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**Citation (APA)**

Khodaei, H., Kamp, L. M., & Xu, X. (2026). Sustainable dynamic business model framework – value changes during the development process of PV companies in China. *Journal of Open Innovation: Technology, Market, and Complexity*, 12(1), Article 100745. <https://doi.org/10.1016/j.joitmc.2026.100745>

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## Sustainable dynamic business model framework – value changes during the development process of PV companies in China

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## ARTICLE INFO

## Keywords:

Business model  
Business model dynamics  
Business model innovation  
Sustainable business model  
Renewable energy  
Value creation

## ABSTRACT

Business model dynamics are key to the success of companies. This is particularly the case for sustainability-oriented companies that aim to tackle grand challenges by rethinking how companies create, deliver, and capture value, which can combine profit orientation with social and environmental purposes. However, understanding how companies transit towards sustainable business models through the change of company value logics remains unclear and current business model frameworks cannot capture such dynamics. Combining insights from the literature on sustainable business models and business model dynamics, our study proposed a comprehensive sustainable dynamic business model framework. The proposed framework takes into account the main elements of a sustainable business model and present the mechanisms that drive different sustainability-oriented values, and how their values change and are influenced by internal and external factors during the company development process. The framework is applied in multiple-case analysis of different PV companies in China. The application of the framework shows that it is able to present the mechanisms that drive different sustainability-oriented values and to capture business model dynamics in a comprehensive way and that it allows for case study comparison. The results of our research have significant implications for business model, both in theory and practice.

## 1. Introduction

Companies need to respond to different environmental changes with different means of organizational change, such as open innovation and business model innovation (Chesbrough, 2003; 2006; Chiaroni, 2011). The field of business model dynamics has garnered significant attention in recent years (e.g., Saebi, et al., 2017). Business Models (BMs) are constantly subjected to re-evaluation for the firm to navigate through a changing environment to produce sustained competitive advantage (Teece, 2010). BM dynamics refer to “how business models come into being (...) and the changes in the architecture between BM elements that produce alterations to the business model” (Foss and Saebi, 2018, p. 17), as well as “shaping, adapting and renewing the underlying business model of the company” for sustained value creation (Achtenhagen et al., 2013). The extent of BM changes varies with different open BMs and with different open innovation strategies (Chesbrough, 2006; 2010; Saebi and Foss, 2015). Certain open innovation strategies require more fundamental restructuring of BMs as a result of the reconfiguration of the downstream activities and capabilities (Yun et al., 2016).

In order to capture the BM dynamics, companies have to change BM elements such as value creation, value delivery and capture (Teece, 2010). However, previous studies lack understanding of value logic change and the factors contributing to the evolution of BMs over time (Chesbrough and Rosenbloom, 2002; Morris et al., 2005; Balboni et al., 2019). This is particularly the case for sustainability-oriented companies that aim to tackle grand challenges related to pressing environmental and social problems (Rosso et al., 2022; Cappa et al., 2022) by open-ended global objectives such as secure, clean and efficient energy production (Kuhlmann and Rip, 2014). These companies should reconsider how value is created, delivered, and captured by integrating profit objectives with social and environmental goals through Sustainable Business Models (SBMs) (Snihur and Bocken, 2022; Snihur and Markman, 2023; Bocken and Geradts, 2020). SBM archetypes depend on the nature of transition within value processes including value proposition, value creation, delivery, and capture (Bocken et al., 2014). This change of firm value logic is key to understanding how companies transition towards SBMs (Laasch, 2018). Previous studies on SBMs remain fragmented, focusing predominantly on separate innovation practices

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<https://doi.org/10.1016/j.joitmc.2026.100745>

Received 9 October 2025; Received in revised form 7 February 2026; Accepted 14 February 2026

Available online 16 February 2026

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(Bocken et al., 2014; Ritala et al., 2018) and are not uncovering the mechanisms of value logic transition when modelling a business through a sustainability lens (Lüdeke-Freund and Dembek, 2017). Besides, current SBM frameworks (e.g., business model canvas) are not able to capture the change and dynamics of BMs (e.g., Saebi et al., 2017; Khodaei and Ortt, 2019). We address this gap by combining insights from SBM framework (Bocken et al., 2014; 2018), and dynamic business model framework (Khodaei and Ortt, 2019; Kamp et al., 2021) into one comprehensive Sustainable Dynamic Business Model (SDBM) framework. Thus, we addressed this research gap and define SDBM framework as a conceptual framework that can present and analyses continuous changes in response to internal and external changes, while integrating environmental, social, and economic value creation into its core logic of value proposition, value creation, value delivery, and value capture. Such a conceptual framework can be used to illustrate and analyze the BM dynamics of sustainable companies over time.

This leads us to the research question for this paper: *How can sustainable business model change during company development and how can this change be conceptualized in a sustainable dynamic business model framework?*

Besides building up our conceptual SDBM framework, we used it to illustrate and analyze five sustainability-oriented companies in China in terms of value proposition, creation, delivery and capture. Our case studies focus on renewable energy companies, particularly solar photovoltaic (PV)-based firms, which adopt sustainable strategies involving practices aimed at regenerating local ecosystems (Konietzko et al., 2020). Subsequently, we will show how the data from multiple case studies can be combined in a cross-case analysis to reveals key results of patterns across cases.

Being able to perform such an analysis with a conceptual framework provides both companies and scientists to better understand the macro-environmental changes that trigger, shape, or enhance value-oriented SBM processes in terms of value proposition, creation, delivery and capture during the sustainability-oriented company development process.

The paper is structured into five sections. The next section will lay the foundation for our SDBM framework by presenting the main BM elements, changes and the origin of change, and the subsequent mechanism by which the BM elements are adapted during the development process of company to keep the model consistent. Section 3 will then present the research method and design. In Section 4, the use of the framework will be illustrated using each cases of PV companies in China and the key results of patterns across cases using the framework will be revealed. Section 5 will present the conclusion and discussion and section 6 concludes the study by pinpointing contributions, implications for research and practice, and areas for future research.

## 2. Theoretical framework

### 2.1. Sustainable business model frameworks

Based on the definitions by Amit and Zott (2001); Johnson et al. (2008); Magretta (2002); Morris et al. (2005); Osterwalder and Pigneur (2010); Teece (2010); and Fielit (2013), BMs are simplified representations of the elements, and the interactions between these elements, that an organizational unit selects to create, deliver, and capture value. The various ways in which the BM can be subdivided into components brings up the question of what subdivision is most appropriate for the analysis of SBM. Economically-oriented BMs do not include the environmental and social values that are appropriate for sustainable solutions (e.g., PV solutions) (Cardeal et al., 2020).

The SBM is seen as a modification of the conventional BM, integrating sustainability considerations into business mechanisms (Geissdoerfer et al., 2018). Taxonomy studies classify sustainability-oriented configurations across ecological, social, and economic dimensions with distinct value mechanisms (Lüdeke-Freund

et al., 2018). An SBM is designed to generate, provide, acquire, and share sustainable value in collaboration with a diverse set of stakeholders, with a particular emphasis on society and the environment (Geissdoerfer et al., 2016).

Different SBM frameworks operationalize this integration through multi-layer representations and recurring patterns (Joyce and Paquin, 2016; Bocken et al., 2014; Lüdeke-Freund et al., 2018). However, current BM frameworks cannot capture the dynamics of BMs (Khodaei and Ortt, 2019). To keep the representation of the SBM clear as well as to represent internal dynamics to a reasonable degree of complexity, a representation distinguishing four main components of the BM canvas, as proposed by Bocken et al., (2013), formed one of the base for this paper (Bocken et al., 2018). The model incorporates a more extensive array of stakeholders, specifically emphasizing society and the environment, rather than solely focusing on customers and shareholders (Bocken et al., 2013). The model is called the SBM Canvas. In this model, the four main components are (1) the value proposition, (2) value creation, (3) value capture and (4) value delivery (Bocken et al., 2018),

### 2.2. Dynamic business model framework

Business model dynamics literature has gained significant interest over the last years (e.g., Saebi et al., 2015; Khodaei and Ortt, 2019; Kamp et al., 2021). According to Khodaei and Ortt (2019), for analyzing and evaluating these dynamics one has to look at different aspects of BMs. These different aspects are completeness, interrelationships, and changes over time.

In their study, Kamp et al. (2021) introduced a dynamic BM framework, building upon the groundwork laid by Khodaei and Ortt in 2019. The dynamic BM framework developed by Kamp et al (2021) comprises three main elements: the value proposition (VP), the value network (VN), and the cost and revenue stream (CRS). In terms of completeness, the framework by Kamp et al (2021) incorporates environmental factors influencing BM variables. These factors are categorized based on their origin as either external (E) or internal (I), and they are further classified as posing a threat (T) or providing an opportunity (O). The interrelationships within the framework involve six distinct groups among the primary BM components. Kamp et al (2021) further categorize these interrelationships based on whether they result from forced changes (F) or strategic choices (C). To illustrate changes over time, the authors represent these interrelationships on a temporal axis.

