Sustainable Business Model Dynamics of Technology-based Start-Ups

The role of external factors in the Dutch PV sector

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by

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Executive summary

Solar photovoltaic (PV) systems have become a vital form of renewable energy, driven by global efforts to transition to cleaner sources. New forms of PV energy are brought into the world by numerous start-ups. However, many start-ups in the PV industry struggle to achieve long-term success, facing challenges such as limited financial resources, difficulties in attracting and retaining employees, and inadequate entrepreneurial mindset.

Understanding business model dynamics is crucial for start-ups operating in a dynamic and uncertain environment. Effective business models aligned with strategic goals and external conditions can lead to higher survival rates and performance. This thesis explores how external factors, such as market competition, policies, or technological developments, influence the business model dynamics of Dutch technology-based PV start-ups and how these external factors differ during the different development phases of these start-ups.

The study employs a dynamic sustainable business model framework to uncover the influence of external factors on business model dynamics. The framework includes business model elements such as value proposition, value creation, value delivery, and value capture. External factors are categorised as political, economic, social, technological, environmental, and legal factors.

To address the research questions, this thesis utilizes a literature review, case studies, and content analysis. It is found that business model dynamics in technology-based start-ups involve four types of changes: creation, extension, revision, and termination (Cavalcante et al., 2011).

Further, business model innovation is a form of business model dynamics that encompasses the evolutionary nature of business models over time. External factors, such as policy changes, changes in economic and business environment, and new technologies play an essential role in driving business model innovation.

Moreover, business model dynamics involve changes in the interrelationships between the four business model elements (value proposition, value creation, value delivery, and value capture). In the case studies the value delivery element is commonly subjected to secondary changes (or follow-up changes), while value creation and value capture are the most dominant elements influencing other elements. Most of these interrelationships are strategic decisions as a primary change, followed by a forced change (type SF, also see Table 3.5).

External factors are identified as significant drivers of business model dynamics, with approximately two-thirds of business model changes originating from external factors in the case studies. In the initial phases of the start-ups, technological and social factors have a substantial impact, influencing the value proposition through ‘emerging technologies’, considering ‘social needs’, and evolving ‘customer preferences’. Technological factors also affect the value creation through opportunities for ‘resource efficiency’. This helps start-ups to overcome the first development phases and overcome their first challenges.

During the early development phases (pre-organization phase), economic and political factors, with ‘subsidies’ and ‘supportive financial resource availability’, have a significant impact on how value is captured. These factors appear most often and are most influential to the business model dynamic of Dutch technology-based PV start-ups. Although this does not result in overcoming growth barriers, it does result in the economic viability of the firms.

While the impact of legal and environmental factors is relatively limited, they do play a role in specific phases of the start-up’s growth journey. Legal factors become more prominent as start-ups focus on securing legal protection and compliance while entering the market. This is done by using patents and certifications. Environmental factors are less influential overall, but their occurrence in the value delivery and value capture element highlights their potential impact.

Overall, the research findings demonstrate that external factors exert a substantial influence on the business model dynamics of Dutch technology-based PV start-ups. Understanding and adapting to these external influences is essential for the sustained success of these start-ups, emphasizing the need for strategic responsiveness and alignment with the evolving external environment.

It also shows (in section 7.1) that the findings of this thesis are not limited to Dutch technology-based PV start-ups but can also be applicable to start-ups in the renewable energy sector, or even start-ups in general.

Lastly, this thesis has both practical implications as it contributes academically. For the practical implication, it emphasises the importance of continuously assessing and monitoring external factors that can impact business models. In the early phases, start-ups should look for opportunities in social and technological factors to meet social needs and enhance resource efficiency. In later phases maximizing the value capture by leveraging political and economic factors, capitalizing on subsidies and financial supportive systems.

It also contributes academically by expanding on the existing literature on business model dynamics and its relationship with external factors. It shows the importance of external factors in business model dynamics. Further, the research identifies and categorizes external factors driving business model changes, providing valuable insight into the influences that start-ups need to consider when designing and adapting their business model.

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Nomenclature

Abbreviations

Abbreviation	Meaning
BM	Business model
BMC	Business model canvas
BMD	Business model dynamics
BMF	Business model framework
BMI	Business model innovation
FF	Forced - forced
FS	Forced - Strategic
ISA	International Standard Atmosphere
PV	Photovoltaic
SBMC	Sustainable business model canvas
SF	Strategic - forced
SS	Strategic - Strategic
VCA	Value capture
VCP	Value capture
VD	Value Delivery
VP	Value proposition

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Introduction

Solar photovoltaic (PV) systems have become one of the most important forms of renewable energy in the global energy mix. The growth of the PV sector has been significant in recent years with an astounding 22% from 2020 to 2021 (IEA, 2022), driven by the increasing demand for clean and sustainable energy. The utilization of PV systems to generate electricity is becoming increasingly popular as it represents a cost-effective (IEA, 2022) and sustainable alternative to traditional fossil fuel-based power generation.

The PV industry has a strong focus on sustainability and environmental impact, aligning with the broader societal push for cleaner energy. This push can be seen in several international agreements suggesting the need for cleaner energy. Such agreements are the Paris Agreement which aims to limit global warming to well below two degrees Celsius above pre-industrial levels (Paris Agreement, 2015), the European Union's Renewable Energy Directive which sets targets to increase the share of renewable energy in the overall energy mix of the EU and reduce greenhouse gas emissions (European Commission, 2018), and the Clean Energy for All Europeans package which is a package of legislation that aims to accelerate the energy transition towards a clean energy system (Commission, 2019).

PV start-ups play a pivotal role in driving innovation and facilitating the energy transition. These emerging companies introduce novel ideas and technologies, explore innovative approaches for revenue generation, and identify new applications for existing technologies. Consequently, they disrupt traditional industry players and create new growth opportunities (Schumpeter & Backhaus, 2003; Storm, 2020). The innovations introduced by these start-ups can lead to more efficient and cost-effective PV systems, aligning with the societal and governmental impetus to transition to sustainable energy sources. Additionally, PV start-ups have the potential to stimulate job creation and contribute to economic development in the regions where they operate (Schumpeter & Backhaus, 2003; Storm, 2020).

Nevertheless, many start-ups face significant challenges and struggle to achieve long-term success (Komi et al., 2015). According to Audretsch et al. (2000), the survival rate of start-ups in the Netherlands is approximately 85% for the first two years and drops to around 45% for the first ten years. Given the low survival rate of start-ups, several studies have investigated the factors influencing business survival (Coad et al., 2016; Gimmon & Levie, 2010; Gompers & Lerner, 2001; Naldi et al., 2007; Shane, 2000).

Numerous obstacles must be overcome for a start-up to achieve success. These obstacles encompass challenges such as limited financial resources, difficulties in attracting and retaining employees, and the absence of a suitable entrepreneurial mindset (Baum & Locke, 2004; van Praag & Versloot, 2007). Alternatively, a lack of demand for innovative start-up ideas and a team lacking the necessary qualifications to manage a business can hinder success (Audretsch & Keilbach, 2004)).

Scholars have emphasized the link between company performance and business model dynamics (BMD). BMD refers to "revising and adapting a firm's business model in response to changes in the business environment, customer preferences, or competitive threats" (Chesbrough & Rosenbloom, 2002). It enables companies to effectively commercialize technological innovations (Chesbrough & Rosenbloom, 2002) and establish a competitive advantage while attaining sustained performance (Teece,

2010). Understanding BMD is particularly crucial for start-ups operating in dynamic and turbulent environments characterized by constant change and uncertainty, as they must adapt and modify their business models to survive and thrive (Demil & Lecocq, 2010; Loch et al., 2008; Mitchell & Coles, 2003a; Trimi & Berbegal-Mirabent, 2012).

Developing an effective business model necessitates a comprehensive understanding of how business models interact with external factors (Teece, 2010). Alignment between a firm's business model, strategic goals, and external conditions, along with the ability to adapt the business model to changing external circumstances, is integral to achieving effectiveness (Casadesus-Masanell & Ricart, 2010; Demil & Lecocq, 2010).

Given the societal imperative for clean energy from the PV sector and the persistently low survival rate of start-ups, comprehending the external factors influencing business model dynamics in this sector becomes increasingly critical. Scholars have sought to uncover the external factors influencing start-ups and their impact on performance. Examples of such factors include industry structure, technological change, regulatory environments, human capital, social capital, customer behaviour, and market conditions (Colombo & Grilli, 2005; Rosenbusch et al., 2011; Shane, 2003; Stam & Elfring, 2008; Wirtz & Göttel, 2016; Zott et al., 2011). Rosenbusch et al. (2011) discovered that market conditions and industry competition can moderate the positive effects on business performance. The lack of economic viability, or the lack of the ability of a business venture to generate profits while adhering to its core business concept, represents another external factor that contributes to the high failure rate of start-ups (Burgelman, 1985). Economic viability encompasses three constructs: demand, supply, and institutional pressures (Shaffer, 1990), all of which are external factors.

Gaining a better understanding of business model dynamics and their relationship with external conditions can enhance the survival rate and performance of start-ups. Analyzing the business model dynamics of PV start-ups and investigating the role of external factors can provide insights into fostering growth. In this study, we aim to examine how external factors influence the business model dynamics of PV start-ups and contribute to their growth. The research will focus on identifying the key external factors impacting Dutch technology-based PV start-ups and exploring how these factors can be leveraged to support their development in the industry. To accomplish this, we will apply a dynamic sustainable business model framework, following the guidelines proposed by Khodaei and Ortt (2019), and conduct case studies with this framework. Utilizing this framework will allow us to uncover the influence of external factors on business model dynamics and provide insights into facilitating start-up growth. In addition to its academic relevance, this research will offer valuable insights for Dutch technology-based PV start-ups, industry entrepreneurs, investors, and policymakers on effectively supporting and promoting the development of these start-ups.

1.1. Background information

This chapter begins by presenting background information on key topics in order to establish a common understanding before delving into the literature review in chapter 2. Furthermore, the chapter will identify gaps and deficiencies in the existing literature subsequent to the background information.

1.1.1. Technology-based start-ups

Entrepreneurship is widely promoted worldwide (Ehsan, 2021). Approximately 150 million new start-ups were established last year (M. Mason, n.d.). However, as mentioned earlier, the survival rate of start-ups is relatively low, with approximately 85% of them surviving the first two years and only around 45% making it past the first ten years (Audretsch et al., 2000).

To investigate the external effects on start-ups, it is necessary to establish a definition of what constitutes a start-up. The definition of start-ups has evolved over time. In earlier studies conducted before 2000, start-ups were predominantly defined based on the novelty of the firm (Audretsch et al., 2000; Carter et al., 1996; Keeble, 1976).

Subsequently, new definitions emerged that encompassed additional important aspects of start-ups. In addition to the company's newness, factors such as innovation and uncertainty were incorporated into the definition. One such definition, proposed by entrepreneur Eric Ries in his book "The Lean

Startup," considers innovation as the development of a new product or service within a context of extreme uncertainty: "A start-up is a human institution designed to create a new product or service under conditions of extreme uncertainty." (Ries, 2011)

Another notable entrepreneur, Steven Blank, put forth a definition that deviates from previous definitions and introduces distinct elements. He defines start-ups as "a temporary organization formed in search of a scalable, repeatable, and profitable business model" (Blank & Dorf, 2020). Despite differing from other definitions, this definition emphasizes the growth potential often associated with start-ups, particularly the pursuit of scalability.

Given the diverse definitions of start-ups that incorporate various elements and characteristics, it is crucial to select a widely accepted and reliable definition within the academic community that aligns with the scope of this research. In Table 1.1, commonly used definitions of start-ups are presented, along with the number of references per source, which indicates the level of acceptance and reliability within the academic community.

Table 1.1: Different definitions of start-ups.

Reference	Definition	Cited by
Ries (2011)	A start-up is a human institution designed to create a new product or service under conditions of extreme uncertainty.	7522
Blank and Dorf (2020)	A start-up is a temporary organization formed in search of a scalable, repeatable, and profitable business model.	2124
Trimi and Berbegal-Mirabent (2012)	Technology-based start-ups can be understood as new ventures where know-how and advanced technological discoveries are capitalised and exploited through new products and services.	582
Luger and Koo (2005)	A start-up is a business entity which did not exist before/during a given period (new), which starts hiring at least one paid employee during the given period (active), and which is neither a subsidiary nor a branch of an existing firm (independent).	173
Krejčí et al. (2015)	A start-up is a new and temporary company that has a business model based on innovation and technology. In addition, these types of companies have the potential for rapid growth and scalability.	47

The main criteria for selecting a definition for this study include public acceptance, reliability, and alignment with the research objectives. From the analysis presented in Table 1.1, it is evident that the definitions proposed by Ries (2011) and Blank and Dorf (2020) have significantly higher citation counts compared to the other definitions. Given that a higher number of citations can be indicative of acceptance and reliability within the academic community, the definitions provided by Trimi and Berbegal-Mirabent (2012), Luger and Koo (2005), and Krejčí et al. (2015) will be excluded from consideration.

The remaining factor to consider is the alignment of the definition with the present research. The definition proposed by Blank and Dorf (2020) exhibits a stronger connection to one of the main subjects of this study, namely, business model dynamics (refer to subsection 1.1.4 for more details), as it defines start-ups based on changes to their business model. Therefore, the definition by Blank and Dorf (2020) is selected over the definition by Ries (2011).

Furthermore, it is appropriate to provide a description of 'technology-based' start-ups. According to the Cambridge Dictionary (2023), the term 'technology-based' refers to "relating to the practical use of technology in business and industry." Consequently, the definition of technology-based start-ups can be defined as "temporary organizations that utilize technology in their pursuit of a scalable, repeatable, and profitable business model."

1.1.2. Business model

Over the past two decades, the concept of business models has garnered significant attention from both practitioners and academics (Zott et al., 2011). Despite efforts made by scholars, economists,

and industry experts to provide a definitive definition of the term 'business model,' a universally accepted definition remains elusive. According to Amit and Zott (2001), a business model encompasses "the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities." Building upon this notion, Chesbrough and Rosenbloom (2002) characterized a business model as a blueprint outlining how a business generates and captures value from new services or products. Subsequently, business models were further described as "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" (Teece, 2010).

For the purposes of this research, the definition proposed by Osterwalder and Pigneur (2010) will be employed. This definition states that a business model represents "the rationale by which an organization creates, delivers, and captures value." Further exploration of different definitions of business models can be found in chapter 2, specifically in the section titled "Business models" (subsection 2.1.1).

Various displays, tools, and representations of business models have emerged to describe the operational dynamics and value capture mechanisms of companies. However, the literature encompasses different definitions of business models. In an effort to provide a visual representation of how business models function, Teece developed a framework that aimed to encapsulate these dynamics. This framework has undergone further refinement and serves as the foundation for the widely recognized Business Model Canvas (BMC) (Osterwalder & Pigneur, 2010). The Business Model Canvas, introduced by Osterwalder and Pigneur, has emerged as one of the most prominent tools for illustrating a company's business model. Comprising of nine interrelated segments, the Business Model Canvas provides a comprehensive depiction of a business model. Given its extensive coverage and widespread adoption, we will utilize the Business Model Canvas as the basis for explaining a business model through its nine key segments. Subsequently, a modified version of the BMC will serve as the fundamental framework for the dynamic sustainable business model framework, which will be further discussed in detail in subsection 2.1.2 and section 3.1.

1.1.3. Business model innovation

Business model innovation (BMI) encompasses the iterative process of creating, adapting, or reinventing a company's business model with the aim of enhancing competitiveness and profitability (Bashir & Verma, 2017; Teece, 2010; Zott et al., 2011). According to Foss and Saebi (2017), Mitchell and Coles (2003b) were among the first to claim that managers proactively engage in business model change. Given the rapidly evolving markets characterized by technological advancements and shifting customer demands, the significance of changing the business model through BMI has become essential, as it allows organizations to adapt to the dynamic landscape and avoid obsolescence (Chesbrough, 2010; Markides, 2013). It is important to note that BMI differs from product or process innovation, which primarily focuses on improving or introducing new products or processes into the market (Zott & Amit, 2008).

BMI has been found to be closely associated with business performance and increased prospects of entrepreneurial success (Wirtz et al., 2016; Zott & Amit, 2007). When strategically employed, BMI can lead to enhanced business performance, as supported by Teece (2010) and Amit and Zott (2012), who argue that BMI can serve as a competitive advantage for firms. Start-up ventures, in particular, have demonstrated the benefits derived from business model innovation (Gassmann et al., 2020; Teece, 2010; Trimi & Berbegal-Mirabent, 2012).

1.1.4. Business model dynamics

One academic stream within the field of business models examines them from a dynamic perspective, focusing on their evolution over time rather than analyzing them as static entities (Khodaei & Ortt, 2019; Meslin, 2019). This approach, known as business model dynamics (BMD), recognizes that business models are not fixed and unchanging, a notion that is well understood by most senior managers and entrepreneurs (Achtenhagen et al., 2013; Amit & Zott, 2012). Business model innovation, as discussed in subsection 1.1.3, is closely associated with business model dynamics. BMI, being a dynamic process itself, can be considered a specific form of BMD (Foss & Saebi, 2017; Saebi et al., 2017). Business model dynamics refer to the changes and adaptations that occur within a business model over time in response to both internal and external factors (De Reuver et al., 2009; Massa et al., 2017; Stoian &

Zaharie, 2019).

To comprehend BMD, it is essential to recognize the existence of four types of business model changes: (1) business model creation, (2) business model extension, (3) business model revision, and (4) business model termination (Cavalcante et al., 2011). Business model creation involves the development of a completely new business model (Cavalcante et al., 2011). Business model extension occurs when additional activities or core processes are integrated into the existing business model (Cavalcante et al., 2011). Business model revision entails the removal of certain components of the business model, modifying the existing model and replacing it with a new configuration (Cavalcante et al., 2011). Lastly, business model termination refers to the elimination or abandonment of certain processes within a business model, which can involve the closure of a business unit or the entire company (Cavalcante et al., 2011).

In order to capture the dynamics inherent in business models, a dynamic business model framework can be employed as a visualization tool. This framework enables the analysis of business model dynamics based on four specific criteria: completeness, interrelationships, interrelationships over time, and framework changes (Khodaei & Ortt, 2019). If a business model undergoes frequent or substantial changes, the degree of BMD is considered high (Khodaei & Ortt, 2019). It is important to note that a dynamic business model should not necessarily exhibit high scores on all criteria proposed by Khodaei and Ortt; instead, a balance must be struck among the four criteria (Khodaei & Ortt, 2019).

1. *Completeness:* This criterion evaluates the extent to which the entire business model is considered, encompassing both internal company aspects and external environmental factors (Teece, 2010). It recognizes that to fully capture dynamics, it is crucial to include all relevant environmental variables and strategic responses within the business model (Khodaei & Ortt, 2019).
2. *Interrelationships:* This criterion examines the relationships among different components of the business model, emphasizing the co-evolutionary dynamics between these components (Khodaei & Ortt, 2019).
3. *Interrelationships over time:* This criterion explores the cause-and-effect relationships within the business model, illustrating how the various components evolve and mutually influence each other over time (Khodaei & Ortt, 2019).
4. *Framework changes:* This criterion focuses on the capability of the business model framework to adapt and undergo changes when necessary (Khodaei & Ortt, 2019).

1.1.5. Business model dynamics leading to growth

To assess the successful implementation of business model dynamics, particularly business model innovation, it is valuable to connect it with theories related to company development. One theory that elucidates the distinct developmental phases of start-ups is proposed by Vohora et al. (2004). This theory delineates various growth phases experienced by start-ups, as well as the challenges encountered at critical junctures. If business model innovation is effectively employed, it is expected to contribute to the growth of start-ups, enabling them to progress to subsequent stages of development.

The theory of growth stages and critical junctures, proposed by Vohora et al. (2004), offers insights into the developmental stages of start-ups and the challenges they encounter at each stage. The growth stages represent distinct periods characterized by specific activities and strategic focuses, while critical junctures encompass the barriers that must be overcome for the venture to progress from one stage to the next.

The first growth stage is the research phase, where “valuable intellectual property is created, which then generates the potential opportunity for commercialization” (Vohora et al., 2004). This is followed by the opportunity framing phase, which involves recognizing opportunities, assessing technological validity and performance, identifying target markets, and devising customer acquisition strategies (Vohora et al., 2004).

The pre-organization phase marks the development of management and the implementation of strategic plans to exploit the product commercially. This phase plays a crucial role as decisions made during this period can significantly impact the future success of the entire firm (Vohora et al., 2004).

Key decisions revolve around leveraging existing resources and capabilities, as well as determining the acquisition of new resources and knowledge.

After these initial phases, the re-orientation phase ensues, where the firm seeks to generate returns by offering the product (Vohora et al., 2004). Continuous reconfiguration becomes essential, particularly for ventures facing limited funding and inexperienced management (Vohora et al., 2004). Finally, the sustainable returns phase is characterized by the achievement of enduring profitability and value creation.

Alongside the growth stages, critical junctures act as pivotal points that must be successfully navigated for firm development. “A critical juncture is a complex problem that occurs at a point along a new high-tech venture’s expansion path preventing it from achieving the transition from one development phase to the next” (Vohora et al., 2004). Four critical junctures are identified: opportunity recognition, entrepreneurial commitment, credibility, and sustainability. Each critical juncture must be overcome to progress to the subsequent growth stage.

The opportunity recognition juncture involves identifying an unfulfilled market need and developing a solution to address it. Overcoming this juncture necessitates the ability to integrate knowledge with an understanding of markets, enhanced by social capital in the form of network connections and partnerships (Vohora et al., 2004).

The entrepreneurial commitment juncture signifies the pivotal moment when potential ventures transition from a mental vision to an operational business engaged in transactions (Vohora et al., 2004).

The credibility juncture underscores the importance of establishing credibility to acquire essential resources, particularly financial resources and secure key customers, during the re-orientation phase (Vohora et al., 2004).

Finally, the sustainability juncture denotes the ongoing process of reconfiguring the business to maintain resources, capabilities, and knowledge, ensuring the continuous creation of value from developed assets (Vohora et al., 2004).

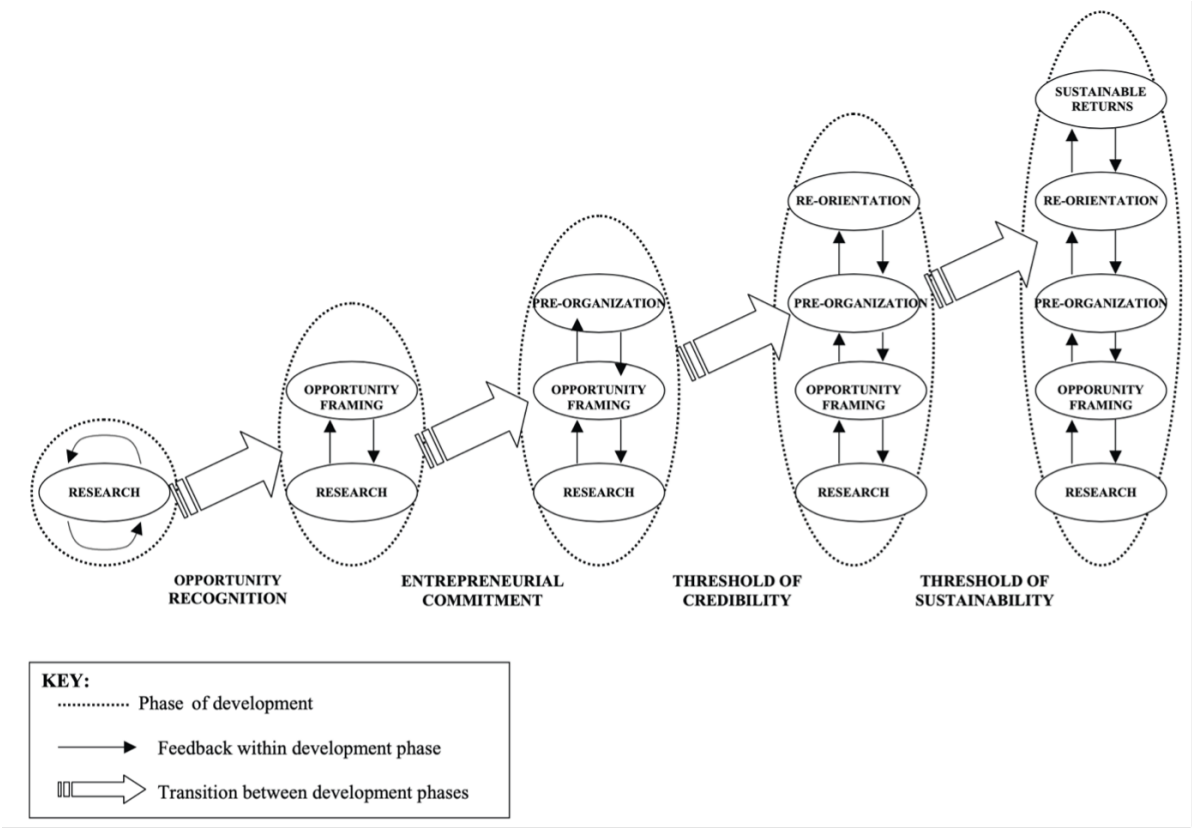


Figure 1.1: The growth stages and critical junctures (Vohora et al., 2004)).

1.2. Problem statement

PV start-ups encounter numerous challenges as they operate in rapidly changing environments characterized by high levels of uncertainty (Loch et al., 2008). Consequently, these start-ups face low survival rates. However, the demand for clean energy is increasing due to new climate agreements and government incentives promoting the use of renewable energy. Furthermore, PV start-ups must grapple with emerging technologies and evolving customer demands, necessitating flexibility and adaptability to change (Demil & Lecocq, 2010; Mitchell & Coles, 2003a; Trimi & Berbegal-Mirabent, 2012). Hence, it is crucial for PV start-ups to enhance their responsiveness to new situations and adjust their business models accordingly (Demil & Lecocq, 2010; Mitchell & Coles, 2003a; Trimi & Berbegal-Mirabent, 2012).

The business model of a start-up plays a pivotal role as its effectiveness significantly impacts its success or failure (Chesbrough, 2010; Osterwalder & Pigneur, 2010; Teece, 2010). More effective business models lead to higher firm performance and ensure survival and success (Osterwalder et al., 2005; Teece, 2010). Nevertheless, the lack of a functioning business model remains one of the reasons for start-up failures. In 2014, it ranked as the seventh among twenty reasons for start-up failure (Griffith, 2015). Similarly, in 2020, a flawed business model was identified as the fourth reason for start-up failure (Insights, 2021).

Understanding business model dynamics becomes crucial when changing business models. Business model dynamics encompass the changes and adaptations that occur in business models over time in response to internal and external factors (De Reuver et al., 2009; Massa et al., 2017; Stoian & Zaharie, 2019). Aligning the business model with changes in the internal and external environment significantly impacts start-ups (Chesbrough & Rosenbloom, 2002). Employing business model innovation as a deliberate strategy for changing the business model can help overcome challenges and maintain a competitive advantage (Teece, 2010).

Despite the importance of comprehending business model dynamics, there exists a literature gap concerning how external factors influence the business model dynamics of PV start-ups. External factors, including market conditions, competition, regulatory changes, and technological advancements, can profoundly influence the business model dynamics of PV start-ups (Barcanova et al., 2018; R. Chen & Huang, 2017; Luo et al., 2018).

Furthermore, there may be overlooked interrelationships that are critical in dynamic environments. The interaction between different business model components and environmental factors deserves attention (Khodaei & Ortt, 2019). By understanding these interrelationships, both researchers and entrepreneurs can gain insights into how external factors affect business models and subsequently modify them to align with evolving environmental conditions.

To address this research gap, this study aims to investigate the external factors influencing the business model dynamics of Dutch technology-based PV start-ups. Specifically, it will examine how changes in the external environment, such as changes in policy changes, regulations, economic shifts, and technological advancements impact the dynamics of PV start-up business models.

To provide a comprehensive analysis, the study will extend the understanding of business model dynamics and their relationship with external factors and integrate business model dynamics with the growth stages and critical junctures outlined in the theory of Vohora et al. (2004). This theoretical framework delineates the different stages and challenges experienced by start-ups. By linking business model changes to these growth stages, the study intends to offer recommendations and insights to enhance the performance of Dutch technology-based PV start-ups at each developmental phase.

In summary, this study seeks to contribute to the understanding of business model dynamics in technology-based PV start-ups. By examining the external factors influencing these dynamics and their relationship with growth stages, the study aims to provide practical insights and recommendations to enhance the performance and success of PV start-ups in the dynamic and competitive PV industry.

1.3. Research gap

During the course of this research, the primary search engines utilized were ScienceDirect, Scopus, and Google Scholar. These platforms were chosen due to their comprehensive coverage of scholarly literature. Given that business model dynamics constitutes a key focal point of this study, the majority of the publications obtained centred around this topic. The materials encompassed various forms, including books, journal articles, and research papers, all of which contributed valuable insights.

To ensure a thorough search, synonymous terms were employed to capture the same concept, thus enhancing the comprehensiveness of the results. For instance, terms such as 'business model adaptation,' 'business model transformation,' and 'business model changes' were employed interchangeably with 'business model dynamics.' This approach aimed to incorporate various perspectives and perspectives on the subject matter.

In assessing the retrieved literature, consideration was given to both the quantity and recency of publications. Specifically, emphasis was placed on recent articles published within the past five years, as they were deemed more pertinent and reflective of current developments in the field.

1.4. Research relevance

1.4.1. Academic Relevance

This study contributes to the academic understanding of business model dynamics by examining the influence of external factors on the evolution of photovoltaic (PV) start-ups and their business models. It seeks to deepen knowledge regarding the relationships between external factors and business model dynamics. Although some studies have explored business model dynamics in technology-based start-ups, limited research exists on the timing, nature, and causes of changes in these dynamics, with few exceptions (e.g., Dmitriev et al., 2014).

Furthermore, this research holds significance for the energy transition from an academic perspective. Given the crucial role of PV start-ups in this transition, studying how these companies can adapt their business models to foster growth and overcome challenges contributes to a better understanding of sustainable energy innovation.

1.4.2. Practical Relevance

This research bears practical relevance with several implications. Insufficient knowledge in the realm of business model dynamics can pose challenges for managers and founders of start-ups, particularly in environments characterized by rapid change and uncertainty. Understanding the dynamics and being able to adjust business models accordingly becomes crucial.

Likewise, this study provides practical insights for technology-based PV start-ups. By investigating business model dynamics, recommendations can be made to enhance the business models of start-ups operating in the PV sector. This empowers them to adapt and evolve in response to external changes, leading to improved strategic decision-making.

Another practical implication lies in the potential to improve the survival rates of PV start-ups. Given the industry's low survival rates, enhancing business model dynamics can pose a significant challenge. By improving these dynamics, PV start-ups can increase their chances of survival, thus contributing to the sector's stability and growth.

Moreover, this research has societal implications, particularly in meeting the growing social demand for clean energy. As we transition towards carbon-neutral energy consumption, the demand for PV start-ups and their innovative solutions increases. By advancing the understanding of business model dynamics and the influence of external factors, this research facilitates the development of sustainable and innovative solutions to meet the demand for clean energy.

Additionally, this study holds relevance for policy and regulatory decision-makers. By uncovering the external factors that impact PV companies, it provides insights for crafting supportive conditions and regulations that foster the growth of this sector. This aligns with government efforts to promote renewable energy while simultaneously stimulating economic growth. Start-ups are recognized as key drivers of economic development (Schumpeter & Backhaus, 2003; Storm, 2020), and supporting their competitiveness contributes to economic growth and the generation of 'better' innovations.

1.5. Research Objective and Scope

As outlined in the problem statement, enhancing the understanding of business model dynamics (BMD) can greatly benefit PV start-ups. The primary objective of this thesis is to investigate the influence of external factors on BMD, with the aim of supporting start-up growth and increasing the understanding of BMD of these start-ups. The focus of this investigation will be on Dutch technology-based start-ups operating in the PV sector, aiming to empower these companies to play a more significant and immediate role in the energy transition.

1.5.1. Research Objective

To achieve the previous goal, a dynamic sustainable business model framework will be employed, integrating external factors, BMD, and the growth phases proposed by Vohora et al. (2004). The ultimate objective is to provide valuable insights that can inform decision-making and strategic choices for entrepreneurs in the PV sector, ultimately leading to a faster and more successful energy transition.

To guide this research, the following objectives have been formulated:

1. Explore the development of business model dynamics in technology-based start-ups.
2. Identify the external factors that drive business model dynamics in technology-based start-ups.
3. Investigate how external factors influence business model dynamics of Dutch technology-based PV start-ups.
4. Determine to what extent external factors contribute to the development of Dutch technology-based PV start-ups.

The framework applied in this research is derived from the works of Kamp et al. (2021), with adaptations from Xu (2022) and Kharbeet (2022). It focuses on the external factors that induce changes in different elements of the business model, the interrelationships among these elements, and their evolution over time. To facilitate visualization and analysis, the external factors will be categorized within the framework.

1.5.2. Scope

This research will focus on technology-based PV start-ups based in the Netherlands. The rationale for selecting start-ups in the Netherlands is to limit the geographical scope to a single country, thus allowing control over country-specific influences. Furthermore, the Netherlands is renowned for its innovative capabilities, consistently ranking high on the Global Innovation Index, holding the 5th position in 2020 and the 6th position in 2021 (World Intellectual Property Organization (WIPO), 2021).

In addition to the significance of innovation and successful start-ups in the Netherlands, the accessibility of start-ups within the country was a determining factor for this geographical focus. Conducting the research in the Netherlands facilitates easier engagement and data collection from start-ups compared to other locations.

Furthermore, additional criteria have been established to select the start-ups included in this study. It is evident that the start-ups under investigation should have undergone changes in their business models since the primary focus is on BMD. Moreover, this research aims to assist start-ups in gaining a better understanding of BMD to foster their company's growth. To achieve this, the start-ups included in this study should have progressed through different growth phases and demonstrated growth.

In subsection 1.1.5 the growth phases and critical junctures were discussed. According to Khodaei et al. (2020), when a company surpasses the credibility juncture, it transitions from the development and prototyping phase to the production and sales phase. This transition indicates that the start-up has identified a beachhead market (which may involve changes in the customer segment) or has adapted its product to meet market needs (which may involve changes in the value proposition), among other modifications to its business model. Therefore, start-ups included in this study should have passed the credibility juncture and entered the re-orientation phase, ensuring that sufficient changes have occurred in their business models.

1.6. Research Question

Based on the problem statement and research objective, the main research question for this thesis is as follows:

How do external factors influence the business model dynamics of Dutch technology-based PV start-ups during different growth phases?

This research question will be addressed through a set of sub-research questions. By answering these sub-research questions, the main research question will be effectively answered. The sub-research questions are as follows:

1. How do business model dynamics develop for technology-based start-ups?
2. What external factors lead to business model dynamics of technology-based start-ups?
3. How do external factors influence the business model dynamics of Dutch technology-based PV start-ups?
4. To what extent can external factors contribute to the development of Dutch technology-based PV start-ups?

These sub-research questions serve to provide comprehensive insights and understanding regarding the influence of external factors on business model dynamics for technology-based PV start-ups during different growth phases. Answering these questions will enable the accomplishment of the research objective described in Section 1.5.1.

1.7. Methodology

To address the research questions raised in section 1.6, a comprehensive methodology will be employed, involving a literature study, data collection through interviews, and subsequent data analysis. The specific details of these methodologies will be elucidated in the subsequent sections, namely subsection 1.7.1 and subsection 1.7.2.

1.7.1. Data Collection

The data collection process for this study will entail a combination of desk research and field research. The desk research phase will primarily involve conducting an extensive literature study, while the field research phase will entail conducting interviews to gather primary data for the case studies.

The literature study will adopt a systematic approach, involving the comprehensive examination of existing information from secondary data sources. To ensure the reliability and robustness of the gathered information, reputable scientific databases such as ScienceDirect, Scopus, and Web of Science will be exclusively used to source articles and journals. A search strategy will be employed, incorporating multiple relevant terms and their synonyms to ensure comprehensive coverage and prevent any inadvertent omissions of pertinent information or articles. The primary objective of the literature study is to address research questions 1 and 2, thus establishing a strong knowledge foundation for the subsequent analysis.

In addition to the literature study, interviews will be conducted as an integral part of the field research component of this study. These interviews will serve as the basis for conducting exploratory case studies, which will contribute to addressing research questions 3 and 4. By analyzing real-life technology-based PV start-ups as the unit of analysis, these case studies will offer valuable insights that can complement and augment the findings from the literature review.

While the literature study may provide initial insights into the causes of business model changes, the case studies have the potential to yield a more nuanced understanding by uncovering novel and specific factors unique to the context of technology-based PV start-ups. The case studies will provide firsthand perspectives and in-depth information that can help elucidate and expand upon the existing literature.

By combining the findings from the literature study with the insights gained from the case studies, a comprehensive and holistic understanding of the influence of external factors on the business model dynamics of technology-based PV start-ups can be achieved.

Table 1.2: The method used for answering the research questions.

Research Question	Method of answering
1	Literature study
2	Literature study
3	Exploratory case studies and cross-case analysis
4	Exploratory case studies and cross-case analysis

1.7.2. Research strategies

To gather the necessary data and provide a comprehensive framework on the business model dynamics, qualitative research methods will be employed. This entails conducting desk research in the form of a literature study (as mentioned in Section 1.7.1) and field research in the form of interviews that will provide the requisite information for the case studies (as mentioned in Section 1.7.1). The interviews will take the form of face-to-face semi-structured interviews.

The literature study offers several advantages, including the availability of extensive research on the most crucial aspects of business models. This provides a convenient starting point for developing the framework, as it eliminates the need to create one from scratch. Furthermore, gathering information from reputable databases ensures the reliability of the obtained data.

