanliness, PV panels could be cleaned automatically and optimized, reducing the ash loss rate and increasing annual power production by around 8%. Such a change in customer value proposition led to secondary changes in value creation, delivery, and capturing (VCA7->8; VD4->5;VCP6->7) due to business model consistency, represented by an arrow with a solid line.

The last change was after 2020 (at an unknown time represented by a dashed line on the time axis). Since 2020, Sungrow has highlighted tackling climate change as one prioritized subject for sustainable development. This internal company decision affected the value creation (VCA8->9). Following the sustainable orientation, Sungrow joined in RE100 (Renewable Energy) climate group, becoming one of the RE100 member companies aiming to support the initiative of utilizing renewable electricity in all business activities by 2028. Sungrow has built DSPV systems on its factory rooftops to achieve the goal. This was not only an opportunity for Sungrow to promote its corporate image by taking social responsibility but also a way towards sustainable development. The primary change in value creation mainly brought environmental benefits (EVP3->4) that carbon emission would be further reduced and social benefits (SVP4->5) that would accelerate change towards zero-carbon power grids.

7.2 JOLYWOOD Minsheng

Jolywood Minsheng, an energy company under the Jolywood Corporation, was founded in 2015 that is committed to the sales of PV system products, DSPV power plants investment, projects operation and maintenance. Jolywood with around six-year experience in the DSPV industry, adopting both TPO and HO business models. National policies highly directed their DSPV business over time. They allocated a majority of resources to household DSPV projects in the past. Customers of them are genuinely families in counties. The TPO model without up-front investment is preferable to these customers compared to the HO model. They rent roofs to Jolywood for building the system and then obtain electricity and rent income. Jolywood develops the DSPV system from design to installation and controls the project O&M. Jolywood enjoys government subsidies and earns most revenue from electricity fees. Since they, themself, are the PV cell manufacturer, other system components come from suppliers like Huawei. They also worked with both local and national banks in financing services.

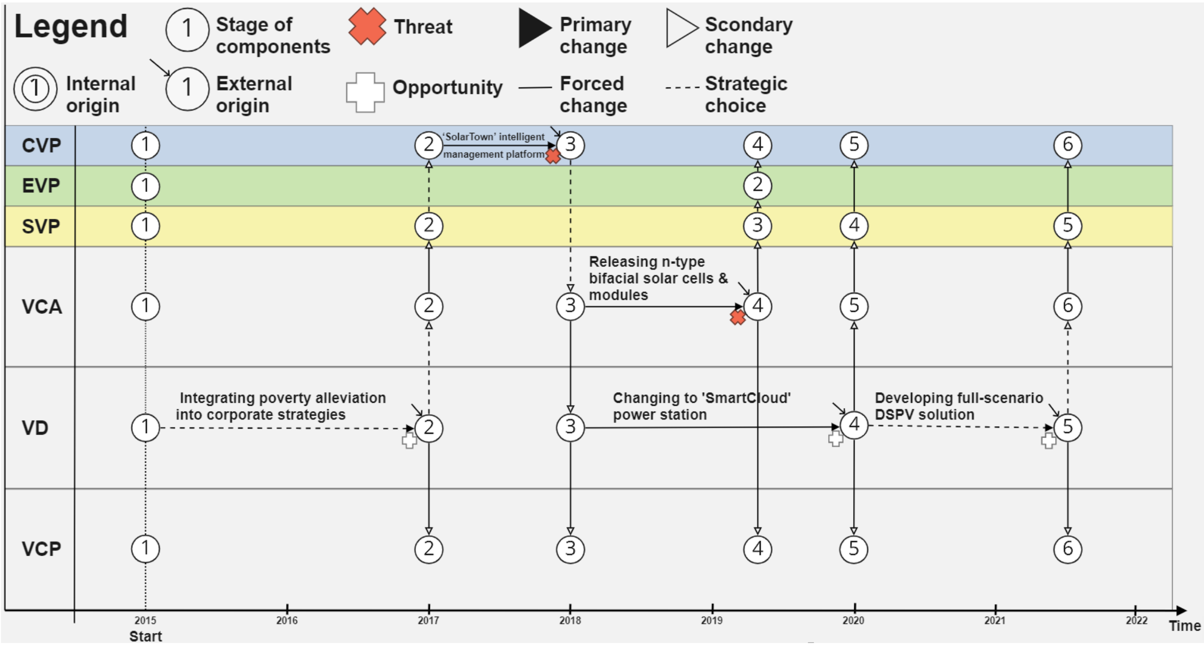

Figure 7.2.1 JOLYWOOD's dynamic sustainable business model framework

Table 7.2.1 Major changes to sustainable business model of JOLYWOOD

N.	Year	Origin		Causing	Primary effect	Follow-up effect
1	2017	Effects of PV poverty alleviation policies	E.O	Integrating poverty alleviation into corporate strategies	VD 1->2: County-level DSPV market for a long length of time	CVP 1->2: No upfront costs; A guaranteed extra yearly return VCA 1->2: Cooperating with local governments and banks VCP 1->2: Employee costs; Construction costs (incl. O&M costs) SVP 1->2: Poverty alleviation; Maximized land use efficiency
2	2018	Increased customer requirements for enterprise credits and after-sale services	E.T	Launching 'SolarTown' intelligent management platform	CVP 2->3: Insurance service; Automatic income settlement; Regular and intelligent O&M	VCA 2->3: Strategic cooperation with national banks, O&M companies, insurance providers (e.g., PICC) VD 2->3: Improved customer experiences by the system VCP 2->3:

						Increased labour costs; Costs in developing intelligent systems;
3	2019	Market competition and short-term impacts of China's '531' policy	E.T	Technology improvement (N-type bifacial solar cells; N-type TOPCon bifacial modules)	VCA 4->5: Technology R&D; Building brand reputation;	CVP 3->4: Electricity generated increased (10%-30%); Increased customer revenue EVP 1->2: Reduced GHG emission due to the technology SVP 2->3: Advanced technology VCP 3->4: Cost in technology R&D
4	2020	Requirements for online channels due to global pandemic	E.O	Changing to 'SamrtCloud' power station	VD 3->4: Online and WeChat applet (engaging in all project process)	CVP 4->5: Intelligent "contactless" services SVP 3->4: Promoting digital energy development VCA 5->6: IT activities; Remove inefficient activities VCP 4->5: Costs reduction due to online project process management
5	2021	Demand of marketspace in the whole county (city, district) roof DSPV program	E.O	Developing full-scenario DSPV solution	VD 3->4: Adding customer segments (incl. households, governments, public buildings (e.g., schools, hospitals))	CVP 5->6: Less requirements of rooftop conditions VCA 5->6: Increased skilled workers; Cooperation with state enterprises, local banks and Huawei SVP 4->5: Changing residents energy habits towards green energy; Promoting local

						energy structure transformation; Promoting local economic; Promoting local employment VCP 4->5: Different costs

Overtime, five major changes were saw in Joywood's DSPV business (see Figure 7.2.1 and Table 7.2.1). The first primary change in value delivery (VD1->2) that occurred in 2017 was induced by a national strategy, Poverty Alleviation, and a series of follow-up incentive policies toward DSPV. The priority objective of China's photovoltaic poverty alleviation project issued in 2014 was to carry out DSPV plants in the next six years to support poverty-stricken households in the basic living income (National Energy Administration, 2014). Influencing by this nationwide notice, supporting policies and subsidies toward DSPV energy generation were largely introduced by national and local governments. The industry viewed these politically decisive incentives as a huge opportunity for expanding the domestic DSPV market. To seize such a growing tendency among the DSPV industry that in responding to the national plan, Jolywood strategically integrated poverty alleviation into its corporate strategy, focusing specifically on the county-level DSPV market. Since then, families in villages were the primary customer segments for Jolywood for a long length of time.

The above change in the value delivery caused subsequent changes in customer value propositions (CVP1->2) and value creation (VCA1->2). Since these customers genuinely had poorer family economic conditions, Jolywood offered a DSPV project solution, eliminating their concerns about the high up-front investment. This was by promising a certain yearly return in twenty years on top of electricity revenues, depending on the DSPV project cost. Besides, Jolywood formed a tripartite cooperation model with local governments and banks for the DSPV system installation costs. Local banks first lent the money to the households, fulfilling most of the costs needed. The enterprise then advanced a large part of the remaining. Ultimately, with the help of subsidies from local governments, these families could be finically capable of installing the DSPV system on their rooftops. Such a tripartite cooperation model plus the promising yearly return guaranteed the customer revenue, making Jolywood an attractive DSPV provider in 2017. Accordingly, costs incurred in marketing salaries and fees, construction and O&M were increased because of the market expansion (VCP1->2). Among all, construction costs made up the most. Moreover, social benefits after the new market segment were outstanding (SVP1->2). First of all, the income from DSPV projects added up to families' total revenues, improving family living standards along the way proceeding the poverty alleviation program. Another benefit was maximizing land-use efficiency by altering the waste land into energy plants. Some of these DSPV systems were built on the idle land in the village that could not be cultivated, such as trenches, garbage dumps and abandoned railways. For explanation, changes in customer value propositions and value creation were strategic choices while changes in value capturing and social value propositions were forced change.

The second significant change was in 2018, during which Jolywood released its 'SolarTown' intelligent management platform mainly due to the increasing customer requirements for enterprise credits and after-sale services. The poverty alleviation program stimulated rapid growth of the DSPV industry, leading to a large quantity of DSPV projects going on. However, problems surfaced even the prosperity. Some unresponsible enterprises left their customers secondary once they made money. Customers became passive and vulnerable in receiving electricity fees and accessing after-sale services (e.g., O&M services), breaking down their relationships with customers and, most importantly, undermining the entire industry's reputation. Additionally, more O&M problems out of increasing projects reinforced the need for relative services. Although this kind of issue was not ripped through the whole industry, it still mobilized the customers, especially families expecting a stable revenue return. Thus, customers were more and more cautious about the DSPV company they would work with. Instead of only paying attention to income, they were now inclined to sign contracts with companies ensuring long-term income stability and delivering efficient after-sale services and value-added services (VAS). The 'SolarTown' intelligent management platform was developed by Jolywood to tackle these issues, forcing immediate changes in customer value propositions (CVP2->3) that offer regular O&M, insurance and automatic income settlement services.

Subsequently, value creation (VCA2->3) was strategically changed to deliver the above customer value propositions. Regarding the transparent and stable income, Jolywood reached strategic cooperation with national banks (e.g., Industrial and Commercial Bank of China, abbreviated as ICBC) that created an income collection system. Instead of monthly receiving contract income as in the regular TPO business model, the revenue would automatically settle in the customer's bank account every three months, according to the electricity generated. The customer would be no longer wary of collecting income from the DSPV companies. In addition to the automatic settlement, this system realized income transparency. Daily electricity generated and monthly electricity fees were available to check on the platform, building up a sense of trust in customers. Furthermore, when it comes to O&M services, Jolywood implemented an O&M monitory system. In case of malfunction, the monitory system would locate the site and automatically send the alarm to the nearest maintenance station. Besides, Jolywood actively offered regular component cleaning and bracket adjustment services rather than maintenance only after manual reports or automatic alarming. The O&M subcontractors included the service providers beyond their local O&M stations. In conditions, such as, extreme weather that damages the DSPV system or causes personal injury over the damaged DSPV system, Jolywood with insurance companies shifted the risk customers confronted. Along the way, customer experiences and relationships were improved by the new channels of delivery financial and after-sales support (VD2->3). Accordingly, value capture changed to the next stage(VCP 2->3) due to business model consistency. Although the well-organized O&M process due to the intelligent O&M monitory system reduced a certain amount of labour costs in project management, costs in O&M were raised in this period due to the increased number of projects. The costs for developing such a system also contributed to the total costs.

The third major change in 2019 was due to external environmental factors. One was the short-term impact of China's "531" policy on the PV industry announced in 2018. The "531" policy limited the production capacity of DSPV power generation in 2018 (about 10MW), and it reduced the subsidies of DSPV projects that adopted the 'self-generation and self-consumption with excess sold to the grid' mode and were grid-connected after the first of June 2018 (National Development and Reform Commission, 2018). This policy affected the entire DSPV market to different degrees. For Joywood, one of the impacts was the decreasing prices of silicon materials on the upstream supply chain because of the limitation on production capacity, leading to lower prices of PV modules. Since Jolywood itself was the supplier of PV modules in DSPV projects, their revenue fluctuated accordingly. The lower subsidy for DSPV projects also reduced their EPC project revenue because most of Joywood's customers were households under 'self-generation and self-consumption with excess sold to the grid' mode. Meanwhile, the limitation on production capacity led to a short-term business downturn in DSPV projects. Under such a situation, Jolywood was forced to think of the approaches to reduce the costs. while more annual electricity generation was one of the ways to increase revenue. Another factor was the competition about n-type PV module technology in the market because the efficiency of p-type solar cells reached the bottleneck as technology improved. Confronting all challenges, Joywood released its n-type solar components in order to keep its competitive advantage and reduce EPC costs. These moved value creation (VCA3->4) to the next stage. In addition to the technology R&D of n-type PV cells, Jolywood has built a brand reputation in the n-type solar cells industry.

This latest technology brought new customer value propositions to their DSPV customers subsequently (CVP3->4). The bifacial cells with higher solar cell efficiency and lower temperature coefficient generated more electricity (by about 10% to 30%) under the same installed capacity and geographical and climatic conditions. For inhabitants on the county level, this means an increase in income. From the environmental perspective, the more electricity generated from clean energy, the less energy from fossil fuels, thus, less carbon emission and dust pollution. These were environment value propositions (EVP1->2). For social value propositions (SVP2->3), Jolywood led the DSPV industry to provide more advanced technology. Accordingly, cost in n-type D&R and production were increased (VCP3->4). For explanation, the secondary changes in value propositions and value capture were forced changes.

The fourth change in 2020 was a response to the global pandemic. China's rigorous 'zero infection policy' made the whole industry alter or transfer as much as possible of their business to online forms to avoid human contact. Joywood changed its channels to the online form, not only delivering the DSPV projects to customers but also undertaking other associated activities (e.g., promotion, business cooperation, etc.) (VD3->4). Except 'closed-loop' supply chain, Jolywood created online platforms (e.g., project management system and WeChat applet) to cover all project processes from customer application, investment, business cooperation, remote site investigation, and project design to operation and maintenance. This provided customers with a 'contactless' service throughout the project (CVP4->5). The cost reduction (VCP4->5) was due to removing inefficient actives by process project management. These channels also promoted digital energy development (SVP3->4).