By integrating these considerations into graphical representation, as depicted in Figure 1, it becomes possible to visually represent subsequent changes in the business model. In the particular example shown in Figure 1, changes in the value proposition (with an external origin) lead to subsequent changes in the value network. The solid lines of the arrows

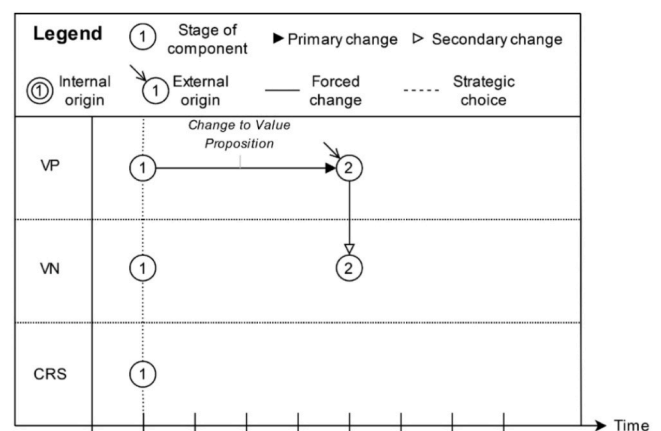


Fig. 1. The Dynamic BM Framework: example –VP change with external origin leading to forced VN change. (Kamp et al. 2021).

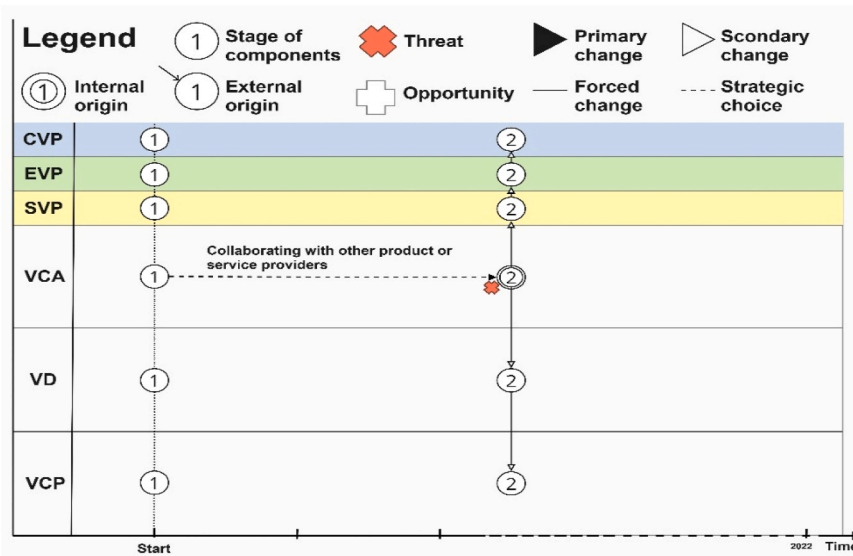


Fig. 2. Sustainable Dynamic Business Model (SDBM) framework.

denote how, following the initial forced change in (VP), (VN) is forced to undergo changes as well.

2.3 Sustainable dynamic business model framework

The SDBM framework combines insights from SBM frameworks (Bocken et al., 2013, 2018) and dynamic BM frameworks (Khodaei and Ortt, 2019; Kamp et al., 2021) into one comprehensive Sustainable Dynamic Business Model (SDBM) framework. We defined it as a business model that continuously evolves in response to internal and external changes, while integrating environmental, social, and economic value creation into its core logic of value proposition, value creation, value delivery, and value capture.

The SDBM framework is composed of four main elements, the value proposition (VP), including social and environmental value propositions as well as value creation (VC), value delivery (VD), and value capture (VCP). Adding to the previous dynamic BM framework of Kamp et al. (2021), the new proposed SDBM framework includes different considerations that can capture both the dynamic BM framework and sustainable BM framework. As a result, the conceptualization of business model change proposed in this paper consists of seven main considerations which together form the SDBM framework. These considerations can be listed as follows:

- The BM is subdivided into four main components: the value proposition, the value creation value delivery and value capture;
- The social and environmental aspects of BM are included in the value proposition as social and environmental value propositions;
- The origin of change can lie inside or outside the company;
- The consistency of BM requires follow-up changes in one or more elements;
- The initial changes are called primary changes and the possible follow-up changes are called secondary changes;
- BM changes can be either forced changes or strategic choices;
- The origin of change can be considered either as an opportunity or threat

Figure 3 illustrates the functioning of the SDBM framework when a shift in value creation leads to changes in value proposition, value delivery, and value capture. In the particular example shown in this figure, a change in value creation leads to a whole array of follow-up changes in all other elements of the business model. The primary change, indicated by a black-tipped arrow (VCA1->VCA2), represents a strategic choice (dashed line arrow) made by the company, triggered by an internal origin (circle with a small arrow attached).

This change in value creation initiates forced changes (solid line arrows) in customer, environmental, and societal value propositions

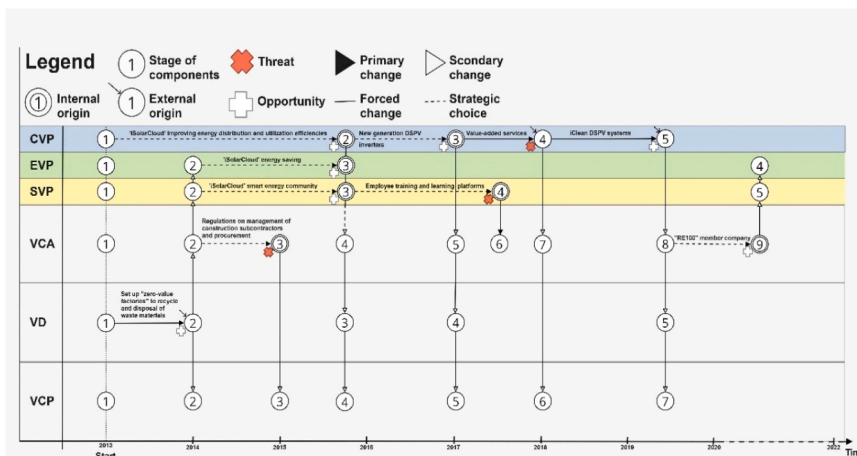


Fig. 3. SDBM framework of Company A.

(CVP1->CVP2, EVP1->EVP2, and SVPI->SVP2) and in the value delivery (VD1 -> VD2) and value capture (VCP1 -> VCP2). These follow-up changes are called secondary changes and are depicted by white-tipped arrows.

The framework, represented in a graphical form, can be used to track and analyze SBM changes over time. Since the goal in this paper is to present a first version of the framework and apply it to a case study for the first time, several simplifications were deliberately adopted, such as the representation of the BM with four main elements only, and locating the origins of change either within or outside the company. It is important to realize that such simplifications can be removed for example by distinguishing more than four BM elements. If more elements are distinguished, then more complex (multi-factor) interactions between these elements and the context can be tracked over time. The next sections will show how the simplified framework can be practically applied in a case study.

### 3. Methodology

#### 3.1. Data collection

To apply the SDBM framework, we employed a multiple case study design (Eisenhardt, 1989). This approach is well-suited for exploring research questions such as ours that address processual phenomena (Langley, 1999) and usually leads to more robust and generalizable theories compared to single cases (Eisenhardt and Graebner, 2007).

We conducted our study in the context of PV companies located in China. China has the largest installed solar power capacity in the world, and strong government policies have significantly accelerated the adoption of PV technology (IRENA, 2024). This makes China a relevant context for this study. The Chinese PV companies are leading high-tech companies, specialized in the production and sale of renewable energy power equipment. Over the past decade, PV companies in China have experienced substantial transformation. National initiatives—such as the Photovoltaic Poverty Alleviation Projects (PPAP) and China's carbon neutrality targets for 2030 and 2060—have reinforced PV as a strategic priority for achieving scalable, decentralized energy solutions. These policies have not only increased market demand but also encouraged innovation in BMs across the sector. Restricting our sample to a relatively homogenous business environment helps to minimize possible external confounding effects, such as sociopolitical factors and other country effects (Zott and Huy, 2007).

The data collection was done by conducting semi-structured face-to-face interviews with PV company representatives holding key positions in the period July - September 2019, based on Xu (2022). The interviews lasted on average an hour and were recorded and transcribed. Informants were asked to describe BM changes in their company through questions related to the value proposition, value creation and delivery, and value capture and the factors affecting these changes. To allow for data triangulation (Yin, 2014), these data sources were supplemented with document analysis of grey literature such as sustainability reports and company websites (Yin, 2014; Eisenhardt, 1989).

#### 3.2. Data analysis

Data analysis was conducted in two phases. In the first phase, within-case analyses were conducted (Eisenhardt, 1989; Miles and Huberman, 1994), focused on BM changes and origins of changes from the vast data collected for each case. In this process, the data were transformed into case studies (Eisenhardt, 1989) and organized following the proposed Sustainable Dynamic Business Model framework (SDBM). When identifying and classifying the components of the conceptual frameworks in each case, the data was manually traced for references to the framework components. For example, we looked at different BM components of VP, VCA, VD, VCP changes during the development of the company, different origins of changes, namely internal and external, as well as

opportunities and threats.

The second phase of analysis consisted of cross-case analysis. We compared cases through mapping their differences and similarities, and identified the emerging patterns. Together with the rigorous case sampling principles used, the cross-case analysis improved the external validity of our results and enabled us to draw broader conclusions (Eisenhardt, 1989) about SDBM value changes of PV companies during the company development process.