However, the literature study also has limitations. The literature may not align perfectly with the scope of this study, potentially leading to the omission or neglect of important aspects and factors that are relevant to our research but overlooked in the literature. Additionally, certain information may be found but prove inapplicable due to contextual differences.

The face-to-face semi-structured interviews provide several advantages as well. They allow for adaptability and clarification of questions during the interview process, while enabling the interviewer to observe nonverbal cues such as body language and facial expressions, thereby enhancing the quality of the interview (Bougie & Sekaran, 2016). However, geographical constraints may arise when conducting face-to-face interviews (Bougie & Sekaran, 2016). Moreover, interviewers' biases can potentially influence the process, but this can be mitigated by restating and rephrasing answers to minimize the impact of biases.

The case studies offer valuable insights by examining the topic within its real-life context and are particularly suited to addressing 'why' and 'how' questions. It is important to acknowledge that case studies may not always provide a sufficient basis for generalization due to their specific contextual nature, although it is a misconception that generalization is never possible (Flyvbjerg, 2006).

Given the nature of business model dynamics, the contextual factors hold significant relevance. The results of the literature study alone cannot guarantee the comprehensive exploration of the research questions. Some findings from the literature may not be applicable or may be absent, underscoring the importance of case studies in confirming, complementing, or refuting the results obtained from the literature study.

2

Literature review

In this chapter, the existing literature on business models, business model innovation, business model dynamics, and external factors will be presented. The aim is to establish a foundational understanding of these concepts and provide the necessary context for this study. To avoid an overwhelming literature review, only the relevant literature pertaining to the research questions will be discussed.

The chapter begins by discussing the concept of business models and exploring various frameworks that have been proposed to represent them. It will provide a definition of a business model and clarifies its components. This understanding is crucial as the elements comprising a business model will serve as the basis for the subsequent development of the business model dynamics framework. Additionally, different business model frameworks will be presented, showcasing how scholars and practitioners have visually captured the essence of business models.

Next, the chapter will delve into the concept of business model innovation, which represents a specific form of business model dynamics. The drivers, importance, and applications of business model innovation will be discussed in detail in section 2.2.

After this, the dynamic view of business models will be reviewed and the concept of business model dynamics will be introduced in section 2.3. Various frameworks illustrating business model dynamics will be explored. These insights will lay the groundwork for developing a framework specific to technology-based start-ups in the solar energy sector, which will be the focus of this research.

The final part of the literature review will provide an in-depth examination of ways to categorize these factors and present a framework for visualizing them. This section can be found in section 2.4.

2.1. Business models

In order to conduct research on business model dynamics (BMD), it is crucial to establish a solid understanding of business model theories. This section focuses on determining the definition of a business model and introducing various frameworks used to visualize business models.

2.1.1. Business models

In recent decades, there has been a growing interest in business models among scholars and practitioners (Zott et al., 2011). This increased attention is due to the realization that business models play a crucial role in a firm's success, surpassing previous assumptions. As stated by Chesbrough (2010), "a mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model." This highlights the significance of business models, considering that every company operates based on a business model (Teece, 2010).

While the primary focus of this research is to examine how external factors influence business model dynamics (BMD), it is indeed crucial to define what a business model is, as it serves as the foundation for how companies operate. It is worth noting that the goal of this research is not to provide a comprehensive analysis and definition of a business model, but rather to ensure a consistent understanding of the concept throughout the study.

In the literature, there is a lack of explicit definitions of business models, as highlighted by Zott et al. (2011). Their study revealed that over one-third of the articles examined did not explicitly define the concept, while only 44% of the articles included a specific definition. The remaining articles referenced other scholars' definitions of business models, leading to a range of interpretations and understandings of the concept. To avoid this ambiguity and ensure clarity in this research, a review of different definitions of a business model is presented in Table 2.1. This review aims to establish a shared understanding of the concept within the context of this study.

To accomplish this, it is necessary to define what constitutes a business model and identify its components. These components will determine the frameworks that can be used as a foundation for developing a dynamic business model framework specifically tailored to technology-based start-ups in the solar energy sector. As the goal is not to provide a definitive definition of a business model, a review of different definitions from various scholars will be presented in Table 2.1. The table will include several studies that compare different definitions of business models to identify common themes, such as the studies of Zott et al. (2011) and Saebi and Foss (2015). However, it is important to note that these studies do not aim to establish a single conclusive definition of a business model, as that is not the objective pursued by most of them.

Table 2.1: The definitions of a business model according to different scholars and studies (adapted from Zott et al. (2011), Saebi and Foss (2015)

Author(s) (Year)	**Definition**
Timmers (1998, p. 4)	"an architecture for the product, service and information flows, including the various business actors and a description of the sources of revenues"
Mahadevan (2000, p. 59)	"a unique blend of three streams that are critical to the business. These include the value stream for the business partners and the buyers, the revenue stream, and the logistical stream"
Linder (2000)	"the organization's core logic for creating value. The business model for a profit-oriented enterprise explains how it makes money."
Amit and Zott (2001); Zott and Amit (2010)	"A business model depicts the content, structure, and governance of transactions designed so as to create value through the exploitation of business opportunities."
Bienstock et al. (2002, p. 174)	"The way we make money."
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 inputs. The business model is thus conceived as a focusing device that mediates between technology development and economic value creation."
Magretta (2002)	"The business model tells a logical story explaining who your customers are, what they value, and how you will make money in providing them that value."
Morris et al. (2005)	A business model is a "concise representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in defined markets" (p. 727). It has six fundamental components: Value proposition, customer, internal processes/competencies, external positioning, economic model, and personal/investor factors.
Osterwalder et al. (2005)	"A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams."

Shafer et al. (2005)	"Business is fundamentally concerned with creating value and capturing returns from that value, and a model is simply a representation of reality. We define a business model as a representation of a firm's underlying core logic and strategic choices for creating and capturing value within a value network."
Tikkanen et al. (2005)	"We define the business model of a firm as a system manifested in the components and related material and cognitive aspects. Key components of the business model include the company's network of relationships, operations embodied in the company's business processes and resource base, and the finance and accounting concepts of the company."
Voelpel et al. (2005)	"The particular business concept (or way of doing business) is reflected by the business's core value proposition(s) for customers; its configurated value network(s) to provide that value, consisting of own strategic capabilities as well as other (e.g. outsourced/allianced) value networks and capabilities; and its leadership and governance enabling capabilities to continually sustain and reinvent itself and satisfy the multiple objectives of its various stakeholders (including shareholders)."
Chesbrough (2007)	"The business model performs two important functions: value creation and value capture. First, it defines a series of activities, from procuring raw materials to satisfying the final consumer, which will yield a new product or service in such a way that there is net value created throughout the various activities. Second, a business model captures value from a portion of those activities for the firm developing and operating it."
Johnson et al. (2008)	"A business model consists of four interlocking elements (customer value proposition, profit formula, key resources, key processes) that taken together create and deliver value."
Santos et al. (2009)	"A business model is a configuration of activities and of the organizational units that perform those activities both within and outside the firm designed to create value in the production (and delivery) of a specific product/market set."
Casadesus-Masanell and Ricart (2010)	"A business model is ... a reflection of the firm's realized strategy" (p. 195).
Osterwalder and Pigneur (2010)	"A business model describes the rationale of how an organization creates, delivers, and captures value."
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" (p. 179).

The definitions of business models presented in Table 2.1 indeed exhibit commonalities. Most of the definitions emphasize the creation of value for a firm rather than solely capturing value (Zott et al., 2011). They generally take a holistic approach to explain how firms conduct their business, placing companies and their activities at the core (Zott et al., 2011).

For this research, the definition put forth by Osterwalder and Pigneur (2010) is selected as the primary definition of business models: "A business model describes the rationale of how an organization creates, delivers, and captures value" (Osterwalder & Pigneur, 2010). This definition is chosen because it aligns well with the overall focus of the study. It encompasses key elements such as value creation, value delivery, and value capture, which are also integral to the framework presented in section 3.4. While the value proposition is excluded from this definition, it provides the most comprehensive perspective on a business model among the alternatives considered.

2.1.2. Business model frameworks

A variety of frameworks and models/tools of business models exist in the academic literature that strives to provide a visual representation of a business model. As the aim of this research is to research the effects of external factors on BMD, a visualization of the BMD needs to be made for several companies.

To visualize the effects of external factors on BMD, a dynamic business model framework needs to be developed or obtained. The foundation of this framework lies in the business model framework (BMF) that will be chosen.

One of the most widely recognized and commonly used business model frameworks is the Business Model Canvas (BMC) developed by Osterwalder and Pigneur (2010). The BMC provides a visual representation of a business model and consists of nine key elements: value proposition, customer segments, customer relationships, channels, key partners, key activities, key resources, cost structure, and revenue structure (see Figure 2.1). These elements collectively capture the essential components of a business. The canvas serves as a tool for both strategic planning and communication, enabling stakeholders to have a shared understanding of how the business operates.

Due to its popularity and effectiveness, the Business Model Canvas has been widely adopted in academia and practice. It provides a solid foundation for developing a dynamic business model framework that can capture the effects of external factors on business model dynamics.

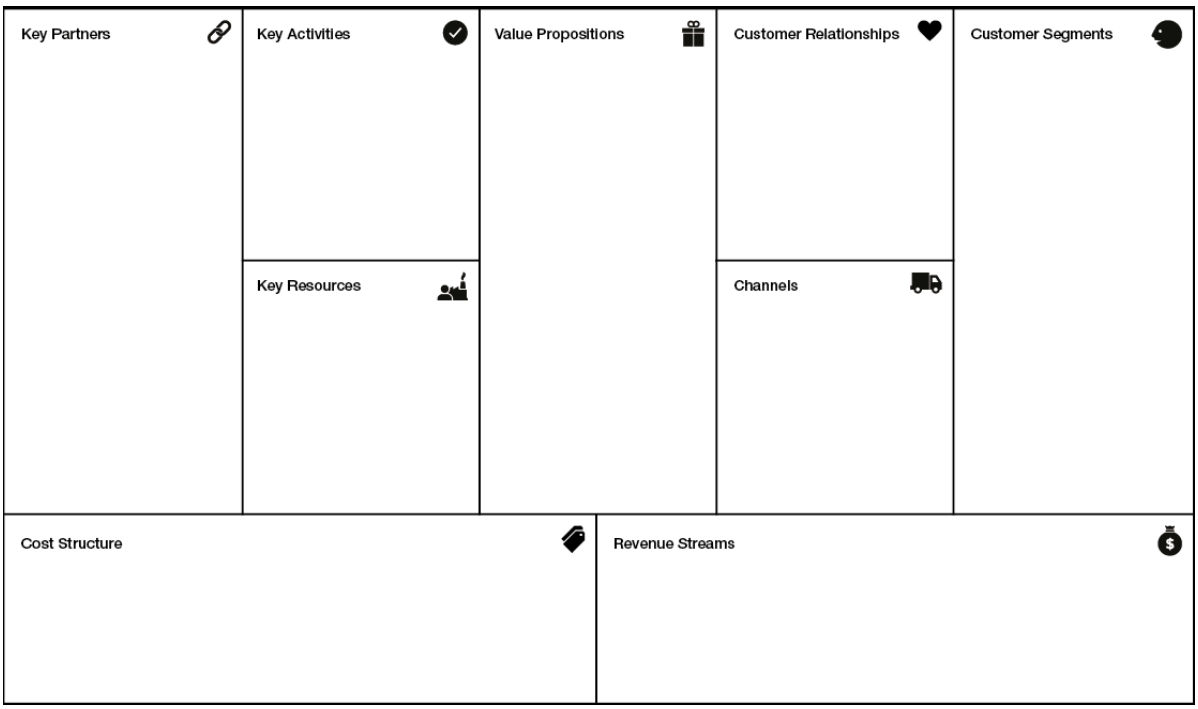


Figure 2.1: The business model canvas of Osterwalder and Pigneur (2010).

With the BMC as a basis, more BMFs appeared. A triple-layered BMC (Figure 2.2) was developed by Joyce and Paquin (2016) with the goal to create more environmentally sustainable business models. This BMC variant has one layer that focuses on capturing economic value, one layer that is focused on the social impact of a company, and a third layer that is focused on the environmental impact of a company. The economic layer is exactly the same as the BMC of Osterwalder and Pigneur. The social layer focuses on the social impacts and is built on the stakeholder management approach. It describes how stakeholders and the firm influence each other and captures the key social impacts of the firm (Joyce & Paquin, 2016). The environmental layer assesses how a firm creates more environmental benefits than environmental impacts (Joyce & Paquin, 2016). Adding the social and environmental layer to the BMC of Osterwalder and Pigneur can capture a more holistic view of the business.

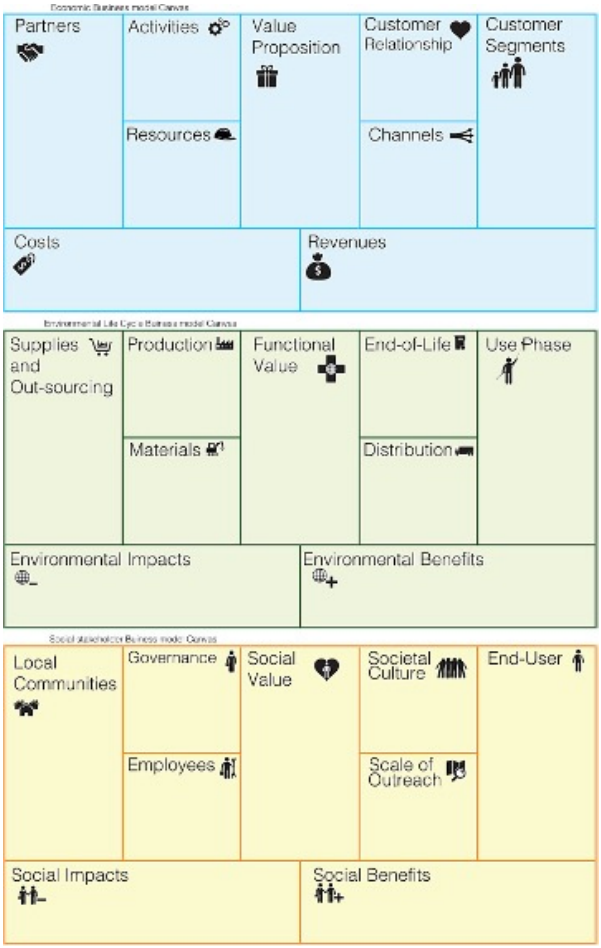


Figure 2.2: The triple layered business model canvas of Joyce and Paquin (2016).

As sustainability gets increasingly important but a tool as the triple-layered BMC is too cumbersome, simpler BMFs were developed as well. Bocken et al. developed a sustainable BMC in 2018 (see Figure 2.3). Bocken et al. did this based on earlier research (such as Short et al. (2014) and Bocken et al. (2015)). Instead of creating a whole new layer Bocken et al. added sub-elements to the value proposition to create three sub-elements here: profit, planet, and people. The three different value proposition elements resemble the value proposition of a sustainable company, covering the economic angle, the environmental angle, and the societal angle.

Additionally, the framework is divided into four main segments: value proposition, value creation, value delivery, and value capture. The value proposition contains the three sub-elements as discussed above and is a representation of the value proposition that a sustainable company offers. Value creation contains all the elements that create value for the business and customers. Value delivery contains the elements that describe how the value proposition is communicated to the customer segment and how the value proposition reaches the customer segment. The value capture component possesses the elements that show how the business earns money.

Besides the triple-layered BMC and the sustainable BMC, also a lean canvas was developed. This canvas is designed for entrepreneurs and start-ups. It focuses more on the problems and solutions that a start-up deals with or tries to solve. The lean canvas replaces the key partners, key activities, key resources, and customer relationships with problem, solution, key metrics, and unfair advantage. Therefore, it is more focused on the problem-solving capabilities of start-ups and starting ventures. This framework gets mentioned because it is specifically focused on start-ups but because this model is (almost) never used in the academic literature the lean canvas will not be further used in this research.

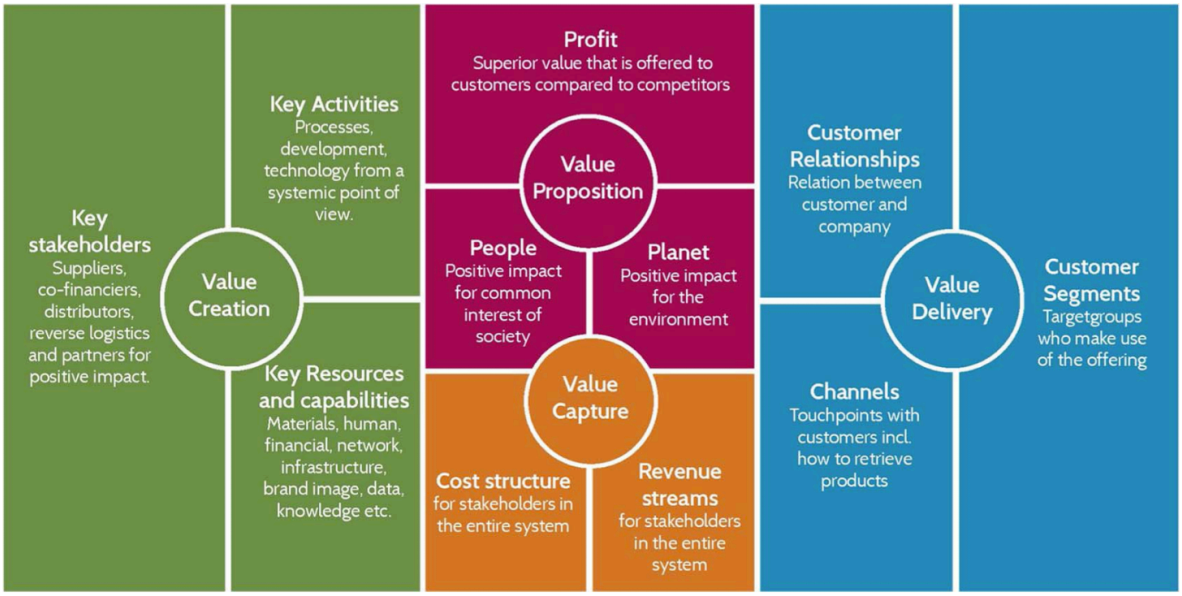


Figure 2.3: The sustainable business model canvas of Bocken et al. (2018).

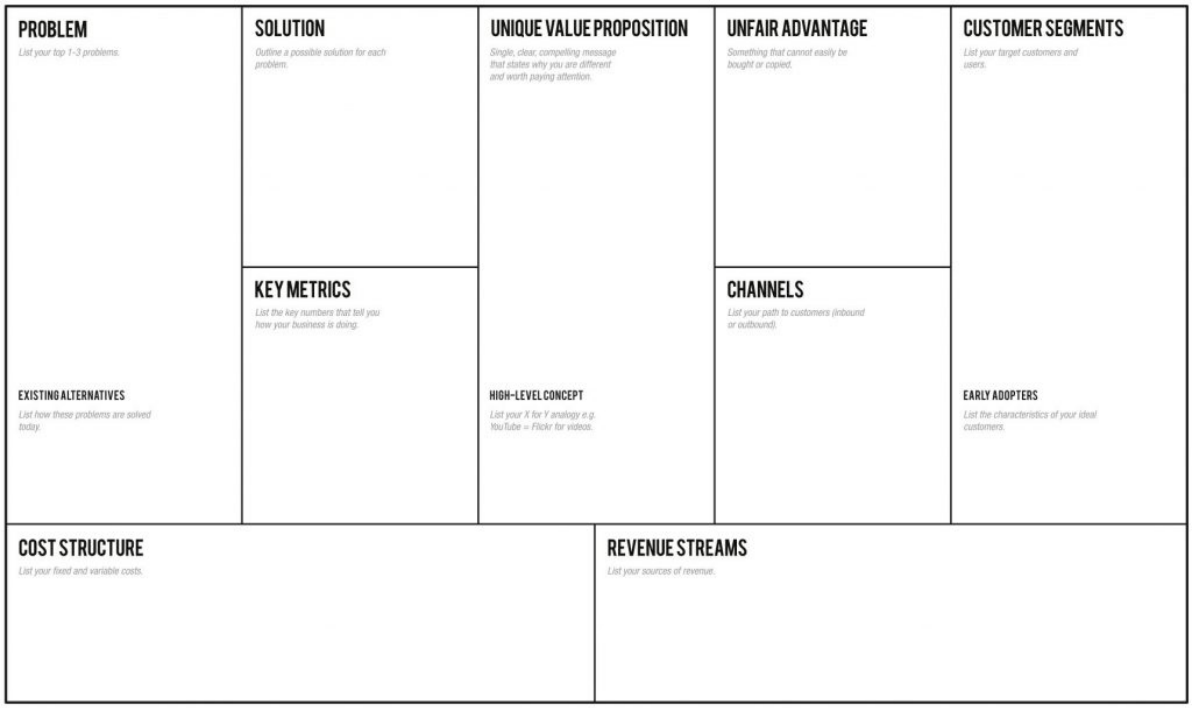


Figure 2.4: The lean canvas that can be helpful for start-ups.

With the different BMFs, different elements of a BM were observed. To use one of these frameworks as the foundation for the dynamic business model framework small adjustments have to be made. One of the foremost adjustments involves changes in the number of elements in order to visualize the dynamic business model framework in an understandable layout while keeping it as holistic as possible. As the focal point of this research involves start-ups in the solar energy sector, BMF which includes sustainability benefits is apparent. The sustainable BMC of Bocken et al. (2018) will be chosen over the triple-layered BMC of Joyce and Paquin (2016). The sustainable BMC has fewer elements which is a benefit compared to the many elements of the triple-layered BMC. The sustainable BMC was also further divided into four sections: (1) value proposition, (2) value creation, (3) value delivery, and (4)

value capture (see Figure 2.3). This originates from the four pillars of business models as suggested by Osterwalder (2004). Osterwalder mentions product, customer interface, infrastructure management, and financial aspects as four pillars. This was phrased as the value proposition, value creation and delivery system, and value capture by Richardson (2005). This means that the division in the four sections as mentioned is directly derived from Osterwalder, one of the creators of the BMC. Therefore, we assume that the four sections of the sustainable BMC reflect all elements of a business model while having as few elements as possible.

2.2. Business model innovation

Business model innovation (BMI) is a significant driver for changes in business models and thus the business model dynamics. As BMI is a part of BMD, it is essential to understand BMI to do proper research into the topic of business model dynamics. First BMI will be explained and a few helpful tools to apply BMI will be discussed. After this, a closer look at the drivers and triggers of BMI will be researched.

2.2.1. Business model innovation

When a new product, service, or process is innovated, chances are that the BM needs to change in order to facilitate and manage the innovation. This adoption of the business model can be seen as an innovation in itself, making the BM the subject of innovation (Mitchell & Coles, 2003b)). This shows that “BMs can be a vehicle for innovation as well as a subject of innovation” (Zott et al., 2011). If the BM is subject to innovation in order to exploit the (technological) innovations, this is called business model innovation (BMI).

Zott et al. (2011) say that BMI complements product, process, and organizational innovation. This proves to be very important for companies as there is widespread consensus that BMI is an important instrument for business transformations and renewals (Trimi & Berbegal-Mirabent, 2012; Zott et al., 2011). These transformations or renewals by means of BMI can help a company gain or keep a competitive advantage (Amit & Zott, 2012; Teece, 2010). Bashir and Verma (2017) even suggest that BMI is a more renowned source of competitive advantage than product innovation or new services. From this, it can be concluded that BMI is essential to success in the rapidly-changing environments of today (Giesen et al., 2010).

There are four types of business model dynamics according to Cavalcante et al. (2011), as also mentioned in subsection 1.1.2. These four types of business model dynamics were (1) business model creation, (2) business model extension, (3) business model revision, and (4) business model termination. A similar division can be noticed when BMI is examined. Four different types of BMI exist: (1) start-up, (2) business model transformation, (3) business model diversification, and (4) business model acquisition (Geissdoerfer et al., 2018). This is also displayed in Figure 2.5. Start-up means there is no BM in place and a new BM is created. This is similar to business model creation as defined by Cavalcante et al. (2011). Business model transformation means that a current BM is changed into another BM which is the equivalent of business model revision. Business model diversification means that an additional BM is created and added to the current BM. Business model acquisition is when an additional BM is identified, acquired, and integrated. These last two types of BMI are similar to business model extension.

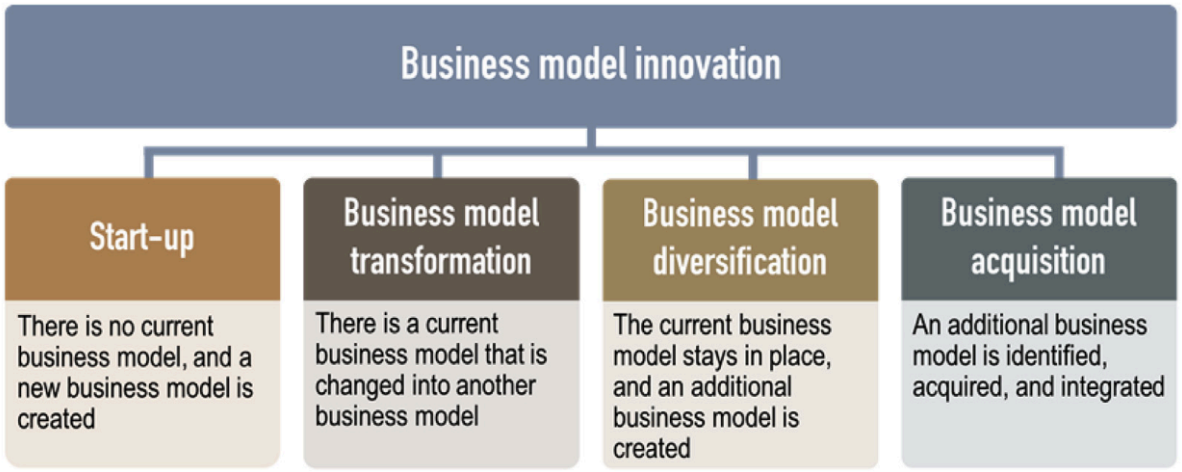


Figure 2.5: The four types of business model innovation (Geissdoerfer et al., 2018).

2.2.2. Drivers of business model innovation

In subsection 2.2.1, BMI is explained. Before BMI can take place, an analysis of the environment should be done (Amit & Zott, 2012; Giesen et al., 2010). Possible opportunities and threats can be detected and handled accordingly by analyzing the environment. Because this step is important, the drivers and antecedents of BMI are discussed in this section.

Knowing the antecedents for BMI is important because it can help start-ups better understand when to change a BM. By identifying the drivers of BMI foresight can be created. Some research has been done on the drivers of BMI, but the research on drivers of BMI has not yet categorized these antecedents in a systematic manner. By identifying the drivers of BMI and categorizing them, the foresight created increases more. It also contributes to the completeness criteria of Khodaei and Ortt (2019) for dynamic business model frameworks if this can be implemented in a framework.

In the framework of Kamp et al. (2021) the drivers for changes in the business models are split into ones with an internal origin and ones with an external origin (also see subsection 2.3.2. This is a division that is used by multiple scholars. Table 2.2 shows internal and external factors reported by Giesen et al. (2010), Andreini and Bettinelli (2017), Saebi et al. (2017), and Xu (2022). The table is originally made by Xu (2022) but adapted and new factors found in the literature are added. Newly added drivers of BMI are underlined. The major factors causing BMI are documented in bold. For the external factors, these major drivers can be linked to economic changes, technological changes, changes in the competitive environment, social and environmental changes, and changes in business operations. The major internal drivers are related to product or service innovation, the revenue and cost structure of the company, resource distribution, and organizational and managerial characteristics.

Table 2.2: Business model innovation drivers (adapted from Andreini and Bettinelli, 2017; Giesen et al., 2010; Saebi et al., 2017; Xu, 2022)

Type of driver	**Category**	**Typical drivers**
External	Political	• Heightened competition resulting from liberalization (Saebi et al., 2017) • Change in local policy (Xu, 2022)
	Economic	• Major changes in business/economic/industry environment (Giesen et al., 2010) • Increasing globalization of the business environment (Giesen et al., 2010) • Economic recession (Giesen et al., 2010) • New business models by new market entrants (Giesen et al., 2010)

Table 2.2 continued from previous page

		• Industry transformation (Giesen et al., 2010) • Changes in the competitive environment (Saebi et al., 2017) • New propositions introduced by competitors (Giesen et al., 2010) • The need to fend off low-end disrupters (Saebi et al., 2017) • The need to response to “good enough” low-end entrants (Saebi et al., 2017) • Need to dislodge competitors (Giesen et al., 2010)
	Social	• Cultural context (e.g. the issue of internationalization; operating in new national contexts) (Andreini & Bettinelli, 2017) • Changes in customer preferences (Giesen et al., 2010)
	Technological	• New information and communication technologies (ICTs) (e.g. Web 2.0, digitization) (Saebi et al., 2017) • New disruptive technology (e.g. a new global positioning technology) (Giesen et al., 2010; Saebi et al., 2017) • A brand-new technology (e.g. Apple player) (Saebi et al., 2017) • A tested technology (e.g. military technologies in the commercial space) (Xu, 2022)
	Environmental	• Global pandemic (Xu, 2022) • The need for sustainability (e.g. sustainable construction, sustainable development, etc.) (Andreini & Bettinelli, 2017) • Changes in customer segments (Giesen et al., 2010)
	Legal	• Changes to regulatory environment (either by industry or geography) (Saebi et al., 2017)
	To be determined	• Shifts in the value chain (e.g. value migration along the value chain) (Saebi et al., 2017) • Changes in partnerships (e.g. new partners; changing demands of stakeholders (e.g. manufacturers)) (Giesen et al., 2010)
Internal		• Products or services innovation • Declining or negative growth relative to the industry (Giesen et al., 2010) • Change in value proposition (Giesen et al., 2010) • Reduction of operation costs (Saebi et al., 2017) • Modification in revenue/cost models (Giesen et al., 2010) • Utilization of new resources (Andreini & Bettinelli, 2017) • Developing a new source of revenues (Andreini & Bettinelli, 2017) • Externalizing a value chain activity (Andreini & Bettinelli, 2017) • Setting new financial arrangements (Andreini & Bettinelli, 2017) • Changes in resources availability (e.g. a lack of financial resources / the need for leveraging the right skills and capabilities) (Andreini & Bettinelli, 2017) • Changes in marketing channels (Andreini & Bettinelli, 2017) • Changes to internal strategic (e.g. corporate strategy) (Giesen et al., 2010) • Re-engineering an organizational process (Andreini & Bettinelli, 2017) • Changes in organizational capabilities (Andreini & Bettinelli, 2017) • Changes in executives’ cognitive processes (Andreini & Bettinelli, 2017) • Challenges in project management (Xu, 2022) • Changes in personnel capabilities (Xu, 2022)

The framework of Xu (2022) (see subsection 2.3.3) made an addition to the frameworks on BMD by adding if the changes were caused by a threat or an opportunity as this was suggested from earlier research (Bucherer et al., 2012). An opportunity is when BMI is used to capture the opportunity at hand. A threat in this context means that a company must innovate their BM because it is forced to.

Bucherer et al. (2012) point this out as well. They also mention that an opportunity for one company might be perceived as a threat to another and vice versa. Accordingly, threats and opportunities should be analysed in the context of the company.

By having an internal/external division and an opportunity/threat division, four categories of drivers for BMI are created: internal opportunity, internal threat, external opportunity, and external threat. This is also classified by Meslin (2019) and adapted by Xu (2022). This can be seen in Table 2.3.

Table 2.3: Origin of business model innovation (Xu, 2022)).

	Category	Opportunity	Threat
External	Political	• Supportive financial system	• Policy and regulatory requirements • Constraining financial system
	Economic	x	• Competitions induced by price erosion • Industry over-capacity • Changes in competitive landscape
	Social	• Changes in public perception of the products • Changes in customer preferences • New customer segmentation	• Changes in customer needs • Lack of social acceptance
	Technological	• Changes in key technologies • Promoting efficiency after a mature Industry chain	x
	Environmental	• Environmental targets / pacts / pledges • More frequently-occurring natural disasters	x
	Legal	x	x
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

2.3. Business model dynamics

All discussed BMFs (see subsection 2.1.2) are a static representation of a business model, as is for most BMFs (Khodaei & Ortt, 2019). It is, however, widely acknowledged that business models change over time due to internal or external factors (Demil & Lecocq, 2010; Khodaei & Ortt, 2019). These dynamics cannot be captured by static frameworks (Demil & Lecocq, 2010).

2.3.1. Business model dynamics

In addition to the static perspective on business models discussed in subsection 2.1.2, a second approach considers business models as “a concept or a tool to address change and focus on innovation, either in the organization or in the business model itself” (Demil & Lecocq, 2010). Amit and Zott (2012) say that “an innovative business model can either create a new market or allow a company to create and exploit new opportunities in existing markets.” By changing and adapting a firm its business model, companies can create a competitive advantage over other companies (Teece, 2010). This is called business model innovation (see section 2.2) and is a form of business model dynamics (BMD). Latest

business model research already gravitates towards the dynamic view of business models (Kamp et al., 2021; Khodaei & Ortt, 2019; Meslin, 2019). As the static view of business models has its limitations, the development of dynamic business model frameworks is capable of capturing the business model of a company and its changes.

The need for companies to be flexible to changing market conditions encourages a dynamic view of business models (Teece, 2018). Teece compares the dynamic view on business models with the evolution theory of Darwin. He makes the analogy that companies need to adjust quickly in the changeable markets of today to survive. This analogy illustrates that BMD is necessary to understand. It helps scholars, companies, and start-ups recognize when business models should be changed in order to benefit the company. When BMD are understood, BMI can be implemented more successfully. This helps start-ups to overcome certain difficulties and increase firm performance.

It is essential to recognize the existence of four types of business model changes: (1) business model creation, (2) business model extension, (3) business model revision, and (4) business model termination (Cavalcante et al., 2011). Business model creation involves the development of a completely new business model (Cavalcante et al., 2011). Business model extension occurs when additional activities or core processes are integrated into the existing business model (Cavalcante et al., 2011). Business model revision entails the removal of certain components of the business model, modifying the existing model and replacing it with a new configuration (Cavalcante et al., 2011). Lastly, business model termination refers to the elimination or abandonment of certain processes within a business model, which can involve the closure of a business unit or the entire company (Cavalcante et al., 2011).

2.3.2. Dynamic business model frameworks

Before research on the effect of external factors influencing BMD can be done, a framework that visualizes BMD and the external factors causing them needs to be established. “Dynamic business model frameworks are defined as business model frameworks that capture relevant changes in the internal and external company aspects, for example, by studying trends or sudden changes in those aspects and by studying how a trend or sudden change in one aspect of the framework can affect another aspect of the framework” (Khodaei & Ortt, 2019). Some researchers have tried to create a framework for dynamic business models already. In this section, the most prominent frameworks will be collected and presented. The approaches to making the frameworks, circumstances, nuances, etc. can be understood by examining the different frameworks. From this, the framework which is best suitable for technology-based start-ups can be chosen and used as a basis for further development of the framework to best apply to technology-based start-ups.

Bouwman et al. (2006) and the De Reuver et al. (2009) framework

The framework developed by Bouwman et al. (2006) is one of the first frameworks (besides, for instance, MacInnes (2005)) that is developed with a dynamic view on business models. The research aimed to answer how external factors influence business models. Bouwman et al. (2006) tried to analyse this by dividing the life cycle of a business model into three phases: 1) the technology/R&D phase, 2) the implementation/roll-out phase, and 3) the market phase. These three phases are created according to the life cycle of innovations. The assumption for dividing the business model into these three phases is that if the innovation develops, a new business model develops in parallel.

To investigate what drives business model change, three main categories of drivers are defined in this research: 1) technology factors, 2) market factors, and 3) regulatory factors. From these BM stages and drivers, a framework was developed as can be seen in Figure 2.6. In this figure, the expected effects of each driver on the business model phase was shown.

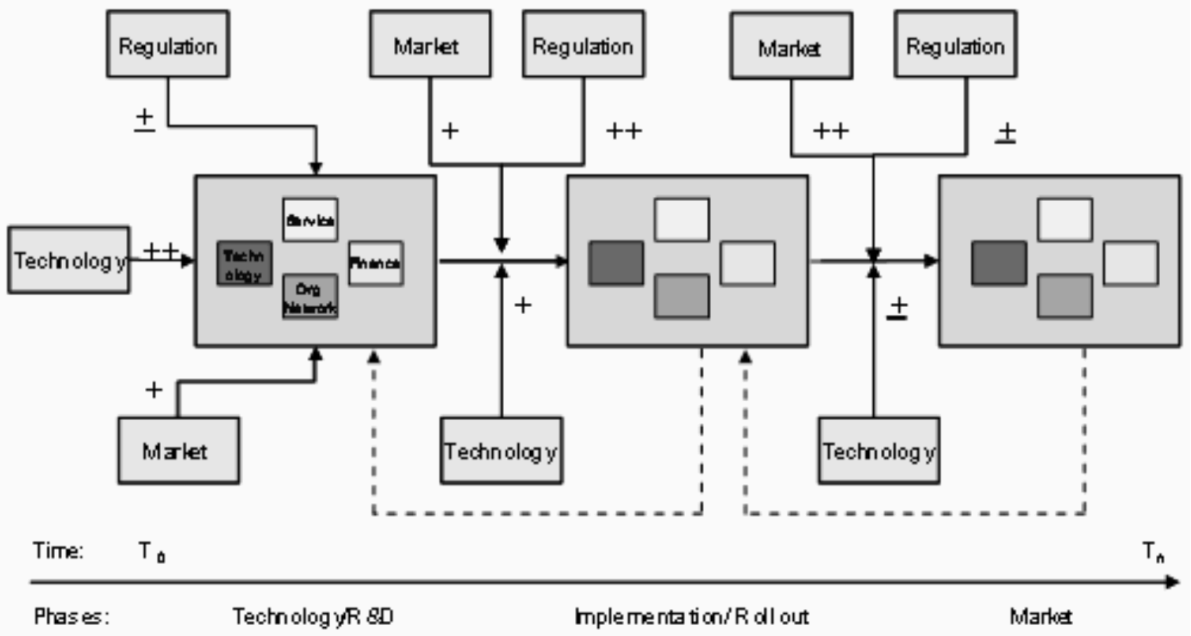


Figure 2.6: The framework created by Bouwman et al. (2006).

