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Thanh Thao Pham

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ECOLE DOCTORALE ORGANISATIONS,
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Thèse de doctorat en Sciences de Gestion

Menée au Laboratoire Interdisciplinaire Sciences Innovations Sociétés
(LISIS) de l'Université Paris-Est

Soutenue par Thanh Thao PHAM

**STRATEGIES DE SURVIE ET DE
CROISSANCE DANS UN CONTEXTE DE
TURBULENCE.
LE CAS DES PETITES ET MOYENNES ENTREPRISES
DANS LE PHOTOVOLTAIQUE**

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Les propos ici tenus n'engagent que son auteur.

Résumé

Stratégies de survie et de croissance dans un contexte de turbulence.

Le cas des petites et moyennes entreprises dans le photovoltaïque.

L'objectif de la thèse est d'enquêter sur les capacités de survie des acteurs opérant dans un segment fragmenté d'une chaîne de valeur, en l'occurrence le photovoltaïque, dont la partie aval subit des turbulences. En particulier cette étude porte sur les entreprises privées de petite taille, de technicité moyenne ou faible. Des entretiens suivis d'une étude quantitative sur 103 firmes ont été réalisés.

Les trois principales contributions sont les suivantes.

Premièrement, une nouvelle taxonomie de diversification industrielle est proposée basée sur les frontières du marché et de l'industrie. Il en découle quatre possibilités : (1) entreprises non-diversifiées ; (2) entreprises diversifiées au sein d'une même industrie ; (3) entreprises diversifiées dans deux industries ; et (4) entreprises diversifiées dans plus de deux industries.

Deuxièmement, quatre business models correspondent à ces quatre possibilités, me permettant de démontrer qu'il existe un nombre limité de business model dans une industrie.

Finalement, j'ai identifié deux facteurs impactant les capacités de survie et la performance de croissance des entreprises à moyen terme : l'horizon stratégique des managers et le temps de réponse. Il en découle quatre trajectoires de performance. Il est également montré que les entreprises ayant les meilleures profitabilités avant la crise optent pour une stratégie de réduction qui a pour effet de réduire leur profitabilité. Inversement, celles qui ont une profitabilité moins bonne au début s'engagent dans de gros investissements, sous condition de ressources, résultant en une meilleure profitabilité. Cela conduit à une homogénéisation des taux de retours.

Mots clés : chaînes de valeur mondiales, photovoltaïque, business model, stratégies de diversification, redressement, capacités de survie, petites et moyennes entreprises.

Abstract

Survival and growth strategies in the context of a turbulent environment.

The case of small and medium enterprises in the photovoltaic industry.

The overall objective of this thesis is to investigate the survival capacities of actors operating in the photovoltaic industry, that is to say, in a fragmented segment of a value chain whose end-markets experienced turbulence. I intend to contribute to a better understanding of the diversification strategy of: (1) smaller and private firms; (2) non-or-low-tech companies; (3) in a specific economic environment (i.e. the context of turbulence). I conducted interviews and realized a quantitative study of 103 firms.

The contributions are threefold.

First, I propose a new taxonomy of industrial diversification based on the frontier of an industry and a market. Four possibilities derive from the intersection of intra- and inter-industry diversification: (1) single-business enterprises; (2) intra-industry diversifiers; (3) inter-industry diversifiers in two industries; and (4) inter-industry diversifiers in more than two industries.

Second, I identify four business models that derive from these four strategies, which allows me to argue that there can only be a limited number of business models in an industry.

Finally, this study identifies two factors impacting a firm's survival capabilities and growth performance of SMEs in the medium term resulting in four growth performances: (1) the managers' business horizon focus, and (2) timing of business responses. The results show four trajectories of firm performance. Moreover, while higher performers are more inclined to engage in retrenchment strategies that reduce their overall performance, lower performers tend to invest large amounts, resulting in a better performance. It results in a homogenization of firm performance over time.

Key words: photovoltaic, global value chain, business model, diversification strategies, turnaround, survival capacities, SMEs

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None of us, acting alone, can achieve the success.

Nelson Mandela

Other things may change us, but we start and end with family.

Antony Brandt

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1. Background

Energy is one of humankind's main preoccupations. In the last decades, there have been growing concerns regarding shortages of certain resources (e.g., crude oil), not to mention environmental degradation (notably from coal). There is a wide consensus among policymakers, notably at the European Commission (as illustrated by the Horizon 2020 program), that the energy industry must respond adequately and rapidly to rising power demand, uncertainty in commodity pricing, and tougher environmental requirements. To tackle these urgent needs, systematic attention has been devoted to a search for effective alternatives, particularly technologies that enable more sustainable energy production and consumption. This doctoral thesis deals with one specific technology which commercial age started in 1954: solar photovoltaic (PV) cells. In a nutshell, this technology converts solar energy into electricity. A PV system consists of PV modules, inverters, batteries and a mounting structure. Extra-terrestrial and other terrestrial applications such as small mobile devices are not considered here.

