THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

# Exploring the Role of Business Models in Large-Scale Diffusion of Solar Photovoltaics

## A study of demand-side solar firms in Sweden

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CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2022

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## ABSTRACT

A rapid and large-scale diffusion of renewable energy technologies, like solar photovoltaics (PV), is crucial to slow down climate change. Research on technology diffusion explains that the rate and scale at which a new technology diffuses in society is influenced by the actors, networks, and institutions that make up its innovation system. Yet, little is known about firms participating in the deployment of solar PV, such as the firms that sell, install, or lease the technology. Particularly, there is a lack of knowledge on what business models firms use to commercialize solar PV, how these business models can be differentiated, and what influences the prevalence of different business models on a market. Such knowledge is essential for understanding under what conditions different business models emerge which, in turn, can lead to improved policy design targeted at facilitating large-scale diffusion of solar PV.

This licentiate thesis takes a qualitative approach to explore business models' role in large-scale diffusion of solar PV. Based on a literature review and a case study of firms involved with solar PV deployment in Sweden, the thesis identifies six types of solar business models that are differentiated based on value proposition, value creation and delivery system, and value capture. The results also show that the prevalence of business models is influenced by firm-internal factors (e.g., resources, partnerships, and strategies) and contextual factors (e.g., technology and institutions). These findings stress the importance of considering both an actor- and system perspective on business models in policy design.

Keywords: business model, diffusion, innovation, system, solar, photovoltaic, policy, firm, Sweden, sustainability.

# LIST OF APPENDED PAPERS

**Paper I**
Bankel, A. and Mignon, I. (2022). Solar business models from a firm perspective – an empirical study of the Swedish market. *Energy Policy, 166,* 113013.

An earlier version of the paper was presented at the 12th International Sustainability Transition conference, 5-8 October 2021, Karlsruhe, Germany.

**Paper II**
Mignon, I., and Bankel, A. (2022). Sustainable business models and innovation strategies to realize them: A review of 87 empirical cases. *Business Strategy and the Environment,* 1–16.

An earlier version of the paper was presented at the 11th International Sustainability Transition conference, 18-21 August 2020, Vienna, Austria.

**Paper III**
Bankel, A. and Mignon, I. (2022). *What explains business model innovation or status quo? Exploring firms' perceptions and reactions in the Swedish solar photovoltaic industry.* Presented at the Druid conference, 13-15 June 2022, Copenhagen, Denmark, and at the Business Model conference 22-23 June 2022, Lille, France.

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# 1. INTRODUCTION

Many of the historical advancements of humankind can be attributed to the development of new technologies. Yet, the value of new technologies are only realized once people start using them and this does not necessarily happen on its own. Even technologies that clearly bring about great benefits can struggle to diffuse in society (Rogers 1962). It can take several years between a new technology is available on the market until it is widely adopted. In fact, some technologies never reach a large-scale diffusion but remain limited to a market niche or fail to attract adopters altogether.

The struggle to realize the potential of new technologies might explain why much research has been devoted to explaining why some technologies diffuse faster and at a larger scale than others. According to diffusion of innovation theory (Rogers 1962, Bass 1969), the diffusion patterns of different technologies depend, not only on the features of the technology, but also on adopters distinctive characteristics, social networks, and decision-making processes, where some individuals in society are more prone to adopt a new technology than others. It has, however, been argued that contextual factors (e.g., social, political, cultural, and geographical) also influence technology diffusion (Grübler 1991, Wejnert 2002). In line with this argument, innovation systems theory emphasizes that the diffusion patterns of new technologies are influenced by an intricate set of actors, networks and institutions, as well as the dynamics between these system components (Carlsson and Stankiewicz 1991, Jacobsson and Johnson 2000). While this theory is widely used for explaining early phases of diffusion, it has been argued that it is underdeveloped when it comes to explaining large-scale diffusion of new technologies once they have matured and become available "off the shelf" (Mignon and Bergek 2016).

Ultimately, for technology diffusion to take place someone needs to adopt the technology. Previous studies have shown that adopters differs in terms of their needs and motives for investing in a new technology (e.g., Rogers 1962, Bergek and Mignon 2017). This signifies that a technology provides adopters with different values. For instance, for one adopter the value of a motorcycle might be that they can quickly transport themselves from one point to another. Another adopter might instead value the social status or image that a motorcycle provides. To exploit the values of a technology, firms can use different business models (BMs) to commercialize it (Chesbrough and Rosenbloom 2002, Chesbrough 2010). A BM describes how a firm creates and delivers value to its customers, as well as how it captures a share of that value in return (Teece 2010).

While the BM literature primarily focuses on how firms can use BMs to achieve and sustain competitive advantage (e.g., Johnson, Christensen et al. 2008, Casadesus-Masanell and Ricart 2010), firms have also been found to enable technology diffusion by using different BMs to make a technology appealing to a variety of adopters (e.g., Drury, Miller et al. 2012, Boons and Lüdeke-Freund 2013). The role of BMs in technology diffusion has recently received particular interest in the energy policy literature, specifically in relation to renewable energy technologies (RETs) like wind and solar photovoltaics (PV) (e.g., Richter 2013, Strupeit and Palm 2016, Aspeteg and Bergek 2020). Due to the urgent need to slow down climate change, a rapid and large-scale diffusion of RETs is needed in society to replace fossil fuel-based alternatives

(Jacobsson and Bergek 2011, IEA 2021). Policymakers and business leaders are thus in need of a better understanding how they can facilitate such diffusion.

Although government funding has played an important part in stimulating early diffusion of RETs, such investments are simply not enough to reach a rate of adoption that would limit the irreversible consequences of climate change (e.g., Wüstenhagen and Menichetti 2012). Instead, RET adoption is needed among private investors (Bergek, Mignon et al. 2013). Many RETs have now also reached a stage of maturity in which a dominant design has emerged (Grübler 1991), the price has decreased (IEA 2021) and they are ready to diffuse on a large scale. To stimulate adoption of RETs among private investors, policymakers have implemented a variety of policies to either impose change through regulatory instruments or by incentivizing it through economic support systems, e.g., investment subsidies or feed-in tariffs (Fouquet 2013). However, studies show that RET adopters are heterogenous in their investment motives and that policies influence their decisions differently and to different extents (Palm and Tengvard 2011, Mignon and Bergek 2016, Bergek and Mignon 2017). Hence, there is no one-size-fits-all policy when it comes to stimulating RET adoption. As an alternative, it has been suggested that policymakers should pay greater attention to the BMs that firms use to commercialize RETs (Johnson and Suskewicz 2009, Bidmon and Knab 2018).

Notably, studies show that policies can have a significant impact on the profitability of RET projects and thus greatly influence the financial viability of different BMs (Herbes, Brummer et al. 2017, Karneyeva and Wüstenhagen 2017). Moreover, regulations also influence which BMs firms use to commercialize RETs as they can limit or enable certain aspects of the application or operation of RETs (Burger and Luke 2017). As a consequence, some BMs are favored by certain policies while others are hindered. Policies thus play a big role in how RETs are commercialized and towards which adopters they are being target. Hence, it is crucial that policymakers and scholars gain a better understanding of firms' BMs and how they contribute to large-scale diffusion of RETs (Bidmon and Knab 2018).

An increased understanding of BMs role in large-scale diffusion of RETs is particularly important in the case of solar PV since it is less capital intensive compared to RETs like wind or hydro power. As such, it opens up for adopters with lower disposable income (e.g., households, farmers, and communities) to invest in the technology. In fact, studies have shown that the use of certain BMs has facilitated adoption of solar PV among investors that cannot (or do not wish to) own a solar PV system (Huijben and Verbong 2013). With the potential of solar PV to appeal to a greater range of adopters, it becomes especially interesting to explore the BMs firms use to commercialize the technology and which adopters they target.

While previous studies have identified a variety of solar BMs (e.g., Schoettl and Lehmann-Ortega 2011, Drury, Miller et al. 2012, Huijben, Verbong et al. 2016, Tongsopit, Moungchareon et al. 2016, Horváth and Szabó 2018, Altunay, Bergek et al. 2021) there are overlaps in how these BMs are distinguished and differences in how they are defined. In particular, there appears to be a mismatch in how solar BMs are characterized in literature and how they are described by solar firms on the market. For instance, in energy policy literature, solar BMs are often characterized based on who owns the solar PV system (e.g., host-owned), where it is applied (e.g., residential) and what activities are involved in providing it (e.g., construction and installation). In contrast, solar firms use BMs to describe how they create and deliver value to their customers and how they, in return, create value for themselves. The fact that solar BMs are understood differently in the energy policy literature and on the market is problematic since the literature informs policymakers who, in turn, influence firms and the BMs they use. If policymakers do not understand why solar firms use certain types of BMs and how these differ there is a risk that they develop poorly targeted policy instruments that are suboptimal in stimulating solar PV diffusion. Thus, in order to better understand how firms can contribute to large-scale diffusion of solar PV, scholars must first understand what BMs these firms use to commercialize solar PV and how these BMs can be differentiated.

Moreover, the prevalence of different solar BMs varies greatly between countries, where a BM that is widely used in one national market is hardly used in another. A potential explanation for this divergence is that the diffusion of BMs, just like technologies, is influenced by contextual factors (Grübler 1991, Wejnert 2002, Strupeit and Palm 2016). In fact, previous studies show that BMs need to be translated in order to be successfully applied in new contexts (Ode and Wadin 2019). Recent studies also suggest that contextual factors alone cannot explain the prevalence of solar BMs and that firm-internal factors also need to be considered (e.g., Huijben, Verbong et al. 2016, Altunay, Bergek et al. 2021). A comprehensive understanding of what factors exists and how they influence the prevalence of solar BMs is essential for understanding under what conditions different BMs emerge which, in turn, can guide policymakers in their efforts to facilitate large-scale diffusion of solar PV. Such knowledge can also benefit firms that are involved with solar PV deployment by helping them gain a better understanding of how they influence and are influenced by their context.

## 1.1. AIM AND RESEARCH QUESTIONS

Against this background, this thesis aims to increase the understanding of the role that BMs play in large-scale diffusion of solar PV by answering the following research questions:

RQ1. What business models do firms use to commercialize solar PV and how can these business models be differentiated?

RQ2. What explains the prevalence of different solar business models?

RQ3. How can an increased understanding of business models in the context of solar PV contribute to policy design?

The thesis adopts a qualitative approach to address this aim by exploring the BMs of firms in the Swedish solar PV industry. The Swedish solar PV industry serves as a suitable context since new BMs have emerged in response to many legislative changes and an exponential market growth over the past ten years (Lindahl, Berard et al. 2021). The findings contribute to energy policy literature by showing that firms can facilitate solar PV diffusion through BMs that target different adopters. The prevalence of different BMs is, however, influenced by both contextual and firm-internal factors, which points to the importance of considering both an actor- and system-level perspective for understanding large-scale diffusion of technology.

# 2. THEORETICAL FRAMEWORK

## 2.1. ACTORS IN TECHNOLOGY DIFFUSION

Technology diffusion is often described in the form an S-curve that illustrates the market share of a technology from when it is first introduced on a market until it has reached saturation. Early phases of diffusion are often slow, targeted at a market niche, and driven by performance rather than price since the technology is still being developed (Grübler 1991). At some point, a dominant design of the technology emerges which leads to standardization and a shift from market competition that is primarily based on performance to one that is based on price (Utterback and Abernathy 1975). Once this occurs, the rate of adoption tends to increase significantly and the technology is diffused beyond its initial market niche and enters a phase of large-scale diffusion (Grübler 1991). As the technology matures the market becomes saturated and the rate of adoption decreases. To understand how, why, and at what rate new technologies diffuse in society, innovation scholars have used two main approaches: diffusion of innovation theory (e.g., Rogers 1962) and innovation systems theory (e.g., Carlsson and Stankiewicz 1991, Grübler 1991).

Diffusion of innovation theory explains that this S-curve pattern emerges since the willingness to adopt a new technology differs between adopters (Bass 1969). Based on this, adopters can be categorized into innovators, early adopters, early majority, late majority, and laggards (Rogers 1962). Adopters in each category are claimed to possess specific personality traits and characteristics that makes them more or less likely to adopt a new technology early on (Rogers 1962). Yet, technology diffusion rarely occurs in isolation and the regularity and timing of diffusion patterns varies greatly between technologies (Grübler 1996). This has led innovation systems scholars to emphasize the importance of taking a systemic perspective on technology diffusion that not only focuses on the characteristics of the technology and its adopters, but instead considers the dynamics of its entire technological innovation system (e.g., Jacobsson and Johnson 2000). Such innovation system has been defined as "a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology" (Carlsson and Stankiewicz 1991 p. 111). Both diffusion of innovation theory and innovation systems theory thus consider different types of actors (e.g., adopters, technology developers, service providers, policymakers, associations, and research institutes) to be central for understanding the diffusion patterns and system growth of new technologies (e.g., Rogers 1962, Carlsson and Stankiewicz 1991).

Despite the importance that is attributed to actors in technology diffusion, both theories provide rather shallow explanations of how different actors behave and what motivates them to engage in technology diffusion. For instance, although adopters constitute the main actors in diffusion of innovation theory, the adopter categorization by Rogers (1962) has been criticized for oversimplifying an adoption process that is, in fact, highly complex (Greenhalgh, Robert et al. 2004). Similarly, innovation systems literature has primarily focused on system structures and dynamics, and it has been argued that the field would benefit from a more explicit consideration of actors (Markard and Truffer 2008). In response, an increasing number of studies has started to explore how the overall system is influenced by different actors (e.g., Farla, Markard et al. 2012, Kivimaa, Boon et al. 2019, Musiolik, Markard et al. 2020). These studies primarily focus on supply-side actors, like technology developers, manufacturers, and research institutes, that are prominent during development and early diffusion of new technologies (Fig. 1) (Bidmon and Knab 2018). However, less is known about the demand-side actors, such as different adopters, project developers, and retailers, that are key for large-scale diffusion of new technologies (Bergek, Mignon et al. 2013, Mignon 2016, Bergek 2020).