In the framework, the three BM phases can be seen and the drivers in each phase can be seen. With the use of pluses, minuses, and plus minuses the importance of each factor in each phase is shown. The impact of the drivers indicated with a ++ shows a strong effect on the business model. A + means that a moderate effect was seen. A +/- means that the driver was mentioned but it was not indicated if any effect was apparent. And lastly, 0 means that there was no effect reported or no changes occurred in the BM.

To see what the impact of the drivers is, the drivers are further divided into market competition driver (M1), market demand driver (M2), technology driver (T), and regulatory driver (R). To see how the business model is affected, Bouwman et al. (2006) their framework splits a business model into the following elements: service component (S), technology component (T), organizational structure (Os), organizational governance (Og), internal organizational arrangements (In), and finance (Fn). This can be seen in Figure 2.6 as four blocks within the BM as all the organizational components are shown as one block. Hereafter, a case study was done. The result of the research can be seen below:

Case	Phase	Industry	Business type	Innovation type	Driver				Business model component						Business model performance	
					M1	M2	T	R	T	S	Os	Og	In	F	NV	CV
I-mode	I	Telecom	Established	Disruptive	++	+	+/-	+	+	+	+	+	+	+	+	0
	II				+/-	0	0	0	+	+	+	0	0	0	+	0
	III				+	++	+	++	+	+	+	+	+	+	+	0
MySQL	I	Software	Start-up	Disruptive	+/-	+/-	++		+	+	+	0	0	0	0	0
	II				+/-	0	0	0	0	+	+	+	+	+	+	+
Skype	I	Telecom	Start-up	Disruptive	++	0	++	+/-	+	+	+	+	+	+	+	0
	II				+/-	+	0	+/-	+	+	+	+	0	+	+	0
	III				0	0	0	0	0	+	+	+	0	+	+	0
C-commerce	I	Pharma	Established	Incremental	+/-	++	+	+/-	+	+	+	+	+	0	0	0
Telmore	I	Telecom	Start-up	Disruptive	+/-	0	0	+	+	+	+	+	+	+	0	0
	II				+/-	0	0	0	0	+	+	+	+	0	+	+

Figure 2.7: The impact of the drivers on the business model (Bouwman et al., 2006)).

This framework later is refined by De Reuver et al. (2009) and used for a case survey. This study aimed to explore which drivers are the strongest in forcing a business model to change. It differentiates

between large companies and (small) start-ups when testing their hypotheses. The difference in the framework between Bouwman et al. (2006)'s and De Reuver et al. (2009)'s is that the technology/R&D phase is called the development/R&D phase and the market phase is called the commercial phase.

The findings of De Reuver et al. (2009) are that:

- Technology drivers are more important in the development/R&D phase than in other phases. It appears that this is only the case for small start-ups and not for larger companies.
- Market drivers seem most relevant in the first phase of business models. This applies, just as the statement for technological drivers, only for small start-ups.
- Regulatory drivers seem to play a minor role throughout all phases, regardless of the size of a company.

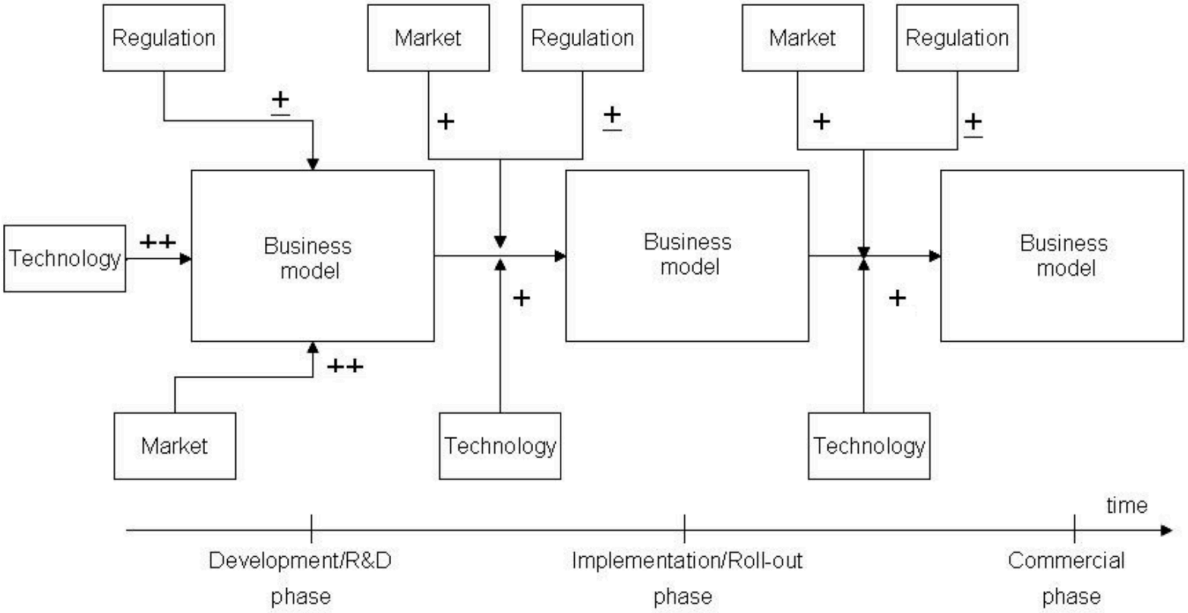


Figure 2.8: The adjusted framework of Bouwman et al. (2006) by De Reuver et al. (2009) for small start-ups.

The advantage of this research is that the conclusions and framework, result in a framework that describes how different stages of start-ups get influenced by external factors. The research did not investigate internal factors, however. It also did not look at BMs as we do today. Instead of the conventional BM elements of Osterwalder and Pigneur, the BM was divided into a technological component, financial component, internal component, and organizational component. This framework further does only show the external influences but not the influences of the BM elements on each other and how they interrelate.

Meslin (2019) and Kamp et al. (2021) framework

In 2019 Meslin created a dynamics business model framework according to the criteria of Khodaei and Ortt (2019) for business model dynamics frameworks. His framework is based on the elements of the BMC of Osterwalder and Pigneur (2010 to capture the business model dynamics of rural renewable energy projects in Indonesia. This framework of Meslin (2019) later, was improved by Kamp et al. (2021). In the framework of Kamp et al. (2021), the visualization and representation are changed but the elements of the framework stayed the same. It contains the value proposition (VP), the value network (VN), and the cost and revenue stream (CRS). These three elements include all the elements of the BMC of Osterwalder and Pigneur (2010) as shown below:

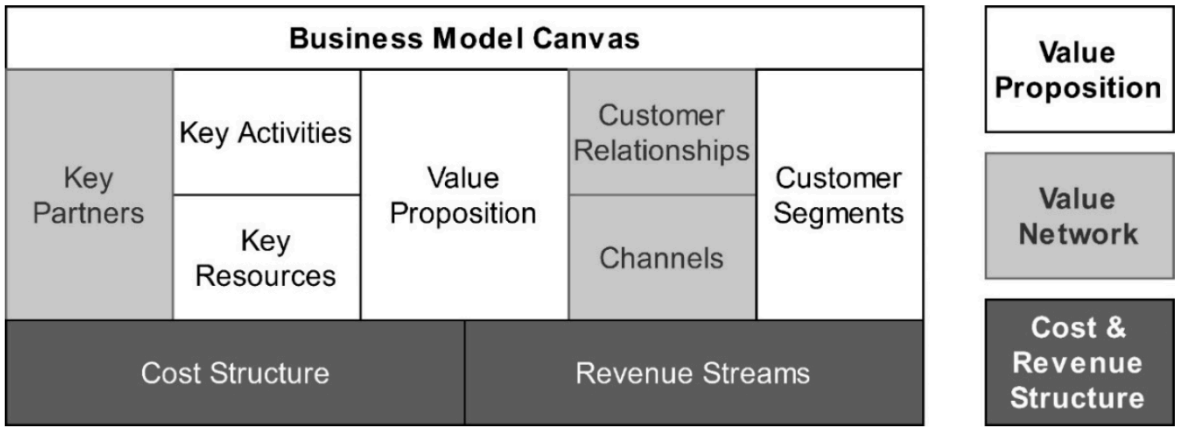


Figure 2.9: The division into value proposition, value network, and cost and revenue stream by Meslin (2019) from the BMC of Osterwalder and Pigneur (2010)

In the framework of Meslin (2019) and later the framework of Kamp et al. (2021), a division is made between the different types of BM changes. The first distinction made, is if the change has an internal or external origin. A change caused by internal factors can be influenced more easily than a change caused by external factors. When the origin is known, it is important to look at the sequence of changes. Meslin (2019) and Meslin (2019) call the initial change in the first BM the 'primary change'. All following changes are called 'secondary changes'. Lastly, the changes can be strategic or forced. This distinction is made because it can show the degree of freedom that an entrepreneur or manager has.

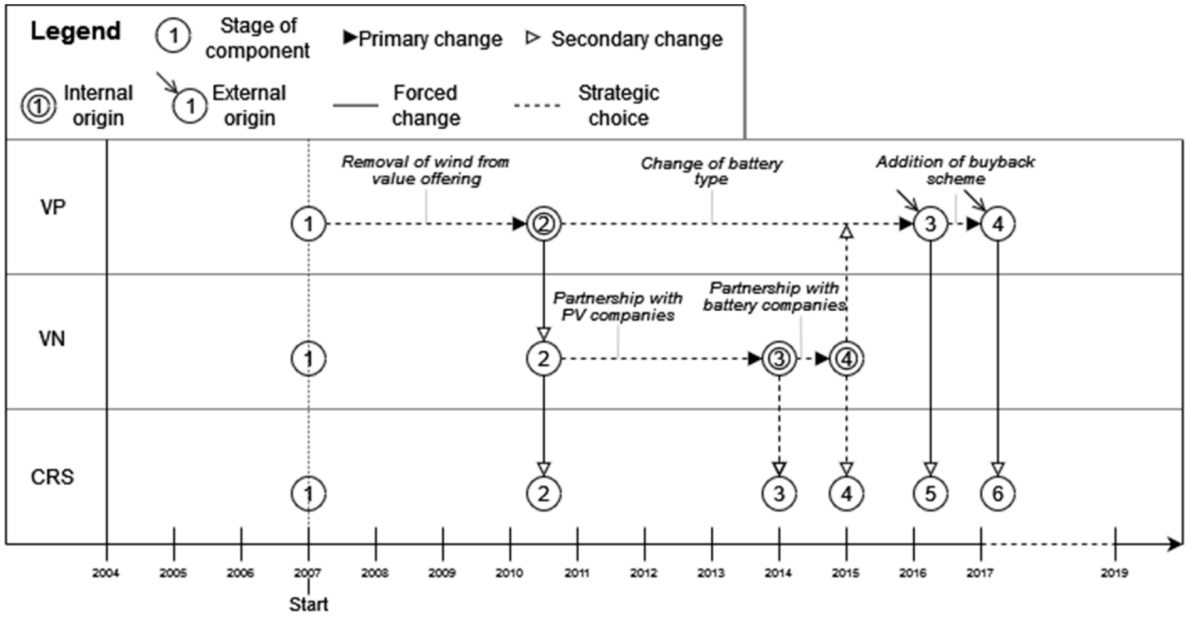


Figure 2.10: The business model dynamics framework of Kamp et al. (2021).

Cosenz and Bivona (2021) framework

The framework of Cosenz and Bivona (2021) is a framework that visualizes a dynamic business modelling approach for SMEs to apply BMI in a better way. It is based on the nine building blocks of the BMC of Osterwalder and Pigneur (2010). Some elements of the BMC of Osterwalder and Pigneur (2010 were modified to better fit SMEs, such as strategic resources, value drivers, and key processes. In this framework, the interrelationships between different BM components are captured and the changes over time are tracked. This framework is shown in Figure 2.11.

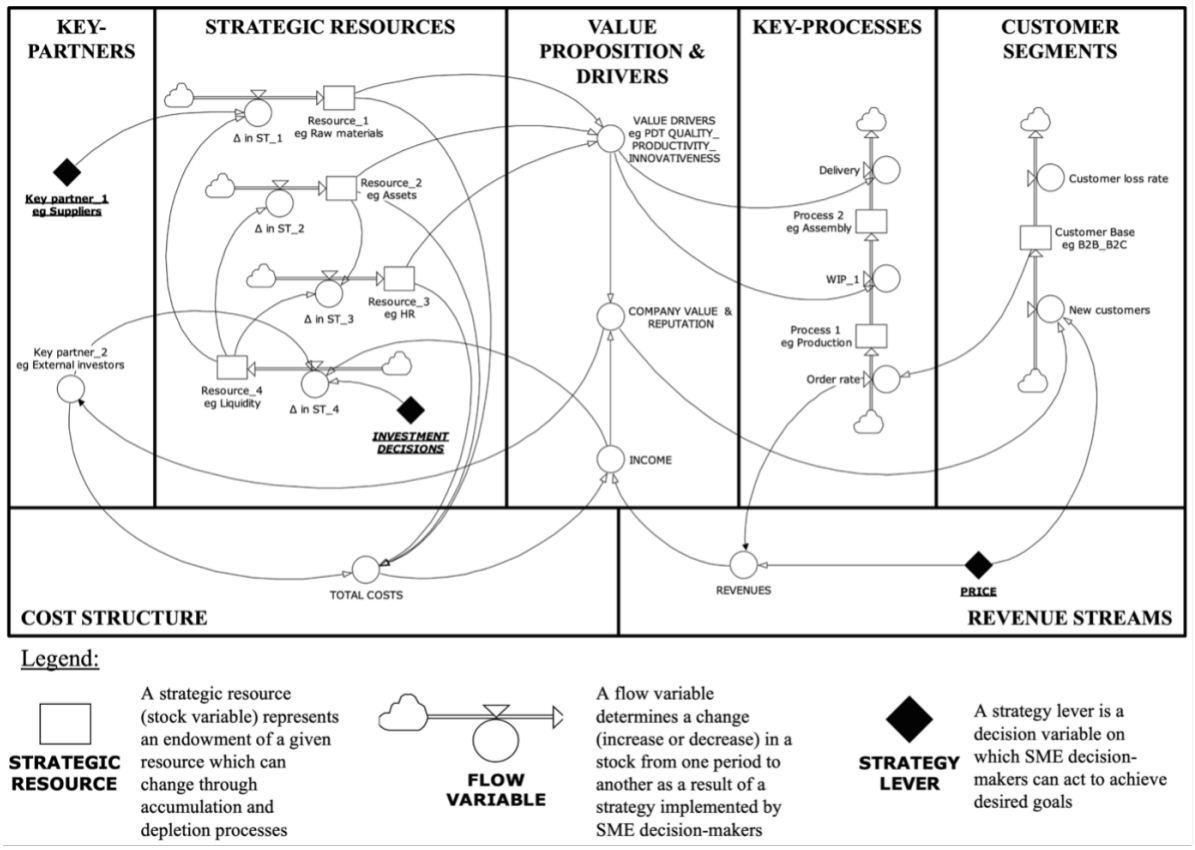


Figure 2.11: The framework of Cosenz and Bivona (2021) showing the dynamics of business models.

Although this framework shows an overall complete picture of the BM and its changes, it is also very unstructured and unclear what is going on. The interrelationships between elements are very complex and because of several feedback loops, it tends to be a lot to comprehend. The timing of all the changes is very unclear because no timeline or time axis is incorporated into the framework. Compared to the frameworks of Kamp et al. (2021) and Deherkar (2020), this framework doesn't define opportunities or threats or entrepreneurial freedom (thus strategic choices or forced choices).

2.3.3. Dynamic sustainable business model frameworks

As PV start-ups are the focal point of this research, also some dynamic business model frameworks are distinguished that relate to sustainable business models. Because PV start-ups have great environmental impacts, their value proposition contains some non-economical advantages as well. Just as the BMC in subsection 2.1.2 has variants that include environmental aspects, some dynamic business model frameworks also have environmental aspects included. In this subsection two of these frameworks will be discussed.

The Xu (2022) framework

This framework is based on the framework of Meslin (2019), Kamp et al. (2021) and the sustainable BMC of Bocken et al. (2018). It is used to evaluate the dynamics of distributed solar PV projects in China. The framework adopted Kamp et al. (2021) their framework to fit the sustainable BMC components of Bocken et al. (2018). This results in some changes. Firstly, the value proposition is shown with three subcategories: a customer (CVP), a societal (SVP), and an environmental value proposition (EVP). Secondly, the framework uses a value delivery section (VD) containing the channels, customer segments, and customer relationships elements of the sustainable BMC. The third section is the value creation (VCA) section. This contains key partners, key recourses, and key activities. The last section is the value capture section (VCP). This is the same as the cost and revenue structure of the Kamp et al. (2021) framework. The Xu (2022) framework also defines if BM changes originate from threats or from opportunities. An example of this framework is given in Figure 2.12.

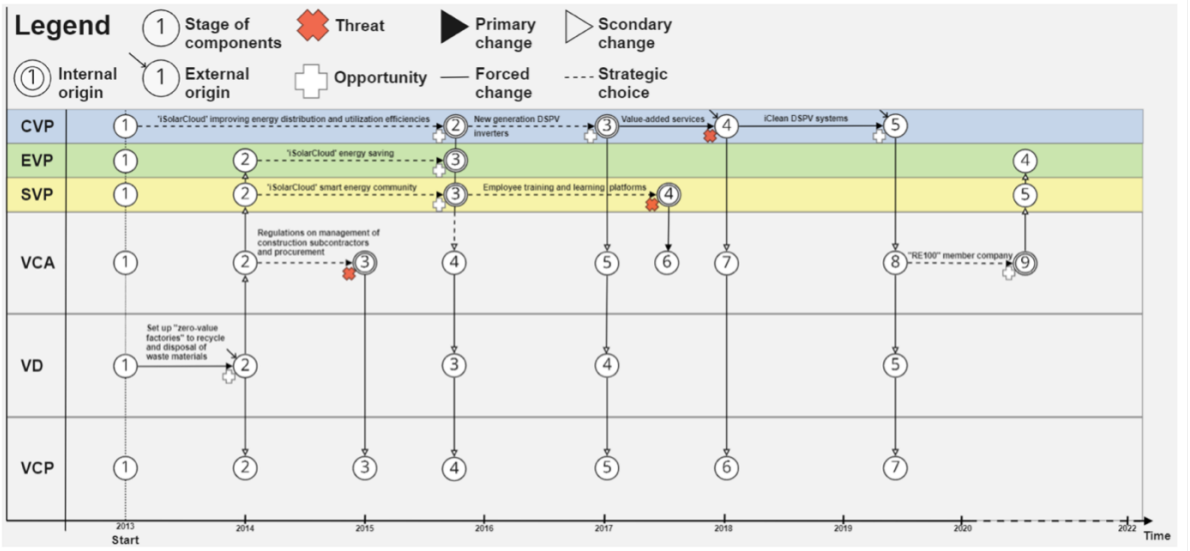


Figure 2.12: The framework of Xu (2022) showing the dynamics of business models of sustainable businesses.

This framework might be very suitable for this research. It depicts more elements (four instead of three if the value proposition is seen as one element) compared to the framework of Kamp et al. (2021), thus showing a more holistic and precise picture of all the events. It does this, while still having an orderly presentation of the BM changes.

The Kharbeet (2022) framework

Kharbeet created the most recent framework discussed in this literature review. He used the framework of Meslin (2019), Kamp et al. (2021), and Xu (2022) as the foundation to build his framework. In this framework, the four criteria of Khodaei and Ortt (2019) are still the basis for designing the framework precisely as with the other frameworks. The framework also represents the six considerations of Kamp et al. (2021). Compared to the framework of Xu (2022) the same division of elements of the business model is used. The simplification of Kharbeet his framework in comparison with the framework of Xu is that the value proposition is not split into a customer value proposition, an environmental value proposition, and a social value proposition. The second difference that Kharbeet made is that opportunities and threats are not defined or mentioned in his framework. This was not necessary because the focus of the research was different. He instead added the growth stages and critical junctures as defined by Vohora et al. (2004) to the framework. The goal of the development of his framework was to link the business model dynamics to the growth stages of start-ups in order to help overcome critical junctures.

In Figure 2.13 his developed framework can be seen. The different main elements of a business model, according to Bocken et al., are visualized in the framework. These main elements can change either through a forced change or by strategic choice. This is visualized as an arrow with a solid line and a dashed line respectively. The difference between primary and secondary changes is also depicted by a filled and hollow arrowhead. And lastly, the difference between the internal origins and external origins of the primary change is illustrated. This is the same as for the frameworks of Meslin (2019), Kamp et al. (2021), and Xu (2022).

The main difference between the mentioned frameworks and the one developed by Kharbeet is the addition of critical junctures and growth stages. The critical junctures are depicted as grey rectangles between the arrows that illustrate a change in the BM and labelled as J1 for the first critical juncture, J2 for the second critical juncture, J3 for the third critical juncture, and J4 for the fourth critical juncture. The growth stages are shown under the timeline and between the critical junctures. This illustration of the critical junctures and growth stages shows how changes in the BM can lead to overcoming critical junctures.

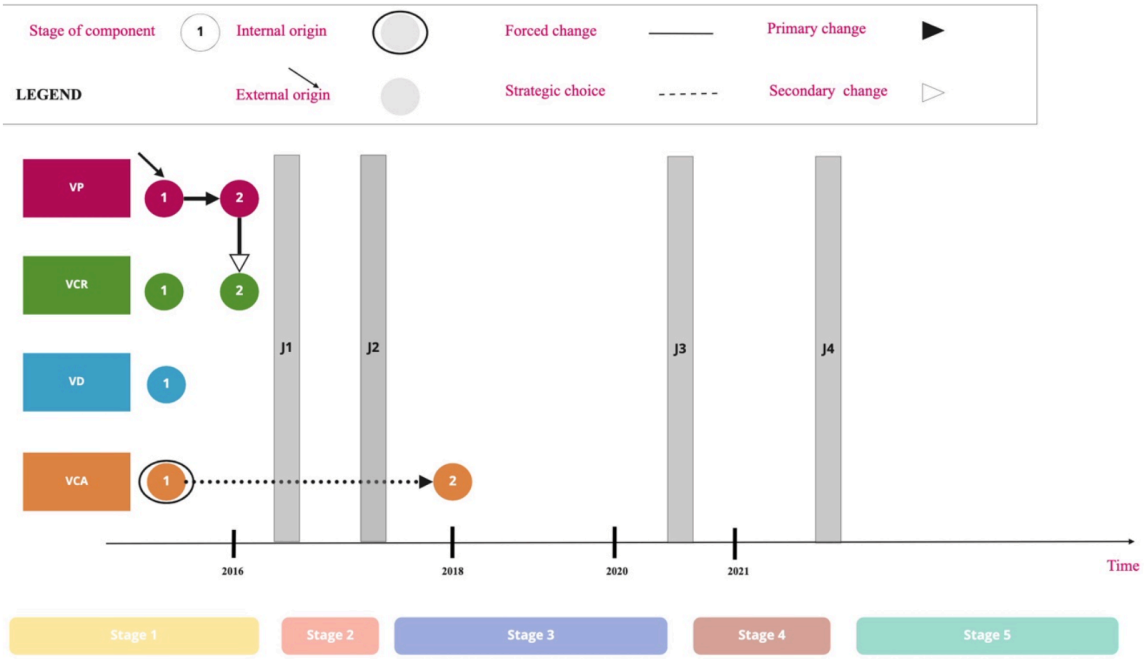


Figure 2.13: The framework of Kharbeet (2022) showing the dynamics of business and linking this to the growth stages of Vohora et al. (2004)

2.4. External factors

In the previous section, multiple dynamic business model frameworks were presented. In this section, the addition of categorization of the external factors is justified. In the framework of De Reuver et al. (2009) the influence of external factors on business models were shown. Other frameworks showed if the primary changes were caused by an external or internal origin, such as in the framework of Kamp et al. (2021) and Xu (2022). As one of the criteria of Khodaei and Ortt (2019) is completeness, which relates to both the internal and the external business environment, the external environment is underrepresented in most of the frameworks. Especially when external factors play such a prominent role for PV start-ups. Besides the external factors in the framework of De Reuver et al. (2009), no framework defines what external factors exactly play a role.

A method to comprehensively analyse the macro-environmental factors that can affect a business or organization is the PESTEL analysis. This analysis consists of six factors: political, economic, social, technological, environmental, and legal.

Political drivers refer to the influence of government activities and policies on a business or organization. These can include taxes, trade policies, subsidies, and other regulations. Political instability in a region can also affect a business, as it can disrupt operations and create uncertainty.

Economic drivers refer to factors such as interest rates, inflation, and unemployment, that can have a significant impact on a business or organization. Economic downturns can lead to decreased consumer spending, which can negatively impact a business's revenue. On the other hand, a strong economy can lead to increased consumer spending and growth opportunities for a business.

Social drivers refer to demographic trends and cultural attitudes that can affect a business or organization. For example, changes in population growth, age distribution, and lifestyle trends can affect a business's target market and marketing strategies. Additionally, cultural attitudes towards a particular product or service can also affect its demand.

Technological drivers refer to advancements in technology and the impact of the internet on a business or organization. The rapid pace of technological change can create new opportunities and disrupt traditional business models. For example, the widespread adoption of the Internet has led to the growth of e-commerce and online marketplaces.

Environmental drivers refer to factors such as climate change and natural disasters that can affect a business or organization. Climate change can lead to changes in weather patterns and natural resource

availability, which can affect a business's operations and supply chain. Natural disasters can disrupt operations, damage property, and cause injury or loss of life.

Legal drivers refer to laws and regulations that can affect a business or organization. These can include labour laws, health and safety regulations, and environmental laws. Compliance with these laws and regulations can affect a business's operations and profitability. Additionally, changes in laws and regulations can create new opportunities or challenges for a business. This sounds similar to the political drivers but is different as political drivers are government policies and regulations, while legal drivers refer to changes in the regulatory environment, such as specific laws and regulations that businesses must comply with.

The PESTEL analysis helps organizations understand how these drivers may impact their operations and can be used to inform strategic decision-making. It's important to regularly evaluate and monitor these drivers in order to identify potential opportunities or challenges and take appropriate actions.

Unlike the three categories of the framework of De Reuver et al. (2009) (market, technology, and regulation), the PESTEL drivers will be used in this research. After contacting Mr De Reuver, he suggested using another categorization method than he used in his study, such as the much-used PEST or PESTEL framework. Besides the fact that Mr De Reuver is an expert in this field, there are several reasons for choosing these drives in this research.

The PEST and PESTEL analysis are both frameworks used to systematically analyse the macro-environmental factors that can affect a business or organization. However, there are some key differences between the two that can make PESTEL more useful for sustainable companies, which are the focus of this research.

The PEST analysis, which stands for Political, Economic, Social and Technological (the first four categories of PESTEL), is a simpler framework that focuses on these four main drivers. While it can provide a good overview of the macro-environmental factors that can affect a business, it doesn't take into account some important factors that are relevant for sustainable companies, such as the environmental and legal drivers. Just like the BMC only looks at the economic value for companies but neglects the social and environmental value, the PEST analysis neglects the environmental factors. These factors might however play a significant role for companies in the sustainability sector.

The PESTEL analysis provides a more comprehensive view of the macro-environmental factors that can affect a business, including those specifically related to sustainability: environmental and legal. Especially, environmental drivers might be important as they refer to factors such as climate change and natural disasters. Climate change can lead to changes in weather patterns and natural resource availability. For companies in the PV industry, weather changes might be of huge influence. Legal drivers refer to laws and regulations that can affect a business or organization. These can include labour laws, health and safety regulations, and environmental laws. Compliance with these laws and regulations can affect a business's operations and profitability. Specifically (international) environmental laws might influence companies in the sustainability sector.

In summary, PESTEL analysis is more comprehensive than PEST analysis and provides a more detailed view of the macro-environmental factors that can affect a business. This makes it more useful for sustainable companies, who are interested in understanding the specific opportunities and challenges related to sustainability.

3

Conceptual framework

With the comprehensive review of relevant literature presented in chapter 2, a solid theoretical foundation has been established for the development of a dynamic sustainable business model framework. This chapter aims to construct such a dynamic sustainable business model framework, adhering to the criteria outlined by Khodaei and Ortt (2019), namely completeness, interrelationships, and changes over time. The resulting framework will be presented at the conclusion of this chapter, drawing inspiration from the frameworks proposed by Meslin (2019), Kamp et al. (2021), Xu (2022), and Kharbeet (2022).

Drawing upon the works of Meslin (2019), Kamp et al. (2021), Xu (2022), and Kharbeet (2022), this study introduces a dynamic sustainable business model framework. The framework is developed by leveraging the sustainable business model canvas (SBMC) proposed by Bocken et al. (2018). Specifically, four primary categories, namely Value Proposition (VP), Value Creation (VCR), Value Delivery (VD), an Value Capture (VCA) are presented as integral components of the framework. Notably, the framework incorporates the six key considerations, as outlined by Kamp et al. (2021), which have been further refined and updated to align with the new proposed framework. This results in nine considerations:

1. The business model is subdivided into four main components: the value proposition, the value creation, the delivery, and the value capture;
2. The initial change in the business model refers to one particular business model element;
3. Business model consistency mostly requires follow-up changes in one or more of the other business model elements;
4. The initial changes are called primary changes and the possible follow-up changes are called secondary changes;
5. Business model changes can either be forced changes or strategic choices;
6. The timeline of the growth stages of the start-ups is incorporated;
7. The growth stages and critical junctures are included in the framework;
8. The origin of change can lie inside or outside the company;
9. External origins are divided into political, economic, social, technological, environmental, or legal factors.

3.1. Completeness

The first criterion to consider in the development of a dynamic sustainable business model framework is completeness, as highlighted by Khodaei and Ortt (2019). This encompasses both the internal aspects of a company and its external environment. The assessment of completeness involves three subaspects: (1) internal company variables, (2) external environment variables, and (3) business model variables.

However, it is crucial to strike the right balance in achieving the optimal level of completeness within a dynamic business model framework (Khodaei & Ortt, 2019). Including too many elements can lead to a distorted representation of the business model, while visualizing an excessive number of elements can result in a cluttered or confusing overview (as observed in Figure 2.11).

For the purpose of this research, the focus is not on the economically-focused Business Model Canvas (BMC) proposed by Osterwalder and Pigneur (2010), but rather on the Sustainable Business Model Canvas (SBMC) developed by Bocken et al. (2018) as the basis for the dynamic business model framework. In contrast to Kamp et al.'s (2021) framework, which visualize business model dynamics using three components based on the BMC (i.e., value proposition, value network, and cost and revenue streams), this research adopts a different division of components.

According to Bocken et al. (2018), the SBMC can be divided into four components: value proposition, value creation, value delivery, and value capture, as depicted in Figure 2.3. The value proposition demonstrates what the company has to offer and why it should be chosen over competitors. This encompasses economic, societal, and environmental value within the SBMC. Value creation involves the key stakeholders, key activities performed by the company, and the key resources and capabilities. Value delivery pertains to the customer segments targeted, as well as the relationships and channels utilized to reach those segments. Lastly, value capture encompasses the cost structure and revenue streams of the company. Table 3.1 provides some illustrative examples of elements within each component of the BM.

Table 3.1: Typical BM elements for start-ups in the solar energy sector.

Element	Component of SBMC	Example
VP	Value proposition	• Product delivery and sales (Gabriel & Kirkwood, 2016) • Technology and system design (Gabriel & Kirkwood, 2016) • Optimization, customization, automation, and cost reduction (Metelskaia et al., 2018) • Renewable electricity generation and DSM devices (Reis et al., 2021) • Reduced energy bills (Horváth & Szabó, 2018) • Independence from utilities (Horváth & Szabó, 2018)
VCR	Key stakeholders	• Networks (Gabriel & Kirkwood, 2016) • Local installers and technicians (Gabriel & Kirkwood, 2016) • Governments (Gabriel & Kirkwood, 2016) • Technology suppliers (Reis et al., 2021) • Banks and financing organizations (Horváth & Szabó, 2018; Reis et al., 2021) • Producers and wholesalers of system components (Horváth & Szabó, 2018)
	Key activities	• System integration (Gabriel & Kirkwood, 2016) • Project development (Gabriel & Kirkwood, 2016) • Electricity generation (Reis et al., 2021) • After-sales services (Horváth & Szabó, 2018) • Customer support service (Horváth & Szabó, 2018)
	Key resources and capabilities	• Money (Gabriel & Kirkwood, 2016) • Financial and non-financial investors (Gabriel & Kirkwood, 2016) • Private investments (Reis et al., 2021) • Distribution network capabilities (Reis et al., 2021) • Technological knowledge (Horváth & Szabó, 2018)

Table 3.1 continued from previous page

		• Close knowledge of consumers and local market (Horváth & Szabó, 2018)
VD	Customer segments	• End-users (Gabriel & Kirkwood, 2016) • SMEs (Horváth & Szabó, 2018; Reis et al., 2021) • Farmers (Horváth & Szabó, 2018) • Homeowners (Horváth & Szabó, 2018)
	Customer relationships	• Direct and indirect relationships with customers or end-users (Gabriel & Kirkwood, 2016; Horváth & Szabó, 2018) • Varied advertising: word of mouth, websites, digital or printed ads (Gabriel & Kirkwood, 2016; Horváth & Szabó, 2018)
	Channels	• Use of word of mouth (Gabriel & Kirkwood, 2016) • Direct sales to end-users (Gabriel & Kirkwood, 2016) • Home exhibitions and other information strategies (Reis et al., 2021) • Sales representatives (Horváth & Szabó, 2018)
VCA	Cost structure	• Operating expenses (Gabriel & Kirkwood, 2016) • Cost of hiring, wages (Gabriel & Kirkwood, 2016; Horváth & Szabó, 2018) • Import duties/taxes (Gabriel & Kirkwood, 2016) • Costs for grid interconnection (Reis et al., 2021) • Stock costs (Horváth & Szabó, 2018)
	Revenue streams	• System sales and infrastructural integration (Gabriel & Kirkwood, 2016) • Maintenance (Horváth & Szabó, 2018) • PV system installation (Horváth & Szabó, 2018)

As highlighted earlier in this section, the completeness criterion encompasses three subaspects, namely internal company variables and external environment variables. To enhance the completeness of the dynamic business model framework, it is necessary to explore the internal and external factors that influence the elements of the Sustainable Business Model (SBM). Furthermore, it can be beneficial to categorize these factors as opportunities and threats, as suggested by Meslin (2019). This distinction allows for a more comprehensive analysis of business model dynamics by providing a clearer definition of their origin, while also enabling a deeper examination of the cause-and-effect relationship underlying business model changes. Several examples of these factors can already be found in Table 2.2, which presents business model innovation drivers, as well as Table 2.3, which highlights the origin of some drivers. For a better understanding, the different types of factors, along with their definitions, are summarized in Table 3.2.

Table 3.2: Types of factors and their definition in the framework.

Type of factor		**Definition**
External origin	E	Factors related to the external environment
Internal origin	I	Factors related to the internal company variables
Opportunity	O	Factors related to opportunities seized by the company
Threat	T	Factors related to avert threats for the company

To ensure a comprehensive representation of BMD, it is essential to capture the environmental variables that impact the business model, as emphasized by Khodaei and Ortt (2019). While the framework proposed by Kamp et al. (2021) distinguishes between internal and external origins of BMD, it does not explicitly differentiate between opportunities and threats. The framework presented by Xu (2022) follows the same internal and external categorization but goes a step further by explicitly considering opportunities and threats. Including this distinction can provide a more nuanced understanding of the factors driving BMD. Table 3.3 provides some examples of these types of factors influencing BMD.

Table 3.3: Examples of the different types of factors affecting the BM elements.

Type of factor	Example
E.O.	• Supportive Financial System (Hamwi & Lizarralde, 2017) • Market forces (Bouwman et al., 2006; Chesbrough, 2010; De Reuver et al., 2009; Hamwi & Lizarralde, 2017) • Customer preferences (Chesbrough, 2010; Giesen et al., 2010; Hamwi & Lizarralde, 2017) • Technological developments (Chesbrough, 2010; De Reuver et al., 2009) • Global pandemic (Xu, 2022) • Subsidies
E.T.	• Import duties • Competition / competing technologies (Horváth & Szabó, 2018; Saebi, 2014) • Restricting regulation (Karakaya et al., 2016; Leisen et al., 2019) • Regulations (Chesbrough, 2010; De Reuver et al., 2009)
I.O	• Product innovation (Giesen et al., 2010) • Resource availability (Giesen et al., 2010)
I.T.	• Production issues (Horváth & Szabó, 2018) • Lack of resource availability (Giesen et al., 2010) • Increasing costs (Xu, 2022)

According to Khodaei and Ortt (2019), certain internal company aspects such as company competencies, as well as crucial external aspects such as competition, are often missing in business model frameworks, despite their criticality. In the framework proposed by Xu (2022), although the origin of external drivers is categorized as either a threat or an opportunity, it is not further specified. For instance, competition as an external aspect highlighted by Khodaei and Ortt (2019) is not explicitly represented in the framework of Xu (2022).

As mentioned in section 2.4, the PESTEL framework serves as a suitable method for categorizing these drivers. A comprehensive explanation of the PESTEL framework can be found in section 2.4. Table 3.4 provides an overview of how various factors can be divided into the six categories of the PESTEL analysis. The table also presents some examples of external factors that influence business model dynamics.