## 4. Results

The conceptual Sustainable Dynamic Business Model (SDBM) framework created in Section 2 was used to analyze the five cases. The first part of this section will present the within-case analyses for the five Chinese PV companies, comprising a description of value changes along the development process of the cases and the factors leading these changes. Next, the five cases are compared in a cross-case analysis using the conceptual framework to summarize the results and identify emerging patterns.

### 4.1. Illustration of the sustainable dynamic business model framework with PV cases

The next subsection presents all the details for the case of Company A in order to give an example of the details and description for each case whereas, in order to save space in this paper, the other cases will be presented in summary in a table and illustrated by the SDBM framework.

#### 4.1.1. The case of Company A

Company A, a leading Chinese high-tech company, specializes in the production and sale of renewable energy power equipment, particularly photovoltaic inverters, with a dedicated focus on delivering comprehensive Photovoltaic (PV) power solutions. Since the initiation of China's 12th Five-Year Plan in 2012, the company strategically entered the development, investment, construction, and operational management of PV power plants. In the early 2010s, around 2013, Company A expanded its offerings to include Distributed Solar Photovoltaic (DSPV) solutions, with a specific emphasis on rooftop power stations. Throughout its history, Company A underwent eight significant transformations, as outlined in Figure 3.

The first pivotal shift in BM occurred in 2014 when Company A established "zero-value factories" dedicated to recycling and appropriately disposing of waste materials. This move was prompted by the enactment of the first Circular Economy Promotion Law in 2009, which mandated production enterprises to use recycled materials or ensure the safe disposal of waste.

The 2011 Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products further outlined responsibilities for entities in recycling and waste product disposal. During the five-year plan period, there was an increased emphasis on research and development of recycling technologies within the Energy Conservation and Environmental Protection Industry Development (State Council, 2012). In response to global environmental awareness and these regulations, Company A explored avenues for waste material disposal. Despite the higher processing costs associated with the introduction of "zero-value factories," Company A perceived this as an opportunity, represented by a white perpendicular cross in Figure 3. This strategic change was a compelled transformation, denoted by a black-tipped arrow with a solid line, originating externally, as indicated by a circle with a small attached arrow.

The shift in value delivery had implications for the subsequent stage of value creation. Depending on their quality and characteristics, certain materials became eligible for reuse or sale to other companies, leading to financial gains. A notable example is the granular material used in supporting the assembly of water surface Distributed Solar Photovoltaic (DSPV) systems, which showed Company A's "zero-value factory"

(VCA1->2). Additionally, value capturing was also impacted (VCP1->2). Company A covered costs associated with waste treatment but also obtained economic payoff, although with a relatively low return compared to costs. Apart from effects on value creation and capturing, this approach delivered environmental value propositions (EVP1->2) and social benefits (SVP1->2). Beyond addressing climate change through the generation of clean (solar) energy, a noteworthy outcome has been the reduction in waste production, especially in terms of electrical and electronic waste. Specifically, the demolishing and recycling of harmful waste, such as circuit boards, contribute to safeguarding the local ecosystem and fostering the well-being of both human and other living organisms in the area. The subsequent changes in value creation and value proposition were compelled changes, as indicated by a white-tipped arrow.

The second significant transformation occurred in 2015, stemming from internal factors within the company (depicted by a double-line circle) and accompanied by inherent risks denoted by a red cross. The use of unstandardized procurement and subcontracting processes posed challenges to integrity, negatively impacting the company's image. Furthermore, the absence of competitive selection in outsourced installations raised the risk of inflating costs beyond actual prices. In response to these internal challenges, Company A took proactive measures by implementing regulations governing construction subcontracting and procurement. This strategic move directly influenced the value creation process within the company (VCA1->2) as part of Company A's BM evolution.

Subsequently, Company A adopted a practice of organizing construction bidding to select subcontractors capable of delivering qualified services at reasonable prices. In addition to bidding, Company A committed to regularly evaluating its supply chain partners, assessing not only product quality but also contributing to overall product improvement. This regulatory approach to subcontractor management effectively reduced costs at the construction stage (VCP2->3). To clarify, the initial change in value creation was a strategic choice, and its subsequent impact on value capture represented a forced change.

During this period, users gained access to the 'iSolarCloud' platform on both PC and mobile devices. This platform played a pivotal role in educating customers about energy usage, fostering the development of users' electricity habits. Notably, a significant portion of Company A's end-users were families participating in poverty mitigation projects. Despite governmental incentives, public perceptions of renewable energy were not as favorable as those of traditional energy sources, with prevailing doubts about the profitability of such projects.

The introduction of the smart community, facilitated by 'iSolarCloud,' allowed end-users to self-monitor their daily energy usage and electricity fees. This approach aimed to convince them of the mutually beneficial feasibility of addressing climate change through renewable energy. The launch of 'iSolarCloud' enriched the value propositions of Company A's projects, offering a comprehensive solution for end-users to engage with and benefit from renewable energy initiatives.

Initially, there was a change in the customer value proposition (CVP1->2). The enhancement of real-time control led to improved energy distribution and utilization efficiencies. Customers experienced a relief in electricity generation tensions as the system intelligently balanced energy supply and demand based on user data collection and optimization of the entire distribution grid. Company A would sell excess electricity over customer demand to utilities or other local users. This system, with insightful monitoring and remote adjustment, effectively saved more energy (EVP2->3), eliminating electricity abandonment and maximizing the value of energy utilization in projects.

Simultaneously, the 'iSolarCloud' initiative created a smart energy community with customers, contributing to the local society's sustainability (SVP2->3). Users accessed the 'iSolarCloud' platform on both PC and mobile devices, allowing Company A to educate customers on energy usage and cultivate electricity habits. The 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 the 'iSolarCloud' project system made the internet company a significant partner to Company A, influencing its value creation (VCA2->3) in the BM. Company A 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 'iSolarCloud' system development and improvement were involved (VCP3->4).

In 2017, Company A underwent a comprehensive upgrade of its business strategy, marking the fourth major change to its projects. This transformation was primarily driven by internal factors. In certain regions of China, power generation costs and feed-in tariffs exceeded those associated with conventional fossil energy, with the projects heavily reliant on government support. Recognizing the industry's shift toward grid parity and anticipating potential changes in governmental subsidies, such as their discontinuation, Company A proactively addressed these risks. To mitigate potential revenue stream impacts from policy fluctuations, Company A shifted its development trajectory. Rather than relying primarily on project investment returns, the company pivoted to become a system provider with clean power conversion at its core. This strategic shift emphasized technology innovation as a cornerstone. In alignment with this direction, Company A introduced a new generation inverter specifically tailored for its projects, offering enhanced customer value propositions (CVP2->3). This new inverter could adapt to various rooftop installation environments, particularly in urban districts, and improve power conversion efficiency, thereby increasing customer revenue. This technological improvement led to a change in value delivery (VD3->4), targeting industrial and commercial customer segments instead of households, thereby expanding Company A's business reach.

Before this strategic shift, early-stage projects primarily focused on households in counties with more available roofs, and the inverters were generally more applicable to large-scale PV projects. With the rapid promotion of solutions incorporating inverter innovation, the proportion of marketing and sales personnel, considered essential resources in value creation (VCA3->4), substantially increased during this year. Simultaneously, costs associated with selling expenses (VCP4->5), including sales staff salaries, related office expenses, travel expenses, and other miscellaneous expenses, saw a notable increase of 81.14 % compared to the figures in 2016.

The fifth internal-originated change unfolded later in 2017, propelled by the rapid expansion of Company A's business during that year. The increased business activities led to a stream in the workforce and higher demands for employee capabilities. Simultaneously, there was a noticeable rise in the turnover rate, particularly in sales positions. In response, Company A implemented training and learning platforms to support the sustainable development of its employees, thereby enhancing its social value propositions (SVP 3->4). To cope with the challenge of onboarding a large arrival of new employees, Company A initiated the "Sunflower Project," designed to provide training in generic skills to facilitate their quick integration. Additionally, the company instituted manager development programs, offering courses in both business and human management to cultivate senior managers. An on-line self-learning platform was also developed, enabling managers to organize courses for attendants based on their specific knowledge and skill needs. As a result of these initiatives, there was a shift in value creation (VCA 5->6), with Company A having a more skilled workforce in areas such as marketing, project management, and technology. The corporate culture prioritizing employee development and satisfaction was effectively communicated to the public, contributing positively to the company's image.

The sixth change, occurring in 2018, was prompted by intensified competition in the Distributed Solar Photovoltaic (DSPV) market. With more enterprises entering the domestic market due to its growth potential, Company A focused on technological advancements to differentiate itself and also introduced value-added services as a means to

sustain its competitive edge. This shift elevated customer value propositions to the next stage (CVP3->4). Value-added services extended beyond customized consulting, planning, and design to include additional offerings in insurance and leasing. This brought about changes in value creation (VCA5->6) and value capturing (VCP5->6). On the customer side, Company A collaborated with insurance companies to provide services, eliminating the need for customers to select insurance independently. Moreover, Company A introduced leasing options for system equipment, generating a new revenue stream. This primary change in customer value propositions led to subsequent changes in value creation and capturing.

The seventh change occurred in June 2019, triggered by an external opportunity. Capitalizing on technological innovation, Company A launched the 'iClean' PV business with the industry's first self-cleaning double nozzle patent design. This innovative system integrated an automatic intelligent self-cleaning mechanism into DSPV projects through programmed operational procedures, including monitoring, cleaning, measuring, and more. Customer value propositions advanced to the next stage (CVP4->5), offering artificial intelligent weather assessment and cleanliness perception. This allowed PV panels to be cleaned automatically, optimizing performance, reducing ash loss rates, and increasing annual power production by approximately 8%. This change in customer value proposition led to secondary changes in value creation, delivery, and capturing (VCA7->8; VD4->5; VCP6->7) represented by an arrow with a solid line.