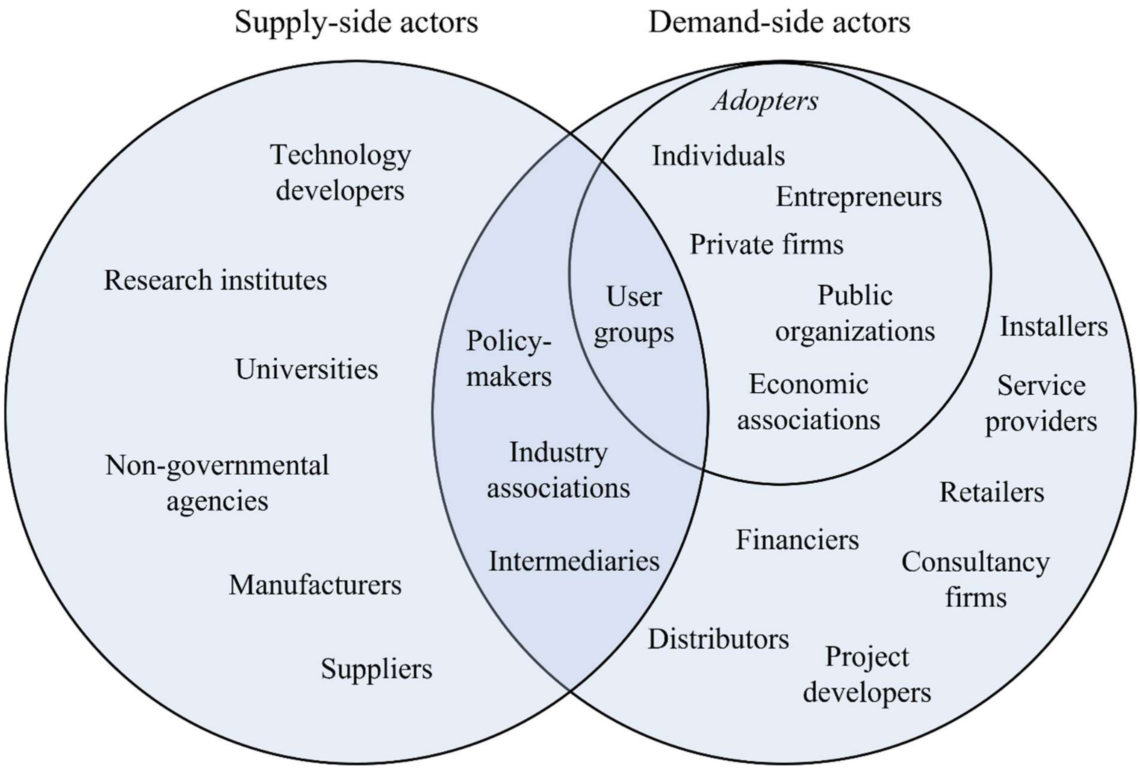


*Figure 1. Examples of actors in a technological innovation system (own illustration).*

Some studies have addressed this issue by providing a more comprehensive understanding of the adopters' role in technology diffusion. For instance, in their review of service organizations, Greenhalgh, Robert et al. (2004) expand Rogers' idealized adopter categories by highlighting that the adoption process is influenced by a multitude of factors, including e.g., personality traits, knowledge about the technology, and the adopters' ability and motivation to adopt it. Similarly in the innovation systems literature, studies show that RET adopters are a heterogenous group of actors that differ in terms of their knowledge, resources, and motives for investing in these technologies (Bergek, Mignon et al. 2013, Bergek and Mignon 2017). As such, it becomes important to consider adopters' motives, background, resources, and personal characteristics in order to understand how and why they adopt a new technology (Bergek, Mignon et al. 2013). Mignon and Bergek (2016) also show that adopters experience challenges both on a system level (e.g., related to market structures or institutional routines) and on an actor level (e.g., lack of resources or behavioral characteristics) that either hinder or hamper the adoption process. This implies that it is important to consider both actor- and system-level influence when studying technology diffusion. Altogether, these studies show that adopters are heterogenous in their motives and abilities to adopt a new technology and that they face different challenges in their adoption processes. In turn, the heterogeneity of adopters points to the importance of overcoming adoption challenges and addressing a diverse set of adopter needs and preferences in order for technology diffusion to occur on a large scale.

The general understanding in innovation systems literature is that diffusion can be facilitated by incentivizing adopters to invest in a technology or by removing impediments to adoption, which, in turn, can be achieved though policy intervention (e.g., Smith 2000, Woolthuis, Lankhuizen et al. 2005, Bergek, Jacobsson et al. 2008). Yet, more recent studies also show that demand-side firms, such as project developers, consultants, and installers (Fig. 1), can address adopter challenges by matching or tailoring solutions to adopters' specific needs and preferences (Owen, Mitchell et al. 2014, Mignon 2017). These findings suggest that demand-side firms can play an important role in facilitating large-scale diffusion by repackaging a technology into a variety of offers that makes it appealing to different adopters. However, a recent study also found that these firms face challenges related to the need to, on the one hand, create value for their target customers and, on the other hand, maximize profit margins to ensure the long-term survival of the firms (Aspeteg and Bergek 2020).

Studies also found that demand-side firms are heterogenous (Bergek 2020) and that their behaviors and motives often differ from common assumptions in the diffusion literature (Owen, Mitchell et al. 2014). For instance, Owen, Mitchell et al. (2014) found that many of these firms are small, and thus more likely to be motivated by employment stability than by conventional economic growth. These findings suggest that firms differ in their behaviors and motives, and that they are faced with different challenges that can influence their ability to facilitate technology diffusion. In spite of this, little is known about how these firms differ and why they act in certain ways. Given that demand-side firms constitute the middlemen that connects a new technology with its potential adopters, it is essential that scholars better understand why these firms decide to target certain adopters and what influences their behaviors in order to understand how large-scale diffusion of new technologies can be facilitated.

In an attempt to address this issue, innovation systems scholars have started to draw on the wealth of research in the strategy literature to better understand the rationale of firms (e.g., Aspeteg and Bergek 2020, Altunay, Bergek et al. 2021). The BM literature, in particular, has received increasing attention in relation to technology diffusion (e.g., Strupeit and Palm 2016, Bidmon and Knab 2018), perhaps because it illustrates different ways in which firms commercialize technologies to create and deliver value to their customers (i.e. adopters) and for themselves (Chesbrough and Rosenbloom 2002). The next section therefore elaborates on how the BM literature can complement the understanding of demand-side firms in large-scale diffusion of technology.

## 2.2. BUSINESS MODELS

The general rationale of a firm is to maximize profit by creating value for customers in a superior way compared to its competitors (Richardson 2008). A BM describes how this is achieved by explaining how the firm creates, delivers, and captures value (Osterwalder and

Pigneur 2010, Teece 2010). This includes what the firm offers to its target customer segments, how it organizes its resources, activities, and partnerships to create and deliver this offer, and how it generates revenues and profit for itself (Richardson 2008). As such, the BM is often described as a holistic representation of the firm (Wirtz, Pistoia et al. 2016). While much of the BM literature has focused on understanding how firms achieve and sustain competitive advantage (e.g., Johnson, Christensen et al. 2008, Zott and Amit 2008, Casadesus-Masanell and Ricart 2010), it has also been used to explain how firms can unlock the value potential of new technologies (e.g., Chesbrough and Rosenbloom 2002), and contribute to solving sustainability issues, e.g., by developing more sustainable BMs (e.g., Bocken, Short et al. 2014) or by enabling the diffusion of sustainable technologies (Boons and Lüdeke-Freund 2013).

Looking at technology diffusion from a BM lens, the prevalence of different BMs can explain which adopters are being targeted with a specific technology. If a technology is commercialized through many different types of BMs, chances are higher that it is being targeted towards different types of adopters. The reason for this is that firms use different BMs to exploit the value potential of a technology, where each BM targets the needs and preferences of specific customer segments (Chesbrough and Rosenbloom 2002). Naturally there can be overlaps in the customer segments that are being targeted by different BMs, but as a general rule it can be assumed that a greater variety of BMs can facilitate technology diffusion by targeting different types of adopters. It has, in fact, been shown that the introduction of a new type of BM increased the total adoption of a technology rather than at the expense of existing BMs because it targeted different customer segments (Drury, Miller et al. 2012). More importantly, if a technology is only commercialized through a few types of BMs, it can signal that not all potential adopters are being targeted. The BM concept can thus be used to understand how a technology can reach more adopters. For the purpose of understanding how technology diffusion can be facilitated through different BMs, it is thus important to examine how these BMs differ to ensure that they target different adopter groups.

Even if there is unexploited demand for a technology among certain adopters, it does not necessarily mean that firms will develop BMs to meet that demand. This is because it is not enough that there is a potential to create value from a technology, firms also have to be able to capture that value (Chesbrough and Rosenbloom 2002). For instance, a firm might be able to provide a technology in a way that fulfills the needs and preferences of a particular customer segment but unless the firm can generate profit from this BM it will not be realized. This means that a technology may not be commercialized towards certain adopters, not because there is a lack of demand, but because there is a lack of incentives for firms to target these adopters. The benefit of the BM concept is that it highlights the importance of both value creation and value capture (Zott, Amit et al. 2011), and that it illustrates different ways in which firms can commercialize a technology to different adopters.

This reasoning suggests that as long as firms can make a profit from fulfilling an adopter demand they will develop BMs to fulfill that demand. However, that is not always the case. Studies show that firms often struggle to innovate their BMs, both in terms of designing new BMs and changing their existing ones (e.g., Johnson, Christensen et al. 2008, Trimi and Berbegal-Mirabent 2012). This might explain why much of the BM literature has focused on identifying factors that influence firms' ability to innovate their BMs and strategies for how to achieve business model innovation (BMI) (e.g., Chesbrough 2010, Amit and Zott 2020, Bocken and Geradts 2020). BM design can be viewed as the operationalization of a firm's strategy (Richardson 2008) which, in turn, reflects how the firm intends to meet its goals given the constraints of its resources and capabilities and in response to threats and opportunities in its environment (Nandakumar, Ghobadian et al. 2010). Much of what influences the design of BMs can thus be attributed to firm-internal decision-making (Zott and Amit 2010).

Based on this, it is reasonable to believe that firms with comparable prerequisites and goals react in similar ways when innovating their BMs, but studies actually show that firms can react differently to the same influence (e.g., Dopfer, Fallahi et al. 2017, Saebi, Lien et al. 2017). For instance, Osiyevskyy and Dewald (2015) found that firms react differently to threats and opportunities in its environment, where some make incremental changes in their BM components and others make radical changes. One explanation for this difference is that firms perceive the same factor in different ways – one firm sees an opportunity while another sees a threat (Saebi, Lien et al. 2017). In their review of studies that examine the antecedents of such perceptions, Sarkar and Osiyevskyy (2018) found that a multitude of factors (e.g., firm size, internal power structures, and management shared interpretations) influences firm perceptions.

In addition to firm decision-making and perception, BM scholars emphasize the influence of path dependencies and inertia (Stinchcombe 1965) on firms that are looking to change their BMs (e.g., Doz and Kosonen 2010, Teece 2010). Existing structures, processes, assets, and cognitive biases have been found to limit established firms' ability to change their BMs (e.g., Chesbrough 2010, Doz and Kosonen 2010), and when they engage in BMI these firms tend to innovate close to their existing BMs (Bohnsack, Pinkse et al. 2014). A proposed solution for overcoming such inertia is for firms to develop dynamic capabilities (Teece 2018) or strategic agility (Doz and Kosonen 2010) that enables them to sense, seize, and transform their BMs in response to threats and opportunities in the environment. Many studies also highlight the importance of strategies to overcome BMI challenges (e.g., Chesbrough 2010, Battistella, De Toni et al. 2017, Amit and Zott 2020). Among these strategies, experimentation, change leadership, and the use of practitioner-oriented tools to facilitate the BMI process are especially emphasized (Chesbrough 2010, Sosna, Trevinyo-Rodríguez et al. 2010, Amit and Zott 2020).

While much of the BM research views firms' external environments as triggers of BMI (e.g., competition, technological progress, changing customer demand, and economic crises) (e.g., Johnson, Christensen et al. 2008, Aspara, Lamberg et al. 2013, Teece 2018), most studies tend to focus on the resulting influence of firm-internal factors on BM design. This firm-internal focus is perhaps not surprising given that the BM literature primarily targets managers and scholars in fields like strategy, organizational design, entrepreneurship, and innovation management (Zott, Amit et al. 2011, Wirtz, Pistoia et al. 2016). It has, however, been argued that the BM literature has neglected the influence of contextual factors on the design and development of BMs (e.g., Provance, Donnelly et al. 2011, Berglund and Sandström 2013). Although the influence of firms' external environment is highlighted in the literature, it is often described in general terms, such as if it is dynamic (Nandakumar, Ghobadian et al. 2010) or characterized by rapid technological change (Teece, Pisano et al. 1997). The literature does, however, appear to lack a system perspective that explains how context-specific conditions influence the design or prevalence of certain types of BMs. In fact, it has been argued that in highly institutionalized contexts like the energy sector, the design of BMs may be more influenced by contextual factors than by firm-internal factors (Provance, Donnelly et al. 2011). Considering that this thesis focuses on solar PV, which belongs to the highly institutionalized energy sector, the influence of contextual factors on BMs should not be disregarded. The next section therefore turns to the energy policy literature where the influence of contextual factors on BMs in solar PV has received increasing interest in recent years. First, the section elaborates on what is already known about the different BMs that are used to deploy solar PV. After that, it elaborates on the factors that are found to influence the design and prevalence of different solar BMs.

## 2.3. BUSINESS MODELS IN SOLAR PHOTOVOLTAICS

When looking at the specific example of solar PV, BMs have received increasing attention in research on technology diffusion and energy policy in recent years (e.g., Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016, Horváth and Szabó 2018, Altunay, Bergek et al. 2021). A range of different BMs involved with solar PV deployment has been identified by previous studies, including host-owned-, turnkey-, third-party-owned (TPO)-, community solar-, leasing-, power purchase agreement (PPA)-, crowdfunding-, and zero generation BMs (Frantzis, Graham et al. 2008, Schoettl and Lehmann-Ortega 2011, Drury, Miller et al. 2012, Huijben and Verbong 2013, Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016, Vasileiadou, Huijben et al. 2016, Horváth and Szabó 2018). These BMs can generally be distinguished based on roles (i.e., who owns the technology and who uses the electricity?), activities (i.e., what tasks are performed to deploy the technology?), and application (i.e., where and at what scale is the technology deployed?). Among these, the host-owned-, TPO-, and community solar BMs have received particular attention in energy policy literature, all of which are characterized by roles.

As suggested by the name, *the host-owned BM* entails that the actor who owns (and invests in) the solar PV system is also the one who owns the property on which the solar PV system is located and the one who consumes the solar electricity that is produced (Horváth and Szabó 2018). This BM has historically been influenced by incentive policies (e.g., feed-in tariffs, tax deductions, or investment subsidies) and as a result is has been used rather widely (Huijben and Verbong 2013, Huijben, Verbong et al. 2016). *The TPO BM* is, instead, based on the principle that a third-party actor acquires, owns, and operates a solar PV system on a property that is owned by the electricity consumer or a lessor (Drury, Miller et al. 2012). In exchange, the electricity consumer enters into a long-term contract in which they agree to pay for using the solar PV system or purchase the electricity that is being produced (Horváth and Szabó 2018). This BM has received particular attention in energy policy literature since it has been found to democratize access to the technology by appealing to adopters that lack the resources (or motives) to purchase a solar PV system up-front (Drury, Miller et al. 2012, Huijben and Verbong 2013). Lastly, in *the community solar BM* a collective of actors share ownership of a solar PV system that is commonly located on a communal property (Nolden, Barnes et al. 2020). The electricity that is produced by the solar PV system is either sold or consumed by the owners.

It has been emphasized in the energy policy literature that the viability of this BM depends heavily on economic incentive policies (Tongsopit, Moungchareon et al. 2016, Nolden, Barnes et al. 2020).

Although these three solar BMs are the ones most highlighted in energy policy literature, there is still a lack of consensus on how to categorize solar BMs and there are clear overlaps in how they are distinguished. For instance, leasing- and PPA BMs are sometimes described as versions of the TPO BM and other times seen as distinctly different solar BMs (Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016). Similarly, a BM in which a solar PV system is crowdfunded is considered by some as a unique solar BMs and as a type of community solar BM by others (Vasileiadou, Huijben et al. 2016, Burger and Luke 2017). While these overlaps may seem trivial, they can in fact be a missed opportunity for policymakers if the solar BMs are treated the same but turn out to target different adopters or respond to policies in different ways. Given that the objective of energy policy literature is to inform policymakers, it is thus essential that scholars gain a better understanding of how solar BMs can be differentiated.