The last major change in Joywood’s DSPV business was a reaction to the whole county (city, district) roof DSPV program announced in 2021. The national announcement drew market attention to vast building roofs resources, not only for households but also for governmental and public building roofs in more than five hundred counties in China, after which Jolywood deliberately oriented its market segments to seize the opportunity (VD4->5). This market orientation brought value propositions, value creation, and value capture changes. Unlike household DSPV systems, buildings over governmental and public customers (e.g., hospitals, schools, etc.) are different in building structures and roof conditions, and customers have different electricity demands and consumptions, which ask DSPV providers to embody various application scenarios. Customers that were previously unable to access the DSPV system due to the requirements of rooftop conditions could now engage in DSPV projects and receive electricity incomes (CVP5->6). Besides, when it comes to value creation (VCA5->6), Jolywood strategically cooperated with several state-own enterprises to jointly deliver DSPV projects. This was because DSPV projects in one county were mostly attributed to one state-own company, and the company then allocated projects to DSPV providers. Zhongdiantou Power Engineering (or SPIC Power Engineering) was one of the state-owned power generators that have worked with Jolywood since 2021. Additionally, local banks, such as Bank OF JANGSU, participated in DSPV projects to provide financial services to local inhabitants. HUAWEI, a high-tech company, was practically employed in offering Jolywood's intelligent green solutions in the coming years. All these require skilled workers and staff in different scenarios' design, construction, value-added services and after-sales services. Regarding social value propositions (SVP4->5), the enlarged market benefited the local economy and people. The local business was boosted by absorbing DSPV service providers and currying relative activities. People no longer need to leave their hometowns for jobs. Instead, there are large job occupations available out of DSPV projects. By integrating renewable energy into their daily energy structure, people's electricity habits are gradually altered. Finally, costs incurred were changed accordingly (VCP4->5) due to business model consistency. For explanation, the subsequent change in value creation was a strategic choice while other secondary changes were forced ones.

7.3 NAMKOO

Guangdong Nankong Power (abbreviated as Namkoo) is a company established in 2013 and committed to renewable energy applications. Solar energy is their priority in business. Namkoo provides one-stop services for its customers, from DSPV system design to installation and operation and maintenance. They also engage in sales of PV system products, such as solar panels, inverters, and mounting brackets. Technology R&D, brand reputation and well-performed project management system are weapons in retaining its market competitiveness. Namkoo services different types of customers since the year entering the DSPV market. Households and industry and commercial (I&C) enterprises are their major customer segments. Midea, Huawei and Siemens are some of their current I&C customers carrying out DSPV. According to customer preferences, they adopt HO or TPO business models in these EPC projects. Foran Energy is one of the top financiers of DSPV projects in the TPO model. Most costs are incurred during the construction period, while the electricity fee is their main revenue stream.

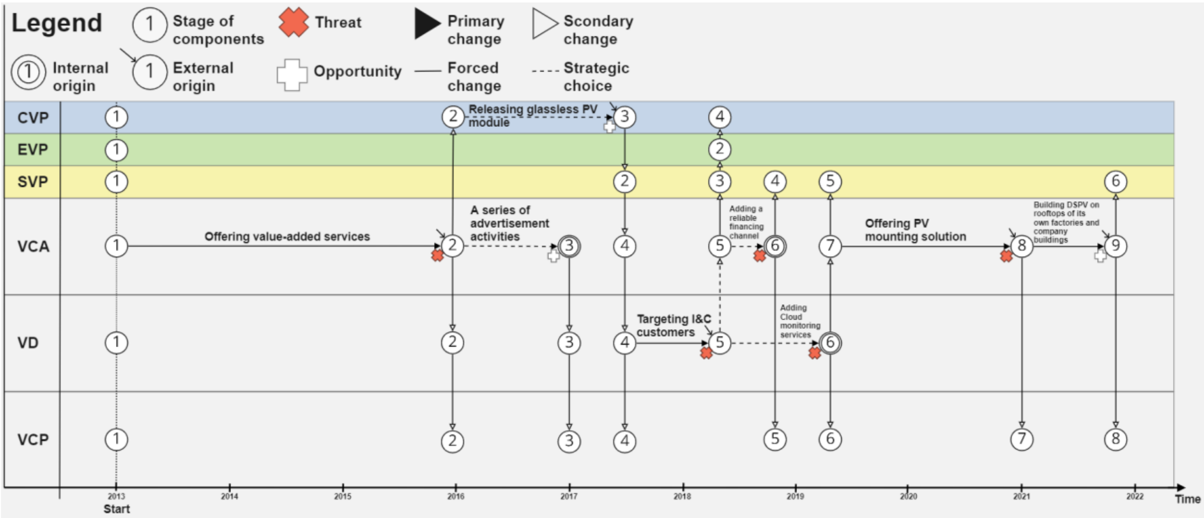

Figure 7.3.1 NAMKOO's dynamic sustainable business model framework

Table 7.3.1 Major changes to sustainable business model of NAMKOO

N.	Year	Origin		Causing	Primary effect	Follow-up effect
1	2016	Increased market competition due to increasing PV developers	E.T	Offering value-added services	VCA 1->2: Project consultation; Insurance services; loan services	CVP 1->2: Removal of tasks VD 1->2: Channels for value-added services VCP 1->2: Employee salaries; Revenue from value-added services
2	2017.7	Company strategy on building brand reputation	I.O	Advertisement activities	VCA 2->3: Advertisement activities; Brand popularity; Soccer clubs	VCP 2->3: Advertisement costs VD 2->3: Awareness channel of the brand
3	2017	Industry technology innovation of eArc technology	E.O	Releasing new glassless PV module	CVP 3->4: Fewer structure constraints (flexible; lighter and thinner; no mounting)	VD 3->4: Carports; Sunrooms; lightweight C&I roofs VCA 3->4: Simple installation; Less equipment VCP 3->4: Reducing cost in transportation, warehouse, and construction SVP 1->2: Solar market expansion and

						technology development
4	2018.6	Market impacts of China's '531' policy	E.T	Targeting new market segments	VD 4->5: Industrial and commercial customers (the core customers ever since then)	CVP 3->4: Reducing customer electricity costs; Increasing customer income SVP 2->3: Use of idle roof; Enhancing interior comfort (by reducing indoor temperature) EVP 1->2: Carbon reduction VCA 4->5: Research institutions (e.g., Sun Yat-sen University, Guangzhou University)
5	2018.11	Financing requirements on market expansion	I.T	Adding a reliable financing channel	VCA 7->8: ICBC bank	VCP 6->7： A stable financing source; Financing costs SVP 3->4: Promoting local economy
6	2019.3	Project management challenges due to increasing number of DSPV projects	I.T	Adding Cloud Monitoring Service	VD 5->6: Intelligent monitoring of the project (an after-sales channel)	VCA 8->9: Standardized O&M activities VCP 5->6: Reducing O&M costs SVP 4->5: Increasing people's awareness of environment protection
7	2021	Increasing upstream material and component prices due to global pandemic	E.T	Offering PV mounting solution	VCA 7->8: Manufacturing and selling PV mounting components	VCP 6->7: Increasing revenue from selling mounting; Reducing project costs by self-produced mounting
8	2021.11	Fluctuating electricity prices in Guangdong; Governmental supports of	E.O	Building DSPV on its own factories and company buildings	VCA 8->9: Generating electricity from DSPV on its own factories	SVP 5->6: Accelerating energy structure transition VCP 7->8:

		Guangdong province			and company buildings	Reducing electricity costs; Revenue from excess electricity

Namkoo experienced eight major changes over time (see Figure 7.3.1 and Table 7.3.1). The first major change was in value creation (VCA1->2) in 2016 due to market competition. During that period, the dispersion of DSPV systems was just in the very early stage over the country, but a large number of PV companies started to touch the DSPV field due to the huge market potential induced by policy support. Competition among DSPV developers was increasing. Namkoo confronted a challenge in maintaining its competitive advantages. Under pressure, Namkoo tended to expand its business, involving value-added services (VAS), to differentiate its solutions from others in the market. Except for carrying out project operations, Namkoo has offered project consultation (e.g., investment feasibility assessment, power generation efficiency evaluation, etc.), loan services and insurance services. Namkoo cooperated with SINOSAFE, an insurance company, purchasing insurance for the customer according to customer needs. Namkoo could also provide authoritative third-party tests and reports of PV projects at every stage for customer requirements.

The above changes led to customer value propositions (CVP1->2) directly. Customers could be free of finding consulting, insurance companies and financers themself owing to the integration of business tasks. Namkoo could channel the services through the online application forms with detailed descriptions of service content and fee, which indicated the next stage of value delivery (VD1->2). The employee salary for relevant services rose the cost, while Namkoo received revenue from customer optional value-added services (VCP1->2). For specification, the change in value creation forced the secondary changes in customer value propositions, value delivery and value capture.

The second significant change in Namkoo occurred in 2017, resulting from an internal company objective for building up brand popularity. At the beginning of this year, Namkoo has strategically set the year 2017 the first year of brand development as they viewed the company brand a vital resource in the competitive market. To promote their products and services, Namkoo organized several advertisement activities (VCA2->3). Namkoo hired three football stars from Guangzhou R&F Football Club to be brand spokespersons and has become a strategic patterner with the club in the long term. They also released a follow-up publicity blockbuster and carried out advertising on the key expressway networks of Guangdong. After undertaking this series of activities, Namkoo has greatly enhanced its brand popularity in southern China. More people have known the brand, raising awareness about Namkoo through these new channels (VD2->3). The above advertisement activities caused an increase in costs (VCP2->3) due to business model consistency.

The third primary change was also in 2017, during which Namkoo launched the glassless PV module to the public. This strategic action was driven by the technological innovation of eARC solar panels that have the same durability and performance as glass panels but are glassless. Namkoo saw new market opportunities from applying such eARC solar modules in DSPV projects, which brought additional customer value propositions (CVP2->3). This glass-free technology places fewer constraints on the building structure, attributing to more flexible, lighter and thinner properties than traditional glass panels. Subsequently, the application of the eARC solar module in the DSPV system opened several markets that were previously underserved (VD3->4). Carports, sunrooms, and lightweight industrial and commercial (I&C) roofs that have requirements in either aesthetic or weight could now implement DSPV systems. Simultaneously, these customer value propositions presented effects on value creation (VCA3->4). Such a system with the eARC solar module would simplify the installation owing to no mounting and flexible structure, thereby less demand for skilled workers and equipment. Following the above changes, transportation, warehouse, and construction costs would be reduced (VCP3->4). The lighter and thinner properties and the simple and flexible installation would reduce the cost by around 50%. By applying the new solar technology to practical cases, Namkoo promoted solar market expansion and industrial-related technology development, bringing social value propositions (SVP1->2).

The fourth major change was in value delivery (VD4->5), which was affected by China's 531 policy in 2018. Because of the limitation on DSPV capacity, the prices of upstream materials and components were dropped, leading to lower DSPV system costs. Although the decreasing subsidies, DSPV projects attracted customers from commercial and industrial (C&I) sectors as the return of investment was shortened by the rapid decrease of system costs. By installing DSPV systems, Namkoo could bring C&I customers value propositions (CVP3->4). Industrial and commercial electricity use follows the peak and valley electricity prices. At the same time, the electricity consumption of C&I customers is much higher than households. Therefore, these customers faced high electricity costs. By DSPV, the enterprise could first self-use the electricity generated, saving electricity bills. The excess electricity could then be sold to the utility grid, obtaining economic income. Generally, a DSPV system could have a payback in six years, indicating an eighteen-year pure income. Moreover, it also delivered social value propositions (SVP2->3) and environmental value propositions (EVP1->2). A large number of idle roofs could now be utilized in generating energy, improving space use efficiency. Building rooftop DSPV also helps enhance people's interior comfort, keeping indoors warmer in winter and cooler in summer. Additionally, involving C&I customers in clean energy would reduce carbon emissions further and encourage enterprises to establish an environmental protection corporate image, accelerating the green electricity grid over the entire society. Finally, Namkoo has cooperated with Sun Yat-sen University and Guangzhou University and established research institutions for system technology improvement for customers' different conditions since 2018 (VCA4->5). For specification, the secondary change in value creation was a strategic choice while others were forced changes.

The fifth significant change happened at the end of 2018, by which Namkoo had a reliable financing channel ever since (VCA5->6). As a newly developing enterprise, Namkoo cannot sustain market expansion in the absence of stable financing channels because technology R&D, project investment and branding are all money demanding. Economic support is also life-saving for the company's cash flow once there is a financing gap. To further expand its business and survive in the competing environment, Namkoo participated in a strategic cooperation conference held by the Industrial and Commercial Bank of China (ICBC) Foshan Branch in 2018. Since then, Namkoo has had a stable and reliable financing channel offering sufficient money to invest in DSPV projects and improve technology and other business activities. This change in value creation brought an effect on value capture (VCP4-5). Such a channel needs Namkoo to pay the bank financing costs accordingly. Besides, this successful corporation with the ICBC affected the local economy (SVP3->4). Namkoo's financing activities with the participation of local banks would not only help themselves, a private enterprise, in business development but also encourage society to create a better business environment for private companies in economic support. For explanation, the primary change was a strategic choice, and the secondary changes were forced responses.

The sixth change was about the approach of project O&M that happened in 2019. This change was due to the increasing number of DSPV projects over time. As more and more projects connected to the grid, Namkoo faced challenges of project management and, at the same time, delivering customer after-sales services efficiently. Under this situation, Namkoo decided to add channels for its customers to obtain O&M services and for themself to smooth its project management (VD5->6). In addition to manual regular system checking and maintenance reporting, Namkoo established an intelligent monitoring system to standardize the O&M process. This system was specific to I&C and households DSPV projects. It automatically detects the difunctional sites and then reports to the central station for subsequent maintenance (VCA6->7). This cut the project budget in the O&M period in terms of labor costs and costs incurred in unnecessary actions (VCP5->6). Besides, it offers real-time information on project states. Customers can access daily, monthly, and yearly power generation. It also shows customers the environmental benefits their DSPV projects exert, including reduced carbon emissions and equivalent cumulative deforestation. By displaying the information, Namkoo educates its customers about ecological protection through using solar energy, increasing environmental awareness in society (SVP4->5). For explanation, the secondary changes in value creation, value capture and value propositions were forced changes.

The seventh major change was in 2021. Due to the effect of the global pandemic, the downstream demand for PV system components was over the supply, leading to the rapidly raised price of upstream PV materials and components. The price of mounting components went higher apart from the PV module. These contributed to higher project construction costs. Facing this threat, Namkoo chose to manufacture their PV mounting components instead of outsourcing and started to sell PV mounting components (VCA7->8). Accordingly, Namkoo earned money by selling mounting components while reducing EPC costs (VCP6->7). The primary and secondary changes were all forced changes.

Last but not least, a change occurred at the end of 2021. Electricity prices for I&C industries in Guangdong province have increased incredibly this year that the peak price rose by about 50% to around 71.96%. Such an increase in price and the growing electricity demand induced an overall rise in business costs. Not only DSPV providers, the entire value chain confronts a similar problem as the electricity prices also rose in most other provinces. Most importantly, according to the latest government announcement of Guangdong province, the electricity generated from DSPV by enterprises themself will no longer be included in the total energy consumption. To promote the DSPV development, the government of Guangdong also simplifies the grid-connection procedure and remains a continuous subsidy incentive. Under this situation, instead of a threat, Namkoo perceived all as an opportunity to reduce business costs by installing DSPV on rooftops of its factories and company buildings (VCA8->9). Aside from cost reduction in electricity bills (VCP7->8), selling excess electricity generated a new revenue stream. The change in value creation brought social benefits (SVP5-6), accelerating energy structure transition into clean.