Table 3.4: Typical examples of the categories of the PESTEL analysis. Where P is Political, E is economic, S is social, T is technical, E is environmental, and L is legal.

Pestel category	Typical examples
Political	• Government policies (Sammut-Bonnici & Galea, 2014) • Local legislation (Sammut-Bonnici & Galea, 2014) • Fiscal policies (Sammut-Bonnici & Galea, 2014) • Permits and licensing (Sammut-Bonnici & Galea, 2014) • Control of corruption (Sammut-Bonnici & Galea, 2014) • Security controls (Ho, 2014) • Using solar power to ensure energy security (Molamohamadi & Talaei, 2022)
Economic	• Local and international economy (Sammut-Bonnici & Galea, 2014) • Inflation (Ho, 2014; Sammut-Bonnici & Galea, 2014) • Customer purchasing power (Sammut-Bonnici & Galea, 2014) • Interest rates (Ho, 2014; Sammut-Bonnici & Galea, 2014) • Economic trends (Sammut-Bonnici & Galea, 2014) • High setup costs for solar power (Molamohamadi & Talaei, 2022)
Social	• Demographics (Sammut-Bonnici & Galea, 2014) • Customer perception of brand (Sammut-Bonnici & Galea, 2014) • Purchasing behaviour (Sammut-Bonnici & Galea, 2014) • Racial, ethnic, and religious influences (Sammut-Bonnici & Galea, 2014) • Language (Ho, 2014) • Living standards (Ho, 2014)

Table 3.4 continued from previous page

	• Public acceptance towards renewable energy sources (Molamohamadi & Talaei, 2022)
Technical	• Innovations in electronic or mechanical processes (Sammut-Bonnici & Galea, 2014) • Effects of technology on product design, production, distribution (Sammut-Bonnici & Galea, 2014) • Technological trends (Ho, 2014)
Environmental	• Solar energy is recyclable (Molamohamadi & Talaei, 2022) • Global pandemic (Xu, 2022) • International contracts to reduce greenhouse gasses (Molamohamadi & Talaei, 2022)
Legal	• Implementation of certain articles to increase solar energy (Molamohamadi & Talaei, 2022) • Enforcing power plants (Molamohamadi & Talaei, 2022) • Strict requirements of environmental institutions (Molamohamadi & Talaei, 2022)

3.2. Interrelationships

The second criterion for developing a dynamic sustainable business model framework is interrelationships. These interrelationships encompass the connections between BM variables and the relationships between BM elements and the environment (Khodaei & Ortt, 2019). Investigating these interrelationships is crucial for comprehending the logic of a BM, as a BM describes how an organization creates, delivers, and captures value (Osterwalder & Pigneur, 2010). In the context of this research, understanding these interrelationships is important to discern the impact of external factors on business model dynamics.

Frameworks proposed by Meslin (2019), Kamp et al. (2021), and Xu (2022) capture these relationships. In these frameworks, the relationships between different business model (BM) components are defined based on the initial reason for change and the subsequent impact of that change on subsequent BM modifications. These initial and follow-up changes can be categorized as either 'forced changes' or 'strategic choices,' highlighting the entrepreneurial freedom in making BM changes (Kamp et al., 2021). Both primary and secondary changes to the BM can be either forced changes or strategic choices. A forced primary change can lead to a forced secondary change or a strategic choice, while a strategic choice as the primary change can result in a strategic secondary choice or a forced secondary change. This framework delineates four distinct interrelationships between BM elements (see Table 3.6).

By incorporating this adapted framework from Xu (2022), a more nuanced understanding of BM dynamics and interrelationships between different components is achieved. This framework can potentially provide insights into the drivers and motivations behind BM changes and their impact on organizational functioning and performance.

Table 3.5: The four types of interrelationships between BM elements and their abbreviations.

Type of relationship	**Meaning**
SS	A primary strategic choice of A leads to a strategic change in B.
FF	A primary forced change in A leads to a forced change in B.
SF	A primary strategic choice of A leads to a forced change in B.
FS	A primary forced change in A leads to a strategic change in B.

Table 3.6 presents examples of interrelationships between different elements of the business model. These elements were adapted from the works of Kharbeet (2022) and Xu (2022). The table illustrates how changes in one element can influence and trigger changes in other elements, highlighting the dynamic nature of the business model.

Table 3.6: Some examples of relationships between business model elements, adapted from Xu (2022) and Kharbeet (2022).

Interrelationships between business model elements	**Examples of interrelationships**
Value proposition	
VP → VCR	"A change in value proposition towards adopting more sustainability in the form of the introduction of new products for disadvantaged communities might require firms to adapt to the supply chain, production, and distribution channels simultaneously" (Ilyas & Osiyevskyy, 2022)
	"A study of the storage energy market shows that key partners have a major change for small-scale energy storage applications as new partnerships arise, while key resources have changed for all cases." (Hamelink & Opdenakker, 2019)
VP → VD	"A sustainable value proposition increases customer willingness to pay and also differentiates the products and services to attract customers." (Ilyas & Osiyevskyy, 2022)
	"Firms explore new and underserved markets such as marginalized communities that offer new opportunities to introduce innovative and sustainable value propositions" (Ilyas & Osiyevskyy, 2022)
VP → VCA	"A sustainable value proposition enhances the financial success of a firm by offering new value product-service systems such as house-, car-, or bike-sharing" (Ilyas & Osiyevskyy, 2022)
	"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)
Value Creation	
VCR → VP	"Networks and partnerships lead to a change in the value proposition towards more sustainability." (Rossignoli & Lionzo, 2018)
VCR → VD	"Software startups reported that the joint involvement of experienced freelancers in the startup activities enhanced customer relationships and customer satisfaction and helped the startups to grow faster in the market." (Gupta et al., 2020)
VCR → VCA	"Software startups reported that the joint involvement of experienced freelancers in the startup activities led to reduce development costs." (Gupta et al., 2020)
Value Delivery	
VD → VP	"Customers collaboration with companies that use digital technology to communicate with customers allowed them to develop customized solutions." (Y. Chen et al., 2021)
VD → VCR	"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)
VD → VCA	"Companies offing new value propositions earn revenue from new customers by different approaches (e.g., up-front installation payment of PV panels)" (Rossignoli & Lionzo, 2018)
Value Capture	
VCA → VP	"A distinct value proposition for various customer segments will result from various cost and revenue distributions inside the company and among end users" (Kulatilaka et al., 2014)
	"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)

Table 3.6 continued from previous page

VCA → VCR	"To reduce the high cost in recycling EOL panels, companies undertake R&D activities related to recycling techniques." (Ndzibah et al., 2021)
VCA → VD	"Long-term customer attraction may be achieved by rewarding loyal customers with a particular incentive or by developing trustful relationships." (Y. Chen et al., 2021)

3.3. Changes over time

The inclusion of changes over time constitutes the final two criteria outlined by Khodaei and Ortt (2019): interrelationships over time and framework changes. Given that a company's business model (BM) is not a static entity (Demil & Lecocq, 2010), it is imperative to incorporate temporal dynamics within the framework. Continuous refinements are necessary for a BM to adapt to its evolving environment. In order to maintain internal consistency subsequent to these refinements, the BM must be responsive to both internal and external changes (Khodaei & Ortt, 2019). When a modification is made to one BM element, it often necessitates corresponding changes in one or more other elements to ensure consistency and enhance the overall model (Kranich & Wald, 2018; Spieth & Schneider, 2016). For instance, a shift in the value delivery component might trigger an alteration in value creation. The dynamic framework portrays such changes by employing a time axis as a visual representation.

3.4. The framework

The proposed dynamic sustainable business model (SBM) framework for this research is built upon the original framework developed by Meslin (2019) and Kamp et al. (2021), with adaptations from Xu (2022) and Kharbeet (2022). Xu's framework combines a dynamic business model framework with the Sustainable Business Model Canvas (SBMC) by Bocken et al. (2018), as depicted in subsection 2.3.3. The primary distinction between Kamp et al.'s framework and Xu's framework lies in the division of elements. Kamp et al. utilizes three components, namely value proposition, value network, and cost and revenue stream, while Xu incorporates four components: value proposition, value creation, value delivery, and value capture, aligning with Bocken et al.'s framework (2018). Also, is the origin of the changes expanded with opportunities and threats in the framework of Xu.

Building upon Xu's framework, the current research introduces an additional aspect concerning external factors, inspired by De Reuver et al.'s framework (2009) (see subsection 2.3.2). De Reuver et al.'s framework investigates and visualizes the impact of external factors on the BM. In this research, the external factors will also be visualized within the framework. However, the focus is not solely on the effect of external factors on the BM, but rather on which specific aspects of the BM are influenced and how this knowledge can benefit start-ups. All components of the framework are presented in Table 3.7. The visual representation of the framework is illustrated in Figure 3.1.

Furthermore, elements from Kharbeet's framework (2022) have been incorporated into the foundation of the research framework. Kharbeet's framework demonstrates how business model changes are linked to growth stages and critical junctures, providing insights into how BMDs contribute to start-up development. This addition aims to visualize the impact of external factors not only on BMDs but also on the overall development of start-ups.

Table 3.7: The different components in the dynamic business model framework.

Framework element	**Presentation in framework**
The stage of the component	A circle with a number
Primary change	A black tipped arrow
Secondary change	A with tipped arrow
Forced change	An arrow with a solid line
Strategic choice	An arrow with a dotted line
Opportunity	A perpendicular cross (a plus)
Threat	A cross

Table 3.7 continued from previous page

Internal origin	A circle with a double line
External political origin	A blue circle with an arrow attached and the letter P next to it
External economic origin	A green circle with an arrow attached and the letter Eco next to it
External social origin	A yellow circle with an arrow attached and the letter S next to it
External technological origin	A red circle with an arrow attached and the letter T next to it
External environmental origin	A grey circle with an arrow attached and the letter Env next to it
External legal origin	A purple circle with an arrow attached and the letter L next to it
Value proposition	VP
Value creation	VCR
Value delivery	VD
Value capture	VCA
Growth stage “Research”	Stage 1
Growth stage “Opportunity framing”	Stage 2
Growth stage “Pre-organization”	Stage 3
Growth stage “Re-orientation”	Stage 4
Growth stage “Sustainable returns”	Stage 5
Critical juncture “Opportunity recognition”	J1
Critical juncture “Entrepreneurial commitment”	J2
Critical juncture “Credibility”	J3
Critical juncture “Sustainability”	J4
A vertical line with 3 double headed arrows.	Going a stage backwards

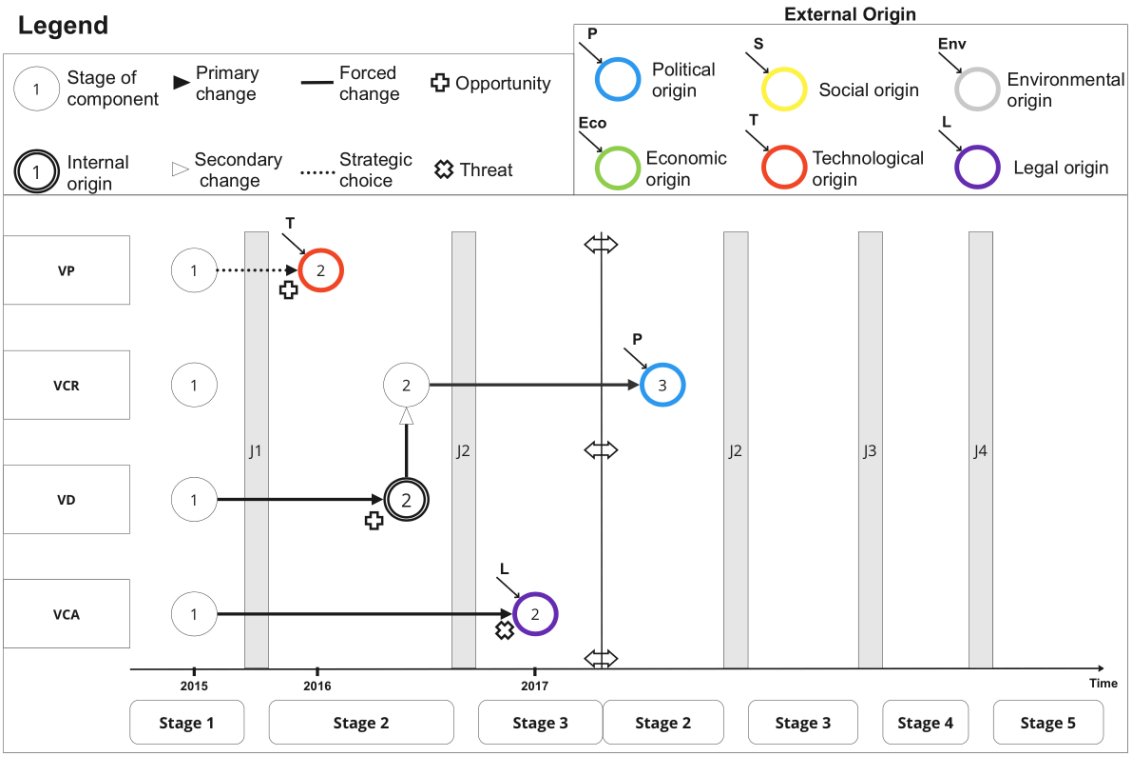


Figure 3.1: The proposed dynamic sustainable business model framework.

4

Methodology

The aim of this chapter is to explain the research methodology employed to investigate the dynamics of sustainable business models and the correlation between external factors and these dynamics within Dutch technology-based PV start-ups. The chapter begins by elaborating the case selection process, which is subsequently followed by a comprehensive portrayal of the methods utilized for data collection. Ultimately, the chapter concludes by furnishing an interview guide to facilitate the data collection process. The specific cases will be presented in chapter 5 and a detailed analysis in chapter 6.

4.1. Case Selection

The methodology starts with the careful selection of cases, as previously indicated in the chapter's introduction. In this research, the focus is on investigating technology-based PV start-ups in the Netherlands. The geographical boundary of the Netherlands was chosen in order to control for national policies and practice-related activities. Start-ups have been chosen as the primary subjects of this study due to their operational environment, which is characterized by time constraints, uncertainty, and heightened motivation (Gersick, 1994). Moreover, early decisions made within start-ups often necessitate subsequent adjustments (Conceição et al., 2012). Hence, their operational context is highly suitable for studying the dynamics of sustainable business models.

The companies selected for inclusion in this research had to fulfill specific criteria, namely: (1) being Dutch technology-based start-ups, (2) being actively engaged in the solar energy sector, and (3) having successfully passed the credibility juncture. Regarding the second criterion, "being actively engaged in the solar energy sector" implies that the company is involved in activities related to the conversion of solar energy into electrical energy, such as the production of solar-powered vehicles. Start-ups failing to meet this criterion are excluded from the study. The third criterion has to be met as this ensures that the company is selling products on the market and therefore had suffient business model changes.

Table 4.1: List of start-ups contacted for the case studies.

#	Start-up	Founding year	Response	Main informant
1	SolarWorks	2007	Yes	COO
2	SuperSola	2017	Yes	Managing director
3	FlexSol Solutions	2011	No	-
4	Lightyear	2016	No	-
5	Solarge	2017	Yes	CEO
6	Solar Skelter	2017	No	-
7	Elemental water makers	2012	-	
8	Solho	2017	Yes	CEO
9	Solar Monkeys	-	-	-
10	Rural Spark	-	No	-
11	Imefficiency	2014	No	-

Table 4.1 continued from previous page

12	Taylor	-	No	-
13	Wellsun	2013	No	-
14	EXASUN	2012	No	-
15	Triple Solar	2009	No	-
16	Solaroad	2018	No	-
17	Rooftop energy	2012	-	-
18	Wattlab	2016	Yes	COO
19	Kameleon solar	-	-	-
20	Zigzag solar	-	No	-
21	A PV company	2016	Yes	Director
22	eternal sun	-	-	-
23	energyra	-	-	-
24	Sunchip	-	-	-
25	Hyet solar	-	-	-
26	PV works	2020	-	-

4.2. Data collection

The complete process, encompassing case selection through to the analysis of cases, is outlined in Table 4.2. The table provides an overview of the data collection steps, excluding the final step of "case reporting," which pertains to the analysis of the cases. The data collection process commences with an extensive investigation of various start-ups, their activities, and their eligibility for inclusion in this study. Subsequently, the start-ups are contacted via email, and in the absence of a response, a follow-up email is sent. If no response is received, direct communication via phone is pursued.

Upon securing the participation of a start-up in the study, additional background information is gathered to facilitate an efficient interview process, thereby minimizing the inclusion of redundant questions or the wastage of time by soliciting information already available. Leveraging the collected online information, the interviews are conducted, with further details regarding the interview process provided in the subsequent section (section 4.3).

Table 4.2: The main steps needed for the data collection of the case studies.

Main steps	**Description**
Initial investigation	• Internet search, website reading, word of mouth investigation
Case selection	• Define criteria for cases and select cases • Determine potential cases
Contacting start-ups	• Send e-mail to potential case informants • If needed, send a follow-up e-mail or call
Information collection	• Interview design • Extensive collection of written documents such as press articles, company websites, and reports • Do the interview • Integrate transcription of the interview with meeting notes and collection of written documents
Case reporting	• Make case description • Create a dynamic sustainable business model framework of the case • Analyse the cases • Discussion and implications • Draw conclusions

4.3. Interview guide

The interview methodology employed in this study entails conducting face-to-face semi-structured interviews, whenever feasible. Face-to-face semi-structured interviews offer the advantage of being able to

observe body language and facial expressions, which can provide valuable insights (Bougie & Sekaran, 2016). However, in cases where an in-person meeting is inconvenient or not possible for the case informant, alternative online channels such as Skype, Zoom, or Teams may be used for conducting the interview.

The interview itself comprises four distinct parts. The first part involves gathering general information from the case informant to ascertain their qualifications for answering the research questions and their level of knowledge regarding the company. The second part of the interview focuses on exploring the business model (BM). It delves into the identification of the original BM, the subsequent modifications made to it, and the specific factors that prompted these changes, ultimately leading to the current BM. The third part of the interview encompasses inquiries concerning the external factors that have influenced the business model of the start-up. This section aims to unravel the external forces and circumstances that have impacted the business model dynamics. Lastly, the fourth part of the interview is dedicated to examining the growth stages and critical junctures experienced by the start-up. These questions aim to identify the critical junctures encountered, the timing of their occurrence, and establish a timeline for the different growth phases.

Table 4.3: The interview questions for the face-to-face semi-structured interview.

Question scope	**Questions**	**Framework related aspects**
General information	What are you currently doing at the company?	-
	For how long are you working at the company?	
	How long are you working in this field? (It might be that the interviewee is not working that long for the company but is active in the field for a long time)	
	What position do you hold in the company? (What do you do in company projects / what does your position mean work-wise?)	
Value proposition	What value or benefits does your company offer to their customers? In other words, what is the added value for a customer to buy your product or service? Can you exemplify this?	Completeness Interrelationships Changes over time External factors
	Did the value offer change? What changed, when did this happen, and how did this happen?	
	Why did it change / what caused the change? For example, an additional service that is added or a change in the product making it more fitting to the market needs.	
	How do you track changes in customer preferences or needs? And how do you respond to these changes if they occur?	
Value delivery	Who are your (targeted) customers?	Completeness Interrelationships Changes over time External factors
	Has your target market changed since the beginning? If so, what different markets were targeted and when? Why did the target market change? What were the effects of the changed target market on your company?	
	Which channels are used by your company to “communicate” with your customers? This includes all communications, from advertisement to selling, to delivery of the product/service (distribution channels). Are there follow-up/feedback meetings with customers after a project? Etc.	

Table 4.3 continued from previous page

	Did your communication channels (such as distribution, advertising, and selling) change? What changed, when did this happen, how did this happen, why did it change / what caused the change?	
Value creation	What are the most important business partners or relationships for your company? Such as government, suppliers, distributors, and co-financiers.	Completeness Interrelationships Changes over time External factors
	Does your company also work together with other institutions or companies?	
	Did the partners or relationships change? What changed, when did this happen, how did this happen, why did it change / what caused the change?	
	What are the most important activities that your company does?	
	Did these activities change over time? What changed, when did this happen, how did this happen, why did it change / what caused the change?	
	What are the most important resources that your company needs? Such as materials, financial recourses, human resources, infrastructure, data, and knowledge.	
	Did the recourses used to change over time? What changed, when did this happen, how did this happen, why did it change / what caused the change?	
Value capture	What are your main sources of revenue?	Completeness Interrelationships Changes over time External factors
	Did the main sources of revenue change over time? What changed, when did this happen, how did this happen, why did it change / what caused the change?	
	What are the most important costs that you have? How do costs get paid by your company?	
	Did the most important costs change over time? What changed, when did this happen, how did this happen, why did it change / what caused the change?	
External factors	What external factors affected your company?	Completeness External factors Interrelationships
	Such as political changes, the global pandemic, the rising markets after that, or possible upcoming recessions.	
	When did this happen and how was your company affected?	
	Was it a forced change on your company, or was an opportunity seized?	
	What changed by these external factors and when? Did the value proposition change? How Did the value delivery change? How Did the value creation change? Did the value capture change	
	What category do you think is most influential for your company and why (rank 1 to 6)? Political, Economic, Social, Technological, Environmental, and Legal.	
Growth stages and critical junctures	What process did you go through from idea till now?	Timeline Completeness Growth stages Critical junctures
	What were milestones along the way that you accomplished?	
	What barriers or difficulties did you face?	

Table 4.3 continued from previous page

	How did you overcome them?	
	Did you change any elements of the business model in order to overcome these barriers?	

4.4. Data analysis

Data analysis is a fundamental aspect of this research study, providing the basis for understanding and interpreting the findings derived from the interviews and case studies conducted. A combination of qualitative research methods, including interviews and cross-case content analysis, was employed to explore the business model dynamics in technology-based PV start-ups and the influence of external factors.

The content analysis serves as a systematic and rigorous approach to analyse the qualitative data obtained from the interviews. By carefully examining the interview transcripts and other textual data, key patterns, themes, and trends related to external factors were identified and categorized. This process enables a comprehensive exploration of the data.

To ensure the reliability of the content analysis, a systematic approach is followed. The initial step, after making the transcripts, involves familiarizing myself with the data by reading and re-reading the transcripts. This allows for a comprehensive understanding of the information contained within the interviews and facilitated the identification of nuances and intricacies within the data.

Subsequently, a systematic coding process is undertaken. Through this process, specific segments of the data were assigned labels or tags based on their content and relevance to the research questions. A selective coding strategy was used for this as a ‘data reduction’ technique. This coding approach organized the data into meaningful units, making it more manageable for further analysis.

Following the coding process, an in-depth analysis of the coded data was conducted to identify patterns, relationships, and emerging themes. By systematically reviewing the coded segments and comparing them across different interviews and case studies, commonalities and variations in the external factors are identified.

Throughout the content analysis process, transparency and reliability should be maintained. This approach also allows for the systematic documentation of the analytical process, enhancing transparency and ensuring the credibility of the findings.

It is important to acknowledge the potential limitations and challenges associated with content analysis, including subjective interpretation and researcher bias. However, a systematic approach, rigorous analytical procedures, and transparent documentation should be employed to enhance the credibility and trustworthiness of the findings.

An example of this process will be described now. The process as described above will be conducted with two quotes to show the process.

> *5 years ago we could not have imagined that the logistics chain from China would come to a complete standstill due to corona.* - CEO of SoLarge

In this quote, the main theme is the impact of COVID-19, specifically related to the disruption of the logistic chain. The code ’Disruption of logistic chain’ is given to this quote. This coding captures the overall context of the quote and the specific aspect related to the logistics chain.

> *We started with BCC just before Covid, so that has put a big brake on their ambition and their sales capacity.* - Managing director of Supersola

For this quote, the main theme is again the impact of COVID-19, and the sub-theme is the broader impact on businesses. The simple code of ’COVID-19’ is given to it.

Both quotes are related to COVID-19. Therefore a main theme, or primary code, is given to both quotes covering the similarity regarding COVID-19 by giving both the primary code ’COVID-19 impact’. This primary code belongs under the family code of economic factors, as this is one of the researcher-derived family codes. These examples can also be found in Appendix B.

5

Case studies

5.1. SolarWorks!

SolarWorks is a market leader in the off-grid solar energy sector in Mozambique and Malawi. They offer smaller systems that can power a few lamps and charge a phone, slightly bigger systems that can power TVs or fridges, and large systems designed for SMEs. The original idea was designed by Bernard Hulshof, who studied industrial design at the TU Delft. Bernard travelled to Madagascar for half a year to do a graduation project in which he designed a solar-powered lamp (Delft, 2017). He did this based on market research and customer preferences in that area. This led to the initial design (VP 1 $\rightarrow$ VP 2).

> *"He [the CEO] asked people in Madagascar for half a year: 'If you had a light running on solar energy, would that help? What should it be able to do?'"* - Chief operating officer of SolarWorks!

During Bernard his time in Madagascar, he met Arnoud de Vroomen. Arnoud de Vroomen travelled through Africa documenting innovation and entrepreneurship (Delft, 2017). With his knowledge and skills, they were able to fulfil market needs by designing a power box that could charge a phone and power a few lamps (VP 2 $\rightarrow$ VP 3). With this new product, Bernard and Arnoud founded SolarWorks in 2009 and had the opportunity to open an office in Johannesburg, South Africa. They sold their product to retailers and wholesalers (VD 1 $\rightarrow$ VD 2).

The head office and its R&D department moved to the YES!Delft building in 2011 to ensure technological advancements and attract financing. PhD Nishant Narayan of TU Delft and Prof. Nick van de Giesen offered help to SolarWorks as well. This corporation led to the installation of multiple weather stations in Mozambique to better predict the available battery capacity based on the weather forecast (VCR 1 $\rightarrow$ VCR 2).

During this phase the company developed more products, offering three different products to the wholesalers and retailers (VP 3 $\rightarrow$ VP 4).

> *"In 2015/2016 more and more products started coming from China; cheaper copies, but qualitative getting better and better. (...) Over time these products were pretty okay, but cost a quarter of our product. Then it concerns mainly price and volume, and we thought 'even if we wanted to take on that battle, we would never win it.'"* - Chief operating officer of SolarWorks!

After several years SolarWorks noticed that market competition was increasing. They detected this threat and knew something had to change to stay competitive. As the strong points of SolarWorks were not in competing on price but in the distribution and network they built over the years, so they decided to revise their business model completely. SolarWorks partnered with Persistent Energy Capital in 2015 (Persistent, 2018) and used this partnership to install a new business model by 2016 (VCR 2 $\rightarrow$ VCR 3). The decision was made to only sell the bigger household systems as the smaller systems were not

commercially viable anymore with the increased competition (VP 4 → VP 5). They stopped selling to wholesalers and retailers and started targeting the end consumers directly (VD 2 → VD 3). And as the last change, they revised the payment method from paying directly for each system to a pay-as-you-go payment method (VCA 1 → VCA 2). By changing to this payment method, customers that could initially not afford a solar system could now by paying multiple smaller amounts.

> *"In the beginning, there were indeed a lot of customer problems, especially because we still developed and produced our own products. Eventually, the landscape and market changes led to changing the business model."* - Chief operating officer of SolarWorks!

With this new business model, SolarWorks opened a new office in Mozambique at the end of 2016 and closed the one in Johannesburg. As the company grew, external agents were hired to help sell more products (VCR 3 → VCR 4). They got paid on a commission basis adding to a different cost structure (VCA 2 → VCA 3).

In 2018 an investment of $2 million from EDP Renováveis SA helped fund the international expansion of SolarWorks (VCA 3 → VCA 4) (Persistent, 2018). This eventually resulted in a new office in Malawi (VCR 4 → VCR 5).

In 2019 a cyclone hit Mozambique and Malawi. It turned out that the pay-as-you-go system of SolarWorks was very vulnerable in these situations. As people did not have the facilities to pay for the system anymore, they would stop paying. A year later COVID-19 also became an issue causing the same problem: the moment people had other (bigger) problems, they would stop paying. SolarWorks decided that part of its revenue stream should come from direct payments instead of pay-as-you-go payments (VCA 4 → VCA 5). To accomplish this, they wanted to offer even larger systems to their customers (VP 5 → VP 6) and target small and medium enterprises (SMEs), healthcare clinics, and weak-grid customers (VD 3 → VD 4).

> *"With the pay-as-you-go system alone, something will spell the end for us by something that cannot be controlled by us."* - Chief operating officer of SolarWorks!

This year also two new parties invested in SolarWorks. A debt arrangement worth $4 million was made with ElectriFI to accelerate the expansion in Southern Africa and a dept arrangement of $2 million was made with SunFunder (VCA 5 → VCA 6) (ElectriFI, 2019; SunFunder, 2019).

In 2022 subsidies were made available in Mozambique for small solar systems (VCA 6 → VCA 7). With this change in policy, the opportunity arose for SolarWorks to reoffer the smaller household systems to their customers as they were not loss-making anymore. This creates a wider range of products offered (VP 6 → VP 7).

> *"In Mozambique, we get subsidies for every small product we sell and that is why we sell them there now again. But there is no such program in Malawi, so we still don't sell them there."* - Chief operating officer of SolarWorks!

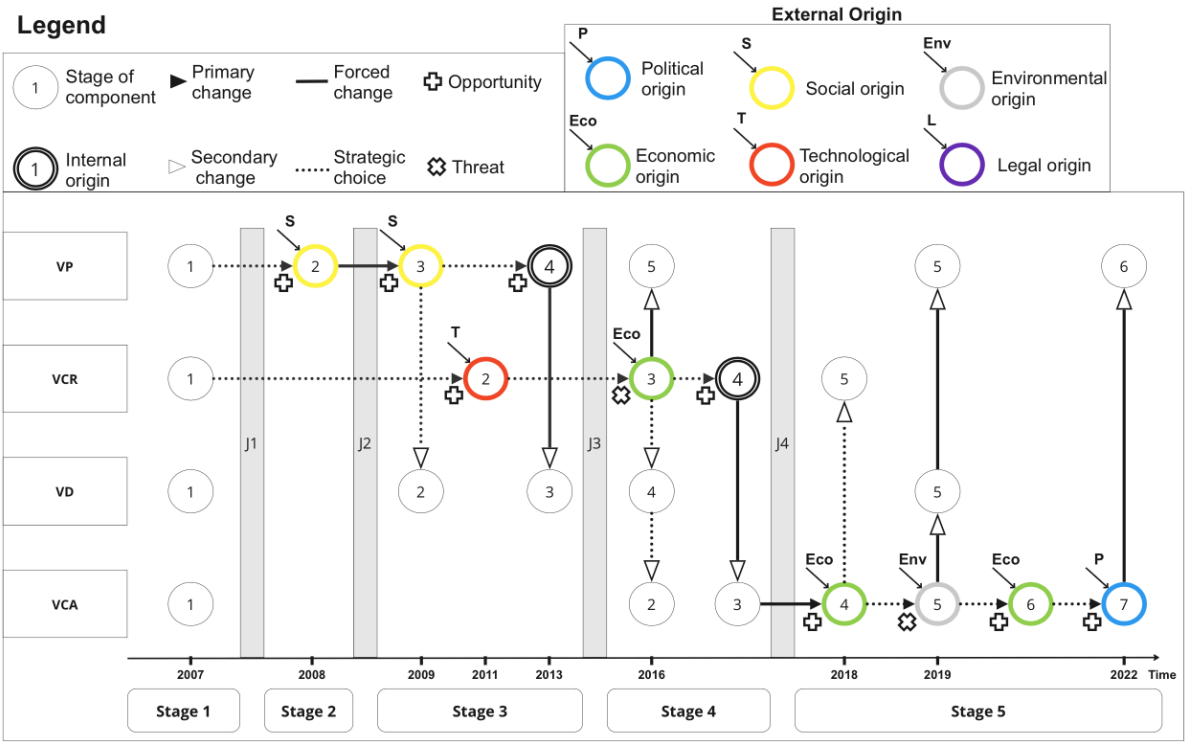


Figure 5.1: The business model dynamics framework showing the business model changes of SolarWorks!

Table 5.1: Some quotes from the interview displaying the importance of external factors on business model dynamics.

External category	Relevance to external factor	Quote
Social	Social need of local community resulting in a new value proposition.	*He [the CEO] asked for half a year to people in Madagascar: 'If you had a light running on solar energy, would that help? What should it be able to do?'*
Economic	Increased market competition led to revising of the business model.	*In 2015/2016 more and more products started coming from China; cheaper copies, but qualitative getting better and better. [...] Then it concerns mainly price and volume, and we thought "Even if we wanted to take on that battle, we would never win it."*
Political	Governmental policy changes led to a renewed value proposition; smaller products are being offered again because they were not long loss-making.	*In Mozambique there is now a subsidy program specifically for those smaller systems because that is the only thing that many poor people can afford. So, in Mozambique, we get subsidies for every small product we sell and that is why we sell them there now again.*

Table 5.1 continued from previous page

Environmental	An environmental disaster, a cyclone, exposed vulnerabilities in their business model resulting in changing the value capture.	*When in 2019, a cyclone hit Mozambique [...] And after that came COVID. Those two things combined made us realize, or rather, we were confronted with the fact that the pay-as-you-go business model is very nice to make it affordable for customers. But it also makes you very vulnerable. [...] So, from that point on, we started looking much more actively at how we can balance the pay-as-you-go with other cash income to ensure we don't just depend on pay-as-you-go.*
Economic	Market forces led to a change in value delivery.	*Well, that first step, from selling to retailers to selling to consumers on credit. That was purely market driven.*
Economic	Devaluation of the currency has an impact on the value capture of SolarWorks!	*In Malawi, from one day to the next, the currency depreciated 25% against the dollar. [...] Therefore, all the money we receive is suddenly worth 25% less. We cannot do anything about these factors, but that makes you very vulnerable.*
Political	Increased import duties, a change in governmental policy, led to an increased cost stream.	*At the beginning of this year, we suddenly had to pay much more import duties in Mozambique than we did before. That has a direct impact on your margin.*
Social / Economic	Changing social needs and markets led to business model changes.	*In the beginning, there were indeed a lot of customer problems [...] Eventually, the landscape and market changes led to changing the business model.*
Political / Legal	An outward search for subsidies and supportive financial resources are used to cover operational costs of new key activities or develop a new value proposition.	*Those larger systems and water pumps that we're looking at right now, those are all new customer segments and new markets for us. The way we usually approach it is by applying for a grant first to try that market. Then we do a pilot with that subsidy and see which product we can sell for what prices. If that is successful, only then, will we actually put money into it ourselves.*
To be determined	This quote shows that uncontrollable external factors play a major role in the survival of start-ups.	*Because with pay-as-you-go only, we will go bankrupt once due to something we do not have control over.*

5.2. Solarge

Solarge is a Netherlands-based start-up engaged in the creation, development, and manufacture of solar panels. Their solar panels distinguish themself from other solar panels through the primary composition of plastics rather than conventional materials such as aluminium and glass. This innovative approach results in the production of sustainable, lightweight, and circular panels. By replacing glass and aluminium with plastics, Solarge not only achieves a lighter weight but also minimizes the panels' CO2 emissions, rendering them more environmentally friendly. Moreover, the panels are designed to be circular, facilitating a straightforward breakdown of the constituent components, including the plastic parts. This is achieved without the use of per- and poly-fluoroalkyl substances (PFAS), which do not naturally occur in the environment and are not biodegradable, but are used in many solar panels nowadays.

> *"Well, the beauty of our panels, which I find quite remarkable, is that it's the only panel that doesn't break. When there's a severe hailstorm, glass solar panels can break, and it has happened before. Now, you can imagine if you have them installed on the IJsselmeer and there's a massive hailstorm, and glass starts falling into the IJsselmeer, that's something we don't want."* - Chief executive officer of Solarge

In 2017, Solarge's founders, Gerard de Leede, Huib van den Heuvel, and Jan Vesseur conceived the idea of creating integrated solar roofs for residential buildings, recognizing a niche market yet to be fully exploited (VP 1 $\rightarrow$ VP 2).

In 2018, Solarge collaborated with construction company Heijmans, knowledge institute Solliance, TNO, and plastic manufacturer SABIC (VCR 1 $\rightarrow$ VCR 2). Due to this partnership a unique, lightweight, and versatile standalone solar panel suitable for various applications, including the agricultural sector and flat roofs market, was created (VP 2 $\rightarrow$ VP 3). First, the agricultural sector was targeted as their main customer segment. In addition to this the flat roofs market, especially roofs that cannot hold the load of regular solar panels, could be targeted because of the lightweight characteristics of the Solarge solar panels (VD 1 $\rightarrow$ VD 2). To fund the project, four informal investors were attracted (VCA 1 $\rightarrow$ VCA 2).

> *"I do think it's important to realize that in the field where we operate, solar panels and energy, political factors are very important."* - Chief executive officer of Solarge

In 2019, Solarge received investment from the Brabantse Startup Fonds (BSF) to help them achieve a good product/market fit (VCA 2 $\rightarrow$ VCA 3) (SoLarge, 2019). With this investment, the hole in Solarge's initial finance chain is filled.

In September 2020 Solarge joined the Techleap Rise Program (SoLarge, 2020a), strengthening its network in the Netherlands. In October 2020, Solarge partnered with Solarfields (SoLarge, 2020b), a market leader in large-scale ground-based solar parks (VCR 2 $\rightarrow$ VCR 3). The goal of the latter partnership is to improve Solarge its ability to reach customers who could benefit from their solar panels (VD 2 $\rightarrow$ VD 3).