More importantly, when comparing the characterizations of solar BMs with the general BM literature there seems to be a mismatch. For instance, the community solar BM does not appear to describe how a specific firm creates, delivers, and captures value. The same can be said for the host-owned BM. Instead, these solar BMs resemble what Sauter and Watson (2007) call *deployment models*. These models provide a holistic description of how to deploy solar PV in different ways, but they lack the actor perspective that explains how and why firms commercialize solar PV through specific BMs. Having an actor perspective on solar BMs is important for both policymakers and energy policy scholars since policy instruments and recommendations may be misdirected if they are based on assumptions of how firms reason and react.

The energy policy literature also emphasizes the influence of contextual factors (e.g., technology, market, and institutions) on the prevalence and design of BMs used for solar PV deployment. Technology-specific factors such as decreasing costs of solar PV and the availability of complementary technologies (e.g., energy storage solutions) have particularly been found to enable certain solar BMs (e.g., Tongsopit, Moungchareon et al. 2016, Burger and Luke 2017). Similar to the general BM literature, market-related factors, such as competition and customer demand, have also been found to influence the prevalence of solar BMs (e.g., Richter 2013, Altunay, Bergek et al. 2021). As have adopter characteristics, such as risk-propensity (Karneyeva and Wüstenhagen 2017) and the ability or preference to pay for a solar PV system up-front (Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016). For instance, when comparing the main solar BMs in Germany, Japan and the US, Strupeit and Palm (2016) found that US citizens tend to relocate quite frequently which made the long-term return on investment benefit of the host-owned BM less attractive than the immediate electricity bill savings of the TPO BM. The existence and configuration of market-related ecosystems have also been found to influence the prevalence of solar BMs. The availability of actors with complementary assets and expertise (e.g., banks, leasing firms, and installers) has been particularly highlighted since it influences firms' abilities to provide solar PV through a specific

BM (Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016, Altunay, Bergek et al. 2021).

As suggested by Provance, Donnelly et al. (2011), solar BMs are also influenced by several factors relating to the institutional context, such as mainstream regulations, technology-specific regulations, and incentive policies. The influence of mainstream regulations on solar BM prevalence mainly refer to the financial-, electricity-, and building regulations that exist in different national and regional contexts (Huijben, Verbong et al. 2016). Uncertainties regarding taxation and the legality of new forms of ownership have especially been found to limit the emergence of certain BMs in some contexts (e.g., Overholm 2015, Tongsopit, Moungchareon et al. 2016, Altunay, Bergek et al. 2021). Mainstream regulations have also been found to influence the configurations of certain BMs by limiting the profitability of BMs that involve offering solar PV systems of a certain size or targeted towards a specific customer segment (Huijben, Verbong et al. 2016). To give an example, Huijben, Verbong et al. (2016) found that the economic viability of community solar BMs in the Netherlands was greatly affected by the legal requirement that solar PV systems that produce more than a certain amount of electricity per year must have a specific (and costly) grid connection.

Technology-specific regulations and policies (e.g., feed-in-tariffs, investment subsidies and tax credits) have especially been highlighted in energy policy literature as having significant influence on the design and prevalence of solar BMs (Overholm 2015, Huijben, Verbong et al. 2016, Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016, Burger and Luke 2017, Herbes, Brummer et al. 2017). For instance, studies show that solar feed-in-tariffs promote technology ownership and thus favor BMs that provide this, like the host-owned BM (Tongsopit, Moungchareon et al. 2016). This also causes feed-in-tariffs to impede the emergence of other types of solar BMs, like the TPO BM, since it interferes with their commercial competitiveness (Overholm 2015). It is also important to highlight that technology-specific regulations and incentive policies influence solar BMs by altering market factors. By enacting policies that encourage the formation of community solar cooperatives (Tongsopit, Moungchareon et al. 2016) or investment in small-scale solar PV systems (Altunay, Bergek et al. 2021), policymakers change the market demand for these offers and thereby encourage the use of solar BMs that can provide these offers.

Apart from hard institutional factors (e.g., regulation and policy), some authors have also emphasized the impact of soft institutions (e.g., norms and values), on the prevalence of solar BMs. In particular, the legitimacy of the TPO BM was found to be questioned by incumbent actors in the energy sector, making it challenging for firms with such BMs to establish themselves on the market (Overholm 2015). Herbes, Brummer et al. (2017) also highlighted ethical concerns in relation to the community solar BM regarding the BMs potential impact on the environment and regional economy.

While the literature on solar BMs has primarily focused on the influence of contextual factors, some authors have started to emphasize the importance of considering both system- and actor-level influence in order gain a comprehensive understanding of the design and prevalence of solar BMs (Richter 2013, Ode and Wadin 2019, Altunay, Bergek et al. 2021). Scholars have particularly emphasized the influence of firm-internal factors like capabilities (Richter 2013), entrepreneur experience (Ode and Wadin 2019), and strategy (Huijben, Verbong et al. 2016, Altunay, Bergek et al. 2021). For instance, in their study of solar BM adoption among Swedish electricity utilities, Altunay, Bergek et al. (2021) found that utilities were more prone to adopt a specific solar BM if its components (e.g., resources, activities, and partnerships) aligned with their existing BM. Interestingly, they also found that alignment between some BM components, such as infrastructure in the case of utilities, were more determinant for whether or not the solar BM would be adopted. The influence of firms' strategies on solar BMs has also been emphasized as important for entrepreneurial firms (Huijben, Verbong et al. 2016). When entering a new market, entrepreneurial firms tend to adopt one of two strategies – they either aim to *fit and conform* to their environment or attempt to change it through a *stretch and transform* strategy (Smith and Raven 2012). Depending on which of these strategies solar firms adopt, they will take different approaches to their BMs, which ultimately affects what solar BMs exist in a certain context (Huijben, Verbong et al. 2016).

## 2.4. SUMMARY

The three strands of literature that are presented above contribute with different perspectives on how the role of BMs in large-scale diffusion of solar PV can be understood (Fig. 2). Diffusion of innovation theory (e.g., Rogers 1962, Bass 1969) and innovation systems theory (e.g., Carlsson and Stankiewicz 1991, Jacobsson and Johnson 2000) provide an understanding of how and why some technologies diffuse faster and at a larger scale than others, and how technological innovation systems grow. Moreover, these theories point to the importance of different actors in diffusion, where supply-side actors (e.g., suppliers and technology developers) and adopters (e.g., individuals, entrepreneurs, public organizations) have received particular attention (Greenhalgh, Robert et al. 2004, Bergek, Mignon et al. 2013, Bidmon and Knab 2018). Less is known about demand-side firms (i.e., those involved with technology deployment) and what role their BMs play in large-scale diffusion (Bergek 2020). More importantly, these theories lack an explicit actor perspective that can explain how and why demand-side firms act in certain ways.

The actor perspective can, however, be found in the BM literature. In particular, the BM literature contributes with an understanding of firm rationale and how firms match a technology with different adopters through the value creation, value delivery, and value capture mechanisms of their BMs (e.g., Chesbrough and Rosenbloom 2002, Richardson 2008). It also motivates RQ1 by highlighting the importance of examining different BMs on a market to see which adopters are being targeted. Furthermore, the BM literature provides an understanding of how firms reason when designing and changing their BMs and how this is influenced by primarily firm-internal factors (e.g., Chesbrough 2010, Dopfer, Fallahi et al. 2017, Amit and Zott 2020). Such understanding can contribute to answering RQ2 since firms' choices related to BM design affects which BMs are prevalent on a specific market. Yet, firm-internal factors cannot alone explain the prevalence of BMs in a highly institutionalized industry like solar PV (Provance, Donnelly et al. 2011). It has been argued that BM literature is currently lacking when it comes to explaining the influence of contextual factors that require a more systemic perspective (e.g., Provance, Donnelly et al. 2011, Berglund and Sandström 2013).

The final puzzle piece for understanding the role of BMs in large-scale diffusion of solar PV comes from the energy policy literature. The influence of contextual factors on solar BMs has received increasing interest in this strand of research during recent years and many different types of solar BMs have been examined, which contributes to answering both RQ1 and RQ2. However, many of these solar BM fail to articulate a clear firm rationale for how a specific firm creates and captures value. Instead, they bear more resemblance to what Sauter and Watson (2007) refer to as solar PV deployment models. While such deployment models are valuable for understanding solar PV diffusion, they lack the actor perspective needed to fully understand the role of BMs in such process. Hence, in order to address RQ3 and the overall aim, a comprehensive understanding that considers both a system- and actor perspective is needed. In particular for RQ3, it is important that policymakers gain a better understanding of under what conditions solar BMs emerge and what role BMs can play in large-scale diffusion of solar PV to better know how they can facilitate it.

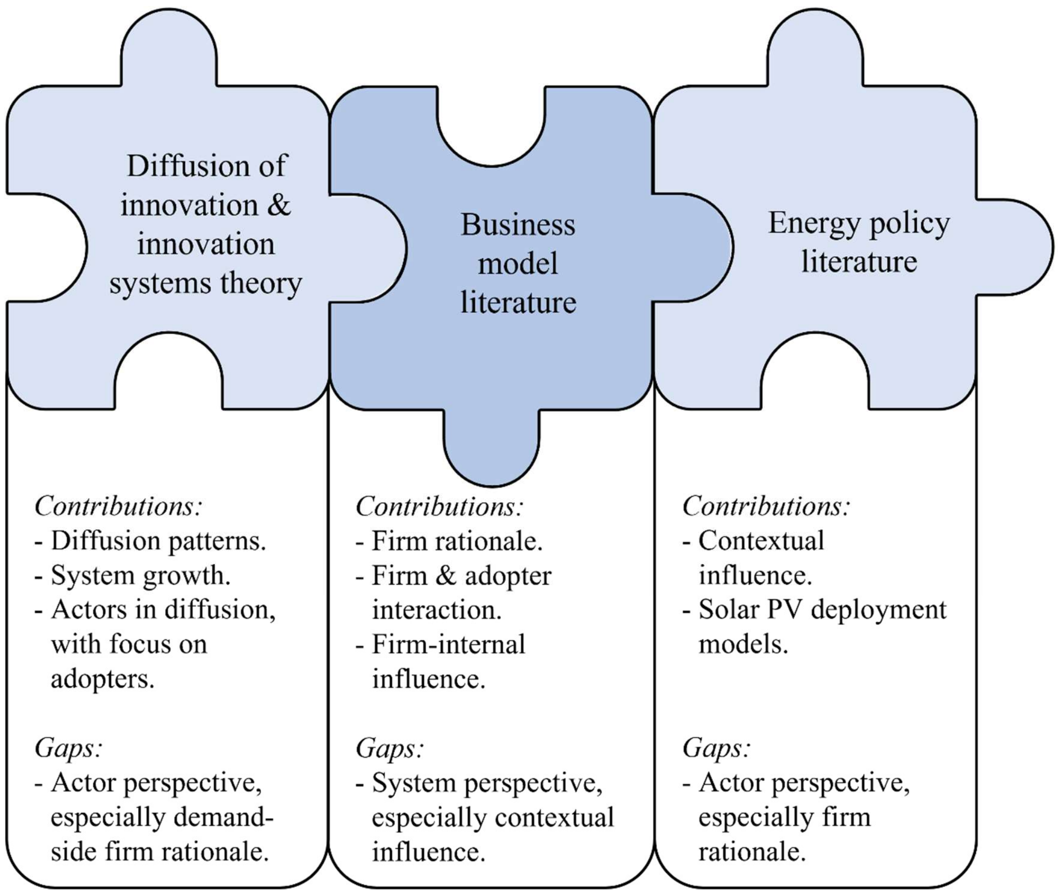


*Figure 2. Contributions and gaps of the different research streams in the theoretical framework (own illustration).*

# 3. METHOD

## 3.1. RESEARCH PROJECT

This licentiate thesis is the result of two and a half years of work conducted in the research project "Innovative business models for a large-scale diffusion of solar PV", funded by the Swedish Energy Agency [grant number P48527-1]. The project aims to understand how innovative BMs can contribute to a large-scale diffusion of solar PV by identifying solar BMs that are used in Sweden and abroad, context-specific conditions that can explain their prevalence, and the conditions needed for a more widespread use of these BMs in Sweden. As such, the thesis is closely linked to the aim of the project but focuses solely on the Swedish context. The project started in January 2020, and I joined in February the same year, by which point the objective of the project had already been formulated. While the focus of this thesis corresponds to the initial project objective to a great extent, three main aspects have been altered during the research process.

First, the term "innovative" BM has been removed on the basis that what is considered innovative is a matter of perspective, i.e., is it new to the firm or new to the industry? (Foss and Saebi 2017). For instance, a solar BM that is new in one country may have been used for a long time in another country. In the context of solar PV diffusion, it is thus of less importance if a solar BM is considered to be innovate and more important why it is used in some contexts and not others. As such, the process of BMI becomes more relevant. Second, in response to a fruitful discussion related to my research proposal and after reviewing extant literature, I decided to not limit the focus of the research to only contextual factors but also be open to the fact that influence can stem from other sources, e.g., from inside the firm. In practice, this did not imply any significant changes to the research design other than broadening the scope. Finally, this thesis puts a greater emphasis on the importance of firms in large-scale diffusion of solar PV, where the BM is seen as a tool for understanding how firms operate. The reason for this focus is that BMs, per se, do not impact solar PV diffusion but it is rather the firms that develop and use these BMs.

## 3.2. RESEARCH DESIGN

The overall research approach in this thesis is explorative and qualitative since the phenomenon of large-scale diffusion of solar PV still remains relatively unexplored (Köhler, Geels et al. 2019), especially in relation to demand-side firms (Bergek 2020). The overall aim and research questions are addressed through two studies, one literature review (Study A) and one case study (Study B). Detailed descriptions for each of these methods are presented as part of their respective study (section 3.3-3.4) and an overview of the aims and methods for each paper is presented in Table 1.

Study A looked beyond the solar PV context and reviewed the BM literature to explore sustainable BMs presented in recently published empirical studies and how firms have innovated their BMs to achieve them. The reason for this study design was that, when conducting qualitative studies, it is often difficult to gain a comprehensive understanding of a relatively unexplored phenomena since it usually requires exploration of different perspectives and longitudinal data collection that covers a variety of organizations in different industries and national contexts. As an alternative, a comprehensive understanding can be gained from reviewing previous empirical studies (Gough, Oliver, & Thomas, 2017). Given that solar BMs can be considered sustainable to some extent because they increase the use of renewables (Bocken, Short et al. 2014), a review of empirical studies of firms innovating towards sustainable BMs can provide insights that are applicable for solar BMs. The study resulted in Paper II.

Study B followed a case-study design and explored the BMs that demand-side firms in Sweden use to commercialize solar PV and how these firms perceive and react to factors that influence BMI. The case study design was chosen because it is particularly suited for exploring new phenomena since it allows for the building of new knowledge (Eisenhardt 1989, Easton 2010). The study was carried out in three phases and resulted in Paper I and Paper III.