7.4 JINKO POWER

Jinko Power (abbreviated as Jinko), founded in 2011, specializes in PV power station O&M, transfer and EPC business. The company started the DSPV business since it entered the PV market. Jinko provides one-step DSPV solutions to industrial, commercial and household customers. The company develops longstanding relationships with its business partners to deliver DSPV solutions. The components and facilities of DSPV projects come from some of the well-known suppliers in the market, such as LONGi, TrinaSoalr, HUAWEI, and Schneider Electric, etc. Jinko also cooperates with two utility enterprises, China Southern Power Grid and State Grid, for grid connection. Their financing channels include national and local banks (e.g., Chain Merchants Bank, Agricultural Bank of China, etc.), financial institutions (e.g., CITIC Financial Leasing, etc.) and state-own power enterprises (e.g., Nantong Shangqi and State Power Investment Corporation). When it comes to costs and revenue, most costs are incurred during the installation period, while electricity fees are the primary sources of project revenue.

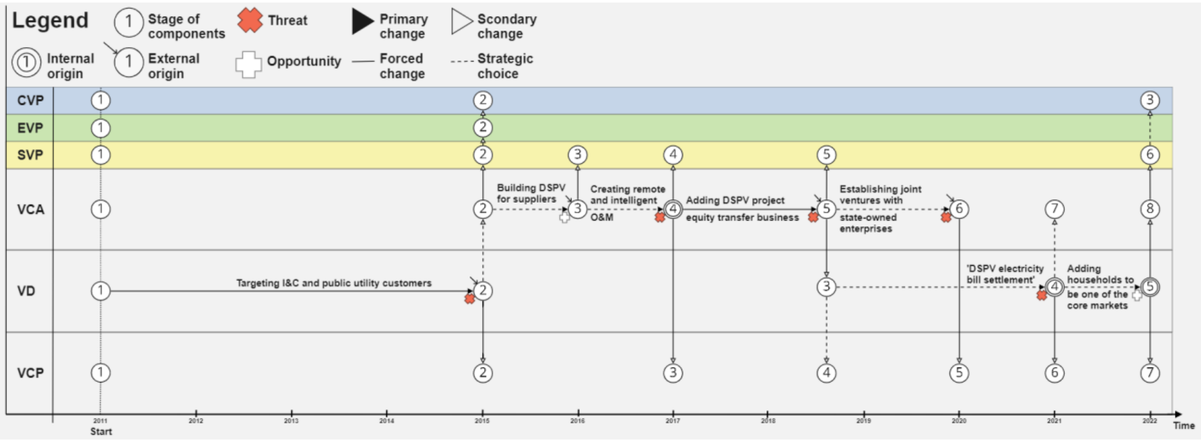

Figure 7.4.1 JINKO's dynamic sustainable business model framework

Table 7.4.1 Major changes to sustainable business model of JINKO

N.	Year	Origin		Causing	Primary effect	Follow-up effect
1	2015	Policy incentives for DSPV (incl. VAT policy, subsidies, national energy development strategies)	E.T	Targeting I&C rooftops (main) and public utility rooftops	VD 1->2: I&C customers; Public utility (e.g., train stations)	CVP 1->2: Reducing electricity bills EVP 1->2: Reducing GHG emissions CVA 1->2: Adding financing channels SVP 1->2: Promoting local economy VCP 1->2: Promotion costs
2	2016	More and more enterprises with environmental awareness and	E.O	Building DSPV for suppliers	VCA 2->3: Cooperation with suppliers in building DSPV	SVP 2->3: Promoting green supply chain

		social responsibility				
3	2017	Challenges in after-sales O&M due to Increasing DSPV projects	I.T	Creating remote and intelligent O&M	VCA 3->4: Cooperation with drone companies; Employee training	VCP 2->3: Reducing O&M costs SVP 3->4: Liberating human labour; Technology communication
4	2018	The effects of China's 531 policy	E.T	Engaging in DSPV project equity transfer business	VCA 4->5: Selling DSPV projects to other DSPV developers and state-own power companies	VCP 3->4: Revenue by equity transfer VD 2->3: Other DSPV developers; State-own power companies SVP 4->5: Promoting BM innovation
5	2020	Increasing prices of system components due to global pandemic	E.T	Establishing joint ventures with state-owned enterprises	VCA 5->6: Financing supports from state-owned enterprises; No biding	VCP 4->5: Eliminating costs induced by bidding
6	2021	Electricity bill settlement issues due to increasing DSPV projects	I.T	Adding 'DSPV electricity bill settlement' to O&M	VD 3->4: Online automatic electricity bill settlement; WeChat applet	VCP 5->6: Reducing labour costs in electricity settlement VCA 6->7: O&M technology cooperation with Zhejiang University EEPC
7	2022	Company strategy -the leading household DSPV provider	I.O	Adding households to be one of the core markets	VD 4->5: Targeting household customers	CVP 2->3: Shifting risks to PV developer; No up-front investment; Income from leasing rooftops VCA 7->8: Building company brand in households DSPV market SVP 5->6: Energy structure transition;

						Poverty alleviation VCP 6->7: Leasing costs

Over time, Jinko experienced seven major changes in its DSPV business model (see Figure 7.4.1 and Table 7.4.1). The first major change was in 2015, during which Jinko started to allocate more business resources to DSPV. This adjustment of business trajectory was induced by a series of policy incentives that encouraged domestic DSPV market expansion since 2013. One example was the value-added tax (VAT) that was retained until December 31, 2018 (State Taxation Administration, 2016). According to it, companies could obtain a 50% VAT refund on the sales of self-produced power products using solar energy (State Taxation Administration, 2013). Another support related to the national and local subsidies for DSPV power generation since 2013 (rather than investment subsidies eliminated in 2012). Due to these policies, together with other national strategies associated with DSPV development, enterprises saw substantial market potential in distributed PV energy. Like other PV developers driven by the external market trend, Jinko was also inclined to undertake more DSPV projects. They began with industrial and commercial (I&C) customers and public utilities such as train stations with high electricity consumption (VD1->2). Targeting such customer segments was a forced change for Jinko to catch the market step, preventing them from weeping out in the future.

The change in value delivery had secondary effects on other business model elements. C&I customers no longer bore high electricity costs as the self-produced electricity by DSPV saved them money, which was an attractive value proposition to I&C customers (CVP1->2). Besides, Jinko strategically cooperated with several banks and financial institutions this year (e.g., CDB Leasing, ICBC, Ping An Bank, etc.) not only to access financing instruments such as project loans and sale-leaseback but also to guarantee sufficient working capital of business (VCA1->2). These solid financing supports helped Jinko carry out projects smoothly and acquire more potential I&C customers, especially those lacking the financial capabilities to self-invest the project. By conducting DSPV projects with local companies and deploying financing resources from various channels, Jinko injected more active capital into the industry, promoting the local economy (SVP1->2). Additionally, the environmental benefits from these I&C enterprises using DSPV power were profound (EVP1->2). The self-produced electricity by DSPV avoided using fossil fuels in bulk, reducing greenhouse gas (GHG) emissions, for instance, sulfur dioxide and carbon dioxide. Accordingly, the deliberate direction of customer segments this year was followed by various promotion activities, causing an increase in costs (VCP1->2).

The second change was a strategic choice by Jinko in 2016 that cooperated with business-related companies in building the green supply chain. This decision was due to more enterprises incorporating environmental protection into their business activities to take social responsibility and gain company reputation. Along the supply chain, Jinko chose to collaborate with its upstream suppliers, building DSPV systems in their factories and office building rooftops (VCA2->3). These suppliers, like LYiTECH, mainly were in the electronic industry, which led to social benefits (SVP2->3). Such a supplier was not only just a customer to Jinko but also a co-operator in creating a green supply chain in the production stage as the power generated by DSPV was utilized to produce electronic components of PV systems. Thus, instead of a unidirectional flow from suppliers to PV developers, they created a bidirectional flow of business in product exchange. Although Jinko did not reach agreements on the recycling process, this business collaboration with suppliers promoted more PV companies to change business models by engaging in the green supply chain.

The third primary change was about value creation (VCA3->4). By 2017, Jinko has become one of the leading DSPV enterprises in the domestic market. With the increasing projects carried on, Jinko confronted a challenge in after-sales O&M. One thing, the large number of projects requires a corresponding large group of skilled workers for O&M, provoking high labour costs. Another thing, DSPV projects turned to disperse in scale, causing management issues. Under such pressures, Jinko proposed long-term cooperation strategies with two drone manufacturers, DJI and Hikvision, this year to achieve remote and intelligent O&M. They customized a batch of drones and cameras specially used for infrared inspection of power stations. The software processes the data obtained by infrared video and arranges modules in an orderly manner so that operators receive precise coordinates of a single module and locate them in the monitoring room. Combined with an intelligent centralized control system, the O&M efficiency has been greatly improved. Jinko also conducted employee training on the relevant technology to help standardize the process. This primary change in value creation brought about subsequent changes. When it comes to value capture (VCP2->3), the costs, especially labour costs, incurred in traditional O&M activities were reduced effectively. The advantages of this cooperation to society (SVP3->4) were that it liberated human labour by eliminating manual inspection, and it encouraged industry communication to innovate and integrate technology in practice.

The fourth significant change to Jinko's business model was in 2018. Due to the effects of China's 531 policy in terms of limited DSPV capacity and reducing subsidies, Jinko projected a contracting of its revenue since then. In this context, Jinko chose to reduce EPC business and simultaneously started to carry out project equity transfer business to improve cash flow and asset liquidity. For the equity transfer business, Jinko would sign an equity transfer agreement with companies to hand over the project after construction and grid connection. That is to sell DSPV projects to other PV developers and state-own power companies through equity transfer (VCA4->5). These DSPV projects were mainly grid-connected projects that enjoyed relatively high subsidies. This business process is also defined as the Build and Transfer (BT) business model. Jinko would profit from the contract for differences (VCP3->4). From the value delivery perspective, other PV developers and state-own power companies would be their new customer segments (VD2->3). Examples of this business were its equity transfer agreement signed with Nantong Shangqi and State Power Investment Corporation in 2018 on PV projects, including DSPV stations. These business activities have promoted PV companies to innovate diverse business models to deal with possible risks posed by policy adjustment (SVP4->5).

The fifth change in Jinko's DSPV business model was in 2020 due to the effects of the global pandemic. The global pandemic since 2020 has caused continuing increases in the system components prices and transportation costs, leading to decreasing EPC project revenue, which deeply impaired Jinko's EPC business. Under this situation, Jinko partly adjusted its EPC projects, establishing joint ventures with state-owned enterprises for conducting EPC projects (VCA5->6). In this way, Jinko could obtain part of its capital from state-owned enterprises with stronger financial strength and low financing costs. Jinko is still responsible for project design, construction, and after-sales O&M. Unlike traditional EPC projects in which Jinko mostly participated through the bidding, it could avoid the bidding that may lower the EPC price owing to the competition. This is because state-owned enterprises usually have available DSPV resources for development. Therefore, such cooperation could save Jinko costs induced in bidding (VCP4->5).

The sixth change was in 2021, during which Jinko launched the ‘DSPV electricity bill settlement’ module on its O&M service management platform. One purpose of adding this specific module about DSPV projects was to simplify the settlement procedure, preventing risks posed by manual work. Conventionally, Jinko relied on manual labor for electricity bill settlement throughout the process, for instance, manual collection, payment, and reconciliation. In the case of manual work, electricity settlement for DSPV projects was more complex as it involved at least three sides, users, investors and PV developers. Incidences of settlement error, lag and overdue could not be evaded completely. At the same time, labour costs during this process would be considerably high regarding a twenty-year project period as usual. The above concerns become more evident in the increasing number of DSPV projects. The ‘DSPV electricity bill settlement’ module was designed to deal with these issues. The primary effect was to value delivery (VD3->4). The transaction has been conducted online and automatically carried out by the system. Besides, the WeChat applet has been created for customers to self-check real-time power generation and monthly electricity consumption online. O&M personnel has regularly updated the payment status of all projects remotely. This change in value delivery directly would reduce the labour costs incurred in conventional manual work (VCP5->6). Furthermore, this approach encouraged Jinko to engage in more intelligent O&M technology research. Jinko has undertaken technology research with Zhejiang University EEPC for more intelligent O&M services (VCA6->7) this year and made a long-term strategic cooperation agreement.

The last major change was in 2022 when Jinko reorientated its business strategy to add household customers to the core customer segment (VD4->5). This decision was made because Jinko has planned to be the leading DSPV developer in the household field. Indeed, such an adjustment in customer segment was also encouraged by policy incentives such as the entire county DSPV rooftop project and the carbon natural national goal. Following the company strategy, Jinko released its ‘Jingnnengbao’ household solution this year, which offers new customers value propositions, especially for households (CVP2->3). Jinko still covers system design, installation and O&M, shifting operational risks. Customers no longer pay up-front costs while Jinko would undertake the investment. Families that previously could not afford systems could have DSPV systems in this way. Besides, customers lease their rooftops to Jinko, obtaining extra rent on top of the electricity income. For Jinko, this means additional leasing costs (VCP6->7). Apart from these, Jinko altered its Logo for the household DSPV solution, adding ‘FAMILY’ to it, in order to build the company brand in the household DSPV market (VCA7->8). Such targeting to household customers would bring profound social value propositions (SVP5->6). One aspect, more families engaged in solar energy could accelerate the energy structure transition to clean energy. Another aspect is that this would contribute to poverty alleviation in China because more families could earn income from DSPV projects.

7.5 INNER

Inner, founded in later 2013, is one of the specialized distributed energy companies in China. Inner is committed to promoting clean energy and DSPV power station is their main business. Inner provides customized one-stop professional services for households and I&C customers, covering the whole project life cycle from pre-consultation, system design and installation to post-operation and maintenance. Because Inner attaches great importance to after-sales service, it exclusively develops an intelligent cloud service center and offers the "Golden Butler" service solution. The project suppliers are well-known companies in China, such as Yingli. Yunying O&M was the major co-operator for after-sales O&M activities. The most costs incur in project construction while electricity fee is Inner's main revenue stream.