At the end of 2021, Vorm became Solarge's first private investor helping to finance the factory to produce the solar panels (VCA 3 $\rightarrow$ VCA 4). Vorm became Solarge's first private investor and major shareholder by doing this (VCR 3 $\rightarrow$ VCR 4). Vorm's investment in Solarge derived from the notion that the activities of Solarge will facilitate the transition towards renewable energy in the Netherlands, without relying on contentious foreign entities (Daling, 2021). Moreover, Solarge aspired to leverage this financial backing to inspire other investors to support its enterprise.

Vorm his example was followed by other investors in March 2022 (VCA 4 $\rightarrow$ VCA 5) (SoLarge, 2022a). Four formal investors invested in Solarge to help their endeavour and became shareholders of the company (VCR 4 $\rightarrow$ VCR 5).

> *"Then there's the energy crisis, as it's being called, caused by Russia. It's making us all realize that as a region, let's take Europe for example, needs to ensure that we can at least manufacture the important elements ourselves."* - Chief executive officer of Solarge

Solarge its solar panels were CERTISOLIS certified in 2022 (SoLarge, 2022b), allowing the company to operate in the strict French market (VD 3 $\rightarrow$ VD 4) while also confirming the low carbon footprint of the panels.

Additionally to adding a new market to their business model, Solarge built and launched an e-commerce platform in 2023, providing a new channel for reaching customers (VD 4 $\rightarrow$ VD 5).

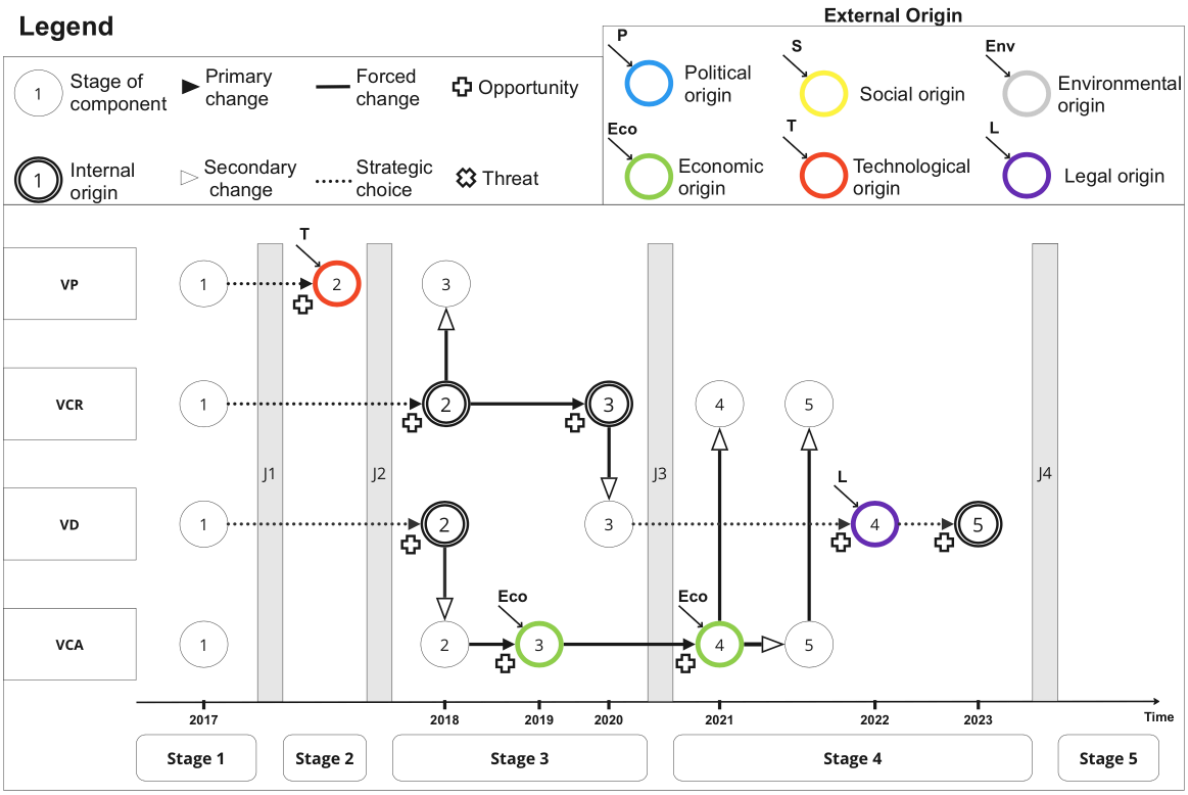


Figure 5.2: The business model dynamics framework showing the business model changes of Solarge.

Table 5.2: Some quotes from the interview displaying the importance of external factors on business model dynamics.

External category	Relevance to external factor	Quote
Economic	The Covid-19 pandemic leads to changes in value creation of SoLarge.	*We couldn't have imagined 5 years ago that due to the pandemic, the logistics chain from China would come to a complete halt, making us all think: "Hey, we need to do things differently!"*
Political / Economic	Geopolitical actions that affect companies.	*Then there's a geopolitical movement where we're all trying to sideline China. […] pursued by the Americans and we'll go along with it. It would be unwise for Europe to do something different in this regard. […] Otherwise you will get an economic war on all fronts, which you don't want!*
Social	The 'energy crisis' causes shifts in the production (value creation) of companies.	*Then there's the energy crisis caused by Russia. It's making us all realize that Europe, as a region, needs to ensure that we can at least manufacture the important elements ourselves.*
Political / Legal	Political incentives and legislation are needed to be profitable (affecting the value capture).	*No one pays us extra for being circular. You need legislation to create value for that.*
Political	Subsidies are important financial resources affecting the value capture of start-ups.	*At the same time, the RVO and the government are very important, because subsidies are a very nice form of financing. And they are much needed.*

Table 5.2 continued from previous page

Environmental	Environmental conditions influence the value proposition (product) of SoLarge.	*Well, the beauty of our panels, which I find quite remarkable, is that it's the only panel that doesn't break. When there's a severe hailstorm, glass solar panels can break, and […] that's something we don't want.*
Political	Governmental incentives are important.	*I do think it's important to realize that in the field where we operate, solar panels and energy, political factors are very important.*
Social & Legal	The combination of legal and social pressure on enforcing certain changes.	*You can enforce that through legislation, but ideally, you want it to be socially enforced, where people say to each other: "Why don't you drive an electric car yet?"*
Political	Changes in the political climate result in changes in the value capture of businesses.	*Europe needs to respond to that, and it's also very interesting for us because it means that there will be completely different rules for state aid. We're working on very large subsidy projects where you get subsidies for two or three factories at once instead of just a small one.*

5.3. Supersola

Supersola is a pioneering start-up situated in The Hague, Netherlands, which provides customers with an innovative "plug play" solar panel solution. The plug play solar panels offered by Supersola are modular and can be conveniently procured at construction markets or electronics stores. Once acquired, the panels can be effortlessly installed on a horizontal surface. This is done by connecting one end of the power cable to the solar panel and the other end to a wall outlet. This approach presents several benefits, including the flexibility to easily expand the solar panel capacity. Customers can begin with a single solar panel and procure additional panels later, resulting in a modest initial investment. Additionally, the use of a single, easy-to-install and easy-to-operate solar panel transforms the panels into a consumer electronics-like product, similar to washing machines or dryers. These types of products are relatively small long-term investments and can be transported if one relocates or encounters any unforeseen circumstances.

In 2017, Julius conceptualized Supersola after recognizing that the solar panel market and its sales methods did not align with the needs of a significant number of individuals. Given the technical nature of solar panels, many lack the knowledge needed to conduct research and install them independently, thereby providing installers and other parties with ample freedom to present varying tenders and recommendations. Julius believed that solar panels should not be treated as a specialized investment but rather, as an ordinary electronics product. This notion led him to develop the idea of a plug play solar panel (VP 1 $\rightarrow$ VP 2).

Subsequently, a suitable customer segment had to be identified for Supersola. The target market primarily comprised individuals who were unsuitable for a roof filled with solar panels, for whom this option was not viable. Such individuals may include renters, those who could not afford the expense, or those who wished to experiment before committing to a full-fledged investment (VD 1 $\rightarrow$ VD 2).

> *"Supersola was started by Julius in 2017 because he saw that the market for solar panels, including the way they were sold and marketed, did not meet the needs of many users."* - Managing director of Supersola

Supersola made the strategic decision to initially distribute their plug play solar panels through an online sales channel (VD 2 $\rightarrow$ VD 3), as this approach offered several benefits such as minimizing overhead costs and maximizing profit margins. Additionally, this direct-to-consumer channel allowed for efficient outreach to potential customers. However, this approach posed a challenge for Supersola in terms of achieving scalability as an online-only presence can limit growth opportunities. Nonetheless,

this was not the sole obstacle faced by the company.

Supersola encountered a significant obstacle with their solar panels, as they were relatively large and required water for ballast, resulting in excessively heavy panels that were difficult to move. This issue contradicted their initial concept of easily installable and transportable solar panels. Despite selling approximately 100 panels at a loss in 2018, Supersola decided to return to the research and development phase to redesign the product, illustrating the iterative process of growth stages as described by Vohora et al. (2004). The company collaborated with the Technical University of Delft and utilized the Validation Lab of YesDelft! to develop a new solar panel, leading to changes in both their key stakeholders and key activities (VCR 1 $\rightarrow$ VCR 2). Moreover, Supersola found a new partner in InnoEnergy, an organization that supports promising start-ups by investing in them to overcome financial challenges in the early stages (VCR 2 $\rightarrow$ VCR 3). InnoEnergy invested in Supersola (VCA 1 $\rightarrow$ VCA 2), and through their extensive network, provided valuable support to the start-up. Supersola also presented an innovation plan to Rabobank to secure additional financial resources, ultimately receiving an "innovation loan" (VCA 2 $\rightarrow$ VCA 3).

> *"We used the validation lab with YesDelft!, which helped us a lot in refining the whole story and proposition."* - Managing director of Supersola

To streamline its operations, Supersola decided to change its primary activities, transitioning from purchasing all the components, manufacturing the product, and delivering the solar panels to outsourcing the assembly and delivery to third-party organizations (VCR 3 $\rightarrow$ VCR 4). This decision was made based on the notion that specialized parties could assemble and deliver the product more efficiently and effectively.

Following the acquisition of financial resources, new insights from the Validation Lab, and a revised vision of value creation, Supersola developed a new product that was launched in 2020 (VP 2 $\rightarrow$ VP 3).

Supersola recognized that it could further leverage the capabilities of other parties and subsequently forged a partnership with BCC, a Dutch retail chain that specializes in the sale of consumer electronics (VCR 4 $\rightarrow$ VCR 5). As a result of this partnership, Supersola its solar panels could be sold through BCC its retail outlets, which expanded Supersola its customer segment and channels (VD 3 $\rightarrow$ VD 4). It is noteworthy that although the consumer base remained the same, Supersola its approach to reaching its consumers underwent a significant transformation.

> *"But it's difficult to scale online, especially if there's not yet awareness for your product. So we sat down relatively early with major retailers."* - Managing director of Supersola

After the successful reintroduction of the improved Supersola solar panel, new obstacles emerged. The Supersola solar panels were not in accordance with NEN standards according to UNETO-VNI, causing uncertainty regarding the legality of Supersola its solar panels. While NEN standards pertain to the Building Decree and electronic devices that are attached to homes, Supersola its solar panels are not affixed to homes, thus not within these regulations. On the other hand, according to the commodity law, the panels are comparable to an inverted refrigerator that meets the CE mark, indicating that they are compliant. The conflicting regulations create a grey area for Supersola, which poses an external threat to the company.

> *"But you can say that we went to France because we were getting complaints from the installation industry in the Netherlands."* - Managing director of Supersola

To address this issue, Supersola sought to broaden its market. They had previously considered expanding to the French solar panel market, which the French government heavily subsidizes for off-grid solutions. With the combination of political opportunities and the legislative challenges in their home market, Supersola decided to accelerate their expansion into the French market (VD 4 $\rightarrow$ VD 5), making it as important as their Dutch market in terms of sales volume nowadays.

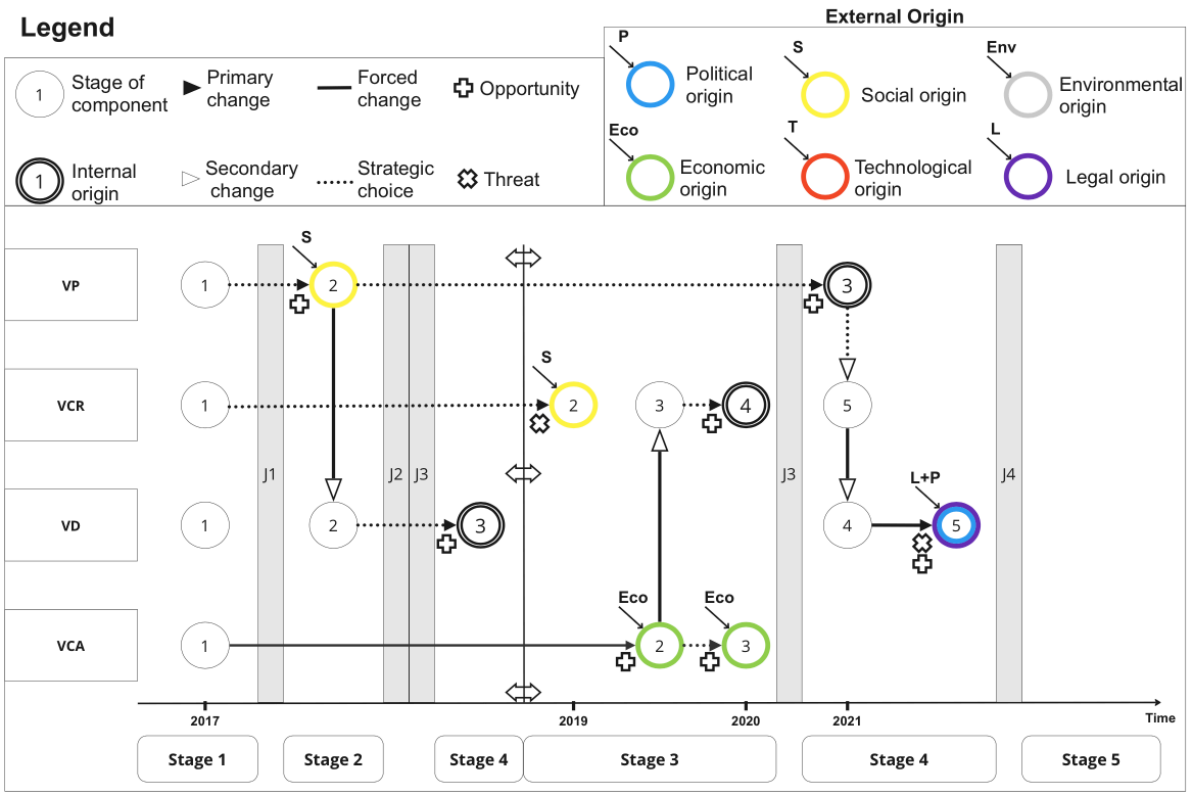


Figure 5.3: The business model dynamics framework showing the business model changes of Supersola.

Table 5.3: Some quotes from the interview displaying the importance of external factors on business model dynamics.

External category	Relevance to external factor	Quote
Social	The social need for accessible solar panels results in the value proposition of a plug&play solar panel.	*Supersola was started by Julius in 2017 because he saw that the market for solar panels, including the way they were sold and marketed, did not meet the needs of many users.*
Social	Social factors determine the success of Supersola and influence the value creation of the company as key activities are added to increase awareness.	*The first hurdle is whether people are aware that it exists and, if they see it, whether they can appreciate its value. So, in the beginning, we started by educating our customers, basically.*
Social	Customer behaviour (social factor) changes and results in more customers wanting products based on solar energy which can result in changes in customer segments.	*Customer behaviour has also changed in relation to the urgency of energy saving or self-energy generation, which is the most visible change. […] And that has also caused a lot of changes around or within the market.*
Social	Lack of social awareness results in targeting new customers (retailers) for Supersola.	*But online it's difficult to scale, especially if there's not yet awareness for your product. So we sat down relatively early with major retailers.*
Economic	External factors such as awards lead to new financial resources, a change in value capture.	*We also won an innovation award in the Home Appliances category. […] It gave us a lot of new leads, which led to more funding.*

Table 5.3 continued from previous page

technological	Partnering to make use of the R&D activities of the partner results in an improved value proposition.	*We used the validation lab with YesDelft!, which helped us a lot in refining the whole story and proposition.*
Legal	Legislation differences per country cause that different countries are targeted resulting in changes in the value delivery.	*We make a plug & play solar panel, which does not comply with the regulations in most European countries. Moreover, these regulations vary from country to country.*
Legal	New key activities, such as extensive testing of the product, are forced upon Supersola due to legislation.	*The installation industry often accuses us of doing things we are not allowed to do. Of course, we have had everything tested and what we do is completely safe and completely legal.*
Legal	Legislation	*But you can say that we went to France because we were getting complaints from the installation industry in the Netherlands.*

5.4. Solho

Solho is a start-up founded by Adriano Desideri en Emilio Casati. Solho provides a sustainable energy solution for different industries. The start-up offers a fully off-grid energy system called “SPHROUT”, which stands for Solar-PoweRed Horticultural Off-grid UniT. With SPHROUT Solho offers a solar-based renewable heating and cooling system. Besides offering SPHROUT, Solho also offers a range of services. They offer energy diagnoses to evaluate heat needs and guarantee the correct sizing of the SPHROUT system. A monitoring and maintenance service is provided when a 100% cover system is bought. And they sell energy to companies at an agreed-upon and fixed price to ensure a low price and clean energy for those companies.

Adriano and Emilio already knew each other from another company. Both did technical consulting work, such as designing turbines for clients, for this company. However, Adriano and Emilio wanted to make a more direct and measurable impact. This is why Solho was founded in 2017. They started the development of renewable-based energy concepts to decarbonize the industry in general (VP 1 $\rightarrow$ VP 2). Solho started to work together with YesDelft! to find the right product-market fit for the technical solution they developed (VCR 1 $\rightarrow$ VCR 2). The conclusion both parties found was to target the greenhouse industry in the Netherlands. This customer segment was chosen because it is a big leading industry in the world with big companies stationed in the Netherlands and this industry has the need to shift from fossil fuel-based solutions to renewable-based solutions in this industry (VD 1 $\rightarrow$ VD 2).

With a solution and customer segment in mind, the technology had to be further developed and a proof of concept needed to be established. Solho financed this with money they received from start-up prizes and with EU subsidies (VCA 1 $\rightarrow$ VCA 2).

> *“We won grants that allowed us to develop the technology and build the first proof of concept, together with one of the largest Dutch greenhouse manufacturers.”* - CEO of Solho

In 2019, the technology of Solho was completely developed and ready to be tested. With a subsidy from the province of Zuid-Holland (VCA 2$\rightarrow$ VCA 3) and the help of Van der Hoeven (one of the largest greenhouse manufacturers) (VCR 2 $\rightarrow$ VCR 3), Solho built the first plant in France to test their SPHROUT.

In the period following the testing of the plant in France, COVID-19 became a worldwide problem. To finance the technological developments of start-ups the EU granted subsidies to these companies. Solho also received such a subsidy (VCA 3 $\rightarrow$ VCA 4) and used it to further develop their product by implementing better control systems and making it ready for commercialization (VP 2 $\rightarrow$ VP 3).

> *"(We expanded to Italy because,) in Italy, there are not many greenhouse farms that are as high-tech as the ones in the Netherlands while the climate requires heating and cooling."* - CEO of Solho

2022 was a year in which a lot changed for Solho. The company started to do feasibility studies for Van der Hoeven (VCR 3 $\rightarrow$ VCR 4) which created their first income (VCA 4$\rightarrow$ VCA 5). Solho also realized that their solution was not only applicable to the greenhouse industry but to all industries that need heating and cooling. To exploit this opportunity Solho started targeting the industry as a whole. This included industries such as the food and beverage industry, textile industry, heating and cooling networks, and the oil and gas industry (VD 2 $\rightarrow$ VD 3).

To finance the development of targeting this new market, a loan from Rabobank. Supported Solho (VCA 5 $\rightarrow$ VCA 6). This year Solho also wanted to expand to Italy (VD 2 $\rightarrow$ VD 3) because there is no competition in Italy for Solho and there are several governmental incentives for the type of solution Solho offers. At the end of 2022, Solho started an investment round and got "SHIFT Invest" on board as a partner (VCR 3 $\rightarrow$ VCR 4, VCA 6 $\rightarrow$ VCA 7).

> *"We just closed the investment round at the beginning of this year and the money we raised is all meant to be spent on covering the operational cost to close as many projects as possible this year."* - CEO of Solho

At the start of 2023 Solho offered an energy company in Italy to do engineering services for them (VP 3 $\rightarrow$ VP 4). To goal of these engineering services is to get in contact with more potential customers to eventually do more projects. Also, an investment round was started with the goal to cover the operational costs and closing as many projects as possible.

> *"These days we are discussing and brainstorming on what will be the best structure, the most cost-effective structure of the company to develop as many projects as possible, to grow as fast as possible, and to maximise profit."* - CEO of Solho

In the coming years, Solho wants to find the business model that best fits their company, consolidate their business in the Dutch and Italian markets, and do more projects as contractors themselves or with their partners.

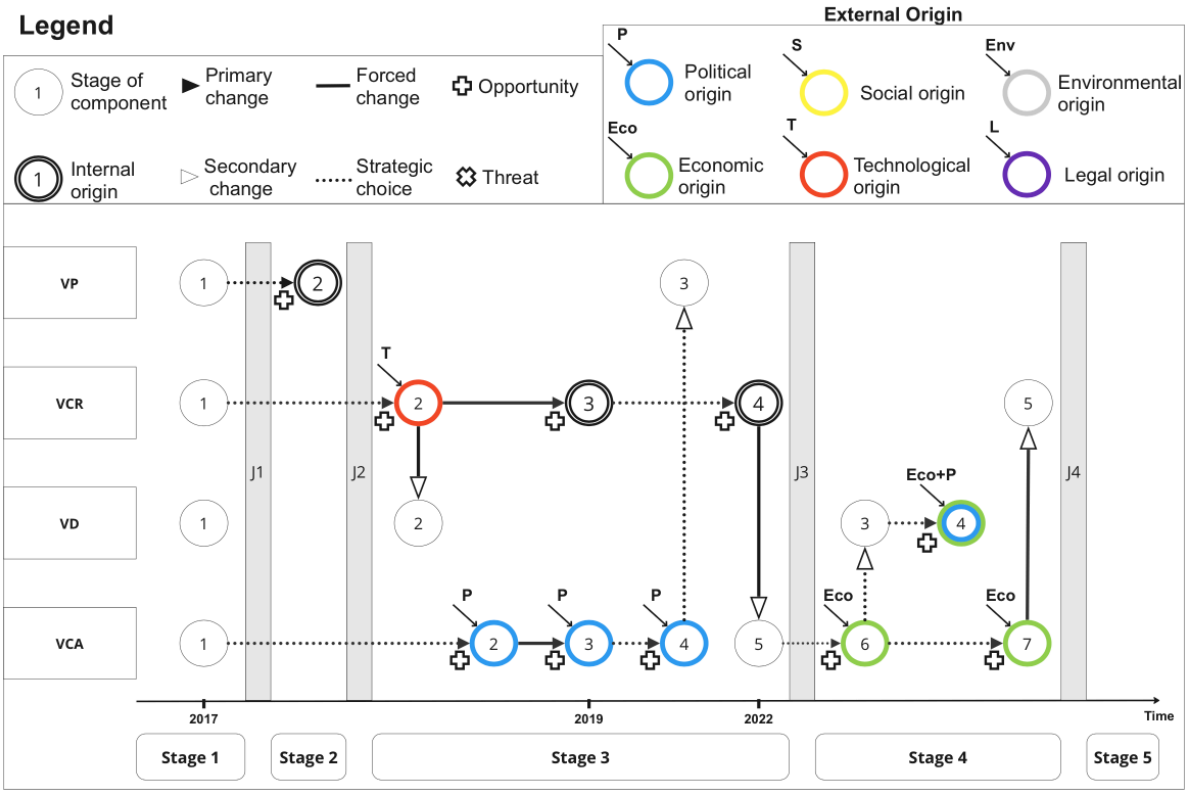


Figure 5.4: The business model dynamics framework showing the business model changes of Solho.

Table 5.4: Some quotes from the interview displaying the importance of external factors on business model dynamics.

External category	Relevance to external factor	Quote
Social	A social need leads to a customer segment to target.	*We identified the need to shift from fossil fuel-based solutions to renewable-based solutions to power greenhouse farms.*
technological	External financial resources enable Solho to develop its technology.	*We won grants that allowed us to develop the technology and build the first proof of concept, together with one of the largest Dutch greenhouse manufacturers.*
Environmental	Unfavorable circumstances force the need to focus on other customers as well.	*The climate (in the Netherlands) is much more mild so you don't need a lot of heating or cooling.*
technological	Technological advancements in the Netherlands cause an expansion to the Italian market as they are not advanced.	*In Italy are not many greenhouse farms that are as high-tech as the ones in the Netherlands.*
Political	Subsidies from Europe facilitate the operations (key activities) of Solho.	*In 2018 we got money from Europe and start-up prizes. This allowed us to fund the development of the technology*
Political	A subsidy from the province of Zuid-Holland facilitate the operations (key activities) of Solho.	*In 2019 we got funded by the province of Zuid-Holland to build the first system in France.*

Table 5.4 continued from previous page

Political	Subsidies from Europe facilitate the operations (key activities) of Solho and helped them overcome the credibility juncture.	*In 2020-2021 we got money from the EU to further develop the technology and we got this SPRHOUT ready for commercialization.*
technological	New technical developments resulted in the value proposition of Solho.	*There have been technological improvements in these past five years that allowed our solution to exist.*
Social	Cultural changes force companies to use renewable energy sources, causing the value proposition of Solho to be more attractive.	*When talking with large industrial groups (we see that) they need to be perceived in a certain way by their customers.*
Economic	Low market competition causes the expansion of the customer segment of Solho.	*We decided to focus on Italy because there is no one in Italy except us proposing this type of solution.*
Economic	External financial resources of investors result in changes in the operations of Solho.	*We just closed the investment round at the beginning of this year and the money we raised is all meant to be spent on covering the operational cost to close as many projects as possible this year.*
Political	Political stimuli cause the expansion of the customer segment of Solho.	*They have very good incentives (political) and a lot of sun (in Italy).*
Environmental	The amount of sunshine in Italy caused Solho to expand its customer segment.	*They have very good incentives (political) and a lot of sun (in Italy).*
To be determined	Interest in the technology, could via economic, social, or political factors result in changes on the business model of Solho.	*There is a lot of interest in technologies like ours or solutions like ours that can decarbonize the industrial sector, the residential sector in Europe*
Economic	Economic viability influences the value capture of Solho.	*Our solution, in order to scale, has to be economically viable and this is something that of course the industries look at when they have to make investments.*

5.5. PV company

A PV company that specializes in the development and commercialization of integrated solar panels emerged from a research collaboration of multiple parties, including a architectural firm UN Studio, TS Visuals, and TNO (previously known as the Energieonderzoeks Centrum Nederland). The concept of creating solar panels that possess both functional and aesthetic value originated from a group of architects who were inspired by their previous project working with LED lights (VP 1 $\rightarrow$ VP 2). To further refine this idea, the researchers approached the Energieonderzoeks Centrum Nederland (VCR 1 $\rightarrow$ VCR 2), which led to the plan to propose for a TKI RVO subsidy to develop the technology (VCA 1 $\rightarrow$ VCA 2). Subsequently, additional parties joined the project, including TS Visuals, a company that is specialized in printing unique objects (VCR 2 $\rightarrow$ VCR 3).

> *"They went to ECN, which later became TNO, and asked if they could do something with the idea. Then it was decided to submit a TKI RVO subsidy […] A project was established with all these parties, and a subsidy was obtained."* – Director of a PV company

This team conducted research to minimize the efficiency loss of solar panels while maximizing their aesthetic appeal. The outcome of this project was a patented technology in 2018. Subsequently, some of the project collaborators established a PV company to commercialize and implement the newly

developed technology. The PV company aimed to target the final customers, the ones that receive an integrated coloured solar panel (VD 1 → VD 2) and create a custom solution for them (VP 2 → VP 3). This would be done while providing and installing the projects themself (VCR 3 → VCR 4). Furthermore, shareholders made investments and an in-kind contribution to cover the operational costs and man-hours required for the venture (VCA 2 → VCA 3).

> *"At that time, some of the involved parties who were also co-owners of a patent that resulted from the project decided to establish a company together to bring that technology to the market."* – Director of a PV company

During the first three years, different subsidies and projects that provide government grants or subsidies covered the costs of the PV company for their technology development (VCA 3 → VCA 4).

> *"We only spend money on development costs if we have secured a subsidy for it. From the very beginning, we have been continuously involved in one or two subsidized projects."* – Director of a PV company

In 2020, the strategic decision was taken to contact AGC Glass Europe with the goal to partner with them (VCR 4 → VCR 5). From this partnership, the targeted market of the PV company can be expanded hugely as AGC Glass was selling in the whole of Europe (VD 2 → VD 3). With this partnership, the business model of the PV company was altered. Firstly, key activities were added, as they now supply AGC with the colour technique of their product and help AGC Glass develop custom solutions (VCR 5 → VCR 6) for which they receive some margins and royalties (VCA 4 → VCA 5). Secondly, the PV company became an AGC agent. They could keep selling their own, coloured solar panels in the Netherlands but also promote the AGC Active Glass solution to the customers that do not need a coloured solar panel (VP 3 → VP 4, VCR 6 → VCR 6). For the AGC Active Glass solutions sold, the PV company receive a commission (VCA 4 → VCA 5).

> *"More on the political side, which is now the most important for us, is that there are certain regulations in the Netherlands and also in the EU that require buildings to have a certain energy generation."* – Director of a PV company

In 2022 the PV company made the strategic choice to stop selling projects as they were doing. Instead of selling projects they wanted to sell just their products instead. As the risks of carrying a whole project do not outweigh the extra margins of doing the project yourself. Where first whole projects were sold to the final customer, now mostly products are sold to the "middleman" (VP 4 → VP 5), such as construction companies and (facade) contractors (VD 3 → VD 4).

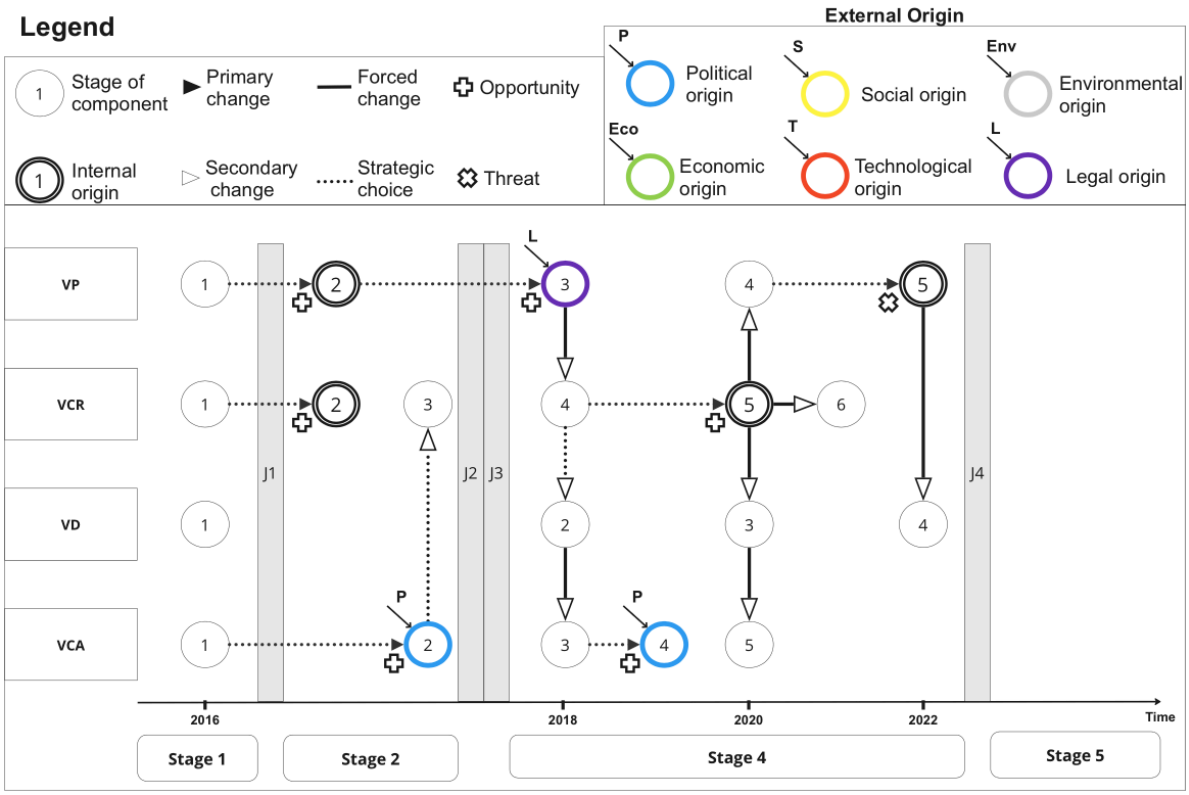


Figure 5.5: The business model dynamics framework showing the business model changes of the PV company.

Table 5.5: Some quotes from the interview displaying the importance of external factors on business model dynamics.

External category	Relevance to external factor	Quote
Legal	Patent law made it attractive to start the PV company causing all the initial incentives to create a working business model.	*Some of the parties involved who were also co-owners of a patent resulting from the project, decided to jointly establish a company to bring that technology to the market.*
Political	A subsidy results in the development of projects.	*Then it was decided to submit a TKI RVO subsidy […] A project was established with all these parties, and a subsidy was obtained."*
Political	Subsidies enable the PV company to cover their development costs.	*We only spend money on development costs if we have secured a subsidy for it.*
Political	Dutch and EU policies create the need for the product of the PV company.	*More on the political side, which is now the most important for us, there are certain regulations in NL and in the EU that buildings must have a certain energy generation.*
Social	A cultural shift forces companies to invest in renewable energy, creating the more demand for the PV company.	*In the beginning, it was really about the environmental and social aspects because the first projects were a kind of greenwashing. And whether people are aware of climate change and what that means.*
Economic	Competitors that produce solar panels more cheaply can form a threat to the PV company.	*There are potentially other companies that manage to do it (produce solar panels) cheaper, usually by producing partly in Asia in countries such as China or Taiwan.*

5.6. Wattlab

Wattlab is a company that produces lightweight, ultra-thin solar panels for ships. The solar panels are integrated with the hatches of the ship, so-called solar hatches. Wattlab provides complete solar systems and battery systems for ships resulting in a solution applicable to all ships. With the solar hatches, the use of generators to supply ships with power when it is not sailing is not needed anymore as the hatches reduce generator time by up to 93% (Wattlab, 2023). This results in less fuel used by the generator, reducing fuel costs and making less to no noise when they are at anchor. Another befit of the solar energy produced, is the lack of need to use shore power and the inconvenience of using power cables that comes with it.

The story of Wattlab begins in 2016. The three co-founders of Wattlab were working at the Nuon Solar team of the University of Technology Delft. That year the team decided to produce their own solar panels for the car they were making. As this team would race at the end of the year the solar panel had to be as light as possible resulting in a very thin solar panel (VP 1 →VP 2). When looking around, the co-founders saw that there were numerous standardized heavy solar panels made of glass, but not many lightweight customizable solar panels.

> *"In the first phases, we mainly looked at the possible applications, so where is the added value of the product; a lightweight thin solar panel? And that resulted in a few projects, including a large project."* - Chief operations officer of Wattlab

To exploit this gap in the market the three founders started Wattlab in 2017 to look at various applications for their solar panels, such as the use of solar panels for transportation cooling or the use of solar panels on yachts (VP 2 →VP 3). While searching for the best application of the thin solar panels some design and research projects were conducted to finance the operational costs (VCR 1 →VCR 2, VCA 1 →VCA 2).

At the beginning of 2019, the final idea of the solar panels was to use them on top of containers (VP 3 →VP 4). With this idea in mind, Wattlab contacted Damen Shipyard. They, however, saw problems in this idea as part of the market is not targeted (only containerships are targeted) and it will result in logistic problems as containers are not owned by the ships. The contact at Damen Shipyard knew someone at Blommaert Aluminium Constructions and introduced Wattlab to Blommaert to work together (VCR 2 →VCR 3).

Wattlab and Blommaert created a new design targeting inland vessels with solar hatches (VP 3 →VP 4, VD 1 →VD 2). A subsidy was granted to Wattlab and Blommaert (VCA 2 →VCA 3) that was used to finance the development of the solar hatches and do a feasibility study (VCR 3 →VCR 4).

One year later, in 2020, another subsidy of the CityLab was granted (VCA 3 →VCA 4) (Gastel, 2020). This financial incentive covered the remaining development costs and made it possible to conduct a proof-of-concept study (VCR 4 →VCR 5).

After the start of the proof-of-concept study, Wattlab noticed in 2021 that the costs of the product were high and would not meet the demand of their customers. To solve this problem and make a more affordable product, a new supplier was attracted. With the new supplier available, Wattlab decides to work with small sub-assemblies instead of making and producing everything themselves. This created a more efficient, and therefore lower cost, production line (VCR 5 →VCR 6). With working and reasonably priced solar hatches, Wattlab and Blommaert decided to do one last test to see if the product was market-ready (VCR 6→VCR 7). This test was found to be a success! This resulted in the commercial selling of the solar hatches (VCA 4 →VCA 5).

> *"The conclusion was that the product was too expensive to be interesting for the market because it is very expensive to make everything ourselves on a small scale here. During that time, we found a supplier we trusted in terms of quality [...] so we were able to reduce the cost price with their help."* - Chief operations officer of Wattlab

Since this year, also inland vessels in South America are targeted as customers by Wattlab and Blommaert (VD 2 →VD 3). Wattlab uses the connections of Blommaert, who already have customers there, to make this step. The reason for targeting this area is that due to social and environmental

awareness, the shipping companies feel the need to change and show the world that they are sustainable while operating in areas such as the Amazon rainforest.