In order to answer RQ3, the findings from Study A and Study B were synthesized and re-interpreted based on their contributions to policy design. More specifically, the findings were analyzed from both an actor- and system perspective on BMs' role in large-scale diffusion of solar PV in relation to policy design.

*Table 1. Overview of the aims and methods for each paper.*

| Paper | Aim / Research questions | Method | Study |
|---|---|---|---|
| I | Bridge the gap between the way energy policy literature describes solar BMs, and the way solar firms use them to communicate with their clients. | Mapping and analysis of the BMs of 241 Swedish solar firms using the BM framework by Richardson (2008) and the roles, activities, and application as presented in solar BM literature. | B |
| II | What are the main sustainable BMs described empirically in the literature and what are their particularities? What are the strategies used by firms to develop and implement sustainable BMs? | Literature review and analysis of recently published empirical studies covering 87 unique cases of BMI towards sustainable BMs. | A |
| III | Explore how firms in the same industry and institutional context perceive and react to factors influencing BMI. | Content analysis of in-depth interviews with founders/managers of 12 firms operating in the Swedish solar PV industry. | B |

## 3.3. STUDY A

Although BMI towards sustainable BMs might not be the first topic that comes to mind when exploring the role of BMs in large-scale diffusion of solar PV, there were several reasons for choosing a literature review on this topic as the first study.

Study A took a starting point in the practical reason that I needed to review state-of-the-art literature to familiarize myself with the topics of the research project. In doing so, it became clear that the energy policy literature consisted of overlaps and unclarities related to the way solar BMs were distinguished and defined, and that there was a lack of explanations as to how and why firms develop and implement certain solar BMs. Turning to the general BM literature for answers, I found that solar BMs had been classified as sustainable BMs on the basis that they increase the use of renewables (Bocken, Short et al. 2014), and that there had been an increasing number of empirical studies published in recent years of firms innovating towards sustainable BMs. Since only a few of these studies focused specifically on firms in the solar PV industry, my co-author and I decided to broaden the scope of the study to gain a comprehensive understanding of the phenomenon (Gough, Oliver, & Thomas, 2017) that I could later apply on the solar PV context by comparing it with the results of Study B. Study A thus involved reviewing empirical cases of firms innovating their BMs to achieve sustainable BMs. More specifically, we reviewed 87 empirical cases of BMI towards sustainable BMs published in academic journals between 2010 and 2020. The review was informed by Petticrew and Roberts (2008) and data was collected and analyzed in six steps (I-VI).

First, we searched the Web of Science for articles published 2010-2020 containing the terms "sustainable business model" and "business model innovation" in the title, topic, or keywords. Step I resulted in 312 articles, reviews, and proceeding papers whose titles and abstracts were screened based on the inclusion of the search terms (i.e., sustainable BM and BMI) and variations of them (e.g., BMI for sustainability) in step II. After this screening, 49 articles proceeded to step III in which the full papers were reviewed and screened. During this step, we also created a database containing information about the articles, including definitions of BMI and sustainable BM as well as empirical case descriptions. The case data in the articles were collected and analyzed in accordance with case study methodology, which means that the cases aimed at exploring a phenomenon in its context (e.g., Eisenhardt 1989, Yin 1994). The screening during step III involved excluding papers that lacked empirical cases or case descriptions, only referred to sustainability as economic viability, or only used the BMI and sustainable BM concepts in passing. This resulted in a final inclusion of 25 articles describing 87 unique empirical cases.

In step IV, we reviewed the selected articles again in full to look for emerging patterns related to BMI and sustainable BMs. This was done separately by each author and the insights were subsequently discussed and compared until two themes could be identified: recurring sustainable BM types and BMI strategies for developing and implementing sustainable BMs. By reviewing the state-of-the-art literature on sustainable BM, we became aware that BMs appear to differ in terms of output, and we decided to explore if such patterns could be found in our selected empirical cases (step V). We started by categorizing cases independently, followed by discussions and adjustments based on our different understandings. Once we had developed a common understanding, I categorized the remaining cases while my co-author checked it for consistency. Some cases could not be categorized, either because the BMs were not claimed to be sustainable or because the case descriptions did not convey why the BMs were considered sustainable. Some cases could also be categorized to more than one sustainable BM type. Typically, these cases had a stronger match with one sustainable BM type and were therefore categorized to the type it matched best. In total, we could categorize 72 cases in 19 articles according to patterns in sustainable BM output.

Step VI followed a similar procedure to step V in that we started by reviewing extant literature on BMI strategies. This led us to examine our selected empirical cases for various strategies used by firms to develop and implement sustainable BMs. While the analysis was guided by previous literature, we were still open for new strategies to emerge. For some cases, we were unable to identify which strategies had been used due to lack of information in the case descriptions or because the articles did not explain or focus on the BMI process of developing or implementing sustainable BMs. We could identify a total of 59 cases in 19 articles that displayed patterns of strategies for developing and implementing sustainable BMs.

## 3.4. STUDY B

Study B was a case study of the BMs of demand-side firms that commercialize solar PV in Sweden. In the case-study design, researchers collect rich data through e.g., interviews, observations, field studies, and archives (or a combination thereof) to conduct in-depth analyses that aim to provide conceptual insight (Yin 1994, Siggelkow 2007). In this study data was collected and analyzed in three separate phases. The objective of the first phase was to build an overall understanding of the Swedish solar PV market. The second phase focused on identifying and differentiating the BMs used by demand-side firms to deploy solar PV in Sweden. Finally, the third phase explored how demand-side solar firms perceive and react to factors influencing BMI to better understand what influences the prevalence of different solar BMs. An overview of the methods used in each phase are shown in Table 2 and are described in more detail under their respective section (3.4.2-3.4.4).

*Table 2. Overview of the methods used in each phase of study B.*

| | **Phase I** | **Phase II** | **Phase III** |
|---|---|---|---|
| **Study objects** | Swedish solar PV market. | The BMs of 241 solar firms involved with solar PV deployment in Sweden. | 12 demand-side firms operating on the Swedish solar PV market. |
| **Data sources** | 2 semi-structured interviews with industry experts. | IEA PVPS database of organizations operating in the Swedish solar PV industry.<br>Websites or social media channels of the selected solar firms. | IEA PVPS database of organizations operating in the Swedish solar PV industry.<br>12 semi-structured interviews with founders/managers of the selected solar firms. |
| **Data analysis** | Content analysis. | Mapping and categorization based on the BM framework by Richardson (2008) and based on roles, activities and application as highlighted in the solar BM literature (section 2.3) | Content analysis using the software analysis tool Nvivo. |

### 3.4.1. *THE SWEDISH CONTEXT*

Given than the prevalence of different solar BMs differs greatly between countries (e.g., Strupeit and Palm 2016), the choice of study context becomes particularly relevant. For this thesis, the context of Sweden was chosen for several reasons.

First, in response to the deregulation of the Swedish electricity market in 1996, many actors have entered the market to produce renewable electricity and to offer supporting services (Bergek, Mignon et al. 2013, Bergek 2020). Sweden differs from many other countries in that its electricity production is largely fossil-free, being primarily based on hydro and nuclear power, with a target of reaching 100 percent renewable electricity by 2040 (IEA 2019). During this time, the Swedish solar PV market is expected to grow between seven to fourteen times over (Svenska Kraftnät 2017, Lindahl, Berard et al. 2021). While the Swedish solar PV market is still small in comparison to many other countries, it is larger than the global average in regards to distributed solar PV per capita (Palm and Lantz 2020). The Swedish market has also been subjected to many legislative changes and has grown exponentially over the past 10 years (Lindahl, Berard et al. 2021). As a result, a variety of solar BMs has emerged.

A final reason for choosing Sweden as the empirical setting is that we had access to a database containing information about 741 known organizations that work or have been working with solar technologies in Sweden. The database is used by the International Energy Agency's Photovoltaic Power Systems Program (IEA PVPS) (https://iea-pvps.org/) to annually report on the technical, economic, social, and environmental conditions of solar PV systems in Sweden. As such, the database provides a comprehensive, reliable, and up-to-date basis for identifying solar firms operating in the same national and institutional context.

#### 3.4.2. *PHASE I*

Two interviews with industry experts were first conducted to gain an up-to-date overview of the Swedish solar PV market. The interviewees were purposefully selected based on their experience of the Swedish solar PV industry, where one interviewee has been part of writing the IEA PVPS national survey reports of PV power applications in Sweden (e.g., Lindahl, Berard et al. 2021) for the past decade and the other is the managing director of the Swedish solar energy industry association.

The interviews were conducted digitally between December 2020 and January 2021 and lasted around one hour each. The focus of the interviews related to which market segments and BMs exist on the Swedish solar PV market, how these have changed over time, and how they compare to other countries, as well as potential reasons for the prevalence of different solar BMs that exist in Sweden. The interviews followed a semi-structured format to keep focus on the research topic while also allowing for new areas of interest to emerge. The existence of the IEA PVPS database was, for instance, brought to my attention during one of these interviews. All interviews were recorded and summarized directly after they were conducted.

The interview summaries were analyzed and categorized in line with the overall research questions of the thesis (i.e., different solar BMs, market segments they can target, and factors influencing their prevalence in Sweden). The findings were checked for accuracy against the recordings of the interviews and subsequently used to inform the following phases of the case study, specifically relating to sampling and design of interview questions.

#### 3.4.3. *PHASE II*

To identify demand-side firms that commercialize solar PV, we selected 351 firms from the IEA PVPS database that were categorized according to the primary business focus: sales, consulting, and installation of solar PV. These firms were selected because they focus on one-shot activities in the downstream value chain of solar PV (i.e., project development, sales, construction, and installation of solar PV systems) (Fig. 3). In turn, they are considered to have the most direct impact on the deployment of solar PV since their BMs are built around implementing new solar PV systems. This does not imply that demand-side firms whose BMs are built around ongoing downstream activities (e.g., operation and maintenance) are unimportant for the diffusion of solar PV. They can, for instance, facilitate diffusion by making it more convenient to own a solar PV system. Nevertheless, since these BMs are not directly involved with solar PV deployment, and in order to keep the scope to a manageable size, we chose to limit our sample to firms that focus on one-shot activities (although some of the selected firms also carry out ongoing activities).

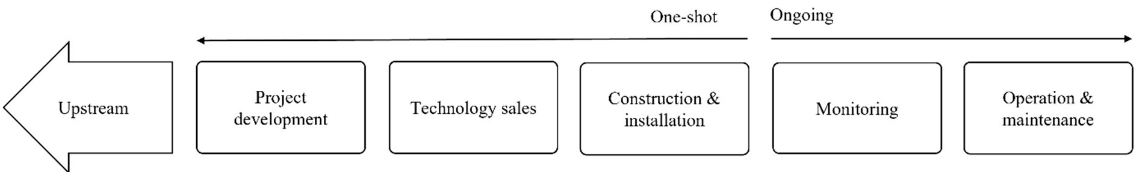


*Figure 3. Activities in the downstream solar PV value chain.*[1]

Since the study focuses on large-scale diffusion which involves adoption of a standardized technology, we also excluded firms that offer non-standard solutions like off-grid- and building-integrated solar PV, as well as firms that only target other solar firms (e.g., wholesalers) and not adopters. Electricity utilities were also excluded from the sample on the basis that they outsource their solar businesses to local installers for the most part (Lindahl, Berard et al. 2021) and that their solar BMs have been studied recently (Altunay, Bergek et al. 2021). Moreover, we conducted a screening during data collection and excluded firms without websites or social media channels as well as firms that did not provide any information to suggest that they offer project development, sales, or installation of solar PV systems. This resulted in a final sample of 241 solar firms.

Secondary data about the selected firms' BMs was collected from the firms' websites or social media channels during April-September 2021 and was mapped according to their value proposition, value creation and delivery system, and value capture (Richardson 2008). The data included firms' target customer segments, offers, activities performed to create and deliver these offers, if these activities were performed in-house or through partnerships, and the revenue structures. Once the data of all 241 solar firms had been mapped, it was analyzed and categorized based on roles, activities, and application – as highlighted in solar BM literature (section 2.3). The roles that were analyzed include property owner, solar PV system owner, and electricity consumer. Activities match those of the one-shot downstream value chain (Schoettl and Lehmann-Ortega 2011), i.e., project development, sales, and installation of solar PV systems. Finally, application refer to the size and location of the solar PV system, including residential-, commercial-, industrial-, and utility-scale solar PV systems. While the roles and applications were not explicitly stated on the solar firms' websites, the information could, for the most part, be deducted from the descriptions of the offers, customer segments, and activities. Any BM components that could not be identified on the solar firms' websites were left blank.

[1] Own illustration adapted from Figure 1 in Paper I.

### 3.4.4. *PHASE III*

In order to identify factors that influence solar firms to innovate their BMs and explore how different solar firms perceive and react to such factors, 12 demand-side solar firms that operate in the Swedish solar PV industry were sampled from the IEA PVPS database. Rather than striving for empirical generalization, we selected these firms using purposeful sampling to capture information-rich cases that could illustrate the rationale of different types of solar firms (Flyvbjerg 2006). Based on the findings from the first phase of study B, we knew that the Swedish solar PV market had been subjected to many legislative changes over the past years. From the second phase, we also knew that some solar BMs were used to a much lesser extent in Sweden than others, and that firms in some other sectors to also operate on the solar PV market. Hence, in order to deepen our knowledge of how solar firms perceived and reacted to this changing environment, why some firms chose to use uncommon solar BMs, and why firms entered the solar PV market from other sectors, we selected firms that fit one or more of these criteria. To operationalize the criteria, we looked for firms that either 1) had been operating in the Swedish solar PV industry for more than five years, 2) were, or had been, oriented towards TPO- or large-scale solar PV systems, franchise, or monitoring, 3) had switched from commercializing another RET to solar PV, or 4) operated in the construction or electrical installation sector alongside their solar business. This resulted in a final selection of the 12 firms presented in Table 3.

Data collection took place between February-May 2021 and involved 12 semi-structured digital interviews[2] with founders/managers of the selected firms. Each interview lasted around one to two hours and was recorded and transcribed. We chose to interview founders or managers of the firms since their position implies that they have been involved in strategic decision-making relating to the firms' BMI processes. As in phase I, we chose the semi-structured interview format to provide opportunities for the interviewees to elaborate on their experiences whilst remaining close to the research topic to enable comparisons between firms. The interviews covered topics such as the role and previous experience of the interviewee, how and why the firm was founded, reasons for moving into solar PV, how the BM had changed over time and why etc. The interviewees were never asked directly of perceived threats and opportunities, instead, we made this interpretation during data analysis. There is always a risk that, when asking founders/managers about events and decisions they have been involved with retrospectively, the answers they provide will not be entirely the same as if they would have been asked the same question at the time. To reduce such biases, we therefore attempted to minimize self-reporting of results as much as possible during the interviews.