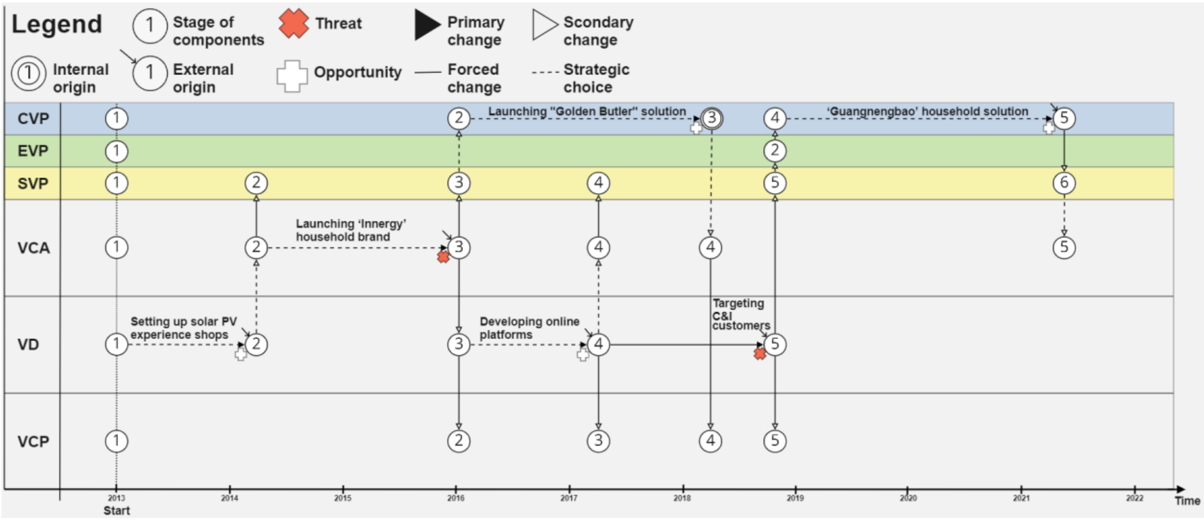

Figure 7.5.1 INNER's dynamic sustainable business model framework

Table 7.5.1 Major changes to sustainable business model of INNER

N.	Year	Origin		Causing	Primary effect	Follow-up effect
1	2014.3	Lack of public perception toward DSPV	E.O	Setting up solar PV experience shops	VD 1->2: First-hand experiences of the system installation; Targeting local households	SVP 1->2: Educating inhabitants about solar energy; Promoting DSPV applications CVA 1->2: DSPV knowledge popularization activities (e.g., public welfare lectures); Sales of PV products
2	2016	Increasing competition in household market	E.T	Launching 'Innergy' household brand	VCA 2->3: Brand reputation	CVP 1->2: Customized household DSPV solution

						VD 2->3: Promoting brand awareness VCP 1->2: Costs in advertising and promotion SVP 2->3: Leading health market development
3	2017.4	Customer needs for online services	E.T	Developing online platforms	VD 3->4: ‘One click to build’ online platform	VCA 3->4: Cooperating with state grid e-commerce; VCP 2->3: Reducing labour costs SVP 3->4: Promoting DSPV e-commerce
4	2018.3	Customer-centric company strategy	I.O	Launching "Golden Butler" solution	CVP 2->3: Full-process services	CVA 4->5: Advertisement; Free system inspections; O&M activities VCP 3->4: Costs in product and service promotion; O&M costs
5	2018.6	Effects of China’s 531 policy	E.T	Targeting C&I customers	VD 4->5: I&C customers	CVP 3->4: Reducing electricity costs; Customer income from selling the excess electricity VCP 4->5: Different value capture EVP 1->2: Reducing GHG emissions SVP 4->5: Accelerating energy structure transition
6	2021	Demand driven by the whole county (city, district) roof DSPV program	E.O	Launching ‘Guangnengbao’ household solution	CVP 4->5: No upfront investment; More income	CVA 5->6: Cooperation with local banks SVP 5->6:

						Old-age care

Over time, Inner has experienced six major changes (see Fig. 7.5.1 and Table. 7.5.1). The first primary change in Inner's DSPV business model was in 2014, during which Inner set up the nation's first solar PV experience shop, creating a new promotion approach for household DSPV business. In that day and age, DSPV was still an emerging technology to inhabitants of China. Although governmental support, generating energy by DSPV systems at residents 'sides was not widely spread. However, Inner saw considerable market potential for households. This was not only because DSPV is flexible to local conditions but also due to a large quantality of household rooftop resources. In that situation, Inner strategically found a new promotion channel to acquire customers, especially households (VD1->2). Unlike conventional channels, the customer could enjoy first-hand experiences in the solar PV experience shop. In addition to learning the principle of PV power generation, they could experience the installation procedures on site. Subsequently, the change in value delivery brought about changes in value creation (VCA1->2). Apart from sales of PV system products, Inner conducted DSPV knowledge popularization activities (e.g., public welfare lectures) through the new channel. Customers could have a comprehensive understanding of the DSPV system and the project profitability. Asides from value creation, this new channel also brought social benefits (SVP1->2). Through on-site experiences and activities, customers were educated about the feasibility of power generation using renewable energy while protecting the environment. Such a channel would also promote DSPV development as follow-up PV providers emulate the marketing approach.

The second change was in 2016, mainly due to external environmental factors. The household market witnessed intense competition after around three years of development. Driven by the significant market potential, more companies have been involved in the DSPV business, targeting household customers. Despite being a market pioneer, Inner confronted challenges from the increasing competitors. At the same time, the household market threshold was relatively low during that period. Some low-priced, low-quality products occupied the market because of the unmatured industry standard and supervision system. As the life cycle of a DSPV system is long (around twenty-five years), less market would be available for high-quality project providers once the low-quality products seize customers. Under this circumstance, Inner decided to develop a brand of household DSPV system quickly and spread it over the country. They launched the 'Innergy' household brand to differentiate their products and services from low-quality competitors. Since then, the brand 'Innergy' has been a vital company resource (VCA2->3). Aligning to the brand, Inner strategically offered new customer value propositions (CVP1->2). Inner provided customized DSPV systems to households from 5.5 kW to 22 kW according to location conditions and electricity demand. Customers could also select from eight types of system assemblies consisting of self-produced high-quality products with twenty-five-year warranties. Besides, costs were incurred in advertising and promoting their series of qualified products (VCP1->2). Inner's decision to build a brand reputation by promising superior services and products to its customers leads the healthy development of the industry (SVP2->3) and also deepened the brand awareness of Inner amongst customers (VD2->3).

The third primary change was about value delivery (VD3->4) in 2017. This change was induced by customer needs revealed in market research from last year. The company found that nearly 53% of users started to value online services. Customers preferred to build their DSPV system through online platforms throughout whole project periods. To meet customers' preferences, Inner strategically developed the 'one-click to build' online service platform. Unlike traditional project initiation, users could directly apply for grid connection online. Once the audit is passed, the customer can purchase components and supporting products online. Then, Inner would directly arrange the component delivery and on-site installation. After the installation is completed, the local power supply company will come to the customer's address to install the electricity meter. The above change in value delivery affected other business model elements. To achieve online services, Inner decided to cooperate with the state-grid e-commerce platform to build its official flagship store for delivering services (VCA3->4). Accordingly, labour costs were reduced since the elimination of human interaction (VCP2->3). The primary change in 2017 also brought social value propositions (SVP3->4) as it not only simplifies the cumbersome procedures of project construction but also promotes DSPV e-commerce development.

The fourth change was driven by the customer-centric company strategy announced in 2018, after which Inner launched the "Golden Butler" solution that offers full-process project services (CVP2->3). Inner saw it as an opportunity to enlarge the household market. The solution provides customers with a package of private services covering pre-construction, construction and after-sale O&M services. This change impacted value creation subsequently (VCA4->5). Inner advertised its "Golden Butler" solution on the national television network, contributing to a rapid increase in telephone consultations and door-to-door visitors. Inner also ran the free system inspection program over the country regardless of system developers. Inner advertised its full-process services to locals through the inspection, especially the lifelong O&M services. Besides, value capture (VCP3->4) was also affected. Costs in advertising and O&M services are involved in the cost structure. For specification, the change in value creation was a strategic choice.

The fifth change also occurred in 2018, attributed to China’s 531 policy. The policy posed threats to projects that had been invested in but not yet connected to the grid before June, as these projects faced investment losses due to the reduction of DSPV subsidy. In addition, Inner confronted liquidated damages since many household projects that have signed contracts but have not yet been built no longer had the conditions for construction because of the poor project rate of return. Under this circumstance, Inner connected projects to the grid as soon as possible to minimize losses. Inner also was forced to find projects that withstand policy changes. Industry and commercial (I&C) customers were their targets, moving value delivery (VD4->5) to the next stage. Not only because I&C electricity price was higher than the most local PV benchmark electricity price but also because the electricity consumption of I&C customers was higher than households. For I&C customers, Inner could offer them customer value propositions (CVP3->4). They would enjoy reduced electricity bills due to electricity generated by the DSPV system and additional income from selling the excess electricity to the grid. Besides, the new market target brought environmental value propositions (EVP1->2) and social value propositions (SVP4->5). Building DSPV systems for companies in I&C sectors would decrease greenhouse gas (GHG) emissions substantially and, at the same time, accelerate energy structure transition.

The sixth change of Inner’s DSPV business model was in 2021. This change was a response to the whole county (city, district) rooftop DSPV program as Inner perceived the program as an opportunity to enlarge the DSPV market. To share the market and catch customer attention, Inner released the 'Guangnengbao' household solution that provides new customer value propositions (CVP4->5). Families and farmers would no longer bear the upfront investment since Inner has strategically cooperated with local banks (e.g., Industrial Bank) for zero down payment (CVA5->6). After selling electricity, customers would repay the loan and then obtain residual income that is higher than the income received by renting roofs to build DSPV projects. Inner believes that this DSPV solution with less investment, less risk and stable income would be an approach for old-age care, especially for the elderly in the county.

7.6 Cross-case analysis

After the case study of each enterprise one by one, this sub-section combines all companies' sustainable business model changes over time to perform a cross-case analysis. To begin with, sustainable business model canvas of DSPV projects in China based on the case study is discussed. Besides, this section discusses important triggers to DSPV business model innovation in China and interrelationships between sustainable business model elements.

7.6.1 Sustainable business model canvas of DSPV project companies in China

The sustainable business model canvas of China's DSPV projects is rebuilt according to the case studies (see Table 7.6.1). This canvas keeps the same SBMC elements included in HO and TPO BMCs in Chapter 3 and SBMC in Chapter 5.3.1. Newly reported SBMC elements in case studies are indicated by 'New.' For each element, a number is attached to represent the occurrence in the five companies. Elements highly related to delivering environmental and social values are recorded in the dark blue.

Regarding the ownership of the DSPV systems, companies in the case study mainly apply host-own(HO) and third-party-owned (TPO) business models, which is the same as the result of the literature review in Chapter 3. While the TPO model dominates the DSPV market from the case study though these two types of business models co-exist in all companies. In host-owned BMs, DSPV systems are owned by the host, the owner of the property on which PV systems are installed. Customers invest in projects, paying high up-front costs. In TPO BMs, the DSPV system is installed on customer properties or premises, and the ownership of the PV system belongs to the third-party financier. Customers in TPO BMs no longer bear the high upfront investment costs. From the interviews, the DSPV developer itself can be the third-party financier investing in the DSPV projects. Otherwise, the financier can be a third party, for example, the state-owned gird power enterprises.

Apart from the above, variations towards HO and TPO business models appear in the case study. One example towards the TPO business model is the case of Jinko regarding its equity transfer business. To improve cash flow and asset liquidity, the DSPV developer would sign an equity transfer agreement with companies to hand over the project after construction and grid connection, selling DSPV projects to other PV developers and state-own power companies through equity transfer. These DSPV projects were mainly grid-connected projects that enjoyed relatively high subsidies. This business process could be identified as the Build and Transfer (BT) business model. The ownership of a system in the HO and TPO business models solely belongs to either the property host or the third-party financier, while the ownership can be transferred after the project construction in the BT business model. From the ownership perspective, the BT business model is a branch of TPO business models under certain business environment conditions, such as a contracting of revenue in EPC business.

Another variation towards TPO business models concerns leasing. In some cases, companies lease their PV systems or system components to customers (e.g., Sungrow), receiving additional revenue from rents. In some cases, customers rent their rooftops to DSPV developers (e.g., Inner, Jinko power, Jolywood). Customers could be only roof renters , or they could also engage in electricity generation and sale. No matter whether system or rooftop leasing, the system belongs to the DSPV enterprise. Business models under these situations also could be viewed as a branch of TPO business models.

Besides, a variation example towards HO business models is in the case of Jolywood. The PV developer can implement a tripartite cooperation model with local governments and banks for the DSPV system investment (e.g., Jolywood). Local banks first lent the money to the households, fulfilling most of the costs needed. The enterprise then advanced a large part of the remaining. Ultimately, with the help of subsidies from local governments, these families could be finically capable of installing the DSPV system on their rooftops. For such a tripartite cooperation model, the system actually belongs to the customer as they will repay the bank and DSPV company through the revenue obtained from the DSPV system. This tripartite cooperation model can be viewed as a branch of HO business models.

Regardless of the type of business model, companies in the case study mainly conduct EPC (Engineering, Procurement and Construction) business in DSPV projects. They provide a full-service solution from early-stage site inspection, arrangement of financing and insurance, securing building permits, negotiation with utilities, to the later system installation and O&M. The EPC contractor carries all the liabilities in the DSPV projects. Selecting subcontractors and suppliers is vital for DSPC project developers. On the one hand, the company (e.g., Sungrow) can organize construction bidding to determine sub-contractors for delivering qualified services at reasonable prices. On the other hand, from the interviews, the difference from traditional EPC projects is that four out of five companies themself conduct most of the activities instead of subcontracting. One reason is that they pay much attention to improving and offering O&M services. In addition, DSPV enterprises also offer optional value-added services (VAS), such as loans, insurance and consulting services. All in all, these indicate that DSPV developers not only rely on electricity bills for revenues but also started to focus on providing customized services to differentiate themselves from competitors while earning revenues. The VAS and optimized O&M services are both a revenue source and an approach to establishing long-term relationships with their customers.

The partnerships in DSPV projects become more divers over time. Suppliers, financial institutions, insurance companies and O&M providers are some necessary partners to carry out DSPV projects. In addition to the above partners, DSPV developers in the case study introduced relationships with e-commerce, football clubs, high-tech companies and local governments to add channels (e.g., channels related to awareness, purchase, and after-sales), facilitating DSPV business reaching customers. They jointly provide new approaches for transactions, advertisement, project O&M activities, and acquiring permits and subsidies. Besides, DSPV enterprises in the case study also created relationships that are vital in bringing social and environmental benefits. For instance, the DSPV company could build DSPV systems on the rooftops of its suppliers, promoting the green supply chain.

Regarding customers in the case study, customer segments mainly include households, I&C companies and public organizations (e.g., train stations, schools, etc.). From the interview, DSPV developers would prefer I&C customers but be cautious in selecting these customers. DSPV projects generally have a twenty-year project period. For one aspect, I&C customers have higher electricity consumption and better rooftop conditions in general. For another aspect, I&C companies with better economic performance could guarantee stable project revenue to DSPV providers for a long-term period. Additionally, I&C customers can play double roles in DSPV projects. In addition to being customers, they and DSPV developers can jointly bring social and environmental benefits by building DSPV systems on the rooftops of their factories and buildings.

Besides, in most cases, electricity generated is first used by the customer, and the surplus energy is fed into the grid and reimbursed by utilities according to energy-supply policies, such as the feed-in-tariff (FiT) scheme (still offered in some regions after 2021). Customers enjoy the reduced electricity bills, government subsidies and tax benefits. In some cases, customers can lease their rooftops to DSPV developers, obtaining extra rent on the electricity income. After the project period, some companies would send DSPV systems for free to their customers, depending on their needs.