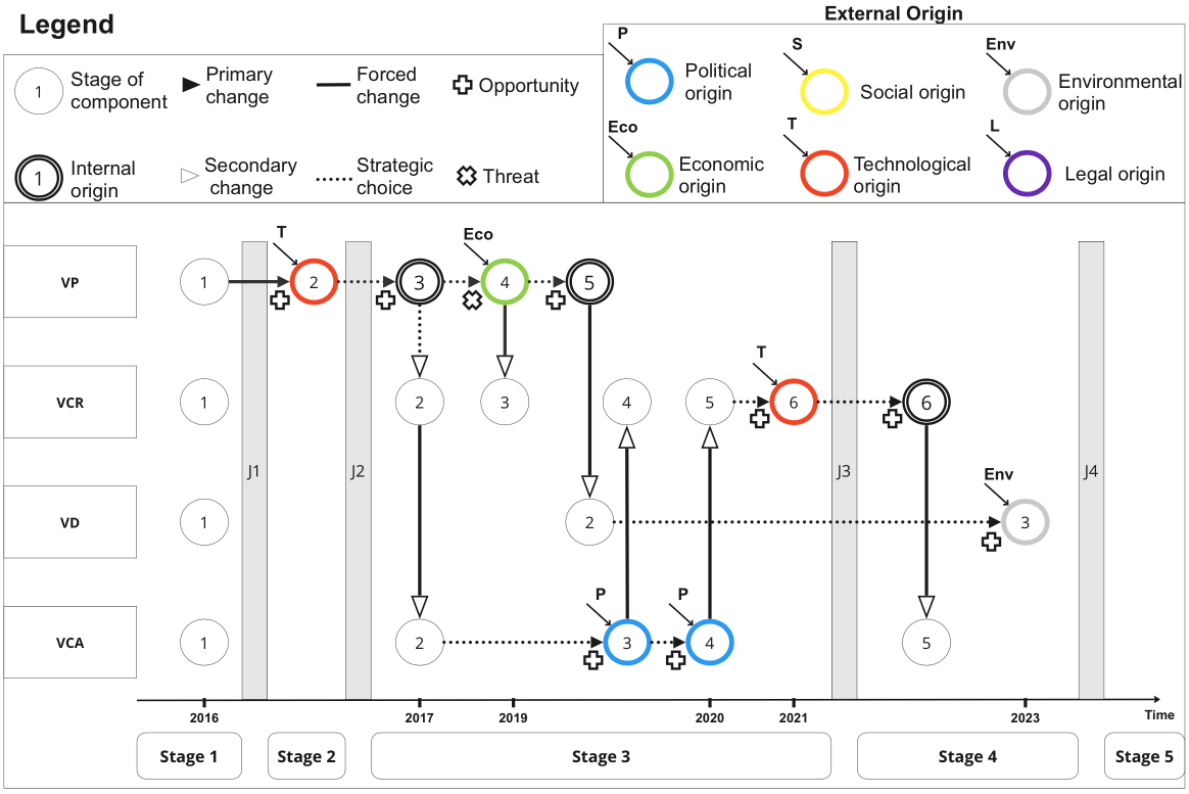


Figure 5.6: The business model dynamics framework showing the business model changes of Wattlab.

Table 5.6: Some quotes from the interview displaying the importance of external factors on business model dynamics.

External category	Relevance to external factor	Quote
Technological	The technological development of the solar panel resulted in different key activities of Wattlab.	*In the first phases, we mainly looked at the possible applications, so where is the added value of the product; a lightweight thin solar panel? And that resulted in a few projects, including a large project.*
Economic	Market competition made Wattlab decide to look for new applications, resulting in a new value proposition.	*We also did various other things for a while, such as developing a product for e-transport, like installing solar panels on the roof of delivery trucks for cooling purposes. [...] There were about 6 other companies also working on it. So, we thought to let that go.*
Technological	A change in supplier to optimize the production process results in changes in key activities.	*The conclusion was that the product was too expensive to be interesting for the market because it is very expensive to make everything ourselves on a small scale here. During that time, we found a supplier we trusted in terms of quality [...] so we were able to reduce the cost price with their help.*

Table 5.6 continued from previous page

Political	Subsidies affect Wattlab in their operations and are incentives for their customers.	*Subsidies (are important), not only for us but also for customers. Because it is still a financial incentive for them, despite the choice of sustainability.*
Economic	Low market competition influences the value proposition of Wattlab.	*One of the reasons why we really wanted to focus on those solar hatches is that there was actually no competition yet.*
Environmental	Environmental scarcity influences the procurement, thus the activities, of Wattlab.	*Our procurement is highly dependent on our suppliers and technologies. If we experience a chip shortage or a shortage of silicon, it becomes a problem.*
Social	Social and environmental awareness results in the decision to target new customers in South America.	*We considered South America because […] they have a lot of inland vessels over the Amazon and Paraná Rivers, and there are also some wealthy companies there that are monitored closely.*

6

Cross-case analysis

This chapter presents a comprehensive content analysis of the qualitative data obtained from six in-depth interviews conducted with Dutch technology-based start-ups in the PV sector. The cases corresponding to these interviews can be found in chapter 5. This analysis focuses on the identification and exploration of the significance of six predetermined overarching themes: political, economic, social, technological, environmental, and legal.

By employing a content analysis approach, this study provides valuable insights into the multifaceted nature of the impact of external factors on the dynamics of business models in PV-sector start-ups. Examining these six overarching themes offers a holistic perspective, enabling a thorough understanding of the subject matter. Each theme will be precisely defined and comprehensively discussed. This entails a deeper investigation into each main theme to uncover its sub-themes and comprehend the relationships that have emerged from the data.

After this content analysis, the data from the case studies will be analysed. By analysing the data from multiple cases together, it becomes possible to identify potential patterns and trends. When combined with the findings from the content analysis, a comprehensive understanding of how external factors influence business model dynamics can be achieved. This holistic view allows for a deeper insight into the interplay between external factors and the evolution of start-up business models.

6.1. Content analysis

Table 6.1 presents a table displaying the occurrence of the six overarching external categories. This chart offers an overview of the distribution of these categories within the dataset, shedding light on the relative emphasis placed on each theme. It shows how each overarching theme, or family code, is divided into primary code, also sub-themes, and secondary code. For the full table including all quotes, see Table B.1 in Appendix B.

Table 6.1: The family codes (overarching themes), primary, and secondary coding of the quotes from six in-depth interviews with Dutch technology-based PV start-ups.

Family code	Occurrence	Primary code	Occurrence	Secondary code	Occurrence
Political	38	Governmental activities	5	Activities to influence political factors	1
				Importance of political awareness	3
				Political awareness	1
		Policy	11	Policies	8
				Policy change	2
				Policy makers	1
		Subsidy	22	Importance of subsidies	3
				International subsidies	3
				Local subsidies	1
				National subsidies	8
				Undefined subsidies	7
Economic	52	COVID-19 impact	2	COVID-19	1
				Disruption of logistic chain	1
		Currency devaluation	2	-	-
		Economic trends	6	-	-
		Economic value	2	-	-
		Economic viability	5	-	-
		Economy of scale	2	-	-
		Market competition	7	High market competition	2
				Low market competition	4
				Market forces	1
		PV market	3	-	-
		Supportive financial resource availability	23	Investments	7
				Importance of investors	1
				Loan	7
				Other	7
				Importance of supportive financial systems	1
		Customer profile	3	-	-
		Influencing	2	Channels	1
				Influencers	1
				Increased social awareness	7

Table 6.1 continued from previous page

Social	25	Social awareness	12	Influence of social awareness	3
				Lack of social awareness	2
		Social need of (local) communities	2	-	-
		Social reputation	5	Social perception	3
				Social awareness	2
		Importance of social factors	1	-	-
Technological	16	Resource efficiency	10	Operational	5
				Research	4
				Importance of resource efficiency	1
		Technology development	6	New technology	4
				Technical difficulties	1
				Importance of technological factors	1
Environmental	24	Circularity	4	-	-
		Environmental awareness	8	-	-
		Environmental disaster	1	-	-
		Environment	4	-	-
		Environmental impact	3	-	-
		Scarcity of materials	4	-	-
Legal	24	Certification	1	-	-
		Legislation	20	Legislation	18
				Importance of legislation	2
		Patents	3	Disrespecting patent law	1
				Patent law of product	2

The table reveals that political and economic factors are mentioned slightly more than half of the time when discussing the external influences on Dutch PV start-ups. The remaining four categories collectively account for approximately half of the mentions, with social, environmental, and legal factors appearing with similar frequency, and technological factors slightly less prominent. This distribution highlights the substantial emphasis placed on political and economic factors, underscoring their significance. The subsequent sections will delve into each category to provide a comprehensive explanation of this phenomenon.

6.1.1. Political factors

One of the overarching themes that elucidate the external factors influencing start-ups in the PV sector is 'Political'. Political factors are identified as the second most influential category in this study. Within this theme, three sub-themes can be discerned: subsidies, policy, and governmental activities.

The concept of 'subsidy' pertains to the financial incentives provided by local, national, and international governmental institutions. These incentives can be granted to start-ups or their customers and serve as supportive financial measures to encourage the development, purchase, or utilization of products and services in the PV sector. Subsidies are considered the most significant stimulus for the business model dynamics of PV start-ups within the policy category and are frequently mentioned by participants. Subsidies hold importance for two primary reasons. Firstly, they create a financial incentive that is crucial for start-ups, as exemplified by the comment from the CEO of SoLarge:

> *"At the same time, RVO and the government are very important because a very nice form of financing is subsidies. And they are desperately needed. You can't do anything like this without subsidies."* - CEO of SoLarge

Start-ups exert considerable effort to secure these subsidies, which leads us to the second point regarding their significance. Subsidies exert a substantial influence on the business model dynamics of start-ups due to the financial incentive, resulting in a direct alteration in the company its value capture. For instance:

> *"In general, this applies to all the new things we try. So, those larger systems, water pumps, that we are now watching, those are all new customer groups and new markets for us. The way we usually do that is that we first make a subsidy request to try it. And then with that subsidy, we do a pilot, and we look at which product we can sell for which prices. And if that is successful, then we will actually put money in it ourselves."* - COO of SolarWorks!

> *"We only spend (money on) those development costs if a subsidy has been brought in."* - Director of a PV company

These examples demonstrate that a change in value capture resulting from subsidies can lead to changes in various elements of the business model, such as the value proposition (offering new products), value delivery (targeting new customer groups and markets), and value creation (development/R&D activities). Multiple participants mentioned such changes driven by the financial incentive provided by subsidies. Consequently, subsidies (representing a primary change in value capture) can indirectly influence all elements of the business model through secondary changes.

The sub-theme of 'policy' pertains to the policies implemented by governments and international institutions. These policies may change with the rise of new governments or international agreements. This sub-theme is closely intertwined with the 'subsidy' theme and can be directly derived from it, as subsidies are one of the most tangible actions that governments can undertake to stimulate specific industries, such as the PV industry. Particularly, international institutions like the EU establish standards and aim for increased renewable energy. As a result, regulations are implemented:

> *"Europe has set out a bunch of directives to push companies to decarbonize their energy generation."* - CEO of Solho

These policies do not directly result in changes to the business model but they exert a significant influence on start-ups and their operations. Essentially, policies can be regarded as the root cause of

business model changes, with the actual implementation of policies leading to those changes.

The final theme within the political category is 'governmental activities.' This construct encompasses the actions and activities undertaken by start-ups, their customers, or other entities in response to governmental actions. Examples of such activities include lobbying and monitoring and adapting to new trends in governmental decision-making. While participants mention these activities, they do not seem to attribute the same level of importance to them as they do to the other sub-themes. This sentiment is also reflected in the comment made by the CEO of Solarge:

> *"Politics is starting to become important when the technology is sound."* - CEO of SoLarge

This statement highlights that politics only assume significance at a certain stage, specifically when the technology is functioning correctly. It implies that influencing activities and keeping an eye on new trends in governmental decision-making become important at a later phase. This observation explains why governmental activities are not regarded as vital as subsidies and policy during the early stages of start-ups as other factors take precedence.

6.1.2. Economic factors

The most frequently mentioned theme in the external environment of start-ups is 'economic'. This theme appears in approximately one-third of the references to external factors. Within the economic category, several sub-themes are discussed, with a focus on the most significant ones.

The primary sub-theme within the economic category is 'supportive financial resource availability', which is of equal occurrence as the social, environmental, and legal themes. This sub-theme encompasses various financial systems and incentives for start-ups, excluding those mentioned in other sub-themes, such as subsidies. Participants mentioned several supportive financial systems, with investments, loans, and other financial incentives being the most prevalent. The term 'other financial incentives' encompasses all financial incentives not covered by loans and investments, including angel investments, prizes, and grants.

> *"There is a lot changing. Getting that cash flow is very difficult for a start-up. Everything changes to get that; to the point that you would move to another place so that an investor gives you money. That is how far it can go."* - Managing director of Supersola

The quote from the managing director of Supersola underscores the importance of financial resources for start-ups and the lengths they are willing to go to secure them. This explains the high occurrence of this sub-theme within the economic category, as it represents one of the most challenging yet crucial aspects for start-ups. The pursuit of financial resources not only directly affects value capture but also exerts an influence on other elements of the business model. For example, financial resources can lead to changes in value creation and delivery, as demonstrated by the following comments:

> *"In 2018 we received funding from Europe and start-up prizes, which enabled us to finance the development of the technology."* - CEO of Solho

> *"Then he first found a few angels who invested money with which they made the first prototypes."* - Managing director of Supersola

The sub-themes of 'market competition', 'economic viability', and 'economic trends' are also noteworthy within the economic category. 'Market competition' emerges as a recurring theme, influencing the markets in which start-ups operate and the target demographics of their customers. High market competition is perceived as a threat, prompting strategic adjustments, as expressed in the following comment:

> *"In 2015, 2016 there were actually more and more products on the market that came from China. They were cheap copies but always getting a little better and better. [...] (this resulted in) from selling to retailers to selling to consumers. That is purely market-driven."* - COO of SolarWorks!

Conversely, low market competition is viewed as an opportunity, as exemplified by the following statement:

> *"One of the reasons that we really wanted to do business in solar hatches is that there was actually no competition."* - COO of Wattlab

The sub-theme of 'economic viability' encompasses discussions on the market viability of the product, which indirectly affects the business model through potential investments and other factors. The sub-theme of 'economic trends' pertains to larger economic trends, including fluctuations in gas and oil prices, energy prices, and customer purchasing behaviour. While this sub-theme moderately influences the business model dynamics of start-ups, it has a broader impact on all companies. For example, economic trends may directly or indirectly result in operational changes for start-ups. An instance of indirect influence can be observed when third-party partners of SoLarge no longer had time to collaborate with them due to the current chaos in the energy market:

> *"But you also need to have those parties that will install it. You now see, because of the current chaos on the energy market, that the large parties are busy and therefore have no time for us at all."* - CEO of SoLarge

The last sub-themes are themes that influenced or relate to economic activities or events. They occurred not as often as the other factors and can, therefore, be perceived as less important.

6.1.3. Social factors

Three themes occurred around the same amount in the data. One of these themes is 'social'. This theme focuses on the social aspect of external factors.

Within the social theme, a recurring sub-theme is 'social awareness'. It is expected to be an important theme for start-ups as it influences value delivery, including customer segments, channels, and customer relationships. However, the influence of social awareness is often indirect and difficult to change, as expressed in the following comment:

> *"If you know that the average item of clothing is worn 7 times, it is shocking. And we may all know it, but we don't behave differently. And influencing that behaviour is, of course, very complicated."* - CEO of SoLarge

Another sub-theme is 'social reputation', which primarily relates to the customers of start-ups. Incorporating solar solutions provided by start-ups helps customers enhance their social reputation or perception, as indicated by this comment:

> *"You see this social aspect when talking with large industrial groups. They need to be perceived in a certain way by their customers."* - CEO of Solho

The sub-theme 'social need of (local) community' has led to the creation of new value propositions for two companies. This sub-theme is particularly relevant in the early stages of start-ups, as it addresses the unmet needs of people in the local community.

6.1.4. Technological factors

The smallest theme observed was the 'technological' theme, which had the fewest mentions in the data. Within this theme, two sub-themes were identified: 'resource efficiency' and 'technology development'.

The 'technology development' sub-theme encompasses discussions about advancements in technology, particularly the development of new technologies. Participants primarily associated this sub-theme with the value proposition of their start-up and the development of their proposed solutions or products.

> *"There have been improvements in these past five years that allowed our solution to exist."* - CEO of Solho

Several participants noted that technological developments are highly significant in the initial stages of a start-up but become less crucial as time progresses. In terms of technical aspects, operational efficiency becomes more important. This is captured in the 'resource efficiency' sub-theme, which includes topics related to efficiency, such as partnerships to enhance knowledge or utilize specific facilities. The term is used to encompass the start-up its utilization of external resources, facilities, and knowledge to create a more efficient environment. The following comment provides insight into the process of forming partnerships to streamline start-up operations:

> *"The most important partners in the first instance were the shareholders and AGC for production."* Director of a PV company

6.1.5. Environmental factors

The fifth major theme that emerged from the data is the 'environmental' theme. Within this category, the sub-themes revolve around environmental factors that influence start-ups and their business models, as well as the existing environmental awareness and societal changes.

The largest sub-theme is 'environmental awareness,' which is expected in the solar energy industry due to the prominent role of environmental considerations in the energy transition. Factors mentioned in this sub-theme pertain to changes in societal behaviour and attitudes compared to previous years.

Following closely in the content are the sub-themes of 'circularity' and 'environmental impact,' which relate to participants' comments about the value proposition of their start-ups and how they contribute positively to the environment or embrace circular practices. The following quote exemplifies how circularity and environmental impact are seen as significant advantages:

> *"At the same time, we do not use PFAS. [...] But PFAS is notoriously very difficult to break down, so that's a big advantage (as we don't use it)."* CEO of SoLarge

Additionally, there are three other sub-themes related to the literal external environment. SolarWorks! mentioned an 'environmental disaster.' Although it was only mentioned once, it had a profound impact on SolarWorks! its business model and dynamics. Such disasters are infrequent but carry significant influence, as demonstrated in SolarWorks! its case.

The remaining two sub-themes are 'scarcity of materials' and 'environment.' The former refers to global scarcity, such as shortages of gas, oil, or computer chips. The latter encompasses environmental factors specific to certain regions, such as climate, hailstorms, and sunlight. The CEO of Solho provided an example of this in the following comment:

> *"In Italy, except for us, nobody is proposing this type of solution, and they have very good incentives and a lot of sun."* - CEO of Solho

6.1.6. Legal factors

The final overarching theme to be discussed is 'legal.' This category is closely linked to the political factors discussed earlier. Three sub-themes will be explored to illustrate the influence of this external factor category: 'legislation,' 'patents,' and 'certification.'

The legal category encompasses all topics related to rules, regulations, and legislation. However, three sub-themes are distinguished because patents and certifications are not imposed by governments or international institutions but rather result from actions taken by start-ups. The 'legislation' sub-theme is the most prominent within the legal category and surpasses the 'patents' and 'certification' sub-themes.

> *"In France, they think it's fantastic what we do; in terms of regulations and in terms of policies, they are very positive."* - Managing director of Supersola

The comment from the managing director of Supersola highlights the close relationship between political and legal factors. As observed in the political category, policies and subsidies play a significant role. Similarly, the occurrence of legislation-related topics can be explained by the enforcement of standards or limitations through legislation, which can be a consequence of implementing policies.

While rules and legislation may not directly impact start-ups, they greatly influence customers, particularly larger clients such as inland vessels, and companies and institutions that need to comply with new policies promoting renewable energy. The COO of Wattlab captures this relationship between policies, subsidies, and regulatory legislation in the following comment:

> *"CO2 goals only work for us if that is concretely translated into subsidies or paying for emissions or that a ship may only have X emissions, etc."* - COO of Wattlab

The other two sub-themes are 'patents' and 'certification'. These sub-themes pertain to the actions taken by start-ups to protect their products through patents or demonstrate the capabilities of their products through certifications. These sub-themes appear to have less importance compared to the 'legislation' sub-theme. Notably, patents and certified products seem to have a greater impact on the business model dynamics of start-ups, as they contribute to the value proposition. In contrast, regulations that customers must comply with do not directly influence the business model. This distinction is evident in two quotes from the director of PV-company. The first quote demonstrates how a patent contributes to the value proposition of a start-up, while the second quote highlights how legislation affects start-ups indirectly through their customers:

> *"At that time, a number of the parties involved, who were also co-owner of a patent that appeared (from the project), decided to set up a company together to bring that technology to the market."* - Director of a PV company

> *"The solar facades are still relatively expensive, but legislation demands that you meet the requirements."* - Director of a PV company

6.2. Interrelationships between business model elements

To examine the interrelationship between different elements of the business model, a detailed analysis was conducted on the six cases presented in chapter 5. The findings of this analysis are visually depicted in Figure 6.1, which illustrates the interrelationships among the business model elements.

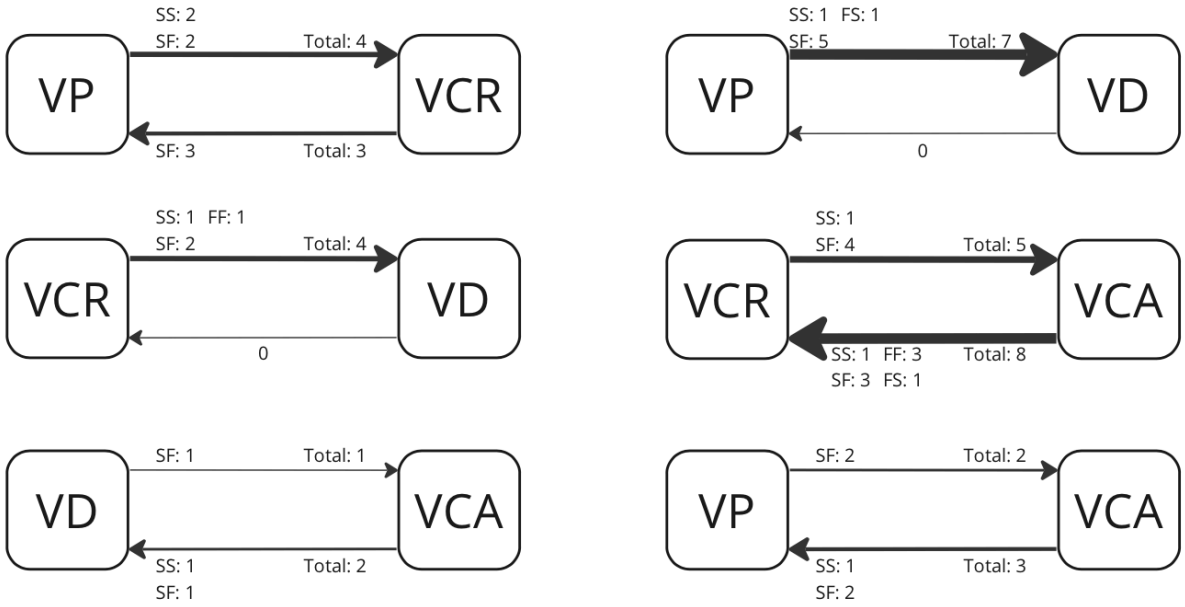


Figure 6.1: A graphical representation depicting the interrelationships of the business model elements and the type of interrelationship in the case studies.

One notable observation is that not all business model elements necessarily exert influence on other elements, even though the reverse relationship may hold true. To illustrate, the value proposition has been found to instigate secondary changes in the value delivery element on seven occasions, whereas the inverse scenario, where the value delivery impacts the value proposition, has not been observed. A

similar pattern emerges between the value creation and value delivery elements. The phenomenon of the value proposition and value creation influencing the value delivery element, while lacking reciprocal influence, can be elucidated by examining the underlying reasons for the occurrence of business model changes.

In the majority of cases where changes in the value delivery element were triggered by the value proposition, it was observed that a new idea emerged (e.g., Wattlab) or new products were developed (e.g., SolarWorks!, a PV company, and Supersola). With the introduction of the new value proposition, there arose opportunities to target a new customer segment or to adopt a new approach to engaging existing customers through alternative channels within the Business Model Canvas (BMC). For instance, Supersola made a strategic decision to shift its customer targeting from online platforms to retailers.

In instances where changes in the value delivery were driven by alterations in the value creation element, such changes consistently stemmed from new partnerships (e.g., SolarWorks!, SoLarge, Solho, and a PV company). These partnerships provided access to a broader customer segment, as the new partners brought along their networks, customers, and additional distribution channels, resulting in a comprehensive transformation of the overall customer relationship.

Based on these findings, it can be inferred that the value delivery element is highly susceptible to influence from other elements within the business model. This phenomenon likely arises from the objective of establishing a cohesive and integrated business model that ensures the harmonization of value delivery with other key elements.

The second noteworthy observation pertains to the dominance of the value creation element in terms of interrelationships. It was found that value creation influenced other elements in the business model on 13 occasions, while also causing secondary changes 13 times. It is worth mentioning a specific case involving a PV company, where a change in the value creation element resulted in subsequent modifications within the same element. Following value creation, the element of value capture exhibits a significant number of interrelationships, being influenced nine times and influencing other elements in the business model 14 times.

The most frequently occurring type of interrelationship observed is the SF type (also see Table 6.2), which represents a strategic primary change followed by a forced secondary change. This type of relationship was observed in 25 out of the total 39 occurrences. Alongside the SS type, which denotes a strategic primary change leading to another strategic secondary change, a total of 33 out of the 39 changes were initiated by strategic decisions. It is worth noting that there were also some business model changes that only influenced a primary change without resulting in a secondary change. Specifically, there were 10 strategic choices leading to a change and 3 forced changes, resulting in a total of 42 out of the 52 primary changes being attributed to the strategic handling of the start-ups. This implies that the start-ups in the case studies actively develop strategies and seek out changes to capitalize on, rather than merely responding to external or internal factors.

When examining the opportunities and threats, it was found that 47 primary changes were driven by opportunities, while only 5 changes were attributable to threats, and one change resulted from a combination of both an opportunity and a threat. The notable prevalence of opportunities aligns with the earlier discussion on the high number of strategic primary changes. It can be expected that when a business strategy is formulated to proactively anticipate rather than react, a greater number of strategic changes and opportunities are likely to arise.

In addition to the strategic nature of the start-ups, a substantial number of forced secondary changes can also be observed. Out of the 39 secondary changes, 29 were of the forced type, represented by the SF or FF types. This can be explained by the fact that these follow-up changes stem from the alignment of the business model. As highlighted by Kamp et al. (2021), secondary forced changes are regarded as realignments of components aimed at ensuring coherence within the business model.

Table 6.2: Interrelationships between business model elements in the case studies.

Primary change in	Resulting in secondary change in	Type of change	Total
VP	VCR	SS: 2, SF: 2	SS: 8 SF: 25 FS: 2 FF: 4
	VD	SS: 1, SF: 5, FS: 1	
	VCA	SF: 2	
VCR	VP	SF: 3	
	VD	SS: 1, SF: 2, FF: 1	
	VCA	SS: 1, SF: 4	
VD	VP	0	
	VCR	0	
	VCA	SF: 1	
VCA	VP	SS: 1, SF: 2	
	VCR	SS: 1, SF: 3, FF: 3, FS: 1	
	VD	SS: 1, SF: 1	

6.3. External and internal factors in the case studies

External factors refer to an origin outside of the business model that contributes to its changes. In Table 3.3 and Table 3.4 numerous external and internal factors were identified based on the literature. However, not all of these factors were observed in the case studies. The table below presents the factors identified in the case studies, along with their respective occurrences.

Table 6.3: External and internal factor occurrence in the case studies.

External / Internal category	Origin	Occurrence	Total # of occurrences per category
Political	Subsidy	8	10
	Policy	2	
Economic	Market competition	3	11
	Supportive financial resource availability	8	
Social	Social need of (local) community	2	4
	Customer preferences	2	
technological	Resource efficiency	3	5
	Technological development	2	
Environmental	(Social and) environmental awareness	1	2
	Environmental disaster	1	
Legal	Certification of product	1	3
	Legislation	1	
	Patent law	1	
Internal	Knowledge availability	5	19
	Customer segment expansion	4	
	Resource availability	4	
	Technological development	3	
	Scale-up	1	
	Outsourcing of activities	1	
	Risk analysis	1	

The factor that appeared most frequently among all the factors examined was ‘subsidy’ within the political category. This factor refers to the granting of financial assistance to a company. It was the most prevalent factor influencing business model dynamics in the case studies, present in all cases except for SoLarge. Another factor in the political category is ‘policy,’ which pertains to governmental policies in (other) countries. When this factor appeared it was because a particular policy was deemed more advantageous or favourable compared to the existing policy within the current context.

The most prevalent external category encompassed economic factors. Within this category, ‘market competition’ emerged as a significant factor that could be perceived both as an opportunity and a threat.

In the case of SolarWorks!, increased market competition necessitated a revision of the entire business model. Conversely, in the case of Solho, the absence of competitors, combined with favourable policy, led to the decision to expand into Italy. Another factor in this category is 'supportive financial resource availability,' which denotes the presence of various financial systems facilitating access to financial resources, including grants and investments.

'Social need of (local) communities' emerged as a driver for business model changes in the social category. This factor was observed during the early phases of SolarWorks! and Supersola, highlighting the importance of addressing the specific product or convenience needs of individuals or communities. The second factor in the social category is 'customer preferences', which closely resembles the social need of communities. However, in this case, it refers to changes in products or services based on differing customer preferences. SolarWorks! and Supersola exemplify instances where adjustments were made to the product due to customer preferences not aligning with initial expectations.

Within the technological category, two factors are evident: 'resource efficiency' and 'technology development.' The former factor pertains to opportunities for enhancing operational efficiency within start-ups. For example, Wattlab achieved this by identifying a more reliable supplier, while Solho and SolarWorks! achieved resource efficiency through their partnership with YesDelft! and leveraging their expertise and facilities. The phrase 'technology development' is applicable to both internal and external factors. In both cases, the development of new technology serves as the foundation for changes in the business model. The distinction lies in the external factor involving technology developed outside the start-up, while the internal factor involves technology development within the firm itself.

(Social and) environmental awareness represents another significant external factor for start-ups operating in the photovoltaic sector. This factor influenced the expansion of the customer segment in the case of Wattlab. Additionally, an 'environmental disaster' emerged as a factor within the environmental category, impacting the case of SolarWorks! where a cyclone prompted adjustments to the company's value capture approach due to overreliance on the pay-as-you-go system.

The final factors pertain to the legal category. Three distinct factors were identified: 'certification of product,' 'legislation,' and 'patent law.' While legislation posed a threat, the other two factors presented opportunities for start-ups. Notably, both the 'certification of product' and 'patent law' were recognized as opportunities by the companies, with efforts made to obtain the necessary certifications or patents.

In addition to the external factors identified in the case studies, seven varieties of internal factors contributing to business model dynamics were determined. The most frequently occurring factor is 'knowledge availability,' encompassing the decision of a start-up to try and use the benefits derived from knowledge development through new partnerships and the advancement of knowledge related to the start-up's products. In the cases of SoLarge and a PV company, the involvement of new partners led to a new value proposition or a change in value delivery. For Solho and Wattlab, the acquired knowledge resulted in a new value proposition without the inclusion of partners.

The internal factor of 'customer segment expansion' involves a start-up's decision to add a new customer segment to its business model and ranks second in terms of frequency, following 'knowledge availability.' Equally prevalent is the factor of 'resource availability,' which refers to the utilization of internal capabilities and resources. Examples include the e-commerce platform of SoLarge, the web-shop of Supersola, and the leveraging of partner resources, as observed in the cases of Wattlab and Solho, where partners' knowledge is employed to further develop the product or technology.

'Technological development' serves as an internal factor denoting advancements in technology within a firm. This can be achieved through various processes such as research and development (R&D), feasibility studies, or other internal mechanisms for technology development.

The remaining three internal factors observed in the case studies are 'scale-up', 'outsourcing of activities', and 'risk analysis,' each occurring once. 'Scale-up' entails making a debt investment to foster company growth. This can be exemplified in the case of SolarWorks!, where the hiring of new agents aimed to increase sales. 'Outsourcing of activities' is evident in the case of Supersola. Lastly, 'risk analysis' emerges as an internal factor in the case of a PV company, as they carefully assessed the risks associated with offering entire projects as opposed to targeting specific companies such as construction firms.

6.4. External factors on business model dynamics

Figure 6.2 and Figure 6.3 illustrate the frequency of business model dynamics resulting from external factors in each category. Figure 6.2 shows the occurrence of each external factor on the business model leading to a primary change. Figure 6.3 specifically highlights the occurrence of each external factor on each business model element. By analyzing this information, one can deduce the categories that drive business model changes for start-ups and identify the most influential factors.

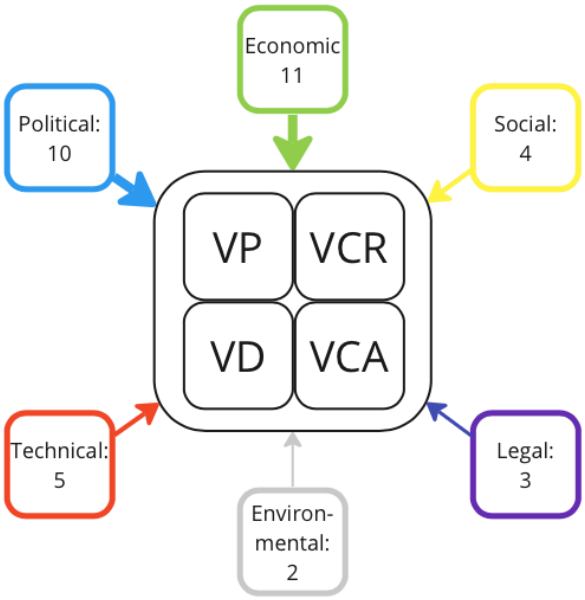


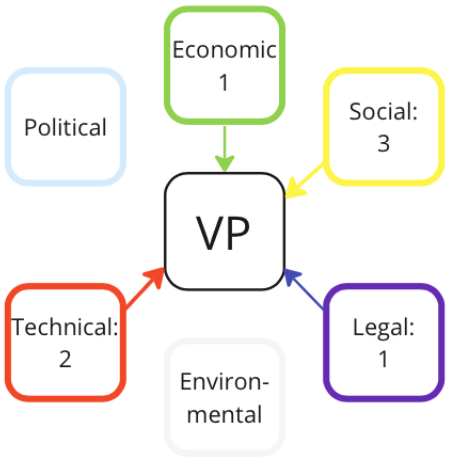
Figure 6.2: A graphical representation depicting the frequency of external factors within each category influencing the business models of the start-ups in the case studies.

One notable observation in Figure 6.2 is that political factors and economic factors emerge as the most influential categories of external factors. With 10 occurrences of political factors and 11 occurrences of economic factors, they significantly surpass the occurrences of other factors, accounting for approximately 60% of all external factors identified. Furthermore, these factors predominantly drive changes in the value capture aspect of business models. This finding aligns with the content analysis conducted, which also identified political and economic factors, specifically subsidies and supportive financial resource availability, as crucial sub-themes. The analysis suggested that these factors hold significance due to their financial impact on start-ups. This assertion finds support in the fact that 80% of political factors and 72% of economic factors result in a change in value capture.

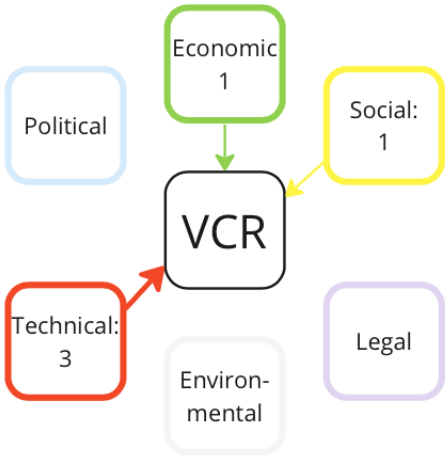
Additionally, it is worth noting that in two instances, political factors led to business model changes that affected the value delivery of start-ups, rather than the value capture. These changes were a result of beneficial policies in other countries, leading to the expansion of the customer segment. In the content analysis, policy emerged as one of the main sub-themes, alongside subsidies, within the political factors category.

Furthermore, in cases where economic factors did not directly impact the value capture but instead triggered changes in other elements of the business model, the primary catalysts were high or low market competition. This finding aligns with the content analysis of economic factors, where market competition emerged as one of the significant sub-themes, following supportive financial resource availability.

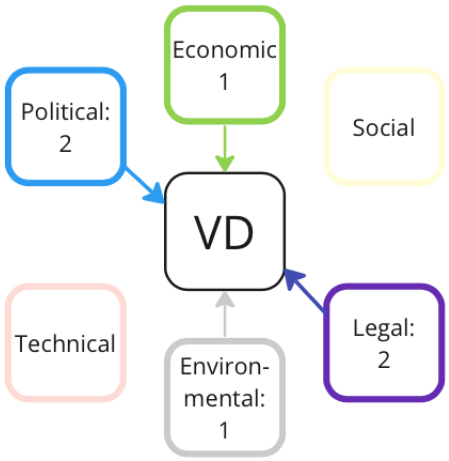
Regarding technological factors, they contributed to business model changes in the value proposition twice and in the value creation three times. The changes in the value proposition, driven by technological factors, were primarily rooted in technology development and the potential for new product offerings. The three instances of changes in value creation were attributed to resource efficiency, leading to new partnerships and alterations in the key resources and activities of the start-ups. In the content analysis, ‘technology development’ and ‘resource efficiency’ were the only sub-themes identified. Notably, resource efficiency appeared more frequently during the content analysis, accounting for



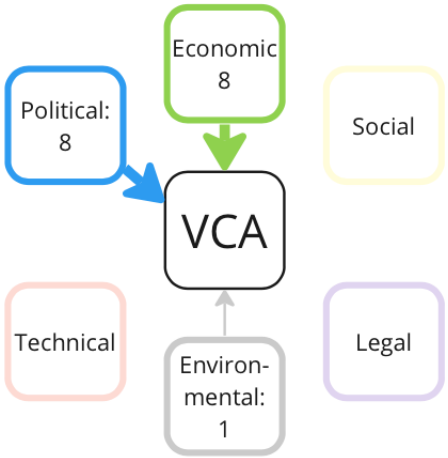
(a) Frequency of external factors influencing the value proposition.