The last change, occurring after 2020 (indicated by a dashed line on the time axis), was an internal company decision highlighting the priority of tackling climate change for sustainable development. This decision impacted value creation (VCA8->9). Aligned with a sustainable orientation, Company A joined the RE100 (Renewable Energy) climate group, becoming one of its member companies committed to utilizing renewable electricity in all business activities by 2028. Company A implemented PV business on its factory rooftops to contribute to this goal. This initiative not only provided an opportunity for Company A to enhance its corporate image by taking social responsibility but also aligned with sustainable development. The primary change in value creation mainly brought environmental benefits (EVP3->4) by further reducing carbon emissions and social benefits (SVP4->5) by accelerating the transition towards zero-carbon power grids.

#### 4.1.2. The case of Company B

Company B, an energy company, was established in the mid-2010s with a focus on the sales of PV system products, investment in power plants, and the operation and maintenance of projects. Company B is involved in the entire process, from system design to installation, and it oversees project operation and maintenance. The company benefits from government subsidies and generates a significant portion of its revenue from electricity fees. Notably, being a PV cell manufacturer themselves, they source other system components from suppliers like Huawei. Additionally, Company B collaborates with both local and national banks to facilitate financing services. Over time, the business has undergone five major changes, as indicated in Table 1 and illustrated in Figure 4.

#### 4.1.3. The case of Company C

Company C is a company founded in the mid-2010s with a dedicated focus on renewable energy applications, particularly emphasizing solar energy. Company C offers comprehensive services to its customers, covering everything from system design and installation to operation and maintenance. Additionally, the company is involved in the sales of various PV system products, including solar panels, inverters, and mounting brackets. Over the course of its development, Company C has undergone eight significant changes, as indicated in Table 2 and outlined in Figure 5.

#### 4.1.4. The case of Company D

Established in the early 2010s, Company D specializes in PV power station operation and maintenance (O&M), transfer, and the engineering, procurement, and construction services. Since its inception in the PV market, the company has been dedicated to providing comprehensive solutions for industrial, commercial, and residential customers. Company D has fostered enduring partnerships with business associates, emphasizing the delivery of effective solutions. The projects undertaken by Company D incorporate components and facilities sourced from reputable suppliers in the market. In terms of financing, Company D leverages various channels, engaging with both national and local banks, financial institutions, and state-owned power enterprises. This diversified approach to financing allows Company D to strategically support its operations and ventures in the PV power sector. In the realm

**Table 1**  
Major changes of Company B's SBM.

| No. | 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<br>VCA 1-> 2: Cooperating with local governments and bank<br>VCP 1-> 2: Employee costs; Construction costs (incl. Operation and management (O&M)) costs<br>SVP 1-> 2: Poverty alleviation; Maximized land use efficiency<br>VCA 2-> 3: Strategic cooperation with national banks, O&M companies, insurance providers<br>VD 2-> 3: Improved customer experiences by the system<br>VCP 2-> 3: 99 Increased labor costs; Costs in developing intelligent systems   |
| 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                          | CVP 3-> 4: Electricity generated increased (10 %-30 %); Increased customer revenue<br>EVP 1-> 2: Reduced GHG emission due to the technology<br>SVP 2-> 3: Advanced technology<br>VCP 3-> 4: Cost in technology R&D  |
| 3   | 2019 | Market competition and short-term impacts of China's '531' policy              | E.T Technology improvement (Ntype bifacial solar cells; N-type modules) | VCA 4-> 5: Technology R&D; Building brand reputation;   | CVP 4-> 5: Intelligent "contactless" services<br>SVP 3-> 4: Promoting digital energy development<br>VCA 5-> 6: IT activities; Remove inefficient activities<br>VCP 4-> 5: Costs reduction due to online project process management<br>CVP 5-> 6: Less requirements of rooftop conditions<br>VCA 5-> 6: Increased skilled workers; Cooperation with state enterprises, local banks and Huawei<br>SVP 4-> 5: Changing residents energy habits towards green energy; Promoting local 100 energy structure transformation; Promoting local economic; Promoting local employment<br>VCP 4-> 5: Different costs |
| 4   | 2020 | Requirements for online channels due to global pandemic                        | E.O Changing to 'SmartCloud' power station                              | VD 3-> 4: Online and WeChat applet (engaging in all project process)  |   |
| 5   | 2021 | Demand of market space 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)) |   |

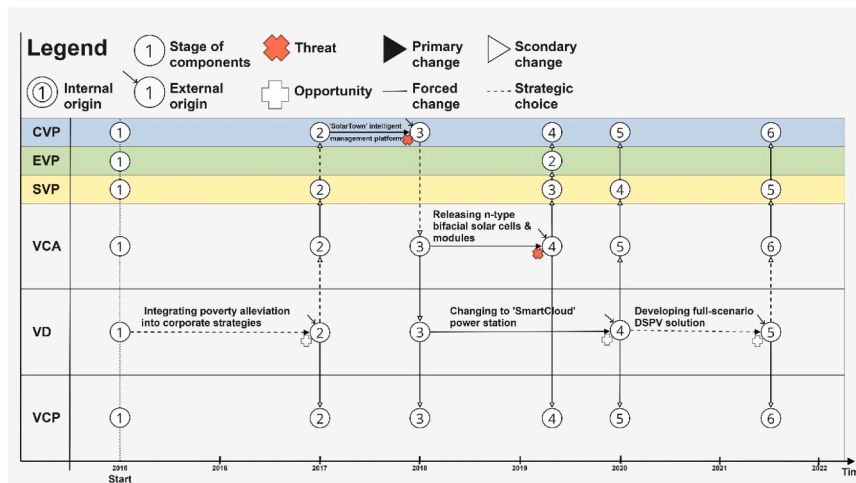


Fig. 4. SDBM framework of Company B.

Table 2 Major changes of Company C's SBM.

| No. | 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    | 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 105 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 incomes SVP 2-> 3: Use of idle roof; Enhancing interior comfort (by reducing indoor temperature) EVP 1-> 2: Carbon reduction VCA 4-> 5: Research institutions           |
| 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   | 2019.7  | 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 for global pandemic   | E.T Offering PV mounting solution                            | VCP 6-> 7: Increasing revenue from selling mounting                                 | 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      | 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: 106 Guangdong province and company buildings Reducing electricity costs; Revenue from excess electricity   |

of costs and revenue for Company D, the predominant portion of costs arises during the installation period, whereas project revenue is primarily derived from electricity fees. Throughout its operational history, Company D has experienced seven noteworthy changes in its BM, as outlined in Table 3 and visually represented in Figure 6.

4.1.5. The case of Company E

Founded in the mid-2010s, Company E is a specialized distributed energy company in China with a focus on promoting clean energy, primarily through Distributed Solar Photovoltaic (DSPV) power stations. The company offers tailored, comprehensive services for households and industrial and commercial customers, encompassing the entire project life cycle from pre-consultation and system design to installation and post-operation and maintenance. Throughout its development, Company E has undergone six significant changes, as depicted in Table 4 and illustrated in Figure 7.

4.2. Case study comparison

The five cases are further compared in a cross-case analysis using the SDBM framework to summarize the results.

4.2.1. Changes in sustainable business model values in case studies

Looking at the overall result of these case studies and their representations through the framework, several interesting patterns can be revealed. Table 5 outlines the alterations in the SBM across the four value components and highlights factors influencing these value changes derived from all case studies. These factors are classified based on the origin of these changes as internal or external as well as if it considered as a threat or an opportunity. Additionally, the table indicates the interrelationships between SBM elements in the case studies with the type of each relationship—forced or based on choice—indicated and displayed in the light grey section.

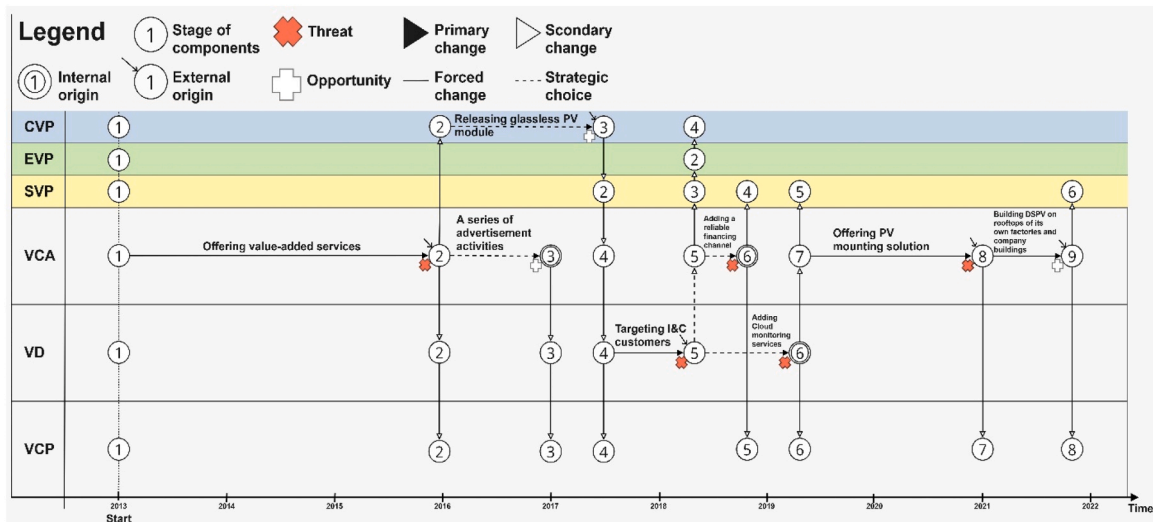


Fig. 5. SDBM framework of Company C.