When considering sustainable values, DSPV projects in the case study bring about various social and environmental benefits. These benefits indicate the advantages of integrating DSPV energy into the power grid, helping create a better ecological and social environment. From the interview, DSPV developers currently do not allocate many resources for EOL PV system retrieval. Only one of the companies, Sungrow, recycles and disposes of waste materials. This is because, for one aspect, companies (e.g., Sungrow) with better technology and finance capabilities tend to see the involvement of waste management as an opportunity to create and capture new values. Another aspect of this is that most DSPV projects in China are still functioning. At present, the management and treatment of EOL systems are still in the early stage. It could be projected that more DSPV projects would be at the end of life in the next ten to fifteen years. Management and treatment of EOL system components and waste materials would be a business, creating more sustainable values.

Table 7.6.1 Sustainable business model elements for DSPV projects in case studies (based upon HO and TPO BMCs in Chapter 3 and SBMC in Chapter 5.3.1)

Main elements	Sub-elements	Typic examples in case studies (occurrence)
Value propositions (VP)	Customer (CVP)	• Pre-fixed packages **(5)** • No up-front costs **(5)** • Reduced energy bills **(5)** • Predictable cost of electricity **(5)** • Benefit from feed-in tariffs (FiT) **(5)** • Independence from utilities **(5)** • Government incentives (e.g., subsides) **(5)** • Removal of tasks (e.g., O&M) **(5)** • Shifting system performance risks **(5)** • Customized DSPV solution **(new) (5)** • Rooftop rent income **(new) (3)** • Fewer constraints on the building structure (e.g., more flexible, lighter and thinner modules; DSPV inverters) **(new) (2)** • Contactless service throughout the project **(new) (1)**

	Society (SVP)	• Improving the financing and regulatory frameworks for energy sector (e.g., managing construction subcontracting and procurement) **(1)** • Diversify local economy **(2)** • Promoting local employment **(4)** • Poverty alleviation **(5)** • Health benefits of improved air quality **(1)** • Advancement in technologies **(5)** • Awakening community about the climate change **(5)** • Promoting green supply chain **(new) (2)** • Liberating human labour **(new) (5)** • Energy structure transition (e.g., zero-carbon grid, green power grid) **(new) (4)** • Educating inhabitants about clean energy technology **(new) (2)** • Developing users' electricity habits **(new) (1)** • Promoting sustainable development of employees **(new) (1)** • Old-age care **(new) (1)** • Maximized land use or space efficiency **(new) (2)** • Promoting DSPV e-commerce development **(new) (1)** • Interior building comfort **(new) (1)**
	Environment (EVP)	• Climate change mitigation **(5)** • Use of clean energy **(5)** • Reduction of greenhouse gas emissions **(5)** • Prevention of toxic gas emissions **(5)** • Less waste (e.g., electrical and electronic waste) **(1)**
Value delivery (VD)	Customer segments (CS)	• Households (e.g., carport, sunroom) **(5)** • Farmers **(5)** • Industrial and commercial companies (e.g., system component manufactures, industrial parks) **(5)** • Public organizations (e.g., schools, hospitals, train stations, etc.) **(5)** • Other PV developers and state-own power enterprises (e.g., in equity transfer business) **(new) (1)**
	Customer relationships (CR)	• Long-term relationships **(5)** • Personal contacts **(5)** • Online contact forms **(5)**
	Channels (CH)	• Company website **(5)** • Sales representatives **(5)** • Conference marketing **(5)** • Ground promotions **(1)** • Active media relations (e.g., football club, national television networks) **(new) (2)** • Solar PV experience shop **(new) (1)** • Official flagship store on state-grid e-commerce **(new) (1)** • WeChat applet **(new) (5)**
		• 'Zero-value factories' for recycling and disposing of waste materials **(new) (1)**
Value creation (VCA)	Key stakeholders (KS)	• Producers of system components **(2)** • National and local banks **(5)** • Other financial institutions (e.g. CDB Leasing) **(2)** • Utilities **(5)** • Insurance companies **(5)** • Installation and O&M companies **(2)** • State grid e-commerce **(new) (1)**

		• Local government **(new) (5)** • Football club for advertisement **(new) (1)** • High-tech companies (e.g., Alibaba Cloud Computing, HUAWEI, DIJ drone, Hikvision drone) **(new) (3)**
		• State and local governments for regulations of life cycle management **(1)** • Insurance companies for collecting and recycling **(1)** • Suppliers for building the green supply chain **(new) (1)** • Environmental organizations for the green power grid (e.g., RE100) **(new) (1)** • Universities for technology R&D **(new) (2)**
	Key activities (KA)	• Providing turn-key solutions (e.g., design, permits arrangement, procurement, arranging interconnections with utilities, installation) **(5)** • Sales of PV panels and or other system components **(3)** • O&M services and after sales services (e.g., warranty service, training, or repair and upgrades) **(5)** • Value-added services (e.g., insurance, leasing, consulting, planning, design, automatic settlement, etc.) **(5)** • Provide lease or PPA contracts **(3)** • Marketing activities (incl. advertisement) **(5)** • DSPV knowledge popularization activities (e.g., public welfare lectures) **(new) (1)** • Free system inspections over the country **(new) (1)**
		• Collection and recycling of waste materials **(new) (1)**
	Key resources (KR)	• Technical knowledge **(5)** • Human capital (e.g. expert staff, sales personnel) **(5)** • Close knowledge of consumers **(5)** • Close knowledge of local markets **(5)** • Company/Brand image, popularity and reputation **(5)** • Project management software **(5)**
		• Recycled materials **(new) (1)**
Value capture (VCP)	Cost structure (C$)	• Sales costs **(5)** • Wages **(5)** • Warehousing costs **(3)** • Insurance **(5)** • Construction, installations, O&M costs **(5)** • Marketing costs (incl. Advertising and promotion costs **(5)** • Technology improvement and innovation **(new) (5)** • Rooftop leasing costs **(new) (3)**
		• Waste treatment costs **(new) (1)**
	Revenue stream (RS)	• Sales of PV panels, or system converters, or mounting supports **(3)** • Government subsidies and incentives **(5)** • Tax benefits **(5)** • Solar lease payments (e.g., system equipment leasing revenue) **(1)** • Electricity bills **(5)** • Excess power sold to the grid **(5)** • After-sale services and O&M services **(5)** • (optional) Value-added services (e.g., consulting, insurance and loan) **(5)** • Revenue by equity transfer (profit from the contract for differences) **(new) (1)**

		• System and equipment rent (**new**) **(1)**

7.6.2 Changes in sustainable business models in case studies

Asides from looking at sustainable business model canvas, Table 7.6.2 presented changes in the business models of the above five case companies focusing on their DSPV projects. In Table 7.6.2, factors that affect BM elements from all case studies are categorized based on the origins of changes. These factors are shown in the light grey table. New factors not involved in Table 5.3.3 of the conceptual framework section are marked by ‘New’ in bold font. Besides, relationships between environmental variables and BM elements are listed with code in the light grey table. Similarly, new relationships not included in the previous conceptual form are marked by ‘New’ in bold font. In addition, interrelationships between sustainable business model elements in the case study are presented. The type of each relationship is indicated and shown in the light grey table.

Table 7.6.2 Changes to sustainable business model in case studies

Origin		**Cause**	**Relationships between environmental variables and BM variables**		**Interrelationships between BM elements**	**Type**
SUNGROW						
Industrial regulations of resource recycling	Regulatory requirements (industrial)	Set up “zero-value factories” to recycle and dispose of waste materials	E.O->VD	E13 **(New)**	VD->VCP/EVP/SVP/VCA	FF
Unstandardized procurement in EPC projects and high costs in outsourced PV system installation	Outsourcing of activities	Introducing “Regulations on the Management of Construction Subcontracting Procurement Business”	I.T->VCA	I8	VCA->VCP	CF
Five-year SUPER development strategy on smart energy solution	Project management system **(New)**	Releasing “iSolarCloud” for smart PV energy system solutions	I.O->CVP/SVP/EVP	I13 **(New)**	CVP/SVP/EVP->VD/VCA/VCP	CC/CF
Business strategy - focusing on Technology Innovation	Company technology innovation	Releasing new generation DSPV inverters (SG15/17/20KTL)	I.O->CVP	I1	CVP->VD/VCA/VCP	CF
Increased employees - requirements for employee capabilities	Personnel capability **(New)**	Providing employee training and learning platforms	I.T->SVP	I14 **(New)**	SVP->VCA	CF
Increased market competition due to increasing domestic enterprises	Market competition	Offering value-added services	E.T->CVP	E14 **(New)**	CVP->VCA/VCP	FF
Industry technology innovation – the self-cleaning double nozzle patent design	Industry technology innovation	Releasing ‘iClean’ DSPV systems	E.O->CVP	E4	CVP->VCA/VD/VCP	FF
Tacking climate change as one prioritized subject in sustainable orientation	Environmental pledges (company)	Becoming one of the RE100 (Renewable Energy) member companies-utilizing renewable electricity in all business activities by 2028	I.O->VCA	I15 **(New)**	VCA->EVP/SVP	CF
JOLYWOOD Minsheng						

Effects of PV poverty alleviation policies	Social & environmental value creation targets (national)	Integrating poverty alleviation into corporate strategies	E.O->VD	E15 **(New)**	VD->CVP/SVP/VCA/VCP	CF/CC
Increased customer requirements for enterprise credits and after-sale services	Customer requirement	Launching ‘SolarTown’ intelligent management platform	E.T->CVP	E9	CVP->VCA/VD/VCP	FC/FF
Short-term effects of China's "531" policy	Industrial policy	Technology improvement (N-type bifacial solar cells; N-type TOPCon bifacial modules)	E.T->VCA	E16 **(New)**	VCA->CVP/EVP/SVP/VCP	FF
Requirements for online channels due to global pandemic	Global pandemic **(New)**	Changing to ‘SamrtCloud’ power station	E.O->VD	E17 **(New)**	VD->CVP/SVP/VCA/VCP	FF
Demand of marketspace in the whole county (city, district) roof DSPV program	Customer demand	Developing full-scenario DSPV solution	E.O->VD	E3	VD->CVP/VCA/SVP/VCP	CF/CC
NAMKOO						
Increasing market competition due to increasing PV developers	Market competition	Offering value-added services	E.T->VCA	E18 **(New)**	VCA->CVP/VD/VCP	FF
Company strategy on building brand reputation	Brand reputation	Advertisement activities	I.O->VCA	I16 **(New)**	VCA->VCP/VD	CF
Industry technology innovation - eArc technology	Industry technology innovation	Releasing new glassless PV module	E.O->CVP	E4	CVP->VD/VCA/VCP/SVP	CF
Market impacts of China’s ‘531’ policy	Industrial policy	Targeting new market segments	E.T->VD	E19 **(New)**	VD->CVP/SVP/EVP/VCA	FC/FF
Financing requirements on market expansion	Financial channel	Adding a reliable financing channel	I.T->VCA	I17 **(New)**	VCA->VCP/SVP	CF
Management challenges due to increasing number of DSPV projects	Project management system **(New)**	Adding Cloud Monitoring Service channel	I.T->VD	I18 **(New)**	VD->VCA/VCP/SVP	CF
Increasing upstream material and component prices due to global pandemic	Global pandemic **(New)**	Offering PV mounting solution	E.T->VCA	E20 **(New)**	VCA->VCP	FF
Fluctuating electricity prices in Guangdong	Local policy **(New)**	Building DSPV on its own factories and company buildings	E.O->VCA	E21 **(New)**	VCA->SVP/VCP	FF
JINKO POWER						
Policy incentives for DSPV (incl. VAT policy, subsidies, national energy development strategies)	Industrial policy	Targeting I&C rooftops (main) and public utility rooftops	E.T->VD	E19	VD->CVP/EVP/SVP/CVA	FC/FF
Increasing enterprises with environmental awareness and social responsibility	Social responsibility (industrial) **(New)**	Building DSPV for suppliers	E.O->VCA	I19 **(New)**	VCA->SVP	CF
Challenges in after-sales O&M due to increasing DSPV projects	Project management system **(New)**	Creating remote and intelligent O&M	I.T->VCA	I20 **(New)**	VCA->VCP/SVP	CF
The effects of China’s 531 policy	Industrial policy	Engaging in DSPV project equity transfer business	E.T->VCA	E16	VCA->VCP/VD/SVP	FF/FC

Increasing prices of system components due to global pandemic	Global pandemic **(New)**	Establishing joint ventures with state-owned enterprises	E.T->VCA	E20	VCA->VCP	CF
Electricity bill settlement issues due to increasing DSPV projects	Project management system **(New)**	Adding 'DSPV electricity bill settlement' to O&M	I.T->VD	I18	VD->VCP/VCA	CC/CF
Company strategy-the leading household DSPV provider	Customer demand	Adding households to be one of the core markets	I.O->VD	I21 **(New)**	VD->CVP/VCA/SVP	CC/CF
INNER						
Lack of public perception toward DSPV	Public perception	Setting up solar PV experience shops	E.O->VD	E22 **(New)**	VD->SVP/CVA	CC/CF
Increasing competition in household market	Market competition	Launching 'Innergy' household brand	E.T->VCA	E18	VCA->CVP/SVP/VD/VCP	CC/CF
Customer needs for online platforms	Customer requirement	Developing online platforms	E.T->VD	E3	VD->VCA/VCP/SVP	CC/CF
Customer-centric company strategy	Customer demand	Launching "Golden Butler" solution	I.O->CVP	I4	CVP->CVA/VCP	CC/CF
Effects of China's 531 policy	Industrial policy	Targeting C&I customers	E.T->VD	E19	VD->CVP/EVP/SVP/VCP	FF
Demand driven by the whole county (city, district) roof DSPV program	Customer demand	Launching 'Guangnengbao' household solution	E.O->CVP	E3	CVP->CVA/SVP	CC/CF

Important internal and external triggers in the case study

According to the cases, five new factors was reported. Internal company factors are associated with project management and personnel capability, while external environmental factors are related to global pandemic, local electricity policy and industry social responsibility. Aside from the above reported new factors, other triggers also play important roles in business model changes. Table 7.6.3 lists the occurrences of factors in the case study.

One thing from the table concerning external and internal origins is that external factors drive most business model changes in the case study. This emphasized the necessity of involving external environmental factors in the investigation of business model innovation. The business models of these DSPV companies not only changed due to changing internal company variables. Another thing, changes in business models attributed to the customer requirement or demand are the most critical factors, followed by industrial policy and regulation. That is, companies in the case study incline to adjust their business models based on customer preference and needs though China's DSPV highly relies on policy incentives. Providing efficient energy solutions and services to customers is still the center of the DSPV business. Additionally, market competition and technology innovation also show importance, triggering business model changes. Market competition is primary attributed to the increasing competitors engaging DSPV business. Both internal company technology innovation and external industrial technology innovation are viewed as opportunities, and they could directly provide the case companies with customer value propositions (CVP).

Among the external policy-related factors, China's 531 policy, poverty alleviation national strategy, and the entire county (District) DSPV program are some common policies affecting or promoting China's DSPV business model changes. Regarding China's 531 policy, it limited the production capacity of DSPV power generation in 2018 (about 10MW), and it reduced the subsidies of DSPV projects that were grid-connected after the first of June 2018 and were adopted the 'self-generation and self-consumption with excess sold to the grid' mode (National Development and Reform Commission, 2018). This policy caused a short-term business downturn in the DSPV industry. The prices of upstream materials and components were dropped because of the limitation on DSPV capacity. For one aspect, it led to lower DSPV system costs. However, the DSPV company itself is the supplier of PV modules and components in DSPV projects, its revenue fluctuated accordingly. Besides, the lower subsidy for DSPV projects reduced EPC project revenue once most of the company's customers were under 'self-generation and self-consumption with excess sold to the grid' mode. For another aspect, DSPV projects attracted customers from commercial and industrial sectors because the rapid decrease of system costs further shortened the return of investment through the decreasing subsidies. Concerning the decreasing subsidy and promoting grid parity, DSPV developers believed that embracing grid parity would be better to create an active investment environment for the entire industry.