The interview transcripts were coded using the data analysis software Nvivo to enable a transparent and efficient process. The data was analyzed in four steps (I-IV). Step I involved reviewing all interview transcripts for text segments describing an influence that led to BMI. There is a lack of consensus in the BM literature on what constitutes BMI (Saebi, Lien et al. 2017), but in this study we take a broad perspective by including both BM creation and change, BMs that are new to the industry or new to the firm, and changes that are made to only one BM component as well as the reconfiguration of the entire BM. In step II, my co-author and I coded

[2] The interviews for firm 7 and firm 11 each occurred over two separate occasions.

the text segments into factors and sub-factors separately and then discussed the categorizations until consensus was reached. We then went back to the interview transcripts and reviewed them once more in step III, this time focusing on text segments that described the identified factors/sub-factors although they did not lead to BMI. These segments were also coded to their corresponding factor/sub-factor. Lastly, in step IV, we coded firms' perceptions and reactions to these factors. Perceptions were coded as threats or opportunities depending on interviewees use of language, where descriptions that included negative words (e.g., difficult, hinder, bad) were coded as threats and positive words (e.g., easy, inspiration, good) as opportunities. Similarly, reactions were coded as BMI or status quo, where BMI implied that the firm had created a new solar BM or made one or several changes to the existing BM components (e.g., customer segments, offers, key resources)  and status quo implied the absence of BMI. Status quo reactions were further coded into no action and externally directed action.

*Table 3. Overview of selected firms and interviewees in phase III of Study B.*

| Firm | Interviewee(s) | Founded | Firm business focus |
|---|---|---|---|
| 1 | Sustainable business development manager | 1887 | International construction group with solar PV as a standard solution in most of its subsidiaries. |
| 2 | Marketing manager | 1995 | Electrical installation firm that started offering solar PV turnkey solutions to professional customers in 2013. |
| 3 | Financial manager | 1997 | Solar heating firm that moved into solar PV wholesales in 2011, followed by solar PV turnkey solutions in 2019. |
| 4 | Founder | 2008 | Solar hybrid firm that turned solar PV turnkey provider in 2012. Has later expanded into solar parks and targets professional customers since 2018. |
| 5 | Founder | 2011 | Solar PV turnkey provider targeting professional customers. Builds solar parks since 2015. |
| 6 | Founder | 2012 | Solar PV wholesales firm that initially offered small-scale hydropower. Moved into solar PV wholesales and turnkey provision by building a solar park in 2014. Has since changed focus to only offer wholesales and services targeted at installers and resellers. Offer leasing and solar PV system monitoring through partnerships since 2020. |
| 7 | Founder | 2013 | Solar energy management firm that started out by offering solar PV system monitoring before expanding into other energy and water management services after a merger in 2017. Has recently moved into balance service provision in partnership with utilities. |
| 8 | Founder | 2013 | Solar PV PPA provider that targets large firms. Offered solar PV leasing solutions at the start. |
| 9 | Founder | 2014 | Diversified solar firm that started out as a solar PV turnkey provider. In 2018, they started building solar parks and has since expanded into PPA, leasing, financing, and electricity retailing. Primarily targets residential customers. |
| 10 | Founder | 2014 | Solar PV turnkey provider that initially offered leasing but quickly changed into turnkey provision targeting professional customers. |
| 11 | Two founders | 2015 | Solar PV leasing provider targeting professional customers. |
| 12 | Founder | 2017 | Solar PV turnkey provider that is a franchise since 2020. |

## 3.5. REFLECTION ON METHODOLOGICAL CHOICES

In order to ensure quality in qualitative research, it is important to reflect on the trustworthiness of the study in terms of its credibility, transferability, dependability, and confirmability (Lincoln and Guba 1985). In relation to this thesis' credibility, one of the main aspects to consider is if the studies examined firms' BMs as intended. For the literature review, I had to rely on the credibility of the included empirical articles, which I believe to be trustworthy given that they have all been published in scientific journals and thereby undergone rigorous double-blinded reviews. For the case study, however, there are two main limitations in this regard.

The first is the use of firm websites to identify solar BMs. The main disadvantages is that firms who do not have websites or social media presence are excluded from the sample, and that the websites do not focus on illustrating the firms' BMs and, as such, may lack information about different BM components. However, in our study, the majority of solar firms were found to have websites that described many of the BM components that are important for understanding firms' role in solar PV diffusion (e.g., target customer segments and value propositions) as well as providing an overview of the firms' value creation, value delivery, and value capture mechanisms. While this information did not provide a detailed understanding of the firms' BMs, it fulfilled the purpose of identifying solar BM types that are useful for understanding solar PV diffusion. For this objective, it was deemed more appropriate to strive for analytical width rather than depth in the second phase of the case study, especially since phase III would go more in-depth.

The second limitation of the case study is the lack of triangulation in regard to only interviewing one representative from each firm in phase III. While the BM can be considered a conceptual representation of the firm, it can also be seen as a "mental model" of how individuals understand the workings of the firm, and these mental models may differ between individuals (Massa, Tucci et al. 2017). By using interviews as means of exploring solar BMs, we thereby capture the interviewee's understanding of the firm's BM and not an objective representation of the BM. Although qualitative research does not strive for objectivity, triangulation using different firm representative's understanding of the BM can provide a more comprehensive picture of the BM. Hence, by only interviewing one representative from each firm, there is a greater risk of biases. However, for the purpose of understanding firms' perceptions and reactions related to the BMI process, choosing the founders/mangers as interview subjects can be seen as a suitable choice since it is their mental models of the BM that are used for BMI decision-making.

Moreover, something that strengthens the credibility of this thesis is that both studies has undergone rigorous feedback processes from multiple sources. The studies have, for instance, been discussed with industry experts and at internal seminars and conferences. Moreover, two of the appended papers have been published in double-blind peer reviewed journals and the third has been accepted and presented at two conferences.

Transferability refers to the extent to which the findings can be applied in other contexts (Lincoln and Guba 1985). In this respect, the sole focus on the Swedish context can be seen as a limitation, especially considering that solar BM prevalence differs between contexts (e.g., Strupeit and Palm 2016). While the characteristics of the solar BMs and influencing factors on the Swedish market cannot be directly applied on other solar PV markets, the learnings that they bring are more generalizable. Moreover, the broader focus of Study A is also an attempt to increase the transferability of the thesis' results.

In terms of dependability (i.e., the consistency between data, analysis, and conclusions) and confirmability (i.e., the neutrality of the researcher in interpreting the data) (Korstjens and Moser 2018), these were ensured by transparently describing the research process and using digital tools for data collection and analysis (e.g., recording interviews, coding data using Nvivo) to be able to easily go back and check the original data sources during the analysis. In particular, my co-author and I ensured to first analyze the data separately and subsequently compare our results to see if we observed similar patterns in the data. Once consensus on how to code the data was reached, one of us finished coding the remaining data while the other took on the role of devil's advocate and checked the analysis for consistence.

# 4. SUMMARY OF APPENDED PAPERS

The thesis includes three papers, all of which are co-authored with my main supervisor Ingrid Mignon. Table 4 presents an overview of each paper, their current status, and which research questions they address. Paper I was published in *Energy Policy* in July 2022 after two rounds of reviews. Both authors contributed equally to the paper. Paper II was published in *Business Strategy and the Environment* in June 2022 after one round of reviews. Ingrid is the main author for this paper and my main contribution was in data collection and analysis as well as writing. Paper III was presented at two conferences in June 2022 – the Druid conference in Copenhagen, Denmark, and the Business Model conference in Lille, France. I am the main author of this paper as I took the lead in developing all parts of it. Ingrid made substantial contributions to the conceptualization, data analysis, and in writing of the paper. Each of the appended papers are summarized in the following sections (4.1-4.3).

*Table 4. Overview of appended papers, their status, and research questions they address.*

| Paper | Title | Status | RQs |
|---|---|---|---|
| I | Solar business models from a firm perspective – an empirical study of the Swedish market. | Published in *Energy Policy,* July 2022. | RQ1, RQ3 |
| II | Sustainable business models and innovation strategies to realize them: A review of 87 empirical cases. | Published in *Business Strategy and the Environment*, June 2022. | RQ1-RQ3 |
| III | What explains business model innovation or status quo? Exploring firms' perceptions and reactions in the Swedish solar photovoltaic industry. | Presented at the Druid conference, 13-15 June 2022, Copenhagen, Denmark, and at the Business Model conference 22-23 June 2022, Lille, France. | RQ2, RQ3 |

## 4.1. PAPER I

Paper I aims to bridge the gap between way energy policy literature characterizes solar BMs and the way solar firms use them to communicate with their customers. This is achieved by mapping and analyzing the BMs of 241 firms involved in sales, project development, and installation of solar PV in Sweden. By drawing on the learnings of both the energy policy- and BM literature six types of solar BMs were identified: consulting-, technology provision-, turnkey-, leasing-, EPC-, and PPA BMs. These differs in terms of their value proposition, value creation and delivery system, and value capture, as well as the roles, activities, and application related to solar PV deployment.

The results show that the prevalence of different solar BMs varies greatly in Sweden, where those that focus on small-scale solar PV systems and host-ownership are used by many firms, and those that are oriented towards large-scale systems and TPO are uncommon. The findings also show that firms can carry out the same activities in the solar PV value chain and still have different BMs. This is because the scale at which they operate requires different resources, capabilities, partnerships, and networks. Many firms also operate on other markets simultaneously and build on their existing resources and capabilities by using their solar BM in parallel with another.

The primary focus of *the consulting BM* is to offer ad-hoc services related to solar PV project development (e.g., pre-studies, engineering, and tendering evaluation) to customers wanting input from an impartial actor (i.e., not a technology provider). The targeted customer segments include public property owners (e.g., municipalities), apartment building owners, as well as commercial-, and industrial property owners. As such, the consulting BM focuses on commercial- and industrial applications, and the roles of property owner, solar PV system owner, and electricity consumer is taken by the customers. Solar firms with this BM create and capture value by utilizing their impartial position and expertise to charge an hourly or daily fee for the services that they provide.

*The technology provision BM* focuses on selling solar PV components (e.g., solar panels, inverters, and racking) to households, farmers, and commercial property owners that wish to acquire a solar PV system for electricity self-consumption on their own property. Customers are thus required to possess or have access to the necessary skills and certifications needed for project development and installation of solar PV systems. Technology providers create and capture value by acquiring large quantities of different components, combining them into standardized solar PV systems, and selling the components for a higher price than what they purchased them for.

*The turnkey BM* is by far the most popular solar BM used by solar firms in Sweden. Although several variations of the BM exist in terms of added services and if installation activities are performed in-house or by partners, the core rationale of the turnkey BM is to offer customers a hassle-free experience of acquiring a tailored solar PV system that is ready for immediate use. The primary targeted customer segments include households, farmers, apartment building owners and commercial property owners. As such, the turnkey BMs spans the residential and commercial application types. Some turnkey providers also offer targeted solutions to specific customer segments, such as individual billing solutions to apartment building owners that enables the solar electricity consumption to be measured and billed for each apartment. Solar turnkey providers create value by managing all one-shot activities in the downstream solar PV value chain (i.e., project development, technology sales, as well as construction and installation). In exchange, they receive a one-time payment for the entire solution that exceeds the value they would have captured if they performed these activities separately.

*The leasing BM* is only used to a limited extent by solar firms in Sweden. The BM primarily targets commercial property owners, but sometimes also households, farmers, apartment building owners, and public property owners. The objective of the leasing BM is to provide access to a solar PV system for electricity production and consumption. The solar PV system is installed at the customer's property and the leasing providers assumes responsibility for technology ownership and all downstream value chain activities, including monitoring, operations, and maintenance of the solar PV system. In exchange, customers grant access to their roofs and enter into a lease arrangement in which they agree to make periodic payments for using the solar PV system over a certain period (e.g., 5, 10 or 20 years).

EPC stands for engineering, procurement, and construction, and is often associated with large-scale construction projects. *The EPC BM* resembles the turnkey BM in that it provides customers with a complete solar PV system through a hassle-free process. However, while both of these solar BMs perform the same activities in the downstream value chain, the EPC BM is oriented towards large-scale solar PV systems (i.e., industrial- and utility applications) and targets large businesses, utilities, and industrial property owners. The complexity of large-scale solar PV systems (e.g., solar parks) also require solar firms to have more financial resources and partnerships with e.g., grid-operators, municipalities, landowners, and local communities.

Similarly, *the PPA BM* resembles the leasing BM in terms of solar PV system ownership and activities performed in the downstream value chain but differ in terms of solar PV system size (i.e., application), project complexity, and targeted customer segments. The PPA BM provides customers with access to solar electricity from large-scale solar PV systems (e.g., solar parks) and primarily targets large business. Customers enter into an agreement in which they agree to purchase the produced electricity over a set period (e.g., 10, 15, 20 years) through periodic payments. The scale of operations also necessitates PPA providers to form partnerships with different actors (e.g., financial institutions, grid-operators, and landowners).

The results show that there is a mismatch between how solar BMs are described in the literature and how they are used by firms on the market. While the energy policy literature focuses on roles, activities, and applications of solar PV deployment, firms design their solar BMs with customers in mind, and how they can fulfill their needs as a way to capture value. For instance, solar firms distinguish between farmers, apartment building owners, commercial property owners, and municipalities, and tailor their BMs to address the needs of each customer segments, whereas the energy policy literature views these customers as one cohesive group of "commercial" adopters. Moreover, while the community solar BM has received much attention among policymakers and in the energy policy, it was not used by any of the studied firms. This does not imply that there are no community-owned solar PV systems in Sweden or no firms are involved with constructing such solar PV systems, only that the solar firms do not design their BMs to target this specific customer segment.

These findings imply that solar BMs need to be understood both from a theoretical and empirical perspective and that it is essential for policymakers and energy policy scholars to consider the rationale of firms in order to better understand how to facilitate solar PV diffusion by targeting different adopters. In particular, Paper I identifies six main types of solar BMs and underlines the importance of better understanding how firms design their strategies and what influences firms to develop certain solar BMs. The findings also points to the significance of having the necessary resources and capabilities available for market actors to realize specific BM, and this an area in which policymakers can contribute.

## 4.2. PAPER II

Paper II draws on the growing stream of research on sustainable BMs to explore what different types of sustainable BMs firms pursue and what BMI strategies they use to realize these BMs. By reviewing and analyzing 87 cases of firms innovating towards sustainable BMs in recently published empirical studies, four main sustainable BM types were identified: sustainable BMs that 1) involve *improvements towards efficiency*, 2) are based on *new ways of making business sustainable*, 3) have a *stronger orientation towards the environment and/or society*, and 4) are “*born” sustainable*. These sustainable BMs differs in terms of how they contribute to sustainability compared to traditional BMs (Fig. 4).