Table 3 Major changes of Company D's SBM.

| No. | 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   | E.O Building DSPV for suppliers                               | VCA 2-> 3: Cooperation with suppliers in building DSPV projects                           | SVP 2-> 3: Promoting green supply chain 110 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-owned power companies | VCP 3-> 4: Revenue by equity transfer VD 2-> 3: Other DSPV developers; State-owned 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 bidding                    | 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                     | 6 VCP 5-> 6: Reducing labor costs in electricity settlement VCA 6-> 7: O&M technology cooperation with Zhejiang University EEPCC   |
| 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 |

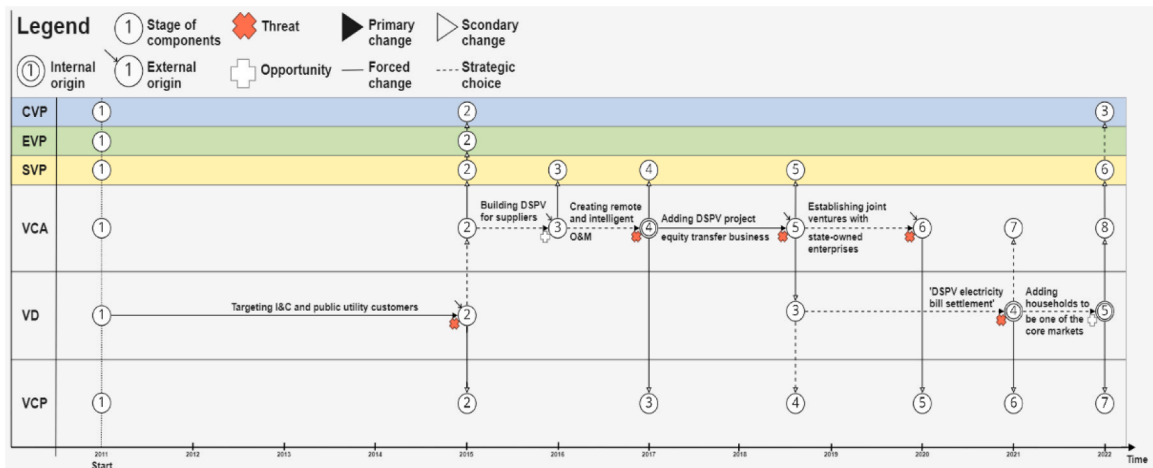


Fig. 6. SDBM framework of Company D.

**Table 4**  
Major changes of Company E's SBM.

| No. | Year | Origin   | Causing                                  | Primary effect   | Follow-up effect  |
|-----|------|--|--|--|---|
| 1   | 2014 | Lack of public perception toward DSPV                                | E.O Setting up solar PV experience shops | VD 1-> 2: Firsthand experiences of the system installation; Targeting local households | SVP 1-> 2: Educating inhabitants about solar energy; Promoting DSPV applications<br>CVA 1-> 2: DSPV knowledge popularization activities (e.g., public welfare lectures); Sales of PV products<br>CVP 1-> 2: Customized household DSPV solution<br>VD 2-> 3: Promoting brand awareness<br>VCP 1-> 2: Costs in advertising and promotion<br>SVP 2-> 3: Leading health market development  |
| 2   | 2016 | Increasing competition in household market                           | E.T Launching company household brand    | VCA 2-> 3: Brand reputation  | VCA 3-> 4: Cooperating with state grid e-commerce; VCP 2-> 3: Reducing labor costs<br>SVP 3-> 4: Promoting DSPV e-commerce<br>CVA 4-> 5: Advertisement; Free system inspections; O&M activities<br>VCP 3-> 4: Costs in product and service promotion; O&M costs<br>CVP 3-> 4: Reducing electricity costs; Customer income from selling the excess electricity<br>VCP 4-> 5: Different value capture<br>EVP 1-> 2: Reducing GHG emissions<br>SVP 4-> 5: Accelerating energy structure transition |
| 3   | 2017 | 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 labor costs<br>SVP 3-> 4: Promoting DSPV e-commerce<br>CVA 4-> 5: Advertisement; Free system inspections; O&M activities<br>VCP 3-> 4: Costs in product and service promotion; O&M costs<br>CVP 3-> 4: Reducing electricity costs; Customer income from selling the excess electricity<br>VCP 4-> 5: Different value capture<br>EVP 1-> 2: Reducing GHG emissions<br>SVP 4-> 5: Accelerating energy structure transition |
| 4   | 2018 | Customer-centric company strategy                                    | I.O Launching "Golden Butler" solution   | CVP 2-> 3: Full process services   | VCA 3-> 4: Cooperating with state grid e-commerce; VCP 2-> 3: Reducing labor costs<br>SVP 3-> 4: Promoting DSPV e-commerce<br>CVA 4-> 5: Advertisement; Free system inspections; O&M activities<br>VCP 3-> 4: Costs in product and service promotion; O&M costs<br>CVP 3-> 4: Reducing electricity costs; Customer income from selling the excess electricity<br>VCP 4-> 5: Different value capture<br>EVP 1-> 2: Reducing GHG emissions<br>SVP 4-> 5: Accelerating energy structure transition |
| 5   | 2018 | Effects of China's 531 policy  | E.T Targeting C&I customers              | VD 4-> 5: I&C customers  | VCA 3-> 4: Cooperating with state grid e-commerce; VCP 2-> 3: Reducing labor costs<br>SVP 3-> 4: Promoting DSPV e-commerce<br>CVA 4-> 5: Advertisement; Free system inspections; O&M activities<br>VCP 3-> 4: Costs in product and service promotion; O&M costs<br>CVP 3-> 4: Reducing electricity costs; Customer income from selling the excess electricity<br>VCP 4-> 5: Different value capture<br>EVP 1-> 2: Reducing GHG emissions<br>SVP 4-> 5: Accelerating energy structure transition |
| 6   | 2021 | Demand driven by the whole county (city, district) roof DSPV program | E.O Launching 'household solution        | CVP 4-> 5: No upfront investment; More income  | CVA 5-> 6: Cooperation with local banks<br>SVP 5-> 6: 116 Old-age care  |

4.2.2. Interrelationships between sustainable business model elements

Due to the inclusion of additional elements in the SBM in terms of social and environmental value proposition, the interrelationships between BM elements have become more intricate. To analyze the effects of a change in one element on another element in the case study, Figure 8 and Table 5 comprehensively illustrate and document these interrelationships. Each pair of elements is represented by a line with arrows, indicating the type of relationships involved, along with the quantity of relationships for each type. The arrow extends from the element undergoing primary change to the element undergoing secondary change influenced by the primary element.

The analysis in Figure 8 reveals several noteworthy findings. Firstly, changes in one element do not consistently result in changes in another element. A specific observation pertains to the relationship between environmental, social, and customer value propositions (EVP, SVP, CVP). The primary changes in CVP tend to induce secondary changes in SVP, with no reverse cases observed. This aligns with the qualitative data presented in Table 5, where most environmental and social benefits stem from primary changes in value creation or value delivery. In essence, EVP and SVP are typically secondary changes resulting from adjustments in business activities, patterns, customer segments, and the implementation of channels for material retrieval and after-sales operations and maintenance services. When both EVP and SVP undergo simultaneous changes, benefits to the environment and society are generally achieved concurrently. Additionally, the analysis highlights a distinctive aspect concerning value capture (VCP). Unlike other elements, VCP is not typically the initial change; rather, it primarily results from changes in other elements. However, this finding does not necessarily imply that value capture cannot influence other BM elements. It simply suggests that such instances are less likely in the context of the case study. This observation aligns with the conceptual framework in the literature review, indicating that value capture may not be the primary driver of changes in other BM elements within the scope of the case study.

The second key finding is that changes in other elements due to alterations in value delivery (VD) play a predominant role in the interrelationships within the case study. This is followed by value creation (VCA), with CVP coming next. Subsequent effects induced by EVP and SVP are notably less frequent. The impact on SBM elements is primarily driven by changes in value creation at first, but subsequent changes resulting from adjustments in value delivery are the most prominent. This observation can be attributed to the sub-elements of VD, including customer segments, customer relationships, and channels. Changes in these sub-elements, such as incorporating material recycling channels, targeting industrial and commercial customers, and establishing channels for after-sales services, have cascading effects on related partnerships, company resources, business activities, relevant costs and revenues, and may bring about changes in CVP, EVP, and/or SVP. It is essential to note that while VD is a critical element in the evolution of SBMs over time, it does not imply that other SBM elements are less important.

Furthermore, the analysis indicates that VCP is primarily a subsequent effect of initial changes. This understanding suggests that costs and revenues are closely related to company business throughout the project period, from early-stage site investigation to post-installation operation and maintenance. Changes in costs and revenues associated with technology improvement, waste material disposal, labor, advertisement activities, transportation, value-added services, additional business, and project management system optimization evolve over time, with the effects on VCP generally being forced either due to pressure from other element changes or for business consistency.