Regarding newly reported external environmental factors, one is related to the global pandemic, which changed the business models of the three enterprises. This factor could be an opportunity or threat to DSPV companies from different perspectives. On the one hand, the system components prices and transportation costs have continued increasing since the global pandemic because the downstream demand for PV system components was over the supply, leading to decreasing EPC project revenue. Companies that only undertake EPC business confronted threats. On the other hand, companies gradually alter or transfer their business to online forms to avoid human contact, witnessing an opportunity for digital DSPV energy development. According to the case study, the effects of the global pandemic can change either value delivery (VD) or value creation (VCA) of business models. Jolywood created online channels covering all project processes. Namkoo manufactured their PV mounting components instead of outsourcing and started to sell PV mounting components. Jinko established joint ventures with state-owned enterprises to conduct EPC projects, acquiring project capital and avoiding the bidding costs. Moreover, other new external factors, local policy incentives of DSPV electricity and company social responsibility, both afford opportunities to companies. These two factors can change value creation (VCA) similarly. Namkoo installed DSPV on its own factories and company buildings. Jinko collaborated with its upstream suppliers, building DSPV systems in their factories and office building rooftops.

Apart from external factors, the most influencing internal factors in the case study are related to project management system (incl. O&M software). Other internal factors are diverse and associated with finance, personnel, operational activities, brand reputation, environmental and social responsibility, and technology improvement. When it comes to newly reported internal company factors that could trigger business model innovation, one is related to project management system. This internal factor could be a threat or an opportunity to companies. Three out of five companies changed their business mole due to different requirements on project management system. The requirements are either driven by the company strategy or induced by management challenges in conducting intelligent O&M activities and electricity bill settlements. Only in the case of Sungrow, a short-term plan for delivering smart DSPV energy solutions, the factor relevant to project management system is an opportunity for the enterprise to achieve its goal. In other cases, the project management system issue poses threats to companies. With the increasing DSPV projects carried out, companies without efficient project management have to bear higher labour costs and face risks posed by manual work. Since DSPV projects turn to disperse in scale and have a project period of around twenty-year, these issues could be critical. This internal company variable impacted SBM elements differently in the three cases. In threat situations, Namkoo added several O&M channels to standardize the O&M process, directly altering value delivery (VD). Jinko cooperated with drone companies and conducted employee training to improve O&M efficiency, changing value creation (VCA). Jinko also created value delivery channels (VD) associated with transaction approaches. Another new internal company factor is personnel capability. The lack of skilled employees could be a threat to the company that has a rapid growth of DSPV business in short time. The company requires new employees quickly learn knowledge of technology and project operation. Responses to this factor, providing employee training and learning platforms (e.g., Sungrow), directly brought social value propositions (SVP).

When considering relationships between environmental variables and business elements, the case studies provide many new relationships not included in the literature review. This can be explained from two aspects. First, one factor can be an opportunity in one company situation and be a threat in another company context, regardless of its external or internal origin. This is because whether a factor causes opportunities or threats to a company is considered in the specific company context. Second, the same factor can impact different business model elements, regardless of being an opportunity or threat. This is due to the effects of the same factor could be different for each company. Enterprises respond to the same factor differently depending on company capability and external business environment. These two aspects together enrich the relationships between environmental variables and business elements.

Table 7.6.3 Factors occurrences in case studies

Origins	External/Internal factors	Occurrence
Customer requirement / demand	External	7
Industrial policy / regulation	External	5
Project management system **(New)**	Internal	4
Global pandemic **(New)**	External	3
Company / industry technology innovation	External (2) ; Internal (1)	3
Market competition	External	3
Outsourcing of activities	Internal	1
Personnel capability **(New)**	Internal	1
Environmental pledges (company)	Internal	1
Social & environmental value creation targets (national)	External	1
Brand reputation	Internal	1
Financial channel	Internal	1
Local policy **(New)**	External	1
Social responsibility (industrial) **(New)**	External	1
Public perception	External	1

Interrelationships between SBM elements in the case study

Because of the additional elements in the sustainable business model, interrelationships between business model elements are more complex than that business model with only three main elements. To discuss the impacts of a change in one element to another in the case study, Figure 7.6.1 and Table 7.6.4 disclose and record these interrelationships listed in Table 7.6.2 in detail. For one pair of elements, interrelationships are presented by line with arrows, attaching the type of relationships included and the number of relationships of each type. The arrow points from one element experiencing primary change to the element seeing secondary change affected by the primary element.

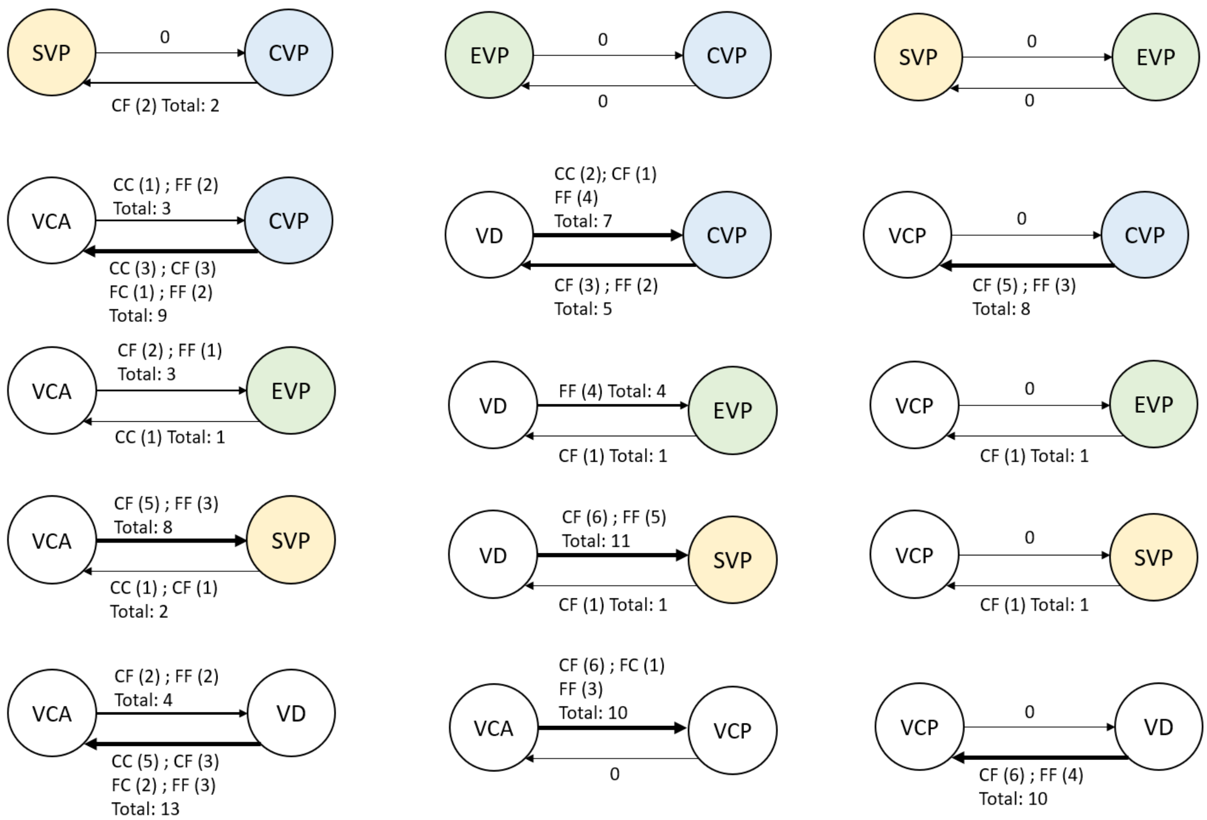

Figure 7.6.1 Interrelations between SBM elements in the case studies(Bold line: more relationships between elements; thin line: less or no relationships between elements)

According to Figure 7.6.1, several investigated results can be noticed. First, changes in one element do not always lead to a change in another element. One of the findings is particularly between environmental, social and customer value propositions (EVP, SVP, CVP). It can be seen that only primary changes in CVP induced secondary changes in SVP, and no reverse cases. This finding can be understood together with data in Table 7.6.2. From the interviews, most environmental and social benefits are brought due to a primary change in value creation or value delivery. That is, EVP and SVP are generally secondary changes to adjustments in business activities, patterners and customer segments and implementations of channels for material retrieval and after-sales O&M services. In the case of both EVP and SVP changing at a time, benefits to the environment and society are commonly gained simultaneously or concomitantly.

Besides, this finding is also distinct concerning value capture (VCP). Value capture is not the initial change in all cases. Instead, it is mostly a result of changes in other elements. However, this finding regarding value capture does not necessarily demonstrate that value capture could not affect other business model elements. Referring to the literature review in the conceptual framework section that involves such relationships, this finding can only mean that it is not likely to happen in the case study.

Second, changes in other elements owing to changes in value delivery (VD) dominate the interrelationships in the case study. This is followed by value creation (VCA) and then customer value propositions (CVP). Subsequent effects induced by EVP and SVP are significantly less than theirs. Regarding factors affecting SBM elements, although these factors mainly impact value creation (VCA) at first, follow-up changes due to VD changes are the most. This can be understood by looking at the sub-elements of VD. Sub-elements of VD include customer segments (CS), customer relationships (CR) and channels (CH). In the case studies, companies altered either of the three sub-elements, such as adding material recycling channel, targeting I&C customers and creating channels for after-sales services, had subsequent effects on related partnerships and company resources to carry out business activities, impacting relevant costs and revenues, and could bring CVP, EVP and or SVP. These subsequent changes are either forced upon owing to VD changes or changes due to business model consistence. All in all, in case studies, VD is one critical element in the changing business models over time as it contributes to the most secondary changes of other elements, but it does not indicate that other business model elements are less important than VD.

Moreover, value capture (VCP) in the case study is mostly the subsequent effect of initial changes. One of the understandings could be that costs and revenues are highly related to company business throughout the project period, from early-stage site investigation to the post-installation operation and maintenance. Costs and revenues associated with technology improvement, the disposal of waste material, labour, advertisement activities, transportation, value-added services (VAS), additional business, and project management system optimization turned to change through business over time. The effects on VCP have generally been forced, either due to force upon it by other element change or for business consistence.

Last but not least, concerning forced change or strategic choice of the interrelationships between SBM elements, the most common type is CF (see Table 7.6.4). That is, initial changes to elements attributed to companies' strategic decisions lead to forced changes in other elements in most cases. One thing, combined with the type CC, this indicates that companies in the case study are inclined to actively develop strategies to respond to internal and external opportunities or threats rather than passively adjusting their business models. Another thing, most secondary changes are forced changes regardless of the types of primary changes. This implies that the follow-up changes in the case study after the initial changes are mostly forced responses in order to facilitate business activities smoothly and effectively.

Table 7.6.4 Interrelations between SBM elements in case studies

Primary change (occurrence)	Secondary change	Type (occurrence)	Total		
CVP (8)	CVP->EVP	(0)		CVP->others: 24 Others->CVP: 10	CC: 13 CF: 49 FC: 4 FF: 38
	CVP->SVP	CF (2)	2		
	CVP->VCA	CC (3) ; CF (3) ; FC (1) ; FF (2)	9		
	CVP->VD	CF (3) ; FF (2)	5		
	CVP->VCP	CF (5) ; FF (3)	8		
EVP (1)	EVP->CVP	(0)		EVP->others: 3 Others->EVP: 7	
	EVP->SVP	(0)			
	EVP->VCA	CC (1)	1		
	EVP->VD	CF (1)	1		
	EVP->VCP	CF (1)	1		
SVP (2)	SVP->CVP	(0)		SVP->others: 4	
	SVP->EVP	(0)			

	SVP->VCA	CC (1) ; CF (1)	2	Others->SVP: 21	
	SVP->VD	CF (1)	1		
	SVP->VCP	CF (1)	1		
VCA (13)	VCA->CVP	CC (1) ; FF (2)	3	VCA->others: 28 Others->VCA: 25	
	VCA->EVP	CF (2) ; FF (1)	3		
	VCA->SVP	CF (5) ; FF (3)	8		
	VCA->VD	CF (2) ; FF (2)	4		
	VCA->VCP	CF (6) ; FC (1) ;FF (3)	10		
VD (12)	VD->CVP	CC (2); CF (1) ; FF (4)	7	VD->others: 45 Others->VD: 11	
	VD->EVP	FF (4)	4		
	VD->SVP	CF (6) ; FF (5)	11		
	VD->VCA	CC (5) ; CF (3) ; FC (2) ; FF (3)	13		
	VD->VCP	CF (6) ; FF (4)	10		
VCP (0)	VCP->CVP	(0)		VCP->other: 0 Others->VCP: 30	
	VCP->EVP	(0)			
	VCP->SVP	(0)			
	VCP->VCA	(0)			
	VCP->VD	(0)			

7.7 Framework development

There are serval improvements on the conceptual framework after applying the framework to the cases in China. One aspect is about sustainable business model elements of DSPV projects. First, the sustainable business model canvas in the chapter on the conceptual model (see Table 5.3.1) by literature review could be complemented by the elements reported through the case study (see Table 7.6.1). Second, the SBMC in the conceptual model based on the literature review is built regarding PV energy in general. The element in conceptual SBMC is a broad combination of different business models (HO, TPO, CS business models) in Chapter 3 and the literature review of sustainable values of PV projects. After the case study, the SBMC is specific for companies regarding DSPV projects in China (see Table 7.6.1).

Another aspect under completeness is concerning factors affecting business model elements. First, factors from the case study complement the table in the chapter on the conceptual model (see Table 5.3.2) that is obtained by the literature review. Second, the factors triggering business model changes in the conceptual model are listed by identifying their type, that is, external and internal opportunity or threat. Factors are recorded in a more general way. For instance, changes in key technologies, supportive financial systems and regulatory requirements. In the case study, the factor triggering business model innovation could be more specific. For example, technology innovation or improvement could be induced by the internal company or external industry. Supportive financial systems could be related to additional financial channels or a settlement system. Regulatory requirements could be concerning environmental or social benefits or about DSPV project install capacity and subsidies. The table of factors can be improved by providing a more detailed description.

When considering interrelationships between sustainable business model elements, the framework can be improved by further identifying relationships between fifteen business model elements instead of six pairs. The relationships table in the conceptual model (see Table 5.3.2) is recorded by interrelationships between value propositions, value creation, value delivery and value capture. Social, environmental and customer value propositions are combined into one for simplification. According to the case study, there are specific relationships between these three value propositions and other main business model elements (see Figure 7.6.1 and Table 7.6.4). Fifteen pairs of interrelations could be used to capture and perform a better presentation.