(b) Frequency of external factors influencing the value creation.



(c) Frequency of external factors influencing the value delivery.



(d) Frequency of external factors influencing the value capture.

Figure 6.3: A graphical representation depicting the frequency of external factors within each category influencing specific elements of the business model.

approximately 60% of the cases, which is consistent with the observed case studies.

Another noteworthy observation pertains to the impact of social factors on the value proposition. The value proposition was most affected by social factors, whereas social factors only influenced the value creation once. The singular occurrence of social factors influencing the value creation was due to customer preferences that deviated from Supersola's product, leading them to return to the development phase and undergo the Validation-lab with YesDelft!. Out of the three instances where social factors caused changes in the value proposition, two were driven by the social needs of the community for the product. Although this is not directly reflected in the content analysis as 'social awareness' and 'social reputation' were more frequently occurring, it was concluded that these themes likely exerted more indirect influence rather than direct influence. The social needs of the community might have a more direct influence on business model dynamics.

6.5. External factors and growth stages

In order to comprehend the impact of external factors on the development of start-ups, it is crucial to investigate the specific factors that drive business model dynamics at different growth stages. This examination provides valuable insights into the timing, origin, and contribution of these factors in overcoming growth barriers. For a comprehensive overview of the external factors during various growth

stages, please see Appendix A.

An analysis of the case studies reveals several observations regarding the influence of external factors on the development of Dutch technology-based PV start-ups. Firstly, no changes were observed in the research phase, which can be attributed to the absence of an established business model at this stage. Business model development begins in subsequent stages, specifically during the opportunity-framing phase, where start-ups identify opportunities or threats that shape their business model.

Secondly, social and technological factors prominently influence the earliest phases of the start-ups in the case studies. Considerations such as meeting the social needs of communities and embracing technological advancements to identify market-fit solutions play a pivotal role in driving business model dynamics.

Thirdly, the highest number of changes is witnessed in the later stages, following the earliest phases. This aligns with the assertion made by Vohora et al. (2004) that decisions made during the pre-organization phase significantly impact a company's future. Start-ups in this phase make crucial decisions related to the commercial exploitation of their product, resource allocation, and acquisition. The high number of political, economic, and technological factors seen during this phase aligns with Vohora et al.'s statements. Political and economic factors primarily involving subsidies granted to start-ups and supportive financial systems, highlighting resource acquisition decisions. Technological factors driving business model changes typically revolve around enhancing resource efficiency, indicating resource allocation decisions.

This phase is followed by a phase where firms strive to generate returns by selling their products. Subsidies decrease in significance, and policy changes become more prominent within political factors. Economic factors gain importance as third-party investments, loans, and market competition come into play. Legal factors are only observed in this phase, primarily relating to certifications, patents, and potential threats posed by legislation. The emergence of legal factors in the re-orientation phase can be attributed to the timing of obtaining patents and certifications. As start-ups prepare to enter the market by selling their products or services, securing legal protection, compliance with regulations, and establishing credibility become crucial steps in safeguarding intellectual property rights, meeting regulatory requirements, and gaining trust from potential customers and investors.

In the final phase, characterized by sustainable return, as stated by Vohora et al. (2004), changes in the business model are exclusively driven by external factors. This may be attributed to start-ups becoming self-sustaining, requiring minimal major business model changes. However, it is important to note that only one case in this study reached this phase, limiting definitive conclusions.

Furthermore, an examination of the case studies reveals that external factors play a significant role in overcoming challenges encountered during the opportunity recognition juncture and the sustainable juncture, as defined by Vohora et al. (2004). Notably, emerging technological advancements and the identification of social needs and preferences emerge as crucial external factors contributing to the successful navigation of obstacles in the early stages of product development and start-up ventures. However, in later phases, the influence of external factors in overcoming these critical junctures diminishes relative to other stages.

Regarding the last growth barrier identified by Vohora et al. (2004), sustainability, it is noteworthy that only one instance was identified where this barrier was successfully overcome, and it was due to an external factor. Given the rarity of such events, caution should be exercised in generalizing the findings regarding this growth barrier to all start-ups. Nevertheless, considering the prevailing pattern of business model changes occurring due to external factors during the sustainable returns phase, it can be argued that external factors progressively assume greater significance in the later stages of the start-up journey.

In conclusion, external factors play a crucial role in overcoming the initial and final challenges in the development of Dutch technology-based PV start-ups. Between the earliest and latest phases, approximately 60% of the changes in business model dynamics are attributed to external factors, highlighting their importance during these phases. Initially, social and technological factors take precedence, while political and economic factors replace social factors in later stages. Legal factors emerge primarily in the re-orientation phase, where obtaining patents and certifications becomes a crucial step. In the final phase of a start-up, external factors exclusively drive business model dynamics.

7

Conclusion, discussion, and recommendations

This chapter presents the conclusions and discussions derived from the study, which are presented in section 7.1 and section 7.2, respectively. Additionally, recommendations for future research will be provided in section 7.3, section 7.4 provides information on the implications of this study, and section 7.5 shows the steps to apply the developed framework.

7.1. Conclusion

The main focus of this thesis is to investigate the influence of external factors on the dynamics of business models in Dutch technology-based start-ups operating in the photovoltaic (PV) sector. To accomplish this objective, several research questions will be addressed.

7.1.1. Research question 1: How do business model dynamics develop for technology-based start-ups?

The research literature on business models is comprehensive and covers various domains and subjects. In order to prevent an overwhelming literature review, this literature review focuses exclusively on literature directly pertinent to the research topics. Given the fragmented nature of the business model literature, conducting a structured literature review becomes imperative to provide a coherent perspective and identify existing gaps and limitations.

In the context of this study's research questions, a review of the business model literature reveals that a significant portion of research focuses on the static nature of "business models as snapshots in time" (De Reuver et al., 2009). However, the latest research already gravitates towards a more dynamic view of business models (Kamp et al., 2021; Khodaei & Ortt, 2019), including their evolution and adaptation over time. It is widely acknowledged that business model dynamics plays a critical role in achieving competitive advantage, especially in rapidly changing environments (Demil & Lecocq, 2010; Loch et al., 2008; Teece, 2010; Trimi & Berbegal-Mirabent, 2012).

A business model can undergo four distinct changes: creation, extension, revision, and termination, as proposed by Cavalcante et al. (2011). For business model innovation, which is a form of business model dynamics, the same four types of business model changes can be seen. To maintain a competitive advantage based on their business model, firms need to assess the need for extending, revising, or even terminating specific business models Cavalcante et al. (2011). This is especially important for companies in order to stay flexible to changing market conditions (Teece, 2018).

Section 2.2 and section 2.3 delves into the concepts of business model innovation and business model dynamics and explores how these terms have been employed differently by researchers. The literature highlights the importance of studying business model change as a dynamic approach. Business

model innovation encompasses the evolutionary nature of business models over time in this dynamic approach. Several drivers of business model innovation can be found in Table 2.2. These drivers include both external factors such as policy changes, changes in economic and business environment, and new technologies, as internal factors such as product innovation, changes in resource availability, and changes in internal strategies.

Business model dynamics can be defined as a process of change in one or more business model components, enabling the necessary response to external and internal factors. To understand the business model dynamics of technology-based start-ups the changes in business model elements over time and the relationships between these elements need to be investigated. The relationships refer to the interconnections among the four business model elements: value proposition, value creation, value delivery, and value capture. These elements are derived from the sustainable business model canvas developed by Bocken et al. (2018). Examples of different interrelationships are presented in Table 3.6 in chapter 3.

7.1.2. Research question 2: What external factors lead to business model dynamics of technology-based start-ups?

Firstly, in order to conduct a systematic examination of the external factors influencing business model dynamics, the PESTEL framework is employed (see section 2.4), which encompasses the following categories: Political, Economic, Social, Technological, Environmental, and Legal. The PESTEL analysis method assists organizations in understanding how external drivers can impact their operations and supports strategic decision-making. Compared to the PEST analysis, the PESTEL framework includes two additional factors, namely Environmental and Legal, making it more comprehensive, especially for sustainable companies. Given the focus of this research on PV start-ups, the inclusion of environmental and legal factors is considered relevant and appropriate.

In chapter 2, a comprehensive literature review was conducted in which the origins and drivers of business model innovation (BMI) were discovered. The findings were then presented in Table 2.2 and Table 2.3. These tables provide a comprehensive overview of the external factors that contribute to changes in business model elements. These factors are not specific to technology-based PV start-ups and encompass various economic and technological aspects, such as economic recessions, competition, new technologies, and technological advancements.

In chapter 3, the conceptual framework delved further into the research question by presenting specific examples of external factors that influence business model elements of start-ups in the solar energy sector. The examples of these external factors are categorized as opportunities or threats, following the classification framework proposed by Meslin (2019). These external factors are presented in Table 3.3. Moreover, an overview of external factors per category was provided in Table 3.4, contributing to a comprehensive understanding of the external influences on businesses. It is important to note that these factors are not exclusively tailored to technology-based start-ups but offer valuable insights into the broader landscape of external influences.

In order to gain deeper insights into the factors specific to technology-based start-ups, chapter 5 presented case studies that examined the dynamics of their business models. The findings of these case studies were summarized in Table 6.3, which provided an overview of the factors driving changes in business models. Notably, the analysis revealed the significant influence of external factors on business model dynamics in technology-based start-ups.

Moreover, a content analysis was conducted to identify additional external factors impacting business model elements in these start-ups. The analysis involved identifying recurring themes within each external category. The results of this analysis are presented in Table 6.1 and can be seen fully in Table B.1 of Appendix B. These tables offer a comprehensive overview of the identified external factors, including relevant quotes that further illustrate their impact on business model dynamics in technology-based start-ups in the context of the Netherlands. Most notable of the results is the number of indirect factors influencing start-ups, as not every external factor in the content analysis of section 6.1 can be seen in the analysis of the external factors on business model changes in Table 6.3.

7.1.3. Research question 3: How do external factors influence the business model dynamics of Dutch technology-based PV start-ups?

The research question regarding the influence of external factors on the business model dynamics yields a multifaceted answer, considering different elements of the business model. The integration of case studies in chapter 5 provides valuable insights and real-world examples, enhancing the depth of understanding and providing the first part of the answer to this research question. Analysis of the data presented in Table 6.3 demonstrates that external factors are the primary drivers of business model changes, with approximately two-thirds of business model changes originating from external factors. Economic and political factors emerge as the most influential, with 'subsidies' and 'supportive financial resource availability' being prominent occurrences. Conversely, technological factors and social factors contribute to a lesser extent, representing a quarter of the occurrences of the total amount of external factors. Legal and environmental factors play an even more subdued role.

Further examination of the individual elements of the business model highlights the significance of social factors in shaping the value proposition. This phenomenon arises from the recognition of the 'social needs of communities' and evolving 'customer preferences'. While the content analysis revealed the frequent occurrence of factors such as 'social awareness' and 'social reputation', such factors are not seen in the cases. It is important to note that these factors might have a more indirect impact on business model dynamics and may not be directly reflected in the observed changes.

In the value creation element, technological factors, particularly 'resource efficiency', have a substantial impact, leading to changes in partnerships, key activities, and key resources. The value delivery element, on the other hand, appears to be influenced by a diverse range of external factors.

Turning to the value capture element, it is noteworthy that political and economic factors emerge as the primary drivers of business model changes. These two categories of influence hold considerable sway over the value capture mechanisms employed by organizations. It is important to highlight that every political factor identified in this analysis is intrinsically linked to 'subsidies', while every economic factor is connected to 'supportive financial resource availability'. This finding reinforces the substantial role played by external stimuli in shaping the strategies and operational frameworks adopted by businesses to maximize value capture.

The interrelationships between the business model elements result mostly from external factors. The interrelationships are analysed in section 6.2. There are six pairs of interrelationships specific to Dutch technology-based PV start-ups that appeared in the case studies. It is important to note that not all interrelationships exist between two elements, indicating that not every business model element necessarily influences other elements, even if the reverse is true. For instance, the value proposition has caused secondary changes in the value delivery seven times, while the value delivery has never affected the value proposition.

A second observation is that the value delivery element is frequently subject to secondary changes and has only caused changes in other elements once. This is because changes in the value delivery primarily involve realigning the business model to maintain coherence among the different elements. On the other hand, value creation and value capture are the most dominant elements in terms of interrelationships.

The most common type of interrelationship identified in the case studies is SF, as shown in Figure 6.1. This indicates that primary changes in business model elements are the result of strategic decisions made by a company, while secondary changes are forced changes.

Lastly, all primary changes were defined as opportunities or threats following the classification approach reported in the dynamic business model framework by Xu (2022). When looking at all primary changes (external and internal) 47 out of 52 changes were opportunities and only five primary changes were categorized as threats. One exception is a change that resulted from a combination of a threat and an opportunity. The exception, 29 opportunities, and four threats can be noticed if only the external primary changes are observed. The high number of opportunities occurring, and the high amount of strategic primary changes that were just discussed (see research question 1) probably has a correlation. When a business strategy is developed to actively anticipate instead of reacting all the time, more strategic changes are expected, and more opportunities can be expected.

In conclusion, the research reveals that external factors significantly impact business model dynamics across various elements. Case studies provide valuable insights and real-world examples, emphasizing the influence of external factors. Economic and political forces are the primary drivers of business model changes, particularly through 'subsidies' and 'supportive financial resource availability'. Technological and social factors play a lesser role, while legal and environmental factors have a limited impact. Social factors strongly shape the value proposition, while technological factors drive value creation. The value delivery element is influenced by diverse factors, and political and economic forces drive value capture.

These findings, although obtained via case studies, can be generalized. As the case studies involve Dutch technology-based PV start-ups, the findings apply to this kind of start-up. 'Subsidies' is seen as one of the most influential factors together with 'supportive financial recourse availability'. The subsidies in the case studies were mostly subsidies granted to companies operating in the renewable energy sector. 'Supportive financial recourse systems' consisted mostly of investments and loans. Both factors are not specific to the PV sector. The subsidies do limit the findings to the renewable energy sector and the Netherlands as they are granted to renewable energy companies and subsidies can vary between countries. It can be assumed, however, that several European countries grant similar subsidies. The social and technical factors of 'social needs of communities,' 'customer preferences,' and 'resource efficiency' are not specific to Dutch technology-based PV start-ups but rather to the initial phases of any start-up.

7.1.4. Research question 4: To what extent can external factors contribute to the development of Dutch technology-based PV start-ups?

To comprehend the impact of external factors on start-up development, it is essential to investigate the specific factors that drive business model dynamics at different development phases. This analysis provides valuable insights into the timing, origin, and contribution of these factors in overcoming challenges. The literature has shown that the theory of Vohora et al. (2004) describes different development phases as growth stages and different challenges as critical junctures. This is used in the conceptual framework of chapter 3 to depict the development phases of start-ups. The framework utilized in this thesis is based on the work of Kamp et al. (2021) and Kharbeet (2022). It provides a visualization of the business model dynamics and the different growth stages and the associated growth barriers of start-ups.

The examination of case studies on Dutch technology-based PV start-ups reveals several observations regarding the influence of external factors. Initially, no changes were observed during the research phase due to the absence of an established business model. Business model development begins in subsequent stages where start-ups identify opportunities or threats that shape their business model. Social and technological factors prominently influence the earliest phases of the start-ups, meeting social needs and embracing technological advancements play a pivotal role in driving changes to the value proposition and value creation of the business models.

The highest number of business model changes occurs in the development stages following the earliest phases, the pre-organization phase of Vohora et al.'s (2004) theory. This aligns with the assertion that decisions made during this phase significantly impact a company's future (Vohora et al., 2004). Political, economic, and technological factors are prominent during this phase, primarily involving subsidies, financial systems, resource allocation, and acquisition decisions. Political and economic factors are the most frequently observed external factors during this phase. This can be attributed to start-ups actively seeking financial resources during these early stages. Political factors slightly outweigh economic factors in prominence, due to the provision of subsidies that are commonly encountered. Both the political and economic factors influence the value capture of the start-ups.

The subsequent phase involves generating returns by selling products. Subsidies decrease, policy changes become prominent, and economic factors gain importance with third-party investments, loans, and market competition. The economic factors still influence the value capture, just as in the pre-organization phase, but political factors influence the value delivery as favourable policies let start-ups explore new markets. Legal factors emerge, relating to certifications, patents, and potential threats posed by legislation, as start-ups prepare to enter the market and establish credibility. This phase is characterized by start-ups preparing to sell their products or services, which often involves ensuring legal protection and compliance. Therefore, an increase in legal factors is not surprising in this phase,

as start-ups prioritize securing the necessary legal foundations as they enter the market. These legal factors influence the value proposition and value delivery.

In the final development phase, as defined by Vohora et al. (2004) business model changes are exclusively driven by external factors. This may be attributed to start-ups becoming self-sustaining and requiring minimal major business model changes. However, only one case in the study reached this phase, limiting conclusive findings.

External factors play a significant role in overcoming the first challenges in their development. Very late on the same observation applies. Technological advancements and the identification of social needs emerge as crucial factors in the early stages, but their influence diminishes in later phases.

Regarding the late challenges, only one instance successfully overcame the sustainability juncture, highlighting its rarity. Caution should be exercised in generalizing findings for all Dutch technology-based PV start-ups. However, external factors progressively assume greater significance in the later stages of the start-up journey based on the pattern of business model changes during the sustainable returns phase.

In conclusion, external factors play a crucial role in overcoming initial and final challenges in the development of Dutch technology-based PV start-ups. Approximately 60% of changes in business model dynamics occur due to external factors between the earliest and latest phases, emphasizing their importance. Social and technological factors are prominent initially, followed by political and economic factors in subsequent phases. Legal factors emerge in later phases when legal action becomes more important. In the final phase, external factors exclusively drive business model dynamics.

Some of these findings can be generalised and are not specific to Dutch technology-based PV start-ups. Regarding the external factors per growth phase, a high number of business model changes in the pre-organization phase can be expected for all start-ups. In the theory of Vohora et al. (2004) this phase is seen as a crucial phase for later development as “it was found that decisions taken at this early stage had an unforeseeable impact upon the entire future success of the USOs (University Spin-Offs) since they directed the path of development and alternatives that were available to the firm at a later date.” Therefore, it is logical for start-ups to spend much time developing and trying to perfect the business model before proceeding.

The great amount of ‘subsidies’ and ‘supportive financial resource availability’ can be explained by the phenomenon of “the valley of death”. This phenomenon explains the struggle to secure funding and bridge the gap between research and commercialization (Lerner, 2009; C. Mason & Harrison, 2000). Because of this phenomenon, similar results can be expected for other types of start-ups.

The importance of social needs and customer preferences in overcoming the first challenges of start-ups is also expected for other types of start-ups than Dutch technology-based PV start-ups. In books about entrepreneurship, such as ‘The lean startup’ (Ries, 2011), ‘Disciplined Entrepreneurship’ (Aulet, 2013) or ’The startup owner’s manual’ (Blank & Dorf, 2020), the first steps are about identifying opportunities and aligning this need to your business model. The findings of this research regarding overcoming the first challenges of a start-up can be generalised to all start-ups as this can be seen as already available knowledge that is validated again.

7.1.5. Main research question: How do external factors influence the business model dynamics of Dutch technology-based PV start-ups during different growth phases?

The aim of this thesis is to investigate the influence of external factors on the business model dynamics of Dutch technology-based PV start-ups during different growth phases. As business model dynamics in start-ups are influenced by a multitude of external factors, it is crucial for these organizations to grasp the interplay of these external factors and comprehend their impact on different elements of the business model at different points in time.

The first research methodology employed in this study involved conducting a comprehensive literature review to gain profound insights into the business model dynamics of technology-based start-ups. This literature review highlights the shift towards a dynamic view of business models. While earlier research focused on static models, recent studies emphasize the importance of understanding their

evolution and adaptation over time. Business model dynamics, including creation, extension, revision, and termination, are crucial for firms to maintain competitiveness in changing markets. Business model innovation, driven by external and internal factors, plays a significant role in this dynamic approach. The interrelationships among elements of a business model are essential for comprehending the dynamics of technology-based start-ups.

Furthermore, this study highlights the substantial impact of external factors on the business model dynamics of technology-based start-ups. The application of the PESTEL framework and in-depth analysis reveals the significance of political, economic, social, technological, environmental, and legal drivers. The literature review demonstrates the diverse range of external factors influencing business model elements, including economic recessions, competition, and technological advancements. These insights provide valuable knowledge for technology-based start-ups in the solar energy sector, contributing to strategic decision-making. The content analysis further identifies recurring themes within each external category, enhancing our understanding of the external influences on business model dynamics.

The findings of the case studies and content analysis indicate that external factors significantly contribute to business model dynamics in Dutch technology-based PV start-ups. Economic and political factors emerge as the primary drivers of business model changes, with ‘subsidies’ and ‘supportive financial resource availability’ playing a crucial role in shaping the value capture. Technological factors also have a substantial impact, influencing the value proposition through emerging technologies and influencing the value creation through opportunities for resource efficiency. Social factors are particularly relevant in shaping the value proposition, considering social needs and evolving customer preferences. While the impact of legal and environmental factors is relatively limited, they do play a role in specific phases of the start-up’s growth journey. Legal factors become more prominent as start-ups focus on securing legal protection and compliance while entering the market. Environmental factors are less influential overall, but their occurrence in the value delivery and value capture element highlights their potential impact.

The findings regarding ‘subsidies’ and ‘supportive financial recourse systems’ can be generalised to technology-based start-ups in the renewable energy sector. The subsidies in the case studies were mostly subsidies granted to companies operating in the renewable energy sector and limit the findings to this sector. It might be the case that it is not limited to Dutch start-ups specifically as several European countries grant similar subsidies. ‘Supportive financial recourse availability’ consisted mostly of investments and loans and is not specific to Dutch PV start-ups but to start-ups overall. The social and technical factors of ‘social needs of communities,’ ‘customer preferences,’ and ‘resource efficiency’ are also not specific to Dutch technology-based PV start-ups but rather to the initial phases of any start-up.

The most common type of interrelationship identified in the case studies is SF, as shown in Figure 6.1. This indicates that primary changes in business model elements are the result of strategic decisions made by a company, while secondary changes are forced changes.

Also, analysis reveals that the majority of primary changes in the business models were classified as external opportunities. Out of 53 primary changes, 34 had an external origin, of which 29 were identified as opportunities (see subsection 7.1.3). The presence of strategic primary changes (see subsection 7.1.1) correlates with the high number of opportunities, indicating that proactive business strategies lead to more strategic changes and the identification of opportunities.

Furthermore, the analysis of external factors in different development phases indicates their importance in transitioning between these stages and overcoming obstacles. Factors such as emerging technologies and understanding social needs prove significant in navigating early-stage challenges, while political and economic factors play major roles in the viability of start-ups during the pre-organization and re-orientation phases. Successful overcoming of the sustainability juncture was rare and only happened once in the case studies. Because there is only one occurrence of this critical juncture being overcome, caution is advised when generalizing the findings. Nonetheless, during the sustainable returns phase, business model changes driven by external factors progressively gain significance, indicating their growing importance in the later stages of the start-up journey.

The findings about navigating early-stage challenges and during the pre-organization and re-orientation phases can be generalised to technology-based start-ups. The importance of social needs and cus-

tomer preferences in overcoming the first challenges of start-ups is expected as books about entrepreneurship, such as 'The lean startup' (Ries, 2011), 'Disciplined Entrepreneurship' (Aulet, 2013) or 'The startup owner's manual' (Blank & Dorf, 2020), describe this by identifying opportunities and aligning this need to your business model. The major influence of political and economic factors can also be generalised to start-up overall as the concept of "the valley of death" emerges and these factors help bridge the gap between research and commercialization (Lerner, 2009; C. Mason & Harrison, 2000). This phenomenon is seen in all start-ups and the findings and conclusions can therefore be generalised.

Overall, the research findings demonstrate that external factors exert a substantial influence on the business model dynamics of Dutch technology-based PV start-ups. Understanding and adapting to these external influences is essential for the sustained success of these start-ups, emphasizing the need for strategic responsiveness and alignment with the evolving external environment. These findings have practical implications, enabling start-ups to navigate the dynamic business landscape and adapt their business models for sustainable success.

7.2. Discussion

In order to examine the influence of external factors on the business model dynamics in Dutch technology-based PV start-ups, a combination of case studies and content analysis was employed. The business model canvas (BMC) elements proposed by Osterwalder and Pigneur (2010) served as the foundational framework, augmented by frameworks developed by Meslin (2019), Kamp et al. (2021), Xu (2022), and Kharbeet (2022). These frameworks provided a structured approach for analyzing the business model dynamics in this thesis. Additionally, considerations derived from the PESTEL framework were incorporated to recognize the significance of external factors in the analysis.

However, it is important to acknowledge that the framework used in this study does not fully represent the complexity of a business model, as certain simplifications were necessary to analyze the cases and draw conclusions. By grouping the elements into four main components, the potential interrelationships were reduced to six distinct relations, whereas the original BMC framework entails 36 possible relationships. Consequently, the complete dynamics of technology-based PV start-ups cannot be fully captured.

Furthermore, the application of the PESTEL framework to identify external factors in Dutch technology-based PV start-ups has inherent limitations. While the PESTEL framework primarily analyses the macro-environmental factors, it may not adequately capture the micro-environmental dynamics. In this study, micro-environmental factors were categorized based on subjective judgment to fit within the PESTEL categories. This subjective judgment introduces potential variations in the interpretation of the same data.

Data acquisition and interpretation represent critical factors in this thesis. Given the content analysis conducted on a limited number of cases, there is a potential lack of diversity in the data, which may introduce biases or restrict variation in the analysis. Moreover, the subjective nature of the data itself is influenced by participants' differing experiences and interpretations of interview questions. As participants may not be experts in the field of business model dynamics, errors in the data may occur, especially if participants provide inaccurate or misleading answers. Furthermore, participants may be hesitant to disclose certain information if it could potentially harm their company strategically or socially.

Similar to the limitations associated with the use of PESTEL categories, subjective judgment is also employed in this thesis. The identification of interrelationships (forced or strategic, and opportunity or threat) involves subjective judgment, potentially yielding diverse results for the same factors and introducing bias and subjectivity into the analysis. Coupled with biases in the data, these factors could lead to errors in the conclusions.

Therefore, it is essential to consider these limitations when interpreting the findings of this thesis. The potential impact of these limitations on the comprehensiveness and reliability of the analysis should be acknowledged. Future research endeavours should aim to address these limitations and explore alternative methodologies or approaches to enhance the understanding of the influence of external

factors on the dynamics of business models in Dutch technology-based PV start-ups.

In conclusion, the significance of external factors is highlighted, and their varying degrees of influence are discussed. However, it is crucial to emphasize that the identification and analysis of external factors in this study, based on six case studies, do not enable predictions of future outcomes. Rather, they serve as a starting point for analysis and interpretation, requiring strategic thinking for successful application.

7.3. Recommendations

It is advisable to explore alternative categorisations for external factors when investigating their influence on business model dynamics. While the PESTEL framework is appropriate for analysing macro-environmental factors, it may not adequately capture the dynamics of micro-environmental factors. Thus, when employing the PESTEL categories, researchers rely on their subjective judgment to categorize micro-environmental factors. To ensure a comprehensive analysis that encompasses both macro- and micro-environmental influences, it is essential to develop an approach that effectively integrates these factors.

It is also noticeable that the political factors mainly concern policy factors and policies and that almost no governmental activities are seen in the cases. Therefore another division of external factors might be better suitable for further research if one wants a better distinction between policies or policy factors.

For future research, it is recommended to include participants from diverse work backgrounds to minimize errors and biases in the data. However, the recruitment of such participants may necessitate careful planning and a longer time frame to ensure an adequate representation. Additionally, conducting a second round of interviews with different participants within the same start-up can enhance the reliability and validity of the data.

In terms of exploring the influence of external factors on business model dynamics, conducting a comparative analysis or examining different contexts can yield valuable insights. A comparative analysis encompassing technology-based PV start-ups in various regions or countries can reveal variations in the impact of external factors on business model dynamics. Likewise, analysing start-ups operating in diverse contexts, such as emerging economies or developing regions, can illuminate the unique opportunities and challenges they encounter, thus fostering a more comprehensive understanding of business model dynamics.

Lastly, it is recommended to complement the analysis of this thesis with quantitative research conducted in the same setting. By quantitatively determining the prevalence and significance of different external factors, researchers can develop actionable advice and strategies to promote the growth of technology-based PV start-ups. This quantitative research can involve surveying a larger sample of start-ups and employing statistical analysis methods to examine the data.

7.4. Implications

7.4.1. Practical implications

The findings of this thesis offer practical implications for entrepreneurs operating in the technology-based PV sector. By applying these implications, entrepreneurs can effectively adapt their business models to external factors and improve their chances of sustained success.

Entrepreneurs can employ the framework proposed in this thesis to assess and analyze their business models in relation to external factors and development phases. By evaluating in which development phase they are situated, evaluating the elements of their business model (value proposition, value creation, value delivery, and value capture) and considering the impact of external factors, entrepreneurs can identify areas for improvement and make informed decisions to adapt their business models effectively. For start-up in the early phases (research phase and opportunity recognition phase) social and technical factors can be exploited and should have the main focus when looking for opportunities. The research findings underscore the importance of considering these factors in shaping the value

proposition and value creation of business models in the early stages. Start-ups should be aware of the social needs of communities and evolving customer preferences. Additionally, they should leverage technological advancements to enhance resource efficiency and drive innovation by leveraging partnerships. In later phases (pre-organization phase and re-orientation phase) the value capture should be maximized by finding opportunities to exploit political and economic factors. This can be done by leveraging subsidies and other supportive financial systems.

Entrepreneurs should cultivate a mindset of strategic responsiveness by actively monitoring and assessing external factors that influence their business models. By staying alert to changes in the political, economic, social, technological, environmental, and legal landscape, entrepreneurs can anticipate opportunities and threats and proactively adjust their strategies and operations accordingly.

Besides the practical implications for entrepreneurs, this research can guide policymakers in their efforts to support technology-based start-ups in the PV sector and create an enabling ecosystem for their success.

Policymakers can leverage the findings of this thesis to design and implement policies that support technology-based start-ups in the PV sector. This includes providing subsidies, financial incentives, and supportive regulatory frameworks to encourage the growth and development of these start-ups. By fostering an enabling policy environment, policymakers can facilitate PV start-ups and enhance their chances of long-term success.

7.4.2. Academic contribution

This study makes academic contributions by embedding the results within the broader literature on business model dynamics, specifically in relation to business model innovation. By building on existing frameworks and theories while introducing novel insights, this research enriches our understanding of the dynamics of business models in Dutch technology-based start-ups operating in the PV sector.

Firstly, this study advances the understanding of business model dynamics by emphasizing the role of external factors in driving business model changes. While prior research has often focused on the static nature of business models, this study takes a dynamic perspective. By exploring the interplay between external factors and business model dynamics, the research sheds light on the mechanisms through which external influences shape and transform business models over time. This contribution is particularly relevant in the context of BMI and BMD, as it highlights the importance of adaptability and agility in responding to external drivers of change.

Secondly, this study expands the knowledge base on the specific external factors that influence business model dynamics in technology-based start-ups. Drawing on the PESTEL framework and employing a comprehensive analysis of case studies, the research identifies and categorizes the external drivers that shape business model changes. This categorization provides valuable insights into the diverse influences that start-ups need to consider when designing and adapting their business models. By delving into the unique context of the PV sector, the findings contribute to a more nuanced understanding of the external factors that impact business models in this specific industry.

7.5. Framework application

To develop and use the dynamic sustainable business model framework of this study including the external factors, the steps as presented in Figure 7.1 can be followed.

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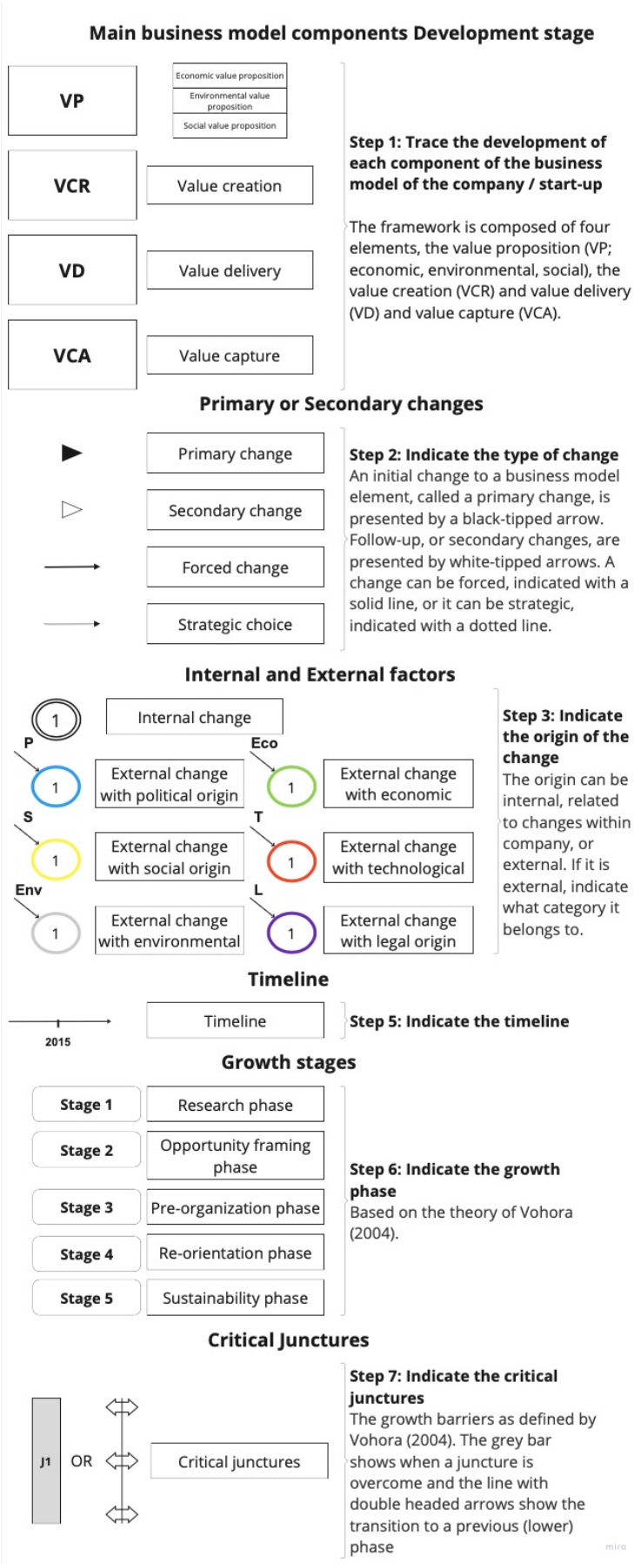

Figure 7.1: The seven steps to develop and use the dynamic sustainable business model framework.

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A

Business model dynamics of case studies

This appendix includes the business model dynamics of the cases from the case study starting in the table on the next page.

Table A.1: The drivers, changes, and follow-up changes to the sustainable business model of SolarWorks! with the corresponding critical junctures they faced.

Origin			Cause	Primary effect	Secondary effects	Critical juncture
Social	E.O.	Social needs of (local) community.	A graduation project based on people their needs.	VP 1 → VP 2: A lamp running on solar energy.	-	Opportunity recognition
Social	E.O.	Customer preferences.	Design a product within customer budget to power lights and phones.	VP 2 → VP 3: The power box running on solar energy.	VD 1 → VD 2: Starting the sell to wholesaler and retailers.	Entrepreneurial commitment
Technological	E.O.	Resource efficiency.	Efficiency opportunities and knowledge sharing by partnering with YesDelft! And TU Delft.	VCR 1 → VCR 2: Partnership with YesDelft! and with the University of Technology Delft.	-	Credibility
Internal	I.O.	Customer segment expansion.	Three new products were developed to cover more customer segments.	VP 3 → VP 4: Three products in sale.	VD 2 → VD 3: Three new customer segments are targeted by the new products.	Credibility
Economic	E.T.	Market competition.	Due to increased market competition from Asian countries, SolarWorks! Partnered with PEC to revise and alter their business model completely.	VCR 2 → VCR 3: Partnership with Persistent Energy Capital.	VP 4 → VP 5: Sell bigger household systems and stop selling the smaller systems. VD 3 → VD 4: Stop selling to wholesalers and retailers and start selling to consumers directly. VCA 1 → VCA 2: Pay-as-you-go payment method.	Credibility
Internal	I.O.	Scale-up.	New external agents are hired to help increase the number of sales.	VCR 3 → VCR 4: Hiring new external agents.	VCA 2 → VCA 3: Commission based payments to external agents.	Sustainability
Economic	E.O.	Supportive financial resource availability.	Financial investment of EDP Renováveis.	VCA 3 → VCA 4: A strategic investment from EDP Renováveis.	VCR 4 → VCR 5: Opening of a new office in Malawi.	Sustainability

Table A.1 continued from previous page

Environmental	E.T.	Environmental disaster.	A cyclone hits Mozambique and Malawi, exposing the weaknesses of the pay-as-you-go system.	VCA 4 → VCA 5: Adding direct payments to the pay-as-you-go payments.	VP 5 → VP 6: Offer larger systems. VD 4 → VD 5: Target SMEs, healthcare clinics, and weak-grid customers.	Sustainability
Economic	E.O.	Supportive financial resource availability.	New financial incentives to expand more.	VCA 5 → VCA 6: Debt investments of ElectriFI and SunFunder.	-	Sustainability
Political	E.O.	Subsidy.	Subsidies were made available for smaller solar systems, creating economic viability for SolarWorks! to sell these products.	VCA 6 → VCA 7: Subsidies for smaller systems.	VP 6 → VP 7: Smaller systems are sold in Mozambique.	Sustainability

Table A.2: The drivers, changes, and follow-up changes to the sustainable business model of SoLarge with the corresponding critical junctures they faced.