Lastly, the examination of forced change or strategic choice in the interrelationships between SBM elements reveals that the most common type is CF (see Table 6). This implies that initial changes to elements, driven by companies' strategic decisions, lead to forced changes in other elements in most cases. This, coupled with the occurrence of type CC,

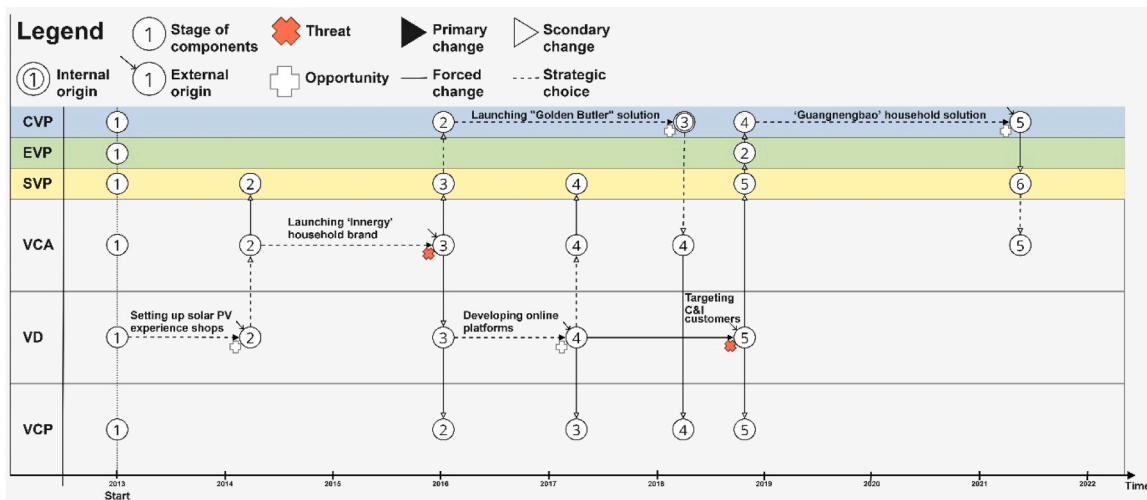


Fig. 7. SDBM framework of Company E.

indicates that companies in the case study tend to actively develop strategies to respond to internal and external opportunities or threats, rather than passively adjusting their BMs. Moreover, most secondary changes are forced changes, irrespective of the types of primary changes. This suggests that follow-up changes in the case study, subsequent to the initial changes, are predominantly forced responses aimed at facilitating business activities smoothly and effectively.

4.2.3. Important internal and external triggers in the case studies

The thorough exploration of external and internal factors provides valuable insights into the complex landscape of the PV industry in China and the dynamic interactions that drive SBM changes. The analysis of the cases highlights the presence of various external and internal factors as well as different triggers that play pivotal roles in driving value changes in SBMs. Firstly, it is evident that external factors play a predominant role in driving most BM changes in the case studies. Secondly, the most crucial factors driving changes in SBMs are identified as customer requirements or demand, closely followed by the influence of industrial policy and regulations. Despite the significant impact of policy incentives in China's PV industry, the case studies reveal a trend where companies adjust their BMs in response to customer preferences and needs. The central focus for PV companies remains on providing efficient energy solutions and services tailored to customer expectations. Market competition and technology innovation are also recognized as pivotal triggers for changes in SBMs. The rise in competitors entering the PV business contributes to market competition, while both internal technological innovation within companies and external industrial advancements are seen as opportunities. These innovations directly enable the case companies to offer enhanced CVP.

Among the external policy-related factors, specific policies such as China's 531 policy, the poverty alleviation national strategy, and the nationwide DSPV program are highlighted as common influences affecting or promoting changes in China's PV BM. For example, the 531 policy significantly impacted the DSPV power generation capacity in 2018 and reduced subsidies for certain DSPV projects. While this led to a short-term downturn in the PV business with downstream effects on costs and revenues, it also prompted changes in customer behavior, attracting commercial and industrial customers due to the decrease in system costs. In response to diminishing subsidies and the push for grid parity, developers in the case studies expressed the belief that embracing grid parity would be beneficial in creating an active investment environment for the entire industry.

The global pandemic has emerged as a significant external environmental factor impacting the SBMs of PV companies, presenting both opportunities and threats. On the one hand, increased system

component prices and transportation costs, driven by high demand and low supply, pose threats to companies solely engaged in the engineering, procurement, and construction business, leading to a decrease in project revenue. On the other hand, companies have seized the opportunity to adapt and transform their BMs to digital forms, capitalizing on the shift towards online engagement to avoid human contact. This shift has implications for both VD and VCA in the SBMs.

Company B, for example, has effectively utilized online channels to encompass all project processes, thereby enhancing value delivery through digital platforms. Company C, on the other hand, has adapted its approach by manufacturing its PV mounting components instead of outsourcing, directly entering the market to sell these components. In response to the challenges posed by the pandemic, Company D has strategically established joint ventures with state-owned enterprises to undertake projects, ensuring project capital and avoiding bidding costs.

Two additional external factors, namely local policy incentives for PV company social responsibility, present opportunities for companies. These factors have the potential to positively impact VCA. Company C, for instance, has aligned with local policy incentives by installing DSPV on its own factories and company buildings. Company D has collaborated with upstream suppliers, implementing PV projects on their factories and office building rooftops.

Internally, the most influential factors identified in the case studies are related to the project management system, including Operations and Maintenance software. This internal factor can be both a threat and an opportunity for companies, depending on their specific situations. Three out of five companies have altered their BMs in response to different requirements of the project management system. Company A, for instance, has designed a short-term plan for delivering smart PV energy solutions, turning the project management system into an opportunity to achieve the enterprise's goals. However, for other companies, the project management system poses threats, necessitating efficient solutions to address labor costs and risks associated with manual work, especially in the context of increasing DSPV projects.

Personnel capability, particularly the shortage of skilled employees, is identified as a potential threat, especially for companies experiencing rapid growth in the DSPV business. Responses to this factor, such as providing employee training and learning platforms, have directly contributed to social value propositions (SVP).

5. Conclusion and discussion

By combining insights from literature on SBM and BM dynamic, this paper presents a comprehensive framework that conceptualizes SBM dynamics. The proposed framework was built on the SBM framework by

**Table 5**  
Changes to SBM in case studies.

| Origin of change   | Internal (I)/ External (E) Opportunity (O)/Threat(T) | Interrelationships between BM elements | Forced changes (F) or strategic Choices (C) |
|--|--|--|---|
| Regulatory requirements (industrial)                     | E.O->VD  | VD->VCP/EVP/SVP/VCA                    | FF  |
| Outsourcing of activities                                | I.T->VCA   | VCA->VCP                               | CF  |
| Project management system                                | I.O->CVP/SVP/EVP                                     | CVP/SVP/EVP->VD/VCA/VCP                | CC/CF                                       |
| Company technology innovation                            | I.O->CVP   | CVP->VD/VCA/VCP                        | CF  |
| Personnel capability                                     | I.T->SVP   | SVP->VCA                               | CF  |
| Market competition                                       | E.T->CVP   | CVP->VCA/VCP                           | FF  |
| Industry technology innovation                           | E.O->CVP   | CVP->VCA/VD/VCP                        | FF  |
| Environmental pledges (company)                          | I.O->VCA   | VCA->EVP/SVP                           | CF  |
| Social & environmental value creation targets (national) | E.O->VD  | VD->CVP/SVP/VCA/VCP                    | CF/CC                                       |
| Customer requirement                                     | E.T->CVP   | CVP->VCA/VD/VCP                        | FC/FF                                       |
| Industrial policy  | E.T->VCA   | VCA->CVP/EVP/SVP/VCP                   | FF  |
| Global pandemic  | E.O->VD  | VD->CVP/SVP/VCA/VCP                    | FF  |
| Customer demand  | E.O->VD  | VD->CVP/VCA/SVP/VCP                    | CF/CC                                       |
| Market competition                                       | E.T->VCA   | VCA->CVP/VD/VCP                        | FF  |
| Brand reputation   | I.O->VCA   | VCA->VCP/VD                            | CF  |
| Industry technology innovation                           | E.O->CVP   | CVP->VD/VCA/VCP/SVP                    | CF  |
| Industrial policy  | E.T->VD  | VD->CVP/SVP/EVP/VCA                    | FC/FF                                       |
| Financial channel  | I.T->VCA   | VCA->VCP/SVP                           | CF  |
| Project management system                                | I.T->VD  | VD->VCA/VCP/SVP                        | CF  |
| Global pandemic  | E.T->VCA   | VCA->VCP                               | FF  |
| Local policy   | E.O->VCA   | VCA->SVP/VCP                           | FF  |
| Industrial policy  | E.T->VD  | VD->CVP/EVP/SVP/CVA                    | FC/FF                                       |
| Social responsibility (industrial)                       | E.O->VCA   | VCA->SVP                               | CF  |
| Project management system                                | I.T->VCA   | VCA->VCP/SVP                           | CF  |
| Industrial policy  | E.T->VCA   | VCA->VCP/VD/SVP                        | FF/FC                                       |
| Global pandemic  | E.T->VCA   | VCA->VCP                               | CF  |
| Project management system                                | I.T->VD  | VD->VCP/VCA                            | CC/CF                                       |
| Customer demand  | I.O->VD  | VD->CVP/VCA/SVP                        | CC/CF                                       |
| Public perception  | E.O->VD  | VD->SVP/CVA                            | CC/CF                                       |
| Market competition                                       | E.T->VCA   | VCA->CVP/SVP/VD/VCP                    | CC/CF                                       |
| Customer requirement                                     | E.T->VD  | VD->VCA/VCP/SVP                        | CC/CF                                       |
| Customer demand  | I.O->CVP   | CVP->CVA/VCP                           | CC/CF                                       |
| Industrial policy  | E.T->VD  | VD->CVP/EVP/SVP/VCP                    | FF  |
| Customer demand  | E.O->CVP   | CVP->CVA/SVP                           | CC/CF                                       |

Bocken et al. (2018) which suits the PV companies as BMs are covering sustainable value and regard the environment and society as primary stakeholders (Geissdoerfer et al., 2018), and the previous dynamic BM framework (Kamp et al., 2021) which was built based on BM dynamics framework criteria of completeness, interrelationship and changes over time (Khodaei and Ortt, 2019).