Concerning changes over time, the dynamic sustainable business model framework could be improved by interviewing companies according to more specific and completed DSPV sustainable business model elements, external and internal factors, and interrelationships between sustainable business model elements complemented through case studies. Overall, the final presentation of dynamic sustainable business model framework is very much the same as the conceptual one (see Fig. 7.7.1).

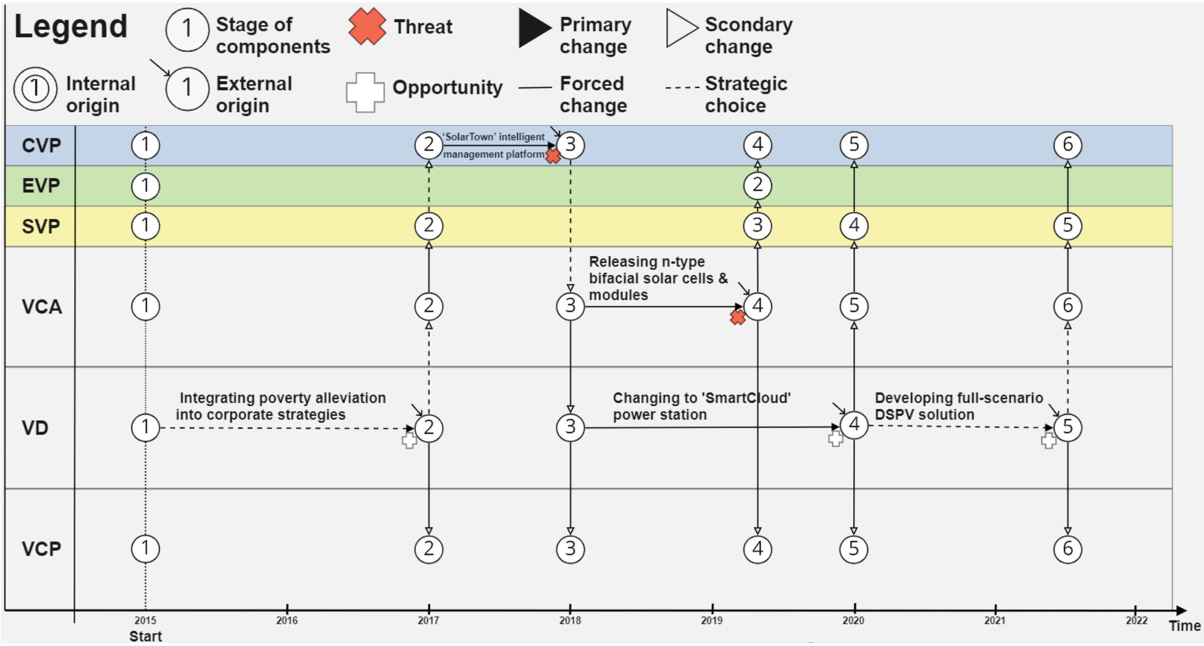

Figure 7.7.1 The final presentation of dynamic sustainable business model framework (An example of JOLYWOOD; the same as Fig. 7.2.1)

Chapter 8 . Conclusion, discussion and recommendation

This chapter presents the conclusions of this study. Answers to the main research question and five sub-questions are in sub-section 8.1. Discussion and recommendations for this work are given in sub-section 8.2.

8.1 Conclusion

RQ1. What are current business models implemented in the DSPV projects, and what are the current business models of DSPV projects in China?

The first sub-question is aimed at understanding the current business models of DSPV projects and the models in China. The answer to this question is firstly investigated through the literature review in Chapter 3. In Chapter 7, business model changes in five of China's DSPV enterprises are described, followed by a cross-case analysis in sub-section 7.6. The case study partly complements answers to the sub-question one. Understanding current DSPV business models and the models in China is necessary for follow-up investigations of changes in the DSPV business model.

According to the literature review in Chapter 3, DSPV business models can be defined from different perspectives, such as from consumption or investors' perspectives. In this thesis study, three main business models currently applied in DSPV projects are introduced based on ownership of the system and cost and revenue to the company. These three main DSPV business models are host-owned (HO), third-party-owned (TPO) and customer shared (CS) business models. For HO business models, DSPV systems are owned by the host, who is the owner of the property on which PV systems are installed. Companies make money in HO BMs primally through system installation. Other revenue could come from charging after-sale services (e.g., O&M) and selling PV panels. For TPO business models, the DSPV system is installed on customer properties or premises, and the ownership of the PV system belongs to the third-party financier. Customer payments for the power purchase agreement (PPA) and leasing contracts contribute to most revenue. For CS business models, multiple subscribers can access energy systems and receive credits for a share of energy generated by DSPV systems that are not physically connected to their properties and premises. The utilities, solar project developers, or non-profit organizations administrate or sponsor the DSPV projects. Customers subscribe to DSPV projects with different subscription options, either by purchasing or leasing panels, by investing in systems, or just by buying energy or capacity. In return, they receive credits on energy bills for paying upfront fees through purchasing panels. In the case of customer investment, they finance the project and thereby buy an equity stake. From the ownership perspective, the CS BMs could be underneath HO BMs or TPO BMs. The detailed elaboration of the three main DSPV business models, business model canvas and flow overviews (financial, energy, and material) can be found in Chapter 3.

When it comes to current DSPV business models in China, only the first two (HO and TPO) are mainly implemented. Through case studies in Chapter 7, this is the same as the literature review results in Chapter 3. According to the case studies, the TPO model dominates the DSPV market. Additionally, companies perform business models that are not entirely coincident with the models in the literature review. There are variations of HO and TPO business models.

In the case study, DSPC companies mainly conduct EPC (Engineering, Procurement and Construction) business in DSPV projects. Unlike conventional EPC projects in which the DSPV developer provides a full-service solution with subcontractors, the DSPV companies can themself offer these services and other value-added services (e.g., loans, insurance, consulting services, etc.) to differentiate themselves from competitors while earning revenues. Regarding the TPO business model, the third-party financier can be the DSPV developer itself or the third-party financier (e.g., the state-owned enterprise). Besides, ownerships of DSPV projects can be transferred to other DSPV developers or state-own power companies after construction and grid connection through equity transfer. This business process could be identified as the Build and Transfer (BT) business model. It can be considered as a branch of the TPO business models from the ownership perspective. Moreover, variations of HO and TPO business models can be also about the investment entity (e.g., a tripartite cooperation model with local governments and banks) and how DSPV developers deliver the system (e.g., leasing PV systems and leasing the rooftops).

Overall, HO, TPO and CS are three major business models used in DSPV projects from the ownership perspectives. The DSPV business models in China are mainly HO and TPO business models, and the TPO model dominates the DSPV market. In actual case applications, there are adjustments to these business models, depending on company and business environment situations.

RQ2. What internal changes within and external changes to enterprises may trigger business model innovation in DSPV projects?

Business model innovation can be defined as a constantly changing process of BMs elements or/and the architecture at the firm level in response to external and internal opportunities and threats (as described in sub-section 2.3.1). The investigation of factors, including internal company variables and external environmental variables, that affect business model elements is necessary. The internal and external changes mentioned in the question refer to factors that affect business model elements. These changes to business model elements owing to external or internal factors can then lead to business model changes.

Firstly, answers to this sub-question are partly provided in Chapter 4, in which business model innovation triggers and drivers are concluded in tables (see Table 4.1 and Table 4.2). These factors are not from the literature specific to DSPV energy but a broad literature review of business model innovation triggers and drivers. From the broad literature review, the external factors could be related to major changes in the industry environment, technological and behavioural developments, changes in the competitive environment, changes in the social and environmental environment, and changes in company business. The internal factors could be associated with products or service innovation, modification in revenue/cost models, changes in resources availability, changes in marketing channels, changes to corporate strategies, and changes in organizational characteristics.

Based on the literature review in Chapter 4, factors affecting business models can be firstly classified according to their attributes to enterprises, in relation to changes in the external environment or changes within the company. Then, the internal company and external environment factors can be further distinguished between opportunity and threat. The factor that causes opportunities or threats to a specific company is considered in the company context.

Secondly, the conceptual framework in Chapter 5 also partly offers the answer. Factors affecting sustainable business model elements are listed according to case study results by Bucherer et al. (2012), the investigation by Meslin (2019) and literature on business models innovation of renewable energy technologies (see Table 5.3.3). These factors are presented by types, external or internal and opportunity or threat, following the classification approach in the literature review of Chapter 4. This classification is also reported in the dynamic business model framework by Kamp et al. (2021) in Chapter 5 which is the base of the dynamic sustainable business model framework of this research. Besides, the effects of the factors on sustainable business model elements are also listed in Table 5.3.3. From the table, one thing can be noticed that a factor can affect different sustainable business model elements. Another thing is that the same factor can be an opportunity in one case and a threat in another case.

Thirdly, factors that are specific to DSPV projects in China, including factors that are not reported in the conceptual framework, are revealed after the case study (see Table 7.6.2 and Table 7.6.3). From the case studies, external factors drive most business model changes. Changes in business models attributed to the customer requirement or demand are the most critical factors among all reported factors. It could indicate that providing efficient energy solutions and services to customers is still the centre of the DSPV business. Other important external factors are related to industrial policy and regulation, the global pandemic, market competition, industrial technology innovation, local policy incentives for DSPV electricity and public perception towards DSPV. Among the external policy-related factors, China's 531 policy, poverty alleviation national strategy and the entire county DSPV program are some common policies affecting China's DSPV projects.

Moreover, internal factors associated with finance, personnel, operational activities, environmental and social responsibility, and technology improvement are recorded. The mostly reported internal company factors are related to project management, either driven by the company strategy or induced by management challenges in conducting O&M activities and electricity bill settlements. The lack of skilled employees with knowledge of technology and project operation can also trigger business model changes. These two are also the newly reported internal company factors from the case study.

Furthermore, the case study again provides conclusions similar to the literature review. for a factor with the same origin, one company could view it as an opportunity while another company could see it as a threat. That is, the factor that causes opportunities or threats to a specific company is considered in the company context. Besides, enterprises respond to the same factor differently depending on company capability and external business environment. Considering business model changes, the same factor can affect different business model elements.

RQ3. What important interrelationships between BMs elements and interrelationships over time should the DSPV project company consider in business model innovation?

By definition, BM innovation is a constantly changing process of BMs elements or/and the architecture at the firm level in response to external and internal opportunities and threats (as described in sub-section 2.3.1). The architecture of BMs, by the literature review, refers to the relations among value creation, delivery and capture mechanisms that jointly construct the BM logic (as described in sub-section 2.2.1). Investigating relationships between BM elements is essential to understanding BM innovation.

In the conceptual framework, these relationships refer to the interrelationships between four main sustainable business model elements. That are value propositions, value creation, value delivery and value capture reported in the sustainable business model canvas (SBMC) by Bocken et al. (2018). Chapter 5, sub-section 5.3.2, offers the investigated results of six pairs of interrelationships by a broad literature review of renewable energy, PV energy, and DSPV energy (shown in Table 5.3.5). In addition, these interrelationships are identified according to whether the initial change in the first component and the resulting change in the correlated component are forced changes (F) or strategic decisions (C). Such identification is based on Meslin (2019) and reported by Kamp et al. (2021).

After the case study, the interrelationships between sustainable business model elements are enriched, entailing fifteen pairs (see Figure 7.6.1). These interrelationships are specific to DSPV project companies in China. The total of fifteen pairs of relationships instead of six pairs is because the value propositions of SBMC by Bocken et al. (2018), including customer, social and environmental value propositions, are determined to be three elements rather than one element to show more sustainable considerations.

The case study shows that not all interrelationships exist between two elements. Changes in one element do not always lead to a change in another element. It can be noticed that environmental value propositions (EVP) and social value propositions (SVP) are generally secondary changes to adjustments in business activities, patterners and customer segments and implementations of channels for material retrieval and after-sales O&M services. Subsequent effects induced by initial changes in EVP or SVP are significantly less than in other elements. Besides, value capture (VCP) is mainly a result of changes in other elements. That is, VCP is mostly the subsequent effect of initial changes. In addition, changes in other components due to changes in value delivery (VD) dominate the interrelationships in the case study, which is followed by value creation (VCA) and then customer value propositions (CVP). Last but not least, the most common type of interrelationship in the case study is CF. This indicates that initial changes to elements attributed to companies' strategic decisions lead to forced changes in other sustainable business model elements is the most.

RQ4. How can we develop a dynamic sustainable business model framework to understand business models innovation in DSPV projects?

The answer to this question is in Chapter 5. To begin with, this thesis study investigates the dynamic business model frameworks and the sustainable business model frameworks in literature to determine the baseline of the dynamic sustainable business model framework for this research.

The first step is to determine the baseline regarding the dynamic business model framework. This thesis investigated four dynamic business model frameworks reported in the literature (as described in sub-section 5.1). That are the Meslin (2019) framework, Deherkar (2020) framework, Cosenz & Bivona (2021) framework, and Kamp et al. (2021) framework. Although all four dynamic frameworks are available to capture BM dynamics, the Meslin (2019) framework and its follow-up improved framework by Kamp et al. (2021) is more applicable to this study. Kamp et al.'s (2021) framework relabels and represents design elements in the framework and shows factors affecting BM components in phrases, making researchers more accessible to read and follow. Therefore, this research adopts the dynamic business model framework by Kamp et al. (2021).

The next step is to determine the baseline regarding the sustainable business model framework. This thesis investigated four sustainable business model frameworks in literature (as described in sub-section 5.2), the sustainable business model framework by Bocken et al. (2015), sustainable business model canvas (SBMC) by Bocken et al. (2018), triple-layer business model canvas (TLBMC) by Joyce and Paquin (2016) and business model canvas for sustainability (BMCS) by Cardearl et al. (2020). Although there are options for sustainable BM frameworks, not all of them are preferable for this research. The sustainable business model canvas (SBMC) by Bocken et al. (2018) is used in the study. The author determined four main components simplifying the framework under the interpretation that the concept of value underpins the BM concept. These four main elements are value proposition, value creation, value delivery, and value capture. Besides, the value proposition has other two pillars, society value propositions and environment value propositions, on top of customer value propositions.

From the above, the dynamic business model framework by Kamp et al. (2021) and sustainable business model canvas (SBMC) by Bocken et al. (2018) together contribute to the baseline of the dynamic sustainable business model framework in this research. After determining the baseline, the next step is establishing the conceptual dynamic sustainable business model framework for this thesis study (as described in sub-section 5.3). Referring to Meslin (2019) and Kamp et al. (2021), building such a framework involves three aspects of business models, including completeness, interrelationships, and changes over time. These three aspects are based on criteria assessing the degree of dynamics of a business model framework by Khodaei and Ortt (2019).