PV generation is a promising option and has distinguished itself from the other clean energy sources for mainly two reasons. Firstly, its generation is mainly distributed (i.e. electrical generation performed by small grid-connected generation units, typically up to 50MW). Secondly, not only is this technology recent but it is also experiencing the fastest growth of all the renewable energy sources (REN21, 2016, p. 29). The number of distributed solar PV installations is rising rapidly across the world. As PV technology matures, it has the potential to provide a significant and increasing share of the international community's electricity demand.

Paradoxically, even though PV energy has been technically possible for many years and there seems to be a demand for it, its exploitation has not yet become a dominant solution. One of the main reasons for this is the cost, despite it having dropped substantially over the years (e.g., SETIS, 2011). Another significant reason is the wide technological variations that exist (IEA-ETSAP and IRENA, 2013, p. 1; International Energy Agency, 2010, p. 7; van de Kaa et al., 2014). Currently, five main commercial technologies compete in the global PV market, and many others are arriving. The last significant reason for this paradox is that the PV market has experienced setbacks.

It is worth considering more closely the latter point. For years, government subsidies and other demand-driven policies (the most important of which are feed-in-tariffs and the obligation of power utilities to buy excess power from customers at relatively high prices) created a financial windfall for energy producers (be they companies or individuals). The result was a proliferation of companies engaging in the PV downstream market – and consequently fraudulent offers as well. This scramble among companies to enter the PV market created confusion and a tremendous financial burden on Governments. In response, in many countries, including Germany and France, Governments implemented a drastic reduction of these financial subsidies from the years 2010-2011 (ADEME, 2011; Fulton and Mellquist, 2011). Specifically, in addition to reducing such supports, the French Government, through a moratorium at the end of the year 2010, temporarily suspended the obligation of Electricité de France (EDF), the main French utility, and other local distribution companies to purchase electricity generated from solar sources. It was furthermore decided that no more new PV projects superior to 3 kWp could be permitted during this period, except for residential installations.

This abrupt and unforeseen policy change, called policy inconsistency, led to a turbulent time for the solar market. The impact of this turbulence was evident on both sides of the market: supply and demand. As subsidies dwindled, companies struggled financially to make up for revenue lost after the moratorium, and some of them exited the market. This was the case throughout the PV value chain, despite the differences between the two parts of the chain (IEA PVPS, 2016a; Platzer, 2015). In the upstream part, which is highly technological, concentrated, and global, only a handful of large and multinational manufacturers dominate the segment. On the other hand, the downstream part is occupied largely by local, low-tech companies and, service providers. This segment is much more fragmented: in France alone, the number of actors is in the thousands, even after the moratorium (ADEME, 2017; ADEME and IEA PVPS, 2016).

It is certain that rigor struck the PV market seven years ago, but time and strategy changes allowed some of them to survive and grow. The ecology of population literature has shed light on the need for enterprises in the affected industry to develop new skills to respond to the new environment. The turnaround literature focuses on the development of new strategies in this context. Adaptation is a matter of time. But the speed and effectiveness of developing new skills of adapting new strategies quickly after a market shock has been shown to influence the survival capacity of many actors (Cooper and Schendel, 1976; Mitchell and Singh, 1996, p. 174; Nelson and Winter, 2004). By survival capacity, I mean “the capacity of an actor (e.g., company) or a group of actors to stay in operation ‘alive’ when confronted by forces that tend to destroy them” (Camarinha-Matos and Afsarmanesh, 2008, p. 256). Also, how managers envision the future when the crisis occurs may influence the speed of recovery (Mitchell and Singh, 1996, p. 174). The survival capacities of businesses facing a sudden turbulence are the subject of this doctoral study.

It is worth pointing out that the global value chain literature does not provide clues to understand the survival capacities of enterprises, especially in a fragmented segment not dominated by large firms. In fact, this literature eclipses sectors that are not dominated by powerful actors, namely lead firms, which determine the division of labor. This is unfortunate because modular global value chains where no-lead-firm actors orchestrate at least a part of the value chain are not a rare occurrence. In such cases, there is value in looking at what is going on through the lenses afforded by a complementary theory.

This thesis focuses on strategic behavior in general and on diversification strategies in particular as a primary determinant of survival in a context of turbulence. The link between survival and diversification, while intensively examined, has been overlooked in many respects.