The study has several scientific contributions. First, our study contributes to the stream of research that trace sustainability-oriented companies through the process of value proposition, value creation, value delivery, and value capture to combine profit orientation with social and environmental purposes through SBM (Snihur and Bocken, 2022; Bocken and Geradts, 2020; Snihur and Markman, 2023; Davies and Doherty, 2019 and Esau et al., 2025).

Second, our study presents a comprehensive framework that conceptualizes SBM dynamics. The SDBM framework considers different external factors that lead to changes in values of sustainable BM during the sustainability-oriented company development process. It contributes to the literature on exploring business model antecedents (Foss and Saebi, 2017) by identifying that both threats and opportunities influence companies to change their business models (Saebi et al., 2017). The proposed framework advances existing theories of business model evolution by analyzing origin of change and subsequent changes of business model elements through company development process to keep the business model consistent (Baden-Fuller and Morgan, 2010; Casadesu and Ricart, 2011).

Finally, the proposed framework provides entrepreneurs, managers, and public policy makers with a simplified tool to better understand the origins and types of changes in BMs, compare cases and get more insights. It can also help in consistently illustrating, comparing and analyzing data regarding the origins and types of changes in BMs in a graphical manner, which allows for more effective information transfer. This enables researchers to test hypotheses that are related to BM dynamics more easily and more rapidly than through textual description.

The SDBM framework describes the explorative multiple-case analysis of different PV companies' SBM. The study has shown how the data from multiple case studies can be combined in a cross-case analysis. A company's BM undergoes constant changes due to the interplay of environmental and business variables, responding to external and internal opportunities and threats (Saebi et al., 2017). This is in line with the notion of open business models (Chesbrough, 2006) as 'the desirable end state of firm transformation' where firms collaborate with the ecosystem by building up value and innovate their business model to make use of emerging opportunities (Weible, 2014). In line with previous studies (e.g., Guckenbiehl, and Corral de Zubielqui, 2022), the COVID-19 pandemic was one of the external factors that led to BM changes and was considered both an opportunity and a threat. Understanding these variables is crucial for comprehending SBM dynamics. PV companies' SBM dynamics can be triggered by changes in external factors (such as policy and regulation, industrial technology innovation, customer demand, market competition, etc.) and internal factors (including company technology improvement, project management, personnel capability, etc.). However, PV companies respond differently to these variables based on their capabilities and the external business environment, guided by their recognition of opportunities or threats.

Regarding external factors, the findings highlight that changes in BMs driven by customer requirements or demand are the most critical factors. Customer feedback and market trigger companies to continuously align their value propositions with evolving consumer needs, market shifts, and competitive pressures (Da Luz Peralta et al., 2020; Sanasi et al., 2020). Previous studies discussed the different active business model-building processes through the customer and user open innovation-based business model developing circle (Yun et al., 2016; Yun, 2017).

Additionally, industrial policy, regulation, market competition, and technology innovation also prove to be important, acting as triggers for changes in SBMs. This is aligned with previous literature focused on

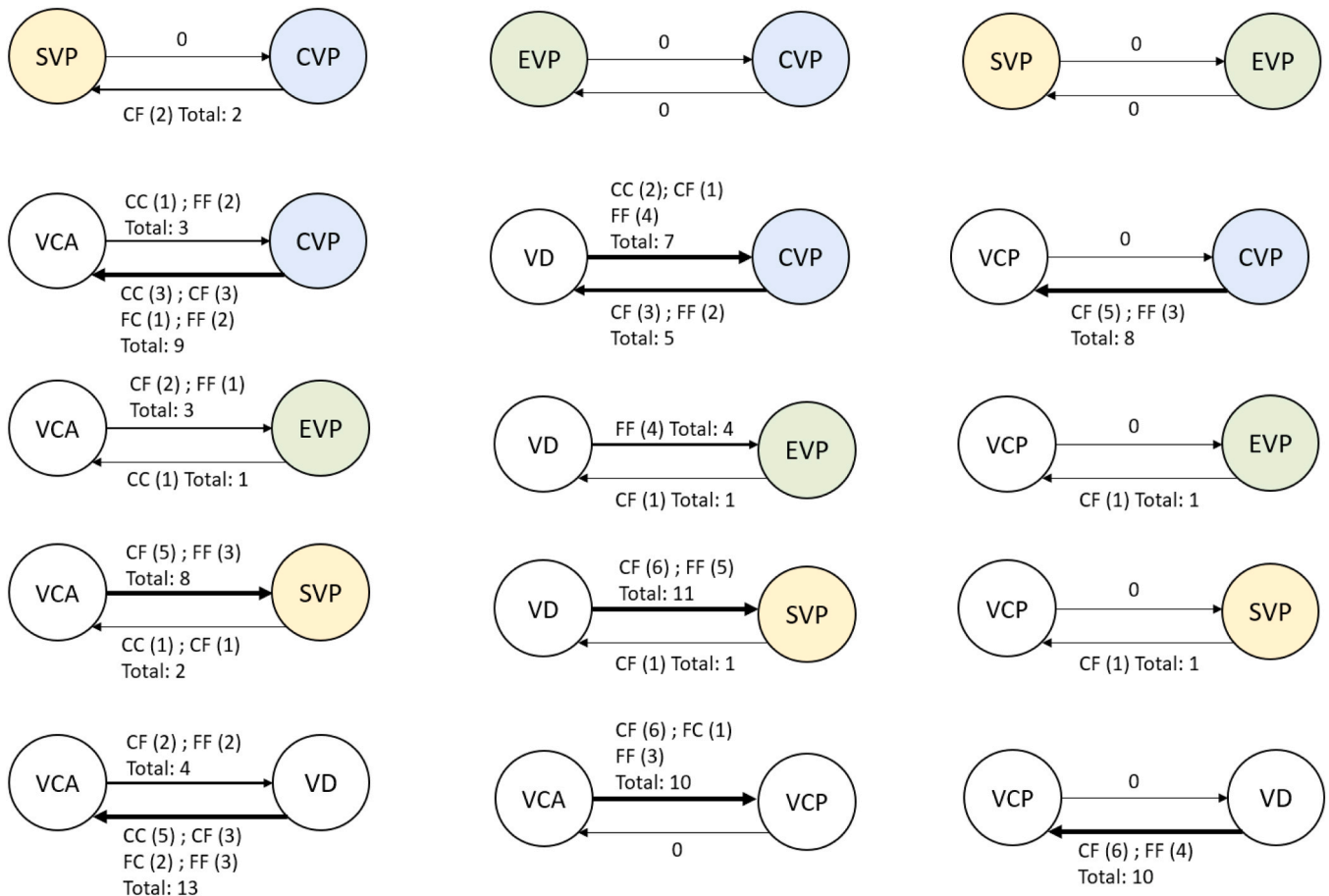


Fig. 8. Interrelations between SBM elements in the case studies (Bold line: more relationships between elements; thin line: less or no relationships between elements).

policy and regulatory factors shaping SBM (Kuckertz et al., 2019; Hoang and Böckel, 2024) as well as impact of digitalization on the development of sustainability-oriented innovative BMs (Acciarini et al., 2022; Böttcher et al., 2024). In addition to external factors, the most impactful internal factors in the case study are associated with the project management system. Other internal factors encompass a diverse range, including finance, personnel, operational activities, brand reputation, environmental and social responsibility, and technology improvement. In addition to exploring the relationships between environmental variables and business elements, the interrelationships among BM elements are unveiled, fulfilling the second criterion.

The other BM dynamics criterion, the changes over time, aligns with the development of the dynamic sustainable BM in this study. It is observed that environmental value propositions (EVP) and social value propositions (SVP) typically constitute secondary changes resulting from adjustments in business activities, patterns, customer segments, and the implementation of channels for material retrieval and after-sales services. The subsequent effects induced by initial changes in EVP or SVP are notably less significant than in other elements. Moreover, value capture (VCP) is predominantly a consequence of changes in other elements; in other words, VCP is primarily the subsequent effect of initial changes. Additionally, changes in other components due to alterations in value delivery (VD) dominate the interrelationships in the case study, followed by value creation (VCA) and then customer value propositions (CVP). This is consistent with a previous study suggesting that offerings and markets should align with a specific benefit provided, as evident in the value creation architecture, and finally, cost and revenue structures are named as resulting elements of value creation and proposition (Demil and Lecocq, 2010).