Origin			Cause	Primary effect	Secondary effects	Critical juncture
Technological	E.O.	Technological development.	A new kind of solar panels for integrated solar roofs.	VP 1 → VP 2: A lightweight solar panel for integrated solar roofs.	-	Opportunity recognition
Internal	I.O.	Knowledge availability.	Knowledge expansion and better understanding of customer demand by partnering.	VCR 1 → VCR 2: Partnerships with SABIC, Heijmans, TNO, Solliance.	VP 2 → VP 3: A standalone, lightweight solar panel with many applications.	Entrepreneurial commitment
Internal	I.O.	Customer segment expansion.	New target customer segment added.	VD 1 → VD 2: Besides the original agricultural sector, also flat roofs are targeted as customers.	VCA 1 → VCA 2: 4 informal investors were attracted to finance the costs of SoLarge.	Credibility
Economic	E.O.	Supportive financial resource availability.	Investments lead to new revenue sources.	VCA 2 → VCA 3: Investment from the Brabantse Startup Fonds.	-	Credibility

Table A.2 continued from previous page

Internal	I.O.	Knowledge availability.	New partners lead to better network connections.	VCR 2 → VCR 3: Partnership with Techleap via the Techleap Rise Program and with Solarfields.	VD 2 → VD 3: Due to new partnership more customers can be reached through new channels.	Credibility
Economic	E.O.	Supportive financial resource availability.	Beliefs of Vorm lead to investments in SoLarge.	VCA 3 → VCA 4: Investment of Vorm.	VCR 3 → VCR 4: Vorm became a major partner due to its investment. VCA 4 → VCA 5: Investments from four informal investors. VCR 4 → VCR 5: The four informal investors became shareholders of SoLarge.	Sustainability
Legal	E.O.	Certification of product.	CERTISOLIS certification leads to new customer segments.	VD 3 → VD 4: New customer segments can be targeted due to certification.	-	Sustainability
Internal	I.O.	Resource availability.	An e-commerce platform is set up to sell the solar panels online.	VD 2 → VD 3: An online webshop is set up.	-	Sustainability

Table A.3: The drivers, changes, and follow-up changes to the sustainable business model of Supersola with the corresponding critical junctures they faced.

Origin			Cause	Primary effect	Secondary effects	Critical juncture
Social	E.O.	Social need of (local) community.	There was no product-market fit for the needs of customers.	VP 1 → VP 2: A plug & play solar panel.	VD 1 → VD 2: Customers who are not suitable for a roof filled with solar panels and those for whom such an option is not feasible are targeted.	Opportunity recognition
Internal	I.O.	Resource availability.	To maximize profit margins and minimize overhead costs, an webshop was set up to sell the solar panels online.	VD 2 → VD 3:An online webshop is set up.	-	Entrepreneurial commitment

Table A.3 continued from previous page

Social	E.T.	Customer preferences.	The product-market fit wasn't as good as initially thought therefore the product was further developed with the use of the resources and knowledge of partners.	VCR 1 $\rightarrow$ VCR 2: The product was not good enough so validation tests were done in the YesDelft! Validation-lab. Besides new key activities this resulted in YesDelft! as a new partner.	-	Credibility
Economic	E.O.	Supportive financial resource availability.	InnoEnergy invested in Supersola to support their operations and help them overcome financial shortcomings.	VCA 1 $\rightarrow$ VCA 2: InnoEnergy invested in Supersola to help them overcome financial obstacles.	VCR 2 $\rightarrow$ VCR 3: A new partnership with InnoEnergy followed from the initiative to optimize the product.	Credibility
Economic	E.O.	Supportive financial resource availability.	More financial resources were acquired to support the R&D phase via an 'innovation loan' of the Rabobank.	VCA 2 $\rightarrow$ VCA 3: An "innovation loan" with the Rabobank gave new financial input.	-	Credibility
Internal	I.O.	Outsourcing of activities.	Assembly and delivery are outsourced to third-party organizations.	VCR 3 $\rightarrow$ VCR 4: Change in key activities where assembly and delivery are outsourced.	-	Credibility
Internal	I.O.	Customer segment expansion.	Supersola decided to expand their customer segment via retailers with the new acquired product from the R&D phase.	VP 2 $\rightarrow$ VP 3: The R&D phase lead to a new improved product.	VCR 4 $\rightarrow$ VCR 5: BCC was made as a new partner to supply the product via their network as well. VD 3 $\rightarrow$ VD 4: A new channel was created, the supply of product via retailers like BCC.	Sustainability

Table A.3 continued from previous page

Legal / Political	E.T. / E.O.	Legislation / subsidy.	Legislation in the Netherlands was not in line with the product of Supersola, forcing them to expand to foreign countries. On the other hand was France political climate advantageous.	VD 4 → VD 5: Start of selling on the France market.	-	Sustainability

Table A.4: The drivers, changes, and follow-up changes to the sustainable business model of Solho with the corresponding critical junctures they faced.

Origin			Cause	Primary effect	Secondary effects	Critical juncture
Internal	I.O.	Knowledge availability.	Development of renewable-based energy concepts to decarbonize the industry in general.	VP 1 → VP 2: Different renewable-based energy concepts.	-	Opportunity recognition
Technological	E.O.	Resource efficiency.	Solho found a new partner in YesDelft! In order to find a good product-market-fit for their technology.	VCR 1 → VCR 2: Partnership with YesDelft!	VD 1 → VD 2: Target customers are identified with the help of YesDelft!	Entrepreneurial commitment
Political	E.O.	Subsidy.	EU subsidies and start-up prizes funded Solho to develop a proof of concept.	VCA 1 → VCA 2: Subsidies and prize money funds Solho its operational activities.	-	Credibility
Political	E.O.	Subsidy.	Subsidy of the province of Zuid-Holland supports the test factory in France.	VCA 2 → VCA 3: The subsidy funds the built of the test plant in France.	-	Credibility
Internal	I.O.	Resource availability.	Partnership with Van der Hoeven to support the development of their technology.	VCR 2 → VCR 3: Partnership of Van der Hoeven helps Solho to develop their technology and helps to set up their test plant in France.	-	Credibility

Table A.4 continued from previous page

Political	E.O.	Subsidy.	An EU subsidy funds Solho in developing their technology during COVID-19	VCA 3 → VCA 4: EU subsidy funds the development costs of Solho.	VP 2 → VP 3: Better control systems are added to the SPHROUT.	Credibility
Internal	I.O.	Technological development.	Feasibility studies are started and generate the first revenue.	VCR 3 → VCR 4: Feasibility studies are executed.	VCA 4 → VCA 5: First revenues from Solho its own product are generated.	Credibility
Economic	E.O.	Supportive financial resource availability.	A loan of the Rabobank finances the development of Solho to target new markets.	VCA 5 → VCA 6: A loan of Rabobank supports Solho in its new course.	VD 2 → VD 3: Industry that needs heating/cooling systems as a whole is targeted.	Sustainability
Economic / Political	E.O.	Market competition / subsidy.	The market of Italy is also targeted as there is no market competition and political stimuli such as subsidies.	VD 3 → VD 4: The customer segment is expended to the Italian market.	-	Sustainability
Economic	E.O.	Supportive financial resource availability.	An investment round lead to new investments and a new partner in ”SHIFT invest”.	VCA 6 → VCA 7: New investments cover the operational costs of Solho.	VCR 4 → VCR 5: SHIFT invest became a new partner.	Sustainability

Table A.5: The drivers, changes, and follow-up changes to the sustainable business model of a PV company with the corresponding critical junctures they faced.

Origin			Cause	Primary effect	Secondary effects	Critical juncture
Internal	I.O.	Technological development.	An idea to develop an aesthetic-looking solar panel.	VP 1 → VP 2: The idea of a coloured solar panel was developed.	-	Opportunity recognition
Internal	I.O.	Knowledge availability.	Partnership with Energieonderzoeks Centrum Nederland to research the idea of a coloured solar panel.	VCR 1 → VCR 2: A partnership with Energieonderzoeks Centrum Nederland.	-	Entrepreneurial commitment

Table A.5 continued from previous page

Political	E.O.	Subsidy.	The PV company applied and was granted a TKI subsidy to develop the technology of their solar panels.	VCA 1 → VCA 2: A TKI subsidy was granted to cover the costs of development.	VCR 2 → VCR 3: The research and development of colored solar panels. Including more parties to help the research and development phase.	
Legal	E.O.	Patent law.	The patent of the coloured solar panel technique led to the establishment of the PV company.	VP 2 → VP 3: With the technology of the PV company aims to create custom solutions for their clients.	VD 1 → VD 2: The customer segment was decided upon, which are the final customers (consumers). VCR 3 → VCR 4: Providing projects that create, deliver, and install the solar panels. VCA 2 → VCA 3: An (in-kind) investment of the shareholders cover operational costs during the first period.	Entrepreneurial commitment
Political	E.O.	Subsidy.	Subsidies cover the operational costs of technology development.	VCA 3 → VCA 4: Subsidies cover the operational costs of technology development.	-	Sustainability

Table A.5 continued from previous page

Internal	I.O.	Customer segment expansion.	Partnership with AGC Glass Europe opens a new market, leads to new activities, and generates new types of income.	VCR 4 → VCR 5: Partnership with AGC Glass Europe.	VD 2 → VD 3: Europe could be targeted as customers. VCR 5 → VCR 6: AGC is supplied with the color technique of the PV company and the PV company helps to develop custom solutions. The PV company also became AGC-agent; promoting, selling, and advertising AGC products. VP 3 → VP 4: AGC Active Glass solutions are also offered and promoted. VCA 4 → VCA 5: Margins and royalty income from the technology supply to AGC is received. Commission is received for selling AGC Active Glass solutions.	Sustainability
Internal	I.T.	Risk analysis.	The margins of selling projects were not worth the risks.	VP 4 → VP 5: Only products are sold instead of projects.	VD 3 → VD 4: The 'middleman' is targeted instead of the final customer / consumer.	Sustainability

Table A.6: The drivers, changes, and follow-up changes to the sustainable business model of Wattlab with the corresponding critical junctures they faced.

Origin			Cause	Primary effect	Secondary effects	Critical juncture
Technological	E.O.	Technological development.	The development of an ultra thin and lightweight solar panel for Nuon Solar Team.	VP 1 → VP 2: A new ultra thin, lightweight solar panel was developed.	-	Opportunity recognition

Table A.6 continued from previous page

Internal	I.O.	Knowledge availability.	Multiple applications for the ultra thin solar panel are explored.	VP 2 → VP 3: Different applications are being explored, such as solar panels for cooling of transportational vehicles and the use of solar panels on yachts.	VCR 1 → VCR 2: Wattlab started doing design and research projects for multiple clients. VCA 1 → VCA 2: Wattlab got paid by clients for their design and research projects.	Entrepreneurial commitment
Economic	E.T.	Market competition.	The opportunity to partner with Blommaert arises from the decision to let earlier activities and idea fall and focus on container surfaces.	VP 3 → VP 4: Solar panels that can be used on container surfaces.	VCR 2 → VCR 3: A new stakeholder and partner is found in Blommaert.	Credibility
Internal	I.O.	Resource availability.	A new design for the solar panels was created in cooperation with Blommaert.	VP 4 → VP 5: The integration of the solar panel into hatches of inland vessels is proposed as idea.	VD 1 → VD 2: With the new idea inland vessels are the targeted customers.	Credibility
Political	E.O.	Subsidy.	DKTI subsidy finances the development and operation costs of the proof of concept test.	VCA 2 → VCA 3: Subsidy finances the development and operational costs.	VCR 3 → VCR 4: With the financial resources the development results into a feasibility study.	Credibility
Political	E.O.	Subsidy.	Subsidy of CityLab Rotterdam finances development and operational costs of Wattlab.	VCA 3 → VCA 4: Subsidy finances the development and operational costs of Wattlab.	VCR 4 → VCR 5: With the financial resources a proof-of-concept study is conducted.	Credibility
Technological	E.O.	Resource efficiency.	A new reliable supplier is found that Wattlab want to work with.	VCR 5 → VCR 6: A new supplier results in a new working process of Wattlab.	-	Sustainability

Table A.6 continued from previous page

Internal	I.O.	Technological development.	A test was conducted to see if the solar panels of Wattlab are market ready. This test was successful, thus the sale of solar panels started commercially.	VCR 6 $\rightarrow$ VCR 7: A new test was conducted to check if the solar panels are market ready.	VCA 4 $\rightarrow$ VCA 5: Commercial sales can be received as Wattlab entered the commercial market.	Sustainability
Environmental	E.O.	(Social and) environmental awareness.	South America is included in the customer segment as social developments force the maritime industry to be more sustainable, creating the opportunity for Wattlab to do business there.	VD 2 $\rightarrow$ VD 3: The customer segment of inland vessels in South-America (Amazone) is included.	-	Sustainability

B

Content analysis

This appendix includes the quotes from the content analysis starting in the table on the next page.

Table B.1: The content analysis coding and quotes.

Family code	Primary code	Secondary code	Quotation	Company	Function
Economic	COVID-19 impact	COVID-19	We started with BCC just before Covid, so that has put a big brake on their ambition and their sales capacity.	Supersola	Managing director
		Disruption of logistic chain	5 years ago we could not have imagined that the logistics chain from China would come to a complete standstill due to corona	SoLarge	Chief executive officer
	Currency devaluation		In Malawi, from one day, on the other the currency was worth 25% less compared to the dollar. [...] These are factors that we cannot do anything about, but that makes you very vulnerable because you sell everything on pay-as-you-go.	SolarWorks!	Chief operations officer
			That devaluation of the currency, for example, is one that again confirms that only doing pay-as-you-go is really very risky.	SolarWorks!	Chief operations officer
	Economic trends		Consumer perception and consumer purchasing behaviour are 2 things that are very relevant to us.	Supersola	Managing director
			But you also need to have those parties that will install it. You now see, because of the current chaos in the energy market, that the large parties are busy and therefore have no time for us at all.	SoLarge	Chief executive officer
			The panels were almost 1.5 times more expensive for us to purchase six months ago.	Wattlab	Chief operations officer
			When we started, the payback time of a solar panel was about 7 years in the Netherlands and perhaps 8. With current energy prices and raw material costs, it is rather 2 or 3 years.	Supersola	Managing director
			If that (fossil fuels) becomes more expensive, that is also good for our product. We also noticed that people were more willing to buy our product once the fuel bills suddenly rose.	Wattlab	Chief operations officer
			The economic trends and the tax world are all elements that play a role, but there are many more operational influencers of a decision such as where you are going to produce or where you are going to do something.	SoLarge	Chief executive officer
	Economic value		The challenge of this is that having a low CO2 footprint and recycling and not using PFAS, have no (economic) value at all.	SoLarge	Chief executive officer
			Nobody pays us extra because we don't use PFAS. Nobody pays us extra because we are circular. You need legislation for that to create value for that.	SoLarge	Chief executive officer
	Economic viability		In the end this is a game that is about volume.	SoLarge	Chief executive officer

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		The same applies to those small systems that we now only sell where there is subsidy. There is the realization that you can sell a lot of it, but in the end, we make a loss, so we don't do it to ensure that we keep the business that we have commercially viable.	SolarWorks!	Chief operations officer
		Our solution in order to scale has to be economically viable.	Solho	Chief executive officer
		The conclusion was that the product is too expensive for the market to be interesting. Because it is super expensive to make everything on a small scale here.	Wattlab	Chief operations officer
		This is something that of course industries look at when they have to make investments.	Solho	Chief executive officer
Economy of scale		The Chinese have completely removed that from us very strategically and very well, purely through volume production.	SoLarge	Chief executive officer
		That is mainly about price and volumes and we thought: "If we would like to fight that fight, we will never win."	SolarWorks!	Chief operations officer
Market competition	High market competition	In 2015 /2016 there were actually more and more products on the market that came from China. It was cheap copies, but always getting a little better and better	SolarWorks!	Chief operations officer
		We have also done different things for a while, so another product for e-transport, so, for example, AH or Picnic with solar panels on the roof for the cooling. But that just didn't go any further. There were around 6 other parties doing the same too. Then we thought we should let that go.	Wattlab	Chief operations officer
	Low market competition	In Italy, there are not many greenhouse farms that are as high-tech as the ones in the Netherlands.	Solho	Chief executive officer
		In Italy, except for us, nobody is proposing this type of solution and they have very good incentives and a lot of sun.	Solho	Chief executive officer
		One of the reasons that we really wanted to do business in solar hatches is that there was actually no competition.	Wattlab	Chief operations officer
		We always thought "We can do it, but a different supplier will get up anyway who will do the same." When we recently went to look, hardly anyone really started doing it yet, so we are still reconsidering whether we should not do that.	Wattlab	Chief operations officer
	Market forces	From selling to retailers to selling to consumers. That is purely market driven. Because for those smaller products, it was only competing on price.	SolarWorks!	Chief operations officer

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	PV-market		You have to imagine that the world market of solar panels is a very uniform market. You just have glass panels of 2.30 by 1 meter, two economical cells, it's all the same. You still have a black one and a non-black one and you have a glass-glass and a glass-plastic. But that's it. With this panel, we can apply a lot of variation in it.	SoLarge	Chief executive officer
			In addition, we have the model in which we wanted to sell ourselves. Then you know what the market looks like and then you can get more margins or committees out. We started with the Dutch market for that.	PV-company	Director
			The ordinary market for solar panels can also make panels in colour, but most people do not choose that because it is also less efficient.	PV-company	Director
	Supportive financial resource availability	Investment	Now we have a VC involved.	Solho	Chief executive officer
			Then you know that you have a product that is correct and commercially selling. And then you have to focus very much on investors. Then you have to raise money.	SoLarge	Chief executive officer
			And the investors, that is interesting, those are all informal investors.	SoLarge	Chief executive officer
			Our most important shareholders are still the founders and then a Venture Capital Firm (Persistent Energy Capital) that specifically focuses on our sector. So they have investments in companies like us and in all of Africa. Then we have an Angel Investor from Delft. And EDP is the Portuguese energy company, that is the fourth large shareholder.	SolarWorks!	Chief operations officer
			We just closed the investment round at the beginning of this year and the money we raised is all meant to be spent on covering the operational cost to close as many projects as possible this year.	Solho	Chief executive officer
			At the end of 2022, we started the investment round. We got SHIFT Invest involved, which is one of the largest Dutch VCs.	Solho	Chief executive officer
			We hope to close a round that is a million plus, because we really have to scale.	Supersola	Managing director

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		Importance of investors	Such a partner helps enormously because, in addition to investing, they also have a network of lawyers etc. So they can help you enormously. Certainly, in the early stages, they pay for things for you that you would never want or could pay for yourself.	Supersola	Managing director
		Loan	We have a bank, the ASN Bank, a nice sustainable bank.	SoLarge	Chief executive officer
			And so the ASN Bank and RVO	SoLarge	Chief executive officer
			There was (two) NWO loan(s).	PV-company	Director
			We also just have innovation loans.	PV-company	Director
			Now we also have the Rabobank involved.	Solho	Chief executive officer
			We got a loan from Rabobank.	Solho	Chief executive officer
			And also with an innovation loan from Rabobank	Supersola	Managing director
		Other	This is paid by USAID, among other comparable organizations	SolarWorks!	Chief operations officer
			Then he first found a few angels who invested money with which they made the first prototypes.	Supersola	Managing director
			We won grants that allowed us to develop the technology and build the first proof of concept.	Solho	Chief executive officer
			2018 we got money from Europe and start-up prizes. This allowed us to fund the development of the technology.	Solho	Chief executive officer
			We had money through grants, startup prizes, European grants, and regional grants.	Solho	Chief executive officer
			It has given us many new leads. That has yielded a lot of financing.	Supersola	Managing director
			In the Netherlands this is a lot less (subsidy) and you get it back through taxes afterwards	Wattlab	Chief operations officer
		Importance of supportive financial systems	There is a lot changing. Getting that cash flow is very difficult for a start-up. Everything changes to get that to the point that you would move to another place so that an investor gives you money. That is how far it can go.	Supersola	Managing director
	Circularity		We are introducing circular plastics in the energy transition in a very nice way.	SoLarge	Chief executive officer

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	If you use a solar panel, you have carbon-free energy. Only at the front, making it, and at the back, breaking it down again, we do still have a huge challenge.	SoLarge	Chief executive officer
	At the same time, we do not use PFAS. […] But PFAS is notoriously very difficult to break down, so that's a big advantage (as we don't use it).	SoLarge	Chief executive officer
	The challenge of this is that, both that low CO2 footprint and recycling and the PFAS, have no (economic) value at all.	SoLarge	Chief executive officer
Environmental awareness	The consumer will realize that he has to do something with that.	SoLarge	Chief executive officer
	That people themselves need to say: "Hey, we want a solar panel on our roof that can be recycled at the end."	SoLarge	Chief executive officer
	We identified the need to shift from fossil fuel-based solutions to renewable-based solutions to power greenhouse farms.	Solho	Chief executive officer
	There is a lot of interest in technologies like ours or solutions like ours that can decarbonize the industrial sector, and the residential sector in Europe. This is linked to environmental and political reasons.	Solho	Chief executive officer
	The customer himself has also changed in behavior. The most visible is related to the urgency of saving energy or generating energy yourself.	Supersola	Managing director
	For example, we see in France that we have an energy customer that traditionally has business in oil and gas. He has gas stations himself and comes to fill your tanks at home. But they also started supplying electricity; only green	Supersola	Managing director
	You see that living sustainably is more important than 5 years ago.	Supersola	Managing director
	If you operate in the Amazon you have to pay attention to the environment.	Wattlab	Chief operations officer
Environmental disaster	Then in 2019 a cyclone in Mozambique just landed in the part where we had expanded a lot. In that piece, half of our portfolio literally blew away. Then Covid came. Those two things together, made us realize [...] that the business model on pay-as-you-go is very nice to make it affordable for customers at all. But it also makes you very vulnerable, because the moment something like that happens, people stop paying and we just don't get our money.	SolarWorks!	Chief operations officer

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	Environment		The climate is much milder so you don't need a lot of heating or cooling while in the Netherlands.	Solho	Chief executive officer
			If there is a large hailstorm, then glass solar panels can break. That has happened sometimes.You can imagine that if that happens on the IJsselmeer and glass falls down in the IJsselmeer that we don't want that.	SoLarge	Chief executive officer
			But I think it is a very interesting argument why our panel functions very well there again. In addition to the fact that we can stand salt better than traditional panels. And our panel already floats by itself.	SoLarge	Chief executive officer
			In Italy, except for us, nobody is proposing this type of solution and they have very good incentives and a lot of sun.	Solho	Chief executive officer
	Environmental impact		If you use a solar panel, you have carbon-free energy. Only at the front, making it, and at the back, breaking it down again, we do still have a huge challenge.	SoLarge	Chief executive officer
			At the same time, we do not use PFAS. […] But PFAS is notoriously very difficult to break down, so that's a big advantage (as we don't use it).	SoLarge	Chief executive officer
			The challenge of this is that, both that low CO2 footprint and recycling and the PFAS, have no (economic) value at all.	SoLarge	Chief executive officer
	Scarcity of materials		What also matters a lot […] are the costs of gas oil and diesel.	Wattlab	Chief operations officer
			But you also need to have those parties that will install it. You now see, because of the current chaos in the energy market, that the large parties are busy and therefore have no time for us at all.	SoLarge	Chief executive officer
			Anyway; now an energy crisis caused by Russia	SoLarge	Chief executive officer
			If we now have a chip shortage or silicon shortage, there is a problem.	Wattlab	Chief operations officer
	Certification		We closed that phase about 1.5 years ago because we officially certified our product.	SoLarge	Chief executive officer
			This world of energy is a very regulated world.	SoLarge	Chief executive officer
			Nobody pays us extra because we don't use PFAS. Nobody pays us extra because we are circular. You need legislation for that to create value for that.	SoLarge	Chief executive officer

		Legislations
Legal	Legislation	

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Typically, a flat roof is made on the regulations that are about the water that it must be able to carry.	SoLarge	Chief executive officer
There are all kinds of legislation for new construction, that is called MPG standard. Our panel has the lowest MPG standard by far.	SoLarge	Chief executive officer
To promote sustainability: on the one hand we have almost energy-neutral buildings with the BENG standard so you have to generate energy, and on the other side have an environmental passport, the environmental performance buildings, MPG.	SoLarge	Chief executive officer
The solar panels, which score very poorly, typically, that is why you see a lot of new-build houses with only 6 solar panels. Why 6? Because of the MPG, you can actually have no more than 6.	SoLarge	Chief executive officer
But because of the BENG you must have a few, so that's why people are still 6 while you would lay our panels, you could lay a lot more.	SoLarge	Chief executive officer
It is the case that there are certain regulations in the Netherlands and also in the EU that buildings must have a certain energy generation.	PV-company	Director
The solar facades are still relatively expensive, but legislation demands that you meet the requirements.	PV-company	Director
And it is also legislation that differs per country.	Supersola	Managing director
When we were in the Netherlands, BCC received a letter from the director of the Uneto VNI after a month that our product does not meet the NEN standards	Supersola	Managing director
At the same time, the Commodities Act says that our product is an inverted refrigerator that meets the CE quality mark.	Supersola	Managing director
In France they find it fantastic what we do; In terms of regulations and in terms of policies, they are very positive.	Supersola	Managing director
So it is quite complicated to get solar panels and to get a permit for solar panels that you often also have to get from the mayor/-municipality.	Supersola	Managing director
But what also happens, is that they must use on-shore current points, but many skippers don't like that.	Wattlab	Chief operations officer
That is why we also look at those things and we hope that they make those rules stricter.	Wattlab	Chief operations officer

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			CO2 goals only work for us if that is concretely translated into subsidies or paying for emissions or that a ship may only have X emissions etc.	Wattlab	Chief operations officer
			You have class bureaus that inspect all ships. All the electricity must be approved and according to certain rules and we were helped there because they thought it was nice to help a start-up.	Wattlab	Chief operations officer
		Importance of legislation	But you can say that we went to France because we got the whining from the installation sector in the Netherlands.	Supersola	Managing director
			I think that a mix of legal and political factors are for us at number 1 and 2 by far because what we make, a Plug & Play solar panel, does not fit the legislation in most European countries.	Supersola	Managing director
	Patents	Disrespecting patent law	They (China) don't respect patents that are there and try to copy things.	SoLarge	Chief executive officer
		Patent law of product	At that time, a number of the parties involved, who were also co-owner of a patent that appeared (from the project), decided to set up a company together to bring that technology to the market.	PV-company	Director
			Now it is also patented.	Wattlab	Chief operations officer
	Governmental activities	Activities to influence political factors	We invited MPs 3 years ago to show what we are doing.	SoLarge	Chief executive officer
		Importance of political factors	In the industry where we are, solar panels and energy, the political factors are very important.	SoLarge	Chief executive officer
			And then more on the political side, which is now most important to us.	PV-company	Director
			Politics is starting to become important when the technology is sound.	SoLarge	Chief executive officer
		Political awareness	The shipping companies […] look more at developments and trends and where they should be in the future. New regulations, less CO2 emissions, carbon credits that you have, etc. ...	Wattlab	Chief operations officer
		Policies	Then a geopolitical movement in which we all try to sideline China	Solarge	Chief executive officer
			There are all kinds of initiatives in Europe to set up more solar industry.	Solarge	Chief executive officer
Political	Policy				

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			Nobody pays us extra because we don't use PFAS. Nobody pays us extra because we are circular. You need legislation for that to create value for that.	Solarge	Chief executive officer
			In Mozambique, there is now a subsidy program specifically for those smaller systems.	SolarWorks!	Chief operations officer
			There is a lot of interest in technologies like ours or solutions like ours that can decarbonize the industrial sector, and the residential sector in Europe. This is both linked to environmental and political reasons.	Solho	Chief executive officer
			Europe has set out a bunch of directives to push companies to decarbonize their energy generation.	Solho	Chief executive officer
			In France they find it fantastic what we do; In terms of regulations and in terms of policies, they are very positive	Supersola	Managing director
			That is why we also look at those things and we hope that they make those rules stricter.	Wattlab	Chief operations officer
		Policy change	Europe has to respond to that and that is very interesting for us because that means that there will soon be completely different rules for state aid.	SoLarge	Chief executive officer
			The same applies that somewhere at the beginning of this year we suddenly had to pay much more import duties in Mozambique than we did before. That has a direct impact on your margin of course.	SolarWorks!	Chief operations officer
		Policymakers	We are introducing circular plastics in the energy transition in a very nice way. That is if you talk about that with the number of policymakers, then everyone will become wildly enthusiastic about it.	SoLarge	Chief executive officer
		Importance of subsidies	Subsidies, not only for us but also for customers. Because it is a financial incentive whether they want it or not.	Wattlab	Chief operations officer
			In Malawi, we only sell larger systems with a TV, because that can be made profitable in itself without a subsidy.	SolarWorks!	Chief operations officer
	Subsidy				

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	In general, this applies to all the new things we try. So those larger systems, water pumps that we are now watching, those are all new customer groups and new markets for us. The way we usually do that is that we first make a subsidy request to try it. And then with that subsidy, we do a pilot and we look at which product we can sell for which prices. And if that is successful, then we will actually put money into it ourselves.	SolarWorks!	Chief operations officer
International subsidies	2018 we got money from Europe and start-up prizes. This allowed us to fund the development of the technology.	Solho	Chief executive officer
	2020-2021 was the period of COVID. We got some money from the European Union to further develop the technology and we got this SPRHOUT ready for commercialization.	Solho	Chief executive officer
	There are a few in Mozambique, and that is also one in Malawi, but there are 2 large subsidy programs in Mozambique and they are generally funded by parties such as the German development organization and the Swedish development organization	SolarWorks!	Chief operations officer
Local subsidies	2019 we got funded by the province of Zuid-Holland to build the first system in France.	Solho	Chief executive officer
National subsidies	A project was set up and a subsidy was brought in with all those parties.	PV-company	Director
	And so the ASN Bank and RVO	SoLarge	Chief executive officer
	For example, in Germany you can get a 60% subsidy on our products.	Wattlab	Chief operations officer
	At the same time, RVO and the government are very important because a very nice form of financing is subsidies. And they are desperately needed. You can't do anything like this without subsidies.	SoLarge	Chief executive officer
	Germany is a priority because the subsidies are so good there.	Wattlab	Chief operations officer
	In Mozambique we receive a subsidy for every small product that we sell and we now sell them again.	SolarWorks!	Chief operations officer
	Then the idea was conceived to submit a TKI RVO subsidy proposal and a lot of other parties were added.	PV-company	Director
	We are working on a very large subsidy project where you receive a subsidy for two or 3 factories instead of a little one.	SoLarge	Chief executive officer

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		Undefined subsidies	CO2 goals only work for us if that is concretely translated into subsidies or paying for emissions or that a ship may only have X emissions etc.	Wattlab	Chief operations officer
			From the start we have been continuously involved in 1 or 2 subsidized projects.	PV-company	Director
			In the beginning we applied for many subsidies and paid little to ourselves. With many subsidies, you can ask for € 60 per hour regardless of the costs. So if you only cost € 30 and apply for € 60,- you can finance the entire project with that subsidy.	Wattlab	Chief operations officer
			The same applies to those small systems that we now only sell where there is a subsidy. There is the realization that you can sell a lot of it, but in the end, we make a loss, so we don't do it to ensure that we keep the business that we have commercially viable.	SolarWorks!	Chief operations officer
			Then we worked out a concept and business case with them, and applied for a subsidy for that project.	Wattlab	Chief operations officer
			We had money through grants, startup prizes, European grants, and regional grants.	Solho	Chief executive officer
			We only spend those development costs if a subsidy has been brought in.	PV-company	Director
Social	Customer profile		And our first idea was perhaps that we could collaborate with a retailer or with a bank or whatever that could then do the entire payment side and then we would deliver the product. But in reality, retailers and banks were not looking forward to it. [...]. They are all customers without a bank account, without financial history anything. In the end, we just started doing it ourselves. The only way to do that is to deliver directly to the customer.	SolarWorks!	Chief operations officer
			It is also a target group that has quite a lot of time to call. They are busy but respond positively to that. And otherwise a lot of mouth-to-mouth, acquaintances, family and a lot of talking to each other.	Wattlab	Chief operations officer
			It is important that they talk to each other. A happy customer is very important to us because, whether he is right or not, they talk to each other.	Wattlab	Chief operations officer
	Influencers	Channels	Exchange is one (channel), Instagram, and Cold-Calling are other channels.	Wattlab	Chief operations officer

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	Influencers	Skippers who talk a lot with each other. Just some are really promoters actually and actively advertise to friends. That does a lot.	Wattlab	Chief operations officer
Social awareness	Increased social awareness	We also won an innovation prize in the Home Appliances category.	Supersola	Managing director
		The first threshold is whether people know it exists and whether they can value it. In the beginning, we started to train our customers.	Supersola	Managing director
		The main goal is to expand our network of clients so that people start to know us.	Solho	Chief executive officer
		As a result, they want to show the world that they are sustainable and are therefore interested in things like this.	Wattlab	Chief operations officer
		The company decided to move from only greenhouses to an industrial sector because we saw an interest in the industries in general into this type of solutions.	Solho	Chief executive officer
		It helps enormously for your awareness and for trust from consumers	Supersola	Managing director
		That social trend also helps us because our product just gets more relevant.	Supersola	Managing director
	Influence of social awareness	If you know that the average item of clothing is worn 7 times, it is shocking. And we may all know it, but we don't behave differently. And influencing that behaviour is of course very complicated.	SoLarge	Chief executive officer
		Retailers see that and look for solutions that can mean something to them. Milieu Centraal sees it, governments see it, and with that, a lot has changed around the market or in the market.	PV-company	Director
		With the Supersola they want to give extra charge to the fact that they are taking a different approach. That is more visible than an energy contract.	Supersola	Managing director
	Lack of social awareness	The idea was always that with the print we can make, you are completely free. […] The question then is how you will explain that to the market.	PV-company	Director
		But online it is difficult to come to scale, especially if there is no awareness for your product. So we sat down relatively early with large retailers.	Supersola	Managing director
Social need of (local) community		He (CEO) has been in Madagascar for six months who asked people from: "If you had a light running on solar energy, would that help?"	SolarWorks!	Chief operations officer

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			SuperSola was founded by Julius in 2017 because he saw that the market for solar panels, so the way it is sold and such, is very moderately in line with customers their needs.	Supersola	Managing director
	Social reputation	Social perception	Consumer perception and consumer purchasing behaviour are 2 things that are very relevant to us.	Supersola	Managing director
			Some people also like that they are not seen as a polluting ship.	Wattlab	Chief operations officer
			You see this social aspect when talking with large industrial groups. They need to be perceived in a certain way by their customers.	Solho	Chief executive officer
		Social awareness	We came up with South America because Blommaert is already supplying there and they have a lot of inland shipping on the Amazon and Parana River […] which are closely watched.	Wattlab	Chief operations officer
			In the beginning it was all about the environmental and social aspects because the first projects are a kind of greenwashing.	PV-company	Director
	Social factors are more important than economic factors		Social factors, for example, would be more important than economic factors.	SoLarge	Chief executive officer
Technical	Resource efficiency	Operational	Then a partnership was set up in which the PV company supplies the technology to AGC and AGC sells the panels.	PV-company	Director
			At that time we found one supplier that we had faith in the quality.	Wattlab	Chief operations officer
			Yes, what was important to us was the fact that suppliers could supply the type of panel on which our company is based. That was also very nice in terms of timing.	Wattlab	Chief operations officer
			Our purchasing is incredibly dependent on our suppliers and technology.	Wattlab	Chief operations officer
			The most important partners in the first instance were the shareholders and AGC for production.	PV-company	Director
		Research	During that R&D phase, these technology institutions and companies that help make something possible like that are important.	SoLarge	Chief executive officer
			We did some research into this with the TU student	SolarWorks!	Chief operations officer
			We started with the YesDelft!-incubator finding a product-market fit and we ended up working with the greenhouse industry in the Netherlands.	Solho	Chief executive officer

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			Yes, and with Yesdelft! we have done a validation-lab.	Supersola	Managing director
		Importance of resource efficiency	That also means that we are vulnerable, because if such a supplier, where there are actually 1 good and a few other options, says we are too small, then we already have a problem.	Wattlab	Chief operations officer
	Technology development	New technology	My two colleagues both found themselves in a corner where they had met each other, sharing the idea of creating integrated solar roofs, particularly for residential houses.	SoLarge	Chief executive officer
			There have been improvements in these past five years that allowed our solution to existing.	Solho	Chief executive officer
			In Italy, there are not many greenhouse farms that are as high-tech as the ones in the Netherlands.	Solho	Chief executive officer
			All solar panels that we see on the market are actually heavy and standard and made of glass and it is not possible with solar energy if you have customized lightweight thin panels.	Wattlab	Chief operations officer
		Technical difficulties	In France they have the problem that they suffer from network issues when everyone uses solar panels.	Supersola	Managing director
		Importance of technological factors	It always starts with technological; you must be able to make it first. So that's 1.	PV-company	Director