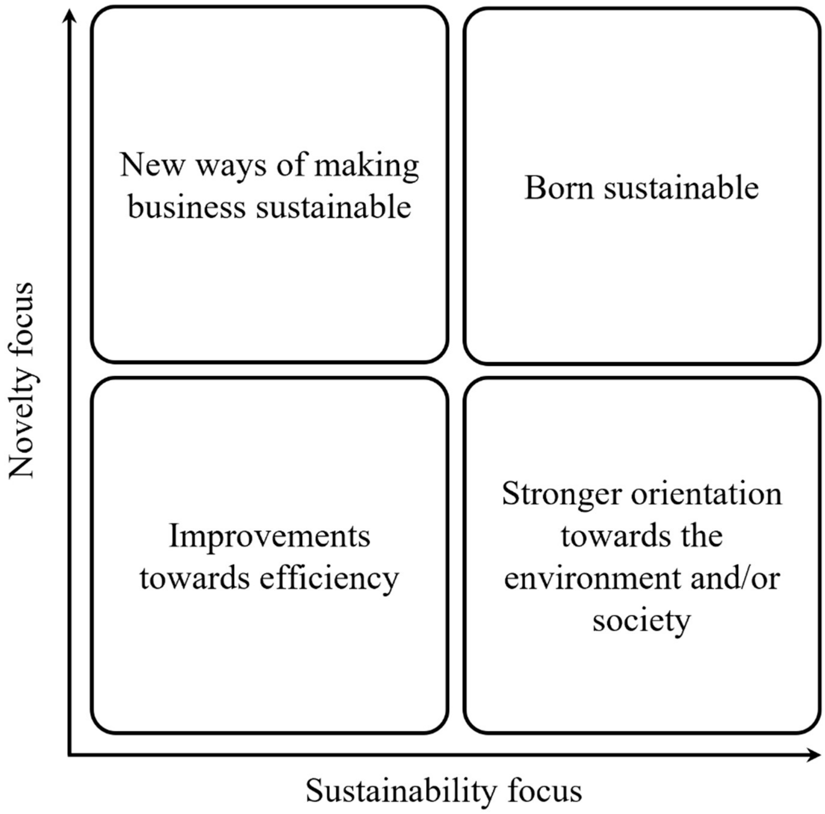


*Figure 4. Primary focus of sustainable BM types (own illustration).*

Sustainable BMs that involve improvements towards efficiency attempt to reduce firms’ negative impact on the environment, e.g., by increasing the use of renewables or by minimizing consumption and waste in the production and delivery processes. Sustainable BMs that are based on new ways of making business sustainable, instead incentivize reduced consumption or more efficient use of products by offering products as services (e.g., lighting as a service rather than lightbulbs), enabling product sharing, or promoting product life extension (e.g., slow fashion). Sustainable BMs with a stronger orientation towards the environment and/or society promote closer collaboration and consideration of stakeholders, e.g., through shared ownership structures. Lastly, sustainable BMs that are born sustainable have a sustainable raison d’être and are created with the purpose to solve a sustainability issue and contribute to the environment and/or society (e.g., social enterprises).

The findings also show four recurring strategies that firms use to innovate towards these sustainable BMs, namely boundary spanning, experimentation, the use of practical tools and guidelines, and corporate management strategies. Boundary spanning strategies involves making changes in the BM that broadens the firm boundaries in a way that ensures more equal distribution of value and power among stakeholders. This includes promoting shared ownership structures, long-term agreements, education, partnerships, and sharing platforms. While boundary spanning strategies have a strong sustainability focus, experimentation strategies are instead commonly used to innovate BMs in general. In terms of achieving sustainable BMs, different experimentation strategies include making sequential or iterative changes to the BM, using pilot projects and test groups, and testing new organizational forms, materials, technologies, or processes. The use of practical tools and guidelines instead support firms in imagining and designing sustainable BMs as well as identifying potential challenges with implementing these BMs, whereas corporate management strategies focus on managing changes that sustainable BMs imply, e.g., by creating a new vision, leading-by-example, or involving employees in the BMI process.

Many firms were found to combine several of these different strategies, especially experimentation and boundary spanning. Interestingly, some strategies were used more frequently to achieve certain sustainable BMs. For instance, boundary spanning strategies appear to be better suited for achieving sustainable BMs that have a stronger orientation towards the environment and/or society, which makes sense given that these sustainable BMs aims to expand traditional firm boundaries to create and share value among different stakeholders.

However, in many cases it is difficult to determine if sustainability was the driving force that motivated these firms to innovate towards sustainable BMs or if they were simply trying to grow their businesses through BMI. The sustainability commitment of firms with sustainable BMs can thus be questioned, especially if sustainability is simply used as a selling point for a BMI initiative that might, in fact, have a lower impact on sustainability than alternatives. This topic requires further investigation, especially considering that most strategies have also been associated with innovating BMs in general, with the exception of boundary spanning that has a clear sustainability focus.

In conclusion, Paper II presents managers with a straightforward portfolio of different sustainable BMs and BMI strategies that can be used to realize them. The findings also stress the importance for future research to be clear in their distinctions between the BMI and sustainable BM concepts. BMI does not automatically lead to BMI, and vice versa.

## 4.3. PAPER III

By studying 12 firms in the Swedish solar PV industry, Paper III explores how firms in the same institutional and market context perceive and react to factors influencing BMI. The results complement previous studies on drivers and barriers of BMI by identifying five overarching factors that influence BMI relating to the market, technology, institutions, partnerships, as well as firm capabilities and strategy. A total of 17 sub-factors were identified, as shown in Table 5. Several factors have been highlighted in previous literature, but others, like institutional voids, are not as well-known. In response to these factors, firms were found to innovate their BMs by changing one or several BM components. These include changing the scope of the offer, limiting or expanding the targeted customer segments, making changes to key resources or partnerships, as well as changing the financial structure of the BM.

*Table 5. Firms' perceptions and reactions to factors that influence BMI.*

| Factor | Sub-factor | Perception | Reaction |
|---|---|---|---|
| Market | Competition | Threat | BMI and status quo |
| | Customer demand | Threat and opportunity | BMI and status quo |
| | Customer characteristics | Threat | BMI and status quo |
| | Lack of intermediaries | Opportunity | BMI |
| | Foreign market | Opportunity | BMI |
| Technology | Price | Threat and opportunity | BMI and status quo |
| | Complementarities | Opportunity | BMI |
| Institutions | Policies | Threat and opportunity | BMI and status quo |
| | Regulation | Threat and opportunity | BMI and status quo |
| | Institutional voids | Threat and opportunity | BMI and status quo |
| Partnerships | Financial | Threat and opportunity | BMI and status quo |
| | Operational | Threat | BMI and status quo |
| | Resource-based | Opportunity | BMI |
| Firm capabilities and strategy | Resources | Opportunity | BMI and status quo |
| | Capabilities | Opportunity | BMI and status quo |
| | Management experience | Opportunity | BMI |
| | Vision and strategy | Opportunity | BMI |

Much of previous research on BMI suggests that factors either drive or hinder firms in their attempts to create new BMs or change their existing ones. In contrast, the findings of Paper III show that the same factor can act as both driver or barrier of BMI and that firms perceive the same factors differently. For instance, many firms considered the ability to form financial partnerships as an opportunity that triggered them to innovate their BMs. Yet, the demands and preferences of the partner firms also restricted the design space of the BMs, e.g., by limiting the customer segments that can be targeted. This suggests that the influence on BMI is not as straightforward as previously assumed (i.e., in that it either drives or hampers BMI). Instead, the same factor can be considered as both a driver and barrier depending on how it is perceived.

Moreover, the results show that even factors that are perceived in the same way can lead to different firm reactions. As shown in Table 5, some firms chose to innovate their BMs in response to an influence whereas others remained status quo. For instance, two solar firms reacted in opposite ways in response to the opportunity of increased customer demand, while one firm extended its offer to meet the demand, another chose not to address it on the basis that a new offer would be misaligned with their existing BM. Firms that decided not to act in response to a factor often showed a clear logic behind their decision, which points to the importance of considering firm agency and rationale when studying factors that lead to BMI or status quo.

Paper III also nuances previous assumptions that status quo is a sign of firm rigidity or conservatism by showing how firms that reacted by keeping status quo made attempts to change their external environment to make it more favorable for new types of BMs. For instance, firms used their resources and capabilities to educate customers of the benefits of a new BM or to lobby for changes in regulation and policies to enable the use of such BM.

In sum, these findings contribute to a deeper understanding of factors that influence BMI and how firms perceive and react to such factors. Paper III shows that the agency and rationale of firms are important aspects to consider in order to understand how and why firms react to stimuli in different ways in their BMI processes. Furthermore, it underlines that status quo cannot be equated to firm rigidity or inertia and that, instead of looking at drivers and barriers of BMI, future research should focus on perceived drivers and barriers, as well as how cognitive processes influence firm decisions related to BMI or status quo.

# 5. DISCUSSION

To better understand the role of BMs in large-scale diffusion of solar PV, the aim of this thesis is threefold: first, to identify what BMs firms use to commercialize solar PV and how these BMs can be differentiated, second, to explain the prevalence of different solar BMs, and finally, to show how an increased understanding of solar BMs can contribute to policy design. This chapter develops the answers to the research questions by synthesizing the findings of the appended papers and discussing them in relation to the theoretical framework. The following sections (5.1-5.3) address one research question each.

## 5.1. DIFFERENTIATING BETWEEN SOLAR BUSINESS MODELS

The thesis shows that there are different ways in which solar BMs can be differentiated, both in terms of the types of solar BMs that are discussed in the energy policy literature and by solar firms on the market (Paper I), and in relation to how solar BMs contribute to sustainability (Paper II).

### 5.1.1. *SOLAR BUSINESS MODEL TYPES*

The results show that the theoretical understanding of solar BMs differs from the way solar firms describe their BMs (Paper I). In the energy policy literature, solar BMs are characterized based on roles (e.g., Huijben and Verbong 2013), activities (e.g., Schoettl and Lehmann-Ortega 2011), and application (e.g., Burger and Luke 2017). While this categorization provides a systemic understanding of different ways in which solar PV can be deployed, it lacks an actor perspective that explains how different firms create, deliver, and capture value (Teece 2010) in such deployment. In contrast, this thesis shows that solar firms use their BMs to describe how they communicate their offers to customers, organize their activities and resources, and create value for their customers and themselves. As such, they have a stronger focus on customers and how firms can capture value by addressing customers' needs, as presented in the general BM literature (e.g., Richardson 2008).

Moreover, the thesis identifies six solar BM types that firms use to commercialize solar PV: consulting-, technology provision-, turnkey-, leasing-, EPC-, and PPA BMs (Paper I). By combining the system perspective on solar BMs from the energy policy literature and the actor perspective from the BM literature, these solar BMs are differentiated based on their value proposition, value creation and delivery system, and value capture, as well as the roles, activities, and application related to solar PV deployment. By differentiating between solar BMs in this way, the thesis highlights important issues that have been overlooked by previous research.

First, it shows that firms who take the same roles and perform the same activities in the solar PV value chain can have distinctly different solar BMs. For instance, the leasing- and PPA BMs that are commonly viewed as variants of the TPO BM in the literature (e.g., Strupeit and Palm 2016), are found to target distinctly different customer segments, operate at different scales, and require different resources, capabilities and partnerships from the firms that use them. As such, they have different ways of creating and delivering value which implies that they are distinct solar BMs, not variants of the same BM. While this distinction might seem trivial, it does in fact have a significant impact on how solar BMs are used to understand technology diffusion. For instance, the leasing BM primarily targets commercial property owners, farmers, households, apartment- and public property owners, whereas the PPA BM targets large businesses. Hence, if policymakers want to understand how to reach the adoption group of large businesses though TPO solar PV systems, there is little value in examining firms with a leasing BM.

Second, the thesis shows that solar firms are more detailed in their customer segmentation compared to the BMs described in literature. For instance, the energy policy literature considers farmers, apartment-, public-, and commercial property owners to be one cohesive customer segment that can be targeted using a commercial application BM (e.g., Burger and Luke 2017). Solar firms, on the other hand, view these as distinctly different customers and develop tailored offers to meet their specific needs, such as individual electricity billing solutions for apartment building owners or impartial consultation during tendering for public property owners.

Third, it is interesting to note that none of the firms included in the study had a community solar BM, even though it has received considerable attention in the energy policy literature (e.g., Tongsopit, Moungchareon et al. 2016, Herbes, Brummer et al. 2017, Nolden, Barnes et al. 2020). This does not mean that community solar PV systems do not exist in Sweden, only that the solar firms do not target communities as a customer segment. For technology diffusion, these findings implies that firms can facilitate solar PV diffusion by designing their BMs to address the needs of specific adopter groups, but at the same time they might also hamper diffusion among other adopter groups by not targeting them (e.g., as shown in the community solar example).

5.1.2. *SOLAR BUSINESS MODELS AS SUSTAINABLE BUSINESS MODELS*

By showing different ways in which firms' BMs are sustainable (Paper II), this thesis provides a new perspective on how to differentiate between solar BMs that does not appear to have been discussed in previous literature. Through a review of recently published empirical studies of firms that have innovated their BMs to achieve sustainable BMs, four recurrent sustainable BM types were identified. These BMs are seen as sustainable because they either 1) involve improvements towards efficiency, 2) are based on new ways of making the business sustainable, 3) have a stronger orientation towards the environment and/or society, or 4) are "born" sustainable.

Looking at solar BMs through the lens of this model (see Fig. 4 in section 4.2.), most solar BMs can, to some extent, be seen as sustainable BMs because they increase the use of renewables (e.g., Bocken, Short et al. 2014, Khripko, Morioka et al. 2017) which falls under the umbrella of the sustainable BM type that implies improvements towards efficiency. However, solar BMs such as leasing and PPA contribute to sustainability in a different way and would thus rather be classified as sustainable BMs that are based on new ways of making business sustainable. This is because, by providing solar PV functionality rather than ownership, these BMs incentivize reduced resource consumption and enhanced product durability (Tukker 2004, Bocken, Short et al. 2014). A community solar BM could, similarly, be seen as an sustainable BM that has a stronger orientation towards the environment and/or society since it promotes shared ownership and closer collaboration between stakeholders (e.g., Lüdeke-Freund, Carroux et al. 2018).

Considering that much of the interest in solar PV diffusion is motived by the need to slow down climate change (Jacobsson and Bergek 2011, IEA 2021), it could thus be relevant to differentiate solar BMs based on, not only how they contribute to solar PV diffusion, but also how they contribute to sustainability.

## 5.2. EXPLAINING SOLAR BUSINESS MODEL PREVALENCE

In relation to solar BM prevalence, this thesis shows that both firm-internal- and contextual factors influence the prevalence of solar BMs, not primarily one or the other as previously suggested in much of the BM- and energy policy literature (e.g., Chesbrough 2010, Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016, Teece 2018). This stresses the importance of considering both an actor-and system perspective for understanding BMs' role in large-scale diffusion of solar PV.

### 5.2.1. *FIRM-INTERNAL INFLUENCE*

The findings illustrate that the resources, capabilities, and networks needed to realize different solar BMs differs depending on the complexity and size (i.e., application) of solar PV projects (Paper I). For instance, solar BMs like EPC and PPA that require large financial resources, capabilities to construct large and complex solar PV systems, and vast networks and partnerships with utilities, grid-operators, landowners, etc. are less prevalent on the Swedish market compared to similar BMs, such as turnkey and leasing, that are smaller in scale and complexity. This underlines the importance of firm-internal influence on the choice and design of solar BMs.

In line with e.g., Casadesus-Masanell and Tarziján (2012), the thesis also shows that solar firms often use complementary BMs in parallel and build on their existing resources and capabilities to operate on different markets simultaneously (Paper I). For instance, several solar turnkey providers were found to operate on the electrical installation market and many of these firms had often started out as pure electrical installation providers before venturing into solar PV. This finding supports previous studies that suggest that firms tend to innovate close to their existing BMs (e.g., Bohnsack, Pinkse et al. 2014) and that strategic fit is an important factor to consider when it comes to BM choice (Altunay, Bergek et al. 2021). Firms' resources, capabilities, partnerships, and strategies can thus, to some extent, explain why some solar BMs are more prevalent than others.