Firstly, empirical studies on diversification in general, and on the diversification-performance relationship in particular, predominantly focus on large and publicly traded companies (Ramanujam and Varadarajan, 1989; Robson et al., 1993; Stern and Henderson, 2004, p. 488). Thus, small firms' diversification strategies are neglected, with few exceptions such as in the work of Robson et al. (1993) and Stern and Henderson (2004). This is unfortunate as the results could be entirely different from the well-studied perspective of large corporations. That is to say that the likelihood of diversification strategy success, i.e. the survival rate, of these two populations is different (Stern and Henderson, 2004, p. 488; Zahavi and Lavie, 2013, p. 978).

Furthermore, diversification strategy has been studied extensively for high-technology firms (Colombo et al., 2014; Tanriverdi and Lee, 2008; Zahavi and Lavie, 2013), while efforts to better understand the challenges related to the impact of diversification strategy on the survival of non-or-low-tech companies have been virtually inexistent.

Finally, although the question of the performance of diversification strategy is in many respects an age-old question, it does not yet enjoy consensus. I believe that this is due to the general context of earlier studies, and therefore consider that the question merits examination in a specific situation: the context of turbulence. Most studies, such as Rumelt (1974), investigate diversification performance in a period characterized by stability, low inflation, and low-interest rates. Conversely, the Michel and Shaked (1984) study involves a period of high uncertainty due largely to the oil shock. It ends with a conclusion in stark contrast to that of Rumelt (1974): unrelated diversifiers outperform related diversifiers in terms of risk returns. As a result, the question in a situation of turbulence may also lead to a different set of results than those reached in a stable environment.

2. Research question and objectives

Against this backdrop, in the wake of the recent PV market crisis and from the perspective of smaller and non-or-low-tech actors, the overall objective is to investigate the survival capacities of actors operating in a fragmented segment of a

value chain whose end-markets experienced turbulence. This poses the following central question:

Which strategies are the most rewarding for the survival and growth of small, private, non-or-low- tech companies in response to turbulence?

It follows that this doctoral thesis addresses three shortcomings. I intend to contribute to a better understanding of the diversification strategy of: (1) smaller and private firms; (2) non-or-low-tech companies; (3) in a specific economic environment, which is the context of turbulence. In order to address the question, I will draw elements from the literature on global value chains, strategies, and business models. Considering that the context of the study, i.e. turbulence, "moves away from everyday phenomena" (Eisenhardt and Graebner, 2007, p. 28), I undertook an exploratory study.

3. Contributions

The contributions of the doctoral thesis are threefold.

First, I propose a new taxonomy of industrial diversification considering the porosity of value chains. In particular, some activities in the PV value chain are common to another value chain. Admittedly, the literature of industrial diversification is full of categories, all based on the relatedness concept between business lines. The most popular are the ones of Wrigley (1970) and Rumelt (1974). Yet, the concept is challenging as it lays on subjectivity and required detailed information about the repartition of a firm's revenues between the various business lines. This raises two issues: replicability and private firm information accessibility. To overcome these limitations, I build my taxonomy based on the frontier of an industry and market instead of relatedness. Four possibilities derive from the intersection of intra- and inter-industry diversification: (1) single-business enterprises; (2) intra-industry diversifiers; (3) inter-industry diversifiers in two industries; and (4) inter-industry diversifiers in more than two industries.

For deepening my understanding of firm's survival capacities, I draw on the business model literature as a business model is a reflection of the strategy which the company has implemented (Casadesus-Masanell and Ricart, 2010). For this purpose, drawing from the business model canvas of Osterwalder et al. (2010), I elaborate a model of ideal business model based on value propositions, key activities, channel, partner network, and key resources. It results from the study that all but the 'channel' component are characteristic for at least one strategy. That is to say, I also contribute in testing the assertion of Teece (2010) and Baden-Fuller and Morgan (2010), that is there is only a limited number of business models in an industry, and confirm the argument of Casadesus-Masanell and Ricart (2010).

Specifically, four ideal business models derive from these four strategies: the PV specialized-based business model (BM1) for single-business enterprises; the energy-based business model (BM2) for intra-industry diversifiers; the complementary function-based business model (BM3) for inter-industry diversifiers in two

industries; and the general-purpose products business model (BM4) for inter-industry diversifiers in more than two industries. Considering the insensibility of inter-industry diversifiers in more than two industries regarding the PV market crisis, I do not study this case.