Concerning completeness, the sustainable business model canvas (SBMC) for DSPV projects is developed firstly (see Table 5.3.1). The SMBC is built based on the BMCs in Chapter 3 (see Table 3.1.2, Table 3.2.2 and Table 3.3.2). The economically-oriented BMC elements are the same as in the three types of BMCs (HO, TPO, and CS business model canvas). Additional elements regarding sustainable considerations are obtained by a broader search of renewable energy technology and PV energy-related articles but revolve around distributed solar PV. After the case study, the SBMC for DSPV projects in China is developed (see Table 7.6.1). Because the DSPV business models in China are mainly HO and TPO business models, the SBMC is revised based on HO and TPO BMCs in Chapter 3, including both HO and TPO business model elements. Additional newly reported elements in case studies complement the SMBC in the conceptual framework. Then, external and internal factors that impact SBM elements are investigated by the literature review (see Table 5.3.3), contributing to completeness. These factors are identified by external or internal origins and opportunity or threat. After investigating interrelationships between different BM components by the literature review (see Table 5.3.5), the dynamic sustainable business model framework can be developed, by which changes over time can be noticed.

RQ5. How can we apply the dynamic sustainable business model framework to DSPV projects in China to understand business model innovation?

This question is to apply the conceptual dynamic sustainable business model framework in actual cases. The answer to this question is in Chapter 6 and Chapter 7. The first step is to select possible companies carrying out DSPV businesses in China that are longer than five years from now to capture dynamics (see Table 6.2). These companies launch DSPV projects that accord with the thesis scope regarding DSPV installed capacities and on-grid systems. Five out of fifteen companies focusing on DSPV business responded positively.

The next step is to prepare a list of issues that need to be discussed. Before the interview, each company's DSPV business is studied through the company website. Changes in DSPV business over time that could affect the company's sustainable business model are also recorded. The semi-structured interview questions in Table 6.3 are adjusted to each company. From the interviews, the participants provide answerers, completing sustainable business model elements that are not clear in company background learning. Meanwhile, participants pointed out decisive triggers to business model changes that are recorded in the pre-interview case study. The participant's perspectives and the company's reaction together decide whether the factors are opportunities or threats to the company. Changes in the DSPV business that are not covered in the pre-interview design are also obtained from the interviews. Besides, the primary change of business model elements, owing to internal or external factors, and the secondary changes are determined based on the participant's replies or information on their companies' websites. Chapter 7 documents all case studies and provides cross-case analysis.

The case studies with the application are to see the performance of the dynamic sustainable business model framework. For each case company, the framework effectively captured changes over time. The framework shows all major changes to the company's DSPV sustainable business models along the timeline. These changes, depicted by primary or secondary changes, together with factors inducing these changes in business model elements and interrelationships within business model elements, describe how the DSPV business changes over time.

Apart from the performance, another objective is understanding business model innovation through real case applications. Factors affecting business model elements, together with origins (internal or external) and types (opportunity or threat), tell possible triggers of business model innovation. This also indicates the importance of investigating both environmental and business variables in the company context when considering business model innovation. Besides, the changes in business model elements and interrelationships between them over time illustrate the constantly changing process of BM elements or/and the architecture by definition of business model innovation. The architecture of a firm's value creation, delivery, and capture mechanisms is shaped constantly in response to external and internal opportunities or threats.

Main RQ. How can we develop a dynamic sustainable business model framework to understand business model innovation in distributed solar PV (DSPV) companies in China?

This thesis aims to investigate business model innovation (BMI) for distributed solar photovoltaic (DSPV) project companies through dynamic sustainable business model frameworks. The dynamic business model framework is developed based on the one established by Kamp et al. (2021), and the sustainable business model canvas (SBMC) by Bocken et al. (2018) is the tool. The dynamic sustainable business model framework for this thesis study is established according to criteria assessing dynamic business model frameworks by Khodaei and Ortt (2019), which are also adopted by Meslin (2019) and its follow-up research by Kamp et al. (2021). Referring to the criteria, building such a framework involves three aspects of business models: completeness, interrelationships, and changes over time.

Before digging into the research, it is essential to have a background learning of China's DSPV energy and understand basic concepts relevant to business models. After the literature review of DSPV energy systems in China, current DSPV business models, business model frameworks, business model innovation and sustainable business model frameworks, the fundamental knowledge for further study can be acquired. Further research is directed by answering the five sub-questions described above.

Since the SBMC by Bocken et al. (2018) is used in this research as a tool, the DSPV business models are revised to cover sustainable value and regard the environment and society as primary stakeholders as well. Based on the interpretation that the SBM is built on the BM concept, the SBM framework can be established on top of the conventional BM framework (Geissdoerfer et al., 2018). In the conceptual framework of this study, the economically-oriented BMC elements remain the same as in the three types of BMCs while adding additional elements for sustainable considerations. To fulfil the completeness, external environmental and internal company factors that affect business model elements are necessary. These factors are classified by their types of origins (external or internal) and effects on the companies (opportunities or threats). Apart from relationships between environmental variables and business elements, interrelationships between business model elements are disclosed, by which the second criterion is met. These relationships are identified according to whether the initial change in the first component and the resulting change in the correlated component are forced changes (F) or strategic decisions (C). The last criterion, changes over time, is fulfilled along with developing the dynamic sustainable business model of this study.

After building the conceptual framework, the framework's performance is measured by case studies of five DSPV project enterprises in China. The framework effectively captured changes in each company's business model over time. The conceptual framework can be further improved by synthesizing the results from the case study.

Through the study, business model innovation at the firm level (DSPV project enterprises) is a dynamic process. Due to environmental and business variables, a company's business model constantly changes in response to external and internal opportunities and threats. These variables are essential for understanding business model innovation. Changes in external factors (e.g., policy and regulation, industrial technology innovation, customer demand, market competition, etc.) and internal factors (e.g., company technology improvement, project O&M management, personnel capability, etc.) could trigger business model innovation. Starting with recognizing opportunities or threats, DSPV enterprises respond to these variables differently depending on company capability and external business environment. Meanwhile, changes within business model elements tend to be coherent and interlinked over time. For an efficient business model innovation, associated business model elements are supposed to be in line with a changed business model element. On the way, these changes can either create or capture value for stakeholders, including customers, society and the environment. The constantly changing process as to BMI is based on a company's flexible operation and management for adapting to the complex and varying environment.

8.2 Discussion and Recommendation

In this research, the SBMC formed in the conceptual framework was based on top of the three types of BMCs in Chapter 3, reported by a simplified presentation (see Table 5.3.1). Only elements covering sustainability considerations were documented. The economically-oriented business model elements were simplified, referring to HO, TPO, or CS business models canvas in Chapter 3. Elements were summarized for a broad view of major DSPV sustainable business models, depending on the ownerships of DSPV systems. Theoretically, such a canvas was not a complete representation. This could not adequately see the SBMC of DSPV business for all. The SBMC can be more thorough in showing all elements.

Aside from forming SBMC, value capture in this research focused on DSPV developers or enterprises. Regarding the SBMC by Bocken et al. (2018), the author defined value capture (VCP) as cost structure and revenue streams for stakeholders in the entire system. However, the SBMC in this research mainly discussed the economic value capture of the DSPV company. The costs and revenues to capture wider stakeholder values, including the environment and society, were not comprehensively reported. This might be because of the lack of case studies and literature reviews. Regarding case studies, only five DSPV project companies positively responded, and accessibility to respondents was lacking.

In this study, the most critical factor was the decisive factor presented in the dynamic SBM framework. The decisive factors were determined according to the interview results and information on company websites. In this way, the decisive factors were more or less based on subjective points of view. The data obtained could be controversial since respondents may offer different answers due to their different work experiences. Participants holding positions in upstream (e.g., logistics) and downstream (e.g., installation, O&M, etc.) value chain might pay attention to different parts of the DSPV business. As a result, the decisive factors decided using this method might not be from a systemic view of the DSPV project business.

Apart from the subjective data obtained by interviews and online searching, another limitation is that the respondents might misunderstand or had less knowledge about the sustainability of the business, giving inadequate or biased information. At the same time, the information might include errors. It could be because the company or participants were unwilling to provide business details to secure interior data. It also could be due to the company being reluctant to give socially undesirable information in order to maintain its brand reputation. Besides, conducting interviews was time-consuming, postponing the rest of the study.

Another aspect was about the identification of the type of change. In this study, the type of a change in business models, either a forced change or strategic choice, is determined in the company context. It was decided based on a factor's effects on a DSPV company's business model. Enterprises' responses to a factor, to some extent, defined the type of the change. Since a change can be a strategic response of the company to some content and also be a forced one, identifying the type of a change by looking at the enterprise's reactions to the factor can be an approach.

Regarding barriers impeding distributed energy development, this study shows that business model innovation can partly solve or reduce these barriers. As DSPV project enterprises are the focal firms of this study, changes of business models mostly reduce barriers that are highly associated with DSPV developers and participants. Financial and company resources barriers could be partly overcome by altering business activities and building necessary business partnerships. Increasing company capabilities in management and technology R&D also could partly reduce barriers regarding resources and technology. However, the development of DSPV industry also rely on other factors, such as industry regulations and policies, industry technology, market competitions and public awareness, that are not completely determined by the DSPV developer. Companies' responses to those factors could be restricted by certain policy terms, technical boatneck or market operations.

Recommendations for future research

In future research, the SBMC should be more thorough in showing elements. One approach could be to combine the three types of BMCs, regardless of the ownership of the DSPV system, to build the economically-oriented BMC base. This is because enterprises usually apply more than one type of business model in DSPV business. Any other types of business model regarding ownership then can also be integrated into the base BMC. After that, the SBMC can be established on top of the base BMC. Another similar approach could be to build the base BMCs without considering the ownership of the DSPV system. Researchers are still suggested to know the ownership of a system before case studies since it could help them understand the business operation and perceive the variations of business models.

Looking at the overall framework application, although the dynamic SBM framework built in this research can reveal the dynamic process of DSPV project companies' business models, additional SBMCs can be adopted to further tell the business story. In the future layout, the left part of the framework could involve the SBMC of the project company, illustrating the elements and variations of BMs. The right part could be the dynamic SBM framework established in this study, only showing the dynamics. Any variation on the right side can be referred to a further description on the left side. It will be more accessible for researchers to learn.

Besides, the SBMC could be established by dividing business model elements into economic, environmental, and social dimensions. That is, each main element will have a tripartite view. Compared with the current canvas, where only value propositions have three perspectives (e.g., CVP, EVP, SVP), the three-dimension canvas could facilitate researchers to gain a more comprehensive picture of business operations with a focus on sustainability considerations. Accordingly, other main elements (e.g., VCA, VD, VCP) of the current dynamic framework will have three dimensions. However, such a framework will have two aspects needed to be concerned. One aspect is about capturing dynamics, and another is about framework presentation. A factor that affects the business model could be relevant to more than one dimension. Similarly, a change in the business model could affect more than one dimension of other elements. It would be chaotic to depict the dynamics of three dimensions in one framework. The researcher may need to decide which dimension is the most important, or which two are more vital, or all three dimensions are equally important. Additionally, the dynamic sustainable business model framework could be shown in three layers. The three layers correspond to economics, the environment, and society. That is, one layer shows all changes related to economics, and the other two layers display business model changes associated with the environment and society, respectively.

In future research, the framework can be applied to more DSPV companies for improvement. This aims to not only complete the SBMC elements but also capture more dynamics of business models. Interviews should be planned several months ahead of implementation to avoid work delays. Participants with various work experiences are needed to reduce errors and biased data, requiring more interviews for each company.

Regarding barriers impeding distributed energy development, this study only shows that business model innovation can partly reduce the barriers regarding financial, technological, regulatory, resources and awareness aspects. Future research can further focus on how BMI overcomes barriers and the extent to which business model innovation can help overcome those barriers. This research could be valuable for investigating the BMI of renewable energy.

Recommendations for DSPV developers

Developing existing BMs is a crucial organizational competence for firms exposed to high uncertainties. DSPV enterprises can innovate their business model to adapt to the complex and changing environment. They also need to incorporate sustainability into their business, as sustainability will be critical under the influence of increasing environmental awareness across the entire society.

Currently, enterprises in China's DSPV industry have started incorporating sustainability considerations into their business but are still at the early stage. For sustainable development, DSPV companies can take social responsibility in various ways. In addition to working with suppliers to recycle and deposit the materials, they can add channels and cooperate with relevant institutions to manage the system through the entire life cycle. This may also require policy incentives and subsidies at the early stage of development since such management may have requirements on technology and finance capabilities.

According to the case study results and literature review, policies will remain one of the key stimulates, encouraging business models innovation. Due to the latest widely applied entire county (district) rooftop DSPV program since 2021, the government and public organizations, over residential, industrial and commercial customers, will become potential customer segments in the future. To capture the market opportunity, DSPV developers may need to adjust their business models to add, such as governments, schools, hospitals, and train stations, to their customer segments. System design, installation, operation, maintenance and other business activities require to alter accordingly.

Based on the case study results, changes in customer demand and requirements are the most critical factor encouraging business model innovation. As for DSPV developers, they need to focus on providing efficient and affordable DSPV products and services to their customers. Apart from it, companies should also allocate their resources to offer after-sales services. Providing support services can be a business strategy since it can not only enhance customer satisfaction and brand loyalty but also diversify revenue sources. From the researcher perspective, the target customer is the central dimension for a business model design.

Besides, DSPV enterprises need to establish stable partnerships with state-owned enterprises, banks and financial institutions to enrich financing channels for loan financing and secure stable investment returns. At the same time, they need to work together with governments to create a more attractive investment environment to promote subsidy-free development of PV. Additionally, since DSPV features miniaturization and decentralization, relationships with grid companies are also indispensable. From the researcher's perspective, the value network incorporating key participants is essential for a company to create value with the help of its business network.

Last but not least, changes in company competencies, entrepreneurial capability, and growth strategies may also trigger companies' business model innovation in certain circumstances. DSPV enterprises need to continue to optimize their management systems for sustainable development in the long term.

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Appendix

Appendix A

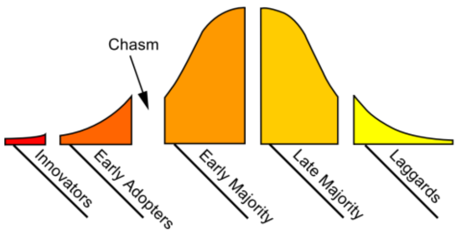

Figure Appendix A. Technology adoption life cycle (Meade and Rabelo, 2004)

Appendix B

Table Appendix-B. National photovoltaic power station benchmark on-grid electricity price list (National Development and Reform Commission, 2013)

Resource area	PV power station Benchmark on-grid tariff (RMB/kWh (tax included))	Areas included in each resource area
Class I	0.9	Ningxia, Qinghai Haixi, Gansu Jiayuguan, Wuwei, Zhangye, Jiuquan, Dunhuang, Jinchang, Xinjiang Hami, Tacheng, Altay, Karamay, Inner Mongolia except Chifeng, Tongliao, Xing'an, Areas outside the League and Hulunbuir
Class II	0.95	Beijing, Tianjin, Heilongjiang, Jilin, Liaoning, Sichuan, Yunnan, Chifeng, Tongtong, Inner Mongolia, Liaoning, Xing'an League, Hulunbuir, Hebei Chengde, Zhangjiakou, Tangshan, Qinhuangdao, Shanxi, Datong, Shuozhou, Xinzhou, Yulin, Yan'an, Shaanxi, Qinghai, Gansu, Xinjiang except Class I
Class III	1.0	Other areas except for Class I and Class II resource areas