In terms of the influence of strategy on BM choice and design, the results particularly show that firms differs in the strategies they use to make their BMs (more) sustainable (i.e., choosing sustainable BM), but also in the strategies they use to develop and implementing such sustainable BMs (i.e., BMI approach) (Paper II). For instance, a social enterprise is more likely to develop a sustainable BM that is "born" sustainable than a sustainable BM that implies improvements towards efficiency because its overall goal and strategy is to solve a sustainability issue, not only reduce their negative impact on the environment and/or society (e.g., Davies and Doherty 2019). Similarly, a firm that aims to develop a sustainable BM with stronger orientation towards the environment and/or society will more likely use a boundary-spanning BMI strategy, such as shared ownership or long-term agreements, to achieve the sustainable BM than, for example, an experimentation strategy (although the two strategies are not mutually exclusive). In particular, firms use boundary-spanning, experimentation, practical tools and guidelines, and corporate management strategies to innovate towards sustainable BMs. These strategies have previously been identified in BM literature as ways to achieve “general” BMI (e.g., Chesbrough 2010, Bojovic, Genet et al. 2018, Amit and Zott 2020), with the exception of boundary-spanning that has clear sustainability motives (Brehmer, Podoynitsyna et al. 2018).

When looking at solar BMs from this perspective, the strategies that firms use to achieve sustainable BMs can provide some insights into why solar BMs like leasing and PPA are scarce in Sweden and why none of the solar firms in the study had a community solar BM. For instance, the findings show that firms often use boundary-spanning strategies to realize sustainable BMs that focus on shared ownership (Paper II), such as the community solar BM. A lack of boundary-spanning strategies and incentives to engage with a larger group of stakeholders among Swedish solar firms could thus be a potential explanation as to why none of the studied solar firms used a community solar BM. Although boundary-spanning strategies and BMs with shared ownership structures have been the focus of studies in the literature on sustainable BMs (e.g., Brehmer, Podoynitsyna et al. 2018, Gallo, Antolin-Lopez et al. 2018, Stubbs 2019), it does not appear to have been explored in relation to BMs for solar PV or other RETs in the energy policy literature. It thus provide a relevant topic for future studies to explore.

Another potential explanation for the lack of community solar BMs among the studied solar firms in Sweden is that the solar firms simply lack motives for developing a sustainable BM with a stronger orientation towards the environment and/or society (Paper II). For instance, unlike firms in many other industries, solar firms might not feel the pressure to develop different types of sustainable BMs since they already provide a “sustainable” product in the form of solar PV. The reason that other types of sustainable BMs (e.g., leasing- and PPA BMs) are used by some solar firms in Sweden could be more connected to the innovativeness of these BMs (e.g., Drury, Miller et al. 2012) than their sustainability ambitions. Considering that community solar BMs appear to have a strong sustainability focus (e.g., Herbes, Brummer et al. 2017), its absence among the studied solar firms may be explained by a lack of sustainability as a main driving force for their BM design. As highlighted by Ciulli and Kolk (2019), it is difficult to determine if the solar firms developed sustainable BMs with the intention to increase their positive impact on the environment or if they were primarily motivated to grow their business through BMI. All in all, this points to the importance of considering firms’ strategies and rationales for understanding which solar BMs firms will develop.

Building on this idea, the thesis also complements previous studies on drivers and barriers of BMI (e.g., Chesbrough 2010, Bocken and Geradts 2020) by identifying factors that influence solar firms’ decisions to develop or change their BMs (Paper III). In terms of firm-internal factors, results show that the BMI decisions of solar firms are influenced by their resources, capabilities, partnerships, and strategies, which correspond to the factors that were found to influence the prevalence of different solar BMs (Paper I). In line with Ode and Wadin (2019), the findings also show that the previous experience of manages can influence the design of solar BMs. For instance, one solar firm decided to design its BM to target professional customer based on the manager’s previous B2B experience.

In contrast with much of previous literature on drivers and barriers of BMI (e.g., De Reuver, Bouwman et al. 2009, Sosna, Trevinyo-Rodríguez et al. 2010, Guldmann and Huulgaard 2020), the results show that the same factor can be perceived both as a threat and as an opportunity by different solar firms (Paper III). For instance, financial- and operational partnerships are necessary for firms to be able to realize certain solar BMs, but the preferences and demands of partner firms are also found to limit the design space of the BM, e.g., by restricting the customer segments targeted. These findings challenge the predominant assumption in the BM literature that the influence on BMI is binary (i.e., it either drives or hinders BMI) and implies that a more nuanced perspective is needed. In line with Saebi, Lien et al. (2017), this thesis argues that, instead of referring to drivers and barriers of BMI, it may be more appropriate to discuss perceived drivers and barriers. In terms of explaining the prevalence of different solar BMs, these findings show that it is of utmost importance to consider the agency of firms as well as their attributes in order to understand what influences them to develop certain solar BMs.

### 5.2.2. *CONTEXTUAL INFLUENCE*

Apart from showing the influence of firm-internal factors on how solar firms choose, design, and change their BMs, this thesis also shows how contextual factors related to institutions, the market, and technology influence the prevalence of solar BMs. The findings show that solar firms in Sweden primarily use solar BMs that are oriented towards host-ownership and residential- and commercial solar PV system application, whereas TPO and large-scale applications are only used to a limited extent (Paper I). This illustrates the impact that policies have on the prevalence of solar BMs since, during the past decade, Swedish polices have been targeted at households and small property owners through investment subsidies (Lindahl, Berard et al. 2021). While these findings are in line with previous studies in the energy policy literature (e.g., Huijben, Verbong et al. 2016, Tongsopit, Moungchareon et al. 2016, Burger and Luke 2017) it contributes to existing research by underlining the magnitude that policies have on the prevalence of solar BMs, both in terms of the number and variety of different solar BMs.

Apart from policies, the findings also show that other institutional factors (e.g., regulation and institutional voids) as well as contextual factors related to the market (e.g., competition, customer demand, customer characteristics, lack of intermediaries and foreign market) and technology (e.g., price and complementary technologies) influence how solar firms innovate their BMs (Paper III). This confirms the results of previous studies on factors that influence solar BM prevalence in the energy policy literature (e.g., Richter 2013, Huijben, Verbong et al. 2016, Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016, Altunay, Bergek et al. 2021), but adds to the existing understanding of how these contextual factors influence the decision-making of firms.

For example, in response to a legislative plan in the EU to establish a new role called balance service provider (BSP) on the electricity market, a Swedish solar energy management firm saw the opportunity to exploit their existing capabilities and technology complementarities and thus started to develop their BM to become a BSP. However, due differences between EU legislation and Swedish regulation, the solar energy management firm was not permitted to become a BSP since only utilities are legally allowed to have this role in Sweden. As a way to circumvent this institutional void, the solar energy management firm decided to partner up with utilities in order to be able to learn about the BSP role before Swedish regulation was harmonized with the EU legislation. This example illustrates how contextual factors like regulation, technology complementarities, and institutional voids (as well as firm-internal capabilities) influence how solar firms innovate their BMs, but also how firms perceive and react to these factors.

In fact, the thesis shows that firms not only perceive the same factor differently (i.e., threat or opportunity), but they also react differently to factors that are perceived the same way, where some solar firms innovate their BMs and other keep status quo (Fig. 5) (Paper III). This is in agreement with recent studies in the BM literature (e.g., Osiyevskyy and Dewald 2015, Saebi, Lien et al. 2017, Osiyevskyy and Dewald 2018, Osiyevskyy, Sinha et al. 2021) that show how both perceived threats and perceived opportunities can lead firms to either innovate their BMs or not. For instance, in response to the perceived opportunity of increased customer demand, one solar firm innovated its BM by expanding the offer to address the demand whereas another solar firm chose not to make any changes in its BM on the basis that the demand did not align with its existing offer.

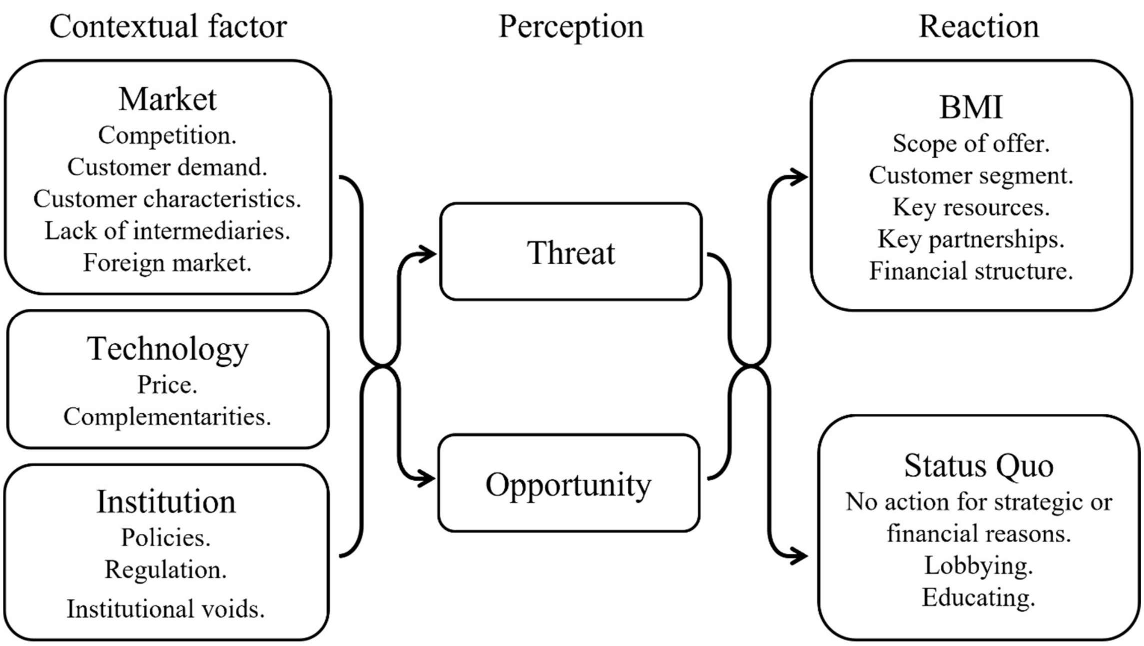


*Figure 5. Firm perceptions and reactions to contextual factors influencing BMI [3].*

Interestingly, while the decision to not act in response to a contextual factor may seem unexpected, the solar firms had clear motives for doing so. In fact, all studied solar firms showed a clear logic behind their actions regardless of whether they decided to innovate their BMs or not (Paper III). The motives behind their decisions related to e.g., their stakeholder strategy, vision, corporate identity, or the economic viability of the new BM. This points to the importance of considering firms' agency in relation to contextual factors in order to better understand how contextual factors influence the prevalence of solar BMs.

[3] Own illustration that is adapted from Figure 2 in Paper III.

The thesis also provides a more nuanced perspective on firms' decisions to keep status quo in response to threats and opportunities, compared to what is commonly assumed in the BM literature. While the lack of BMI in response to contextual influence is often seen as a sign of firm rigidity or limited entrepreneurial thinking in previous studies (e.g., Osiyevskyy and Dewald 2018, Osiyevskyy, Sinha et al. 2021) the findings show that status quo is not necessarily synonymous with inertia or conservatism (Paper III). As a matter of fact, many of the studied solar firms that did not innovate their BMs instead attempted to make changes in their environment, e.g., by lobbying for more favorable policies or by educating customers on the benefits of their offers. In the energy policy literature, such behavior is often associated with a stretch-and-transform strategy (e.g., Smith and Raven 2012, Huijben, Verbong et al. 2016) that aims to change the contextual conditions to better suit the characteristics of the firm and its BM. In comparison to the more commonly used fit-and-conform strategy (in which the firm attempts to alter its BM to match the context), the stretch-and-transform strategy is considerably more radical (Smith and Raven 2012) and not a sign of firm rigidity or inertia. Huijben, Verbong et al. (2016) also show that firms design their solar BMs differently depending on which of these strategies that they take, which suggest that a mix of strategies, as shown in this thesis, could lead to a greater variety of solar BMs.

## 5.3. CONTRIBUTIONS TO POLICY DESIGN

By exploring the solar BMs that firms use to commercialize solar PV in Sweden and the factors that influence their prevalence, this thesis contributes to policy design in several ways. In particular, it shows that policymakers could benefit from considering solar BMs from both an actor- and system perspective in order to develop effective policy instruments aimed at facilitating large-scale diffusion of solar PV.

### 5.3.1. *POLICY DESIGN FROM AN ACTOR PERSPECTIVE ON BUSINESS MODELS*

The thesis shows that there is a mismatch between the way solar BMs are understood theoretically in the energy policy literature and the BMs that are used empirically by solar firms (Paper I). While theoretical solar BMs are characterized by roles, activities, and application in relation to solar PV deployment, empirical solar BMs focus on specific customer needs and how solar firms can create value for themselves by fulfilling these needs. This implies that policymakers need to gain a better understanding of the perspective of solar firms if they want to stimulate solar PV diffusion by attracting new types of adopters or increase the use of certain solar BMs. The risk is otherwise that policymakers overestimate the influence of certain solar BMs in solar PV diffusion (as the example of the community solar BM in Sweden) or misinterpret the impact that some policies have on the market.

The findings also show that the empirical solar BMs that are seen as variants of theoretical solar BMs (e.g., leasing- and PPA as types of TPO BMs), constitute distinct solar BMs because they target different customer segments, require different resources and capabilities, and operate at different scales (Paper I). Basing policy decisions on the current theoretical solar BMs is thus a missed opportunity for enabling diffusion among adopters with more specific needs (e.g., apartment building owners or public property owners). These findings also highlight the importance of policymakers being aware that the profiles of solar firms that focus on large-scale solar PV systems (e.g., EPC- and PPA BMs) differ from those that carry out similar activities on a smaller scale (e.g., turnkey- and leasing BMs). For instance, due to differences in economic stability and/or financial mechanisms, some solar firms are more sensitive to policy changes than others and may thus take different risks and react differently to incentives. This implies that there is no one-size-fits-all solution and that targeted incentives that address the prerequisites of different firms might be more suitable if policymakers want to stimulate solar PV diffusion through different solar BMs.

Moreover, the findings show that only a limited number of solar firms in Sweden possess the necessary capabilities to offer large-scale solar PV systems (Paper I). The fact that these capabilities are concentrated among very few actors could indicate a weakness in the energy system. This is something that policymakers need to consider if they want to encourage larger solar PV projects. The fact that different solar BMs require different competences, and that solar firms often build on their existing resources and capabilities to exploit synergies between solar BMs and other types of BMs (e.g., electrical installation BMs) also have consequences for policy design. In particular, it is essential that policymakers understand that they have a role to play in ensuring that the necessary resources and capabilities are available to actors on the solar PV market and that these can be reallocated from other markets. Considering that the Swedish solar PV market is experiencing exponential growth (Lindahl, Berard et al. 2021) it is crucial that the resources and capabilities needed for a rapid scale-up of solar PV diffusion are available on the market. This could be achieved by setting up educational programs and promoting competence development at e.g., employment agencies.