Notably, the most prevalent type of interrelationship in the case study is CF, indicating that initial changes to elements attributed to companies' strategic decisions lead to forced changes in other SBM elements. Meanwhile, changes within BM elements tend to be coherent and interlinked over time. A modification in one element of the BM typically induces changes in one or more other elements to ensure overall consistency, as highlighted by Kranich and Wald (2018). Demil and Lecocq (2010) also emphasize that alterations made to one component within a system can have repercussions, influencing other interconnected components. This underscores the interconnected and interdependent nature of BM elements, where adjustments in one part can cascade and affect the entire system. To capture BM dynamic, associated BM elements are supposed to be in line with a changed BM element. In this process, these changes can either create or capture value for stakeholders, including customers, society, and the environment.

### 5.1. Practical implications

SBM dynamics are crucial for companies operating in uncertain environments, especially sustainability-oriented companies such as PV. Companies in this industry can adapt and innovate their BMs to navigate the intricate and ever-changing landscape. Besides, integrating sustainability into their BM is essential, given the growing environmental awareness across society. A dynamic BM framework allows for companies to analyse the main changes that are required to envision potential value logic sequences of or changes in BMs over time. By identifying the main changes in the context, it is also possible to assess the ongoing changes and constantly monitor whether business model changes are required or not. This is far more useful than re-doing the

**Table 6**  
Changes in SBM of case studies.

| Primary change (occurrence) | Secondary change | Type (occurrence)              | Total                                  |
|-----------------------------|------------------|--------------------------------|--|
| CVP (8)                     | CVP->EVP         | (0)                            | CVP-                                   |
|                             | CVP->SVP         | CF (2)                         | >others:                               |
|                             | CVP->VCA         | CC (3); CF (3); FC (1); FF (2) | 24Others-<br>>CVP: 10                  |
|                             | CVP->VD          | CF (3); FF (2)                 | 13CF:<br>49FC:<br>4FF: 38              |
|                             | CVP->VCP         | CF (5); FF (3)                 | 8                                      |
| EVP (1)                     | EVP->CVP         | (0)                            | EVP-                                   |
|                             | EVP->SVP         | (0)                            | >others:                               |
|                             | EVP->VCA         | CC (1)                         | 3Others-                               |
|                             | EVP->VD          | CF (1)                         | >EVP: 7                                |
|                             | EVP->VCP         | CF (1)                         | 1                                      |
| SVP (2)                     | SVP->CVP         | (0)                            | SVP-                                   |
|                             | SVP->EVP         | (0)                            | >others:                               |
|                             | SVP->VCA         | CC (1); CF (1)                 | 4Others-                               |
|                             | SVP->VD          | CF (1)                         | >SVP: 21                               |
| VCA (13)                    | SVP->VCP         | CF (1)                         | 1                                      |
|                             | VCA->CVP         | CC (1); FF (2)                 | 3 VCA-                                 |
|                             | VCA->EVP         | CF (2); FF (1)                 | >others: 28                            |
|                             | VCA->SVP         | CF (5); FF (3)                 | 8 Others-                              |
|                             | VCA->VD          | CF (2); FF (2)                 | 4 >VCA: 25                             |
| VD (12)                     | VCA->VCP         | CF (6); FC (1); FF (3)         | 10                                     |
|                             | VD->CVP          | CC (2); CF (1); FF (4)         | 7 VD->others:<br>45 Others-<br>>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                                     |
| VCP (0)                     | VD->VCP          | CF (6); FF (4)                 | 10                                     |
|                             | VCP->CVP         | (0)                            | VCP->other:                            |
|                             | VCP->EVP         | (0)                            | 0Others-                               |
|                             | VCP->SVP         | (0)                            | >VCP: 30                               |
|                             | VCP->VCA         | (0)                            |  |
| VCP->VD                     | (0)              |                                |  |

same type of analysis over time with a static BM framework to see whether a new BM is required (Khodaei ad Ortt, 2019). This is particular the case for sustainability-oriented companies where the challenges are rarely isolated product or process improvements. They often involve interdependent expectations across supply chains, regulatory regimes, customer practices, and social norms, forcing coordinated changes across BM dimensions (Bocken and Geradts, 2020; Coffay et al., 2024).

The SDBM framework is designed to encapsulate the BM evolution occurring within a company, encompassing sustainability-oriented value changes in response to internal and external environmental factors. In the case of Chinese companies in the solar photovoltaic industry are in the early stages of incorporating sustainability into their business practices and it was evident that policies will continue to be a key driver in encouraging changes to BMs. Policymakers are actively exploring innovative approaches to regulate markets and provide incentives for sustainable BMs, aiming to establish the groundwork for a transition toward a more inclusive and sustainable society (Mazzucato, 2015).

This necessitates adjustments to system design, installation, operation, maintenance, activities and BM, The case study findings highlight that the most crucial factor propelling BM innovation is the evolution in customer demand and requirements. This implies that DSPV developers must modify their BMs to include entities such as governments, schools, hospitals, and train stations in their customer segments. Developers of DSPV systems must prioritize the delivery of efficient and cost-effective products and services to align with customer needs. Furthermore, companies should invest resources in after-sales services, transforming support services into a strategic element that not only enhances customer satisfaction but also fosters brand loyalty and diversifies revenue streams. From a research standpoint, the identification of the target customer plays a central role in shaping a BM.

Furthermore, PV firms should forge stable partnerships with state-

owned enterprises, banks, and financial institutions to diversify financing channels for loans and ensure steady investment returns. Collaboration with governmental entities is also crucial for fostering an appealing investment climate and advancing subsidy-free PV development. Given the miniaturization and decentralization of DSPV, establishing relationships with grid companies is indispensable. Lastly, shifts in company competencies, entrepreneurial capability, and growth strategies may serve as catalysts for SBM under specific circumstances. PV companies ought to consistently refine their management systems for enduring sustainable development.

For founders, the framework helps diagnose the points to where coordinated BM change is needed across value proposition, creation, delivery, and capture They can proactively shape their strategies and operations by staying attentive to changes in the political, economic, social, technological, environmental, and legal landscape. Through a close examination of how these changes impact the startup's immediate market environment, entrepreneurs can foresee both opportunities and threats. This foresight equips entrepreneurs to make well-informed adjustments to their approach and operations promptly.

The SDBM framework is designed to encapsulate the SBM evolution occurring within a company, encompassing sustainability-oriented value changes in response to internal and external environmental factors. The framework aims to provide a comprehensive understanding of how SBMs adapt and respond to the dynamic interplay between organizational shifts and changes in the external business environment.

### 5.2. Limitations and future research

The dynamics of BMs encompass unfolding activities over time. Our framework is crafted to precisely capture specific changes in the structure of the SDBM. Further research is crucial to determine how additional aspects of the complex reality should be incorporated into a dynamic BM framework, striking a balance between increased realism for higher validity and simplification for usability and an overarching view (Kamp et al., 2021).

In future research, the framework can be applied to other sustainability-oriented companies for improvement. Regarding the three types of value propositions, future studies can explore the trade-offs in achieving economic, social, and ecological values. While this study primarily explores macroeconomic factors, future studies can benefit from micro-level factors that drive SBM changes. Exploring the aspirations, motivations, and goals of individuals involved in value-oriented SBM (Spence et al., 2011; Hoogendoorn et al., 2019), as well as the competencies and skills necessary for success in this field (Kuckertz and Wagner, 2010; Shepherd and Patzelt, 2011), can offer valuable insights into driving value-oriented sustainable entrepreneurship and how their values change over time.

Our decision to focus on key overarching components of the BM is aimed at illustrating and explaining sustainable BM dynamics while limiting complexity. However, future research can enhance the framework by distinguishing more elements within a BM and categorizing various internal elements influencing changes. Our qualitative study is vulnerable to generalizability challenges. We focused on companies located in China. While focusing on Chinese companies as global leaders in PV, this reduces sample variation in terms of the external factors such as sociopolitical factors and other country effects (Zott and Huy, 2007). Future studies should investigate whether similar results would emerge in other countries.

Additionally, there is potential for future studies to benefit from more longitudinal examinations of companies, expanding the analysis through the exploration of diverse case studies across different industries and countries.

### Ethical Statement/ Informed Consent Statement

Informed consent was obtained from all subjects involved in the

study.

## Funding

This work was not supported by any particular grant or fund.

## Ethical statement

This study is based on a previously published MSc thesis and did not involve any new primary data collection. As such, this study did not require review or approval by the Human Research Ethics Committee (HREC) of Delft University of Technology. For the original thesis, all interview participants were recruited voluntarily and provided informed consent prior to participation. Participants were assured of confidentiality, and no personally identifiable information was collected. The data were used solely for academic research purposes.

## CRedit authorship contribution statement

**Hanieh Khodaei:** Conceptualization, Visualization, Methodology, Writing – original draft, Writing – review & editing, Supervision. **Kamp, Linda:** Methodology, Writing – original draft, Writing – review & editing, Supervision. **Xiaojing Xu:** Conceptualization, Methodology, Investigation, Formal analysis, Validation, Writing – original draft, Visualization.

## Declaration of Generative AI and AI-assisted technologies in the writing process

Not applicable

## Declaration of Competing Interest

This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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