The thesis also contributes to policy design by showing that firms use different strategies for innovating their BMs towards sustainable BMs, where boundary spanning strategies are associated with achieving sustainable BMs that are based on shared ownership (Paper II). A potential explanation for why none of the studied solar firms used a community solar BM could be due to a lack of boundary-spanning strategies among solar firms and that they do not view community groups as an attractive customer segment. Considering that the community solar BM has received much attention among policymakers and energy policy scholars for its potential to democratize access to solar PV (e.g., European Commission 2017, Nolden, Barnes et al. 2020, Cohen, Azarova et al. 2021) it is essential that policymakers gain a better understanding of firms' rationale for developing (or not developing) BMs that involve shared-ownership, like community solar BMs. However, as underlined by Ciulli and Kolk (2019) it is difficult to know what motivates firms to develop sustainable BMs. It cannot be assumed that sustainability is the main motivation simply because a firm has a type of sustainable BM. Neither should it be assumed that all firms are exclusively motivated by economic gains, e.g., as shown in studies on firms that adopt RETs (Bergek and Mignon 2017). Hence, if policymakers want to increase the share of community groups among solar PV adopters, a starting point could be to develop policies that aim to increase the demand from community groups to make them interesting for solar firms to target. Policymakers could also directly target solar firms by incentivizing them to engage in boundary-spanning activities.

The thesis also shows how solar firms both perceive and react differently to contextual and firm-internal factors (Paper III). This illustrates how difficult it can be for policymakers to achieve the desired impact of policies and to anticipate how market actors will react. It is thus important for policymakers to understand that solar firms perceive and react to policies in different ways – some firms respond by making changes in their BMs, others do not respond at all, and some even work actively to change the policies. Although firm reactions may seem unpredictable, there is in fact often a clear logic that lies behind the decision. In an attempt to better predict how firms will perceive and react to certain policies, policymakers should strive to understand the strategies and rationale of firms with different solar BMs. This could be achieved through increased transparency and communication with solar firms and industry associations.

### 5.3.2. *POLICY DESIGN FROM A SYSTEM PERSPECTIVE ON BUSINESS MODELS*

From a system perspective, while previous studies have shown that policies influence the viability of certain solar BMs (e.g., Burger and Luke 2017, Herbes, Brummer et al. 2017, Karneyeva and Wüstenhagen 2017), this thesis illustrates the magnitude of the effect that policies have on solar BM prevalence, both in terms of scale (i.e. which BMs that are widely used) and in terms of portfolio (i.e., how many different BMs that are used). The findings show that, by targeting households and small property owners with investments subsides, Swedish policymakers have incentivized solar BMs that are focused on small-scale solar PV systems and host-ownership (Paper I). As a consequence, solar BMs that are orientated towards e.g., large-scale solar PV systems and TPO have been used to a significantly lower extent in Sweden, since they become less competitive (Overholm 2015).

While this implies that the demand for solar PV among adopters that have the ability and preference to own a solar PV system can be met faster in the short-term, it also means that diffusion occurs at the expense of adopters with other needs and preferences. This might, in turn, have negative consequences for large-scale diffusion of solar PV in the long-term since many solar firms will have to change their BMs once the demand for solar PV has been saturated among the initially targeted adopter group (and we know that firms often struggle to make such changes (e.g., Johnson, Christensen et al. 2008)). In order to stimulate a faster and more widespread diffusion of solar PV, policymakers should therefore attempt to design policy instruments in a way that enables a more equal diffusion of solar PV among adopter groups. In the Swedish context, this could, for instance, be achieved by encouraging solar firms or other actors to take on solar PV system ownership. In a larger context, these findings highlight the importance for policymakers to have a good understanding of the BMs that solar firms use in order to discern the influence that policies have on solar firms, their BMs, and the customer segments they target.

Moreover, by stimulating host-ownership of solar PV systems, policymakers also make it less appealing for solar firms to develop BMs that contribute to sustainability in different ways. While all solar BMs can classify as sustainable BMs since they increase the use of renewables, the findings show that some solar BMs also contribute to sustainability in additional ways, for instance by incentivizing enhanced product durability (e.g., leasing- and PPA BMs) and shared ownership (e.g., community solar BMs) (Paper II). Although the sustainability dimensions of solar BMs are not directly linked to the diffusion of solar PV, they are relevant for the overall objective of transitioning towards more sustainable societies (UN 2022). For instance, the community solar BM is seen by policymakers as having an important role in democratizing the energy system and encouraging people to participate in the energy transition (e.g., European Commission 2017, Cohen, Azarova et al. 2021). As such, it could be beneficial for policymakers to consider, not only how the prevalence of different solar BMs can facilitate diffusion among different adopter groups, but also how these BMs contribute to fulfilling other sustainability targets.

Although much of previous energy policy literature has emphasized the influence of contextual factors on solar BMs (e.g., Huijben, Verbong et al. 2016, Strupeit and Palm 2016, Tongsopit, Moungchareon et al. 2016, Burger and Luke 2017), this thesis illustrates the hampering effects of e.g., institutional voids or lack of policy stability and predictability (Paper III). This calls for increased transparency and communication with market actors about the long-term objectives and strategies that guide policy design. Furthermore, the influence of complementary technologies (e.g., energy storage solutions and electric vehicle charging) necessitates a holistic policy approach that takes into account how support for one complementary technology affects the diffusion of others.

# 6. CONCLUSIONS, IMPLICATIONS, AND FUTURE RESEARCH

## 6.1. CONCLUSIONS

The aim of this thesis was to increase the understanding of the role that BMs can play in large-scale diffusion of solar PV by answering the research questions: 1) What BMs do firms use to commercialize solar PV and how can these BMs be differentiated? 2) What explains the prevalence of different solar BMs? 3) How can an increased understanding of BMs in the context of solar PV contribute to policy design? By drawing on the learnings from diffusion of innovation theory, innovation systems theory, BM literature and energy policy literature, this thesis highlights that an integrated actor- and system perspective is needed. Through a qualitative research approach, involving a literature review of 87 empirical cases of firms innovating towards sustainable BMs, and a case study based on two expert interviews, mapping and analysis of 241 solar BMs, and interviews with 12 founders/managers of solar firms in Sweden, this thesis reached several results that contribute to an increased understanding of BMs' role in large-scale diffusion of solar PV.

With regard to the BMs firms use to commercialize solar PV, six main types of solar BMs were identified, namely the consulting-, technology provision-, turnkey-, leasing-, EPC-, and PPA BMs. These are differentiated based on their value proposition, value creation and delivery system, and value capture (i.e., actor perspective) as well as their roles, activities, and application related to solar PV deployment (i.e., system perspective). The prevalence of these solar BMs were found to differ greatly in Sweden, where solar firms primarily use BMs that are oriented towards small-scale solar PV systems and host-ownership (e.g., turnkey BMs) and only a few firms use solar BMs that focus on large-scale solar PV systems and TPO (e.g., PPA BMs). The thesis also found that solar BMs can be distinguished based on their sustainability focus. From this perspective, solar BMs can be considered sustainable BMs that either 1) imply improvements towards efficiency, 2) are based on new ways of making business sustainable, 3) have a stronger orientation towards the environment and/or society, or 4) are "born" sustainable.

In relation to the prevalence of different solar BMs, solar BMs were also found to be influenced by both firm-internal and contextual factors that determine how solar firms innovate their BMs in terms of designing and changing BM components. From an actor perspective, the findings show that solar firms need certain resources, capabilities, and partnerships for realizing specific solar BMs, and that management experience and firm strategies influence firms' decisions related to BMI. In particular, firms were found to use different strategies for innovating their BMs towards sustainability, where some strategies were more frequently used to achieve certain types of sustainable BMs. These strategies include boundary spanning, experimentation, the use of practical tools and guidelines, and corporate management strategies.

From a system perspective, factors related to the market (e.g., competition and customer demand), technology (e.g., price and complementarities), and institutions (e.g., policies and regulations) were found to influence how solar firms innovate their BMs. Interestingly, solar firms perceive and react to firm-internal factors and contextual factors differently, where the same factor can be perceived both as a threat and an opportunity by different firms and lead to either BMI or status quo. Notably, firms who react by not engaging in BMI often have a clear logic for this, and some firms instead attempt to make changes in their contexts.

Finally, these findings contribute to policy design by showing that policies have great influence on the prevalence of solar BMs, both in terms of the number of different solar BM types that exist on a market and to what extent these are used. This implies that policymakers need to have a good understanding of the solar BMs that exist on a market, especially in terms of the customer segments that they target and the rationale and strategies of the solar firms that use these BMs. Moreover, the results imply that policymakers have a role to play in ensuring that solar firms have access to resources and competences that are needed to realize and scale up different solar BMs. Policymakers might also want to consider how sustainable different solar BMs are in order to stimulate firms with more ambitious sustainability undertakings.

## 6.2. IMPLICATIONS FOR MANAGERIAL PRACTICE

In terms of implications for managers, the thesis provides an increased awareness of the different solar BMs that firms can pursue in solar PV. For instance, due to the complexity of projects, EPC- and PPA BMs require specific competences which means that firms with such solar BMs can expect higher value capture than e.g., leasing- and turnkey BMs. Moreover, solar BMs are also found to target specific customer segments, where the needs of some potential customers, such as community groups, are unaddressed on the Swedish solar PV market. Considering the interest that the community solar BM has received among policymakers and in the energy policy literature (European Commission 2017, Cohen, Azarova et al. 2021), this provides an opportunity for solar firms to occupy a wanted market need.

Solar BMs are also sustainable in different ways, where most solar BMs are considered sustainable because they increase the use of renewables. However, solar firms can also be more ambitious with how their BMs contribute to sustainability, for instance by developing BMs that involve TPO, such as leasing- and PPA BMs, or BMs that are based on shared ownership, like the community solar BM. For firms that are looking to innovate towards sustainable BMs, a portfolio of strategies for how to develop and implement sustainable BMs is present, which can facilitate the process of BMI for managers. For instance, managers should be aware that boundary-spanning strategies are particularly suitable for achieving sustainable BMs with a stronger orientation towards the environment and/or society (e.g., BMs that are based on shared ownership). Hence, if a solar firm wants to develop a community solar BM, boundary-spanning strategies could be a suitable approach to achieve it.

An increased understanding of solar BMs from a system perspective also has implications for managerial practice, especially in terms of the influence that contextual factors have on the viability of different solar BMs. For instance, the thesis demonstrates the impact that policies have had on the prevalence of different solar BMs on the Swedish market, where some solar BMs (e.g., the turnkey BM) have been greatly facilitated and others (e.g., the leasing BM) are hardly competitive. For managers of solar firms, this result points to the importance of being aware of the effects that policies can have on the competitiveness of certain BMs and to be informed on the objectives that guide policy design.

The findings especially highlight the consequences of contextual influence on solar BMs and how firms innovate their BMs in response. Hence, it is of utmost importance that managers of firms in solar PV or similarly institutionalized industries are aware that market demand is, to some extent, fabricated. The demand can therefore change very quickly in response to changes in regulations or policies. To handle such conditions, managers might be required to diversify their businesses to reduce risks and be proactive in making changes to their BMs. However, solar firms are not limited to making changes in their own BMs since the dynamic nature of the market also provides opportunities for managers to create more favorable external conditions for their BMs, e.g., by lobbying for changes in regulations. It is thus essential that managers understand the role that their firms' BMs play in diffusion of solar PV and how contextual factors influence their businesses.

## 6.3. IMPLICATIONS FOR FUTURE RESEARCH

By identifying six types of BMs that firms use to commercialize solar PV and showing how these can be differentiated, the thesis contributes to the energy policy literature. More specifically, it highlights the importance of considering both an actor- and system perspective on solar BMs in order to understand how solar firms resemble or differ in terms of targeted customer segments, offers, capabilities, partnerships, roles, sustainability impact and/or intent, as well as synergies with parallel BMs. In turn, this has implications for research on large-scale diffusion of solar PV since the lack of incentives for firms to use a specific solar BM means that certain adopter groups might not be targeted, or that solar BMs with a greater sustainability impact might not be used to the same extent as a less sustainable one. This stresses the importance for future research to pay greater attention to the strategies and rationale of firms in relation to policy design.

Moreover, the thesis contributes to energy policy literature by showing how firm-internal- as well as contextual factors influence the prevalence of solar BMs. Solar firms are found to react very differently in response to e.g., changes in polices, which implies that it is difficult, if not impossible, to predict how firms will perceive and react to external stimuli. The findings suggest that decision-making related to BMI depends on firms' rationale and strategies, which calls for further research aimed at better understanding the decisions and cognitive processes that influence the design and development of solar BMs. The thesis also contributes to the BM literature by challenging previous assumptions that status quo is a sign of firm rigidity or inertia, and instead shows that firms can use their resources and capabilities towards making the external environment more favorable for new BMs. This opens up for future studies to nuance the concept of firm rigidity and explore reasons for firms to keep status quo.

In terms of theoretical implications related to large-scale diffusion of technology, demand-side firms are shown to play an important part in facilitating technology diffusion by targeting the needs of different adopter groups through their BMs. Contextual and firm-internal factors do, however, greatly influence which BMs are used, and consequently which adopter groups that are being target. Given that the prevalence of solar BMs differs between contexts (e.g., Strupeit and Palm 2016) it is expected that the solar BM types that are prevalent in Sweden may differ from solar BMs in other countries. Further empirical studies that explore this topic in other contexts are therefore needed to address this limitation. It could, for instance, be interesting to compare the emergence of solar BMs in different contexts and investigate the relative importance of contextual factors on this emergence.

To address another limitation of this study and to further improve the understanding of large-scale diffusion of technology, future research should also explore other actors in technology diffusion. While this thesis has focused on demand-side firms that are involved with technology deployment, and previous studies have focused on adopters' role in large-scale technology diffusion (e.g., Mignon 2016), a technological innovation system consist of many more actors that could be relevant for understanding technology diffusion (e.g., Figure 1, section 2.1.). For instance, even though policymakers are seen as key actors in technology diffusion (e.g., Grubb 2004, Bergek, Jacobsson et al. 2008), much of the research on solar BMs make assumptions on how policymakers behave without explicitly asking them. Hence, by taking an empirical approach to better understand the role of policymakers in technology diffusion, future studies could shed light on potential mismatches between policymakers' perceptions and behaviors and theoretical understandings in the energy policy literature.

There are also opportunities for future research to explore the dynamics between actors, networks, and institutions in the technological innovation system during large-scale diffusion. Future research could, for instance, explore how different demand-side actors interact around a BM and how such interactions influence the prevalence of different BMs. Moreover, future research could explore why adopters choose to adopt a technology like solar PV through a specific BM, in order to better understand how the matchmaking between technology and adopter can be achieved through different actors in the technological innovation system.

### 6.3.1. *NEXT STEPS*

In terms of potential avenues for my remaining PhD studies, there are especially two topics that I am currently considering to explore further. The first topic concerns how different demand-side actors collaborate around solar BMs. It has been suggested by previous studies in the BM- and energy policy literature that several actors may be needed to realize a BM (e.g., Berglund and Sandström 2013, Huijben and Verbong 2013), and in my studies I have noticed that some of the rarer solar BMs in Sweden appear to rely on more actors than those that are used by many solar firms. It would therefore be interesting to deepen the understanding of the actors and networks that are required to realize a solar BM, how these configurations differ between solar BM types, and if/how this influences the prevalence of solar BMs on a market.

For the second topic, I would like to address one of the limitations of this thesis by comparing solar BMs in Sweden with another country to explore differences in national and institutional contexts. It would also be interesting to study solar PV adopters, especially in terms of why they choose to adopt solar PV from a specific solar firm or through a certain BM.

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