Finally, I also establish a link between industrial diversification, business model and, growth performance. A review of the turnaround literature shows that a firm's survival capabilities and performance may depend on not only the business horizon focus of managers largely depending on a firm's capacity to change (cf. resources), but also the timing of business responses. It identifies two possible reactions: retrenchment (i.e. cost efficiencies, asset retrenchment, focus of firm's core activities; (Schoenberg et al., 2013) and investment strategies (i.e. investment, innovation, and diversification into new markets; Civi, 2013; Hayter, 1985; Kitching et al., 2009; Pearce and Michael, 2006, 1997; Roberts, 2003; Sands and Ferraro, 2010).

The first one is by far the most popular strategy especially in the short run (Geroski and Gregg, 1997), but results in limiting their potential gains from the PV market upturn. The two variables (i.e. business horizon focus and timing of business responses) lead to four performance growth groups. What is striking is that there is no perfect match between a class performance growth and a business model. However, there is a general trend. BM2 firms, and to a lesser extent BM1, tend to start the period with a low performance but increase it over time thanks to investment strategies. Conversely, BM3 companies were the best performers in 2010 but decrease their level due to retrenchment strategies. A linked result is that the performance range between groups reduced with the crisis. The results obtained contradict those of Geroski and Gregg (1997).

4. Structure

This doctoral thesis is composed of seven chapters, which can be grouped into three parts. The first three chapters lay the theoretical foundations of my doctoral research. In part 2, Chapter 4 provides details of the methodological work. The last part, which contains Chapter 5 to 7, presents the results.

In Chapter 1, my attention is on the global value chain literature. Specifically, this chapter shows that global value chain scholars are interested in various industries (e.g., automobile, apparel, and vegetables) but have almost exclusively investigated the power exercised by lead firms (i.e. a handful of large companies determining the division of labor). Lead firms are primarily active in unipolar value chains, whose governance is hierarchical.

It is worth noting that previous studies on global value chains have been unsatisfactory for analyzing modular value chains (i.e. the internal workings of a value chain segment are highly independent of those of the other segments) since their stories and potentially their governance are totally different. It follows that little is known about modular value chains. I, therefore, intend to fill this gap with the case of the PV value chain. The PV value chain is interesting for my research as it is modular.

This characteristic offers a wide variety of governance and presumably a segment without lead firms. This leads us to Chapter 2.

After outlining the specific features of the PV technologies and value chain, Chapter 2 concludes that, at first glance, the global value chain literature is insightful for the study of the upstream PV value chain. As the upstream part is governed largely by lead firms, studying this segment fits into the mainstream global value chain research. Turning to the downstream segment, in many countries the industry encompasses a large number of actors, mainly new entrants. Unlike traditional electricity production, small players (i.e. small and medium enterprises and local communities) occupy center stage in this segment. None of the large companies in the downstream segment could be considered as lead firms. This suggests that the global value chain literature does not explain the downstream situation.

Considering that the energy sector is a regulated market, investigating the impact of government policies provides important insight to understand the proliferation of actors, be they small or large, in the downstream part. This is the topic of Chapter 3. Specifically, this chapter describes the regulatory framework as the main driver for the development of PV technologies and markets. In particular, based on the French and German cases, it draws attention to the variation of the regulatory framework that has resulted in turbulence. The lack of policy consistency in many countries (e.g., on-again-off-again renewable energy policies) is considered to demonstrate the indirect impact of demand-focus policies on the number of actors in the downstream segment. In the midst of the chaos, few companies have managed to make their mark. One may wonder what makes some actors able to survive. That leads my research to the question of survival capacities.

In particular, six hypotheses are elaborated and presented in Chapter 4. This chapter also presents the design of my research on these questions. Specifically, I used a mixed method with a qualitative research based on 18 interviews as a preliminary phase. The first and foremost conclusion drawn from these interviews is that companies adopted various strategies when confronted with declining prospects in the PV market. The common thread is diversification, be it industrial, vertical, or global. Departing from this first step, I elaborated six hypotheses.

Considering that I did not want to confine the research to a descriptive approach, I also undertook quantitative research on the capacities of firms that enable them to recover from the turbulence. This was the second step. The objective of the quantitative phase was to enrich my research, based on the analysis of the recovering capacities of diversified, small and medium companies in the context of turbulence. The emphasis here is on SMEs and the French situation.

For this purpose, the six hypotheses were tested on a six-year longitudinal sample of companies (from 2010 to 2015). I used a sample of companies listed from two significant databases of French PV-based enterprises. The initial sample considered 276 enterprises operating in the PV value chain, from which 103 firms met the criteria required for inclusion in this research.

To have a closer look at the actors populating the downstream segment of the PV value chain, I examine their industrial diversification strategies, as this is the strategy of choice for many companies seeking to enhance their performance, if not to

survive. Looking at this issue from the standpoint of diversification strategy should allow us to deepen our understanding of this diversity of actors and industry structure. Specifically, [Chapter 5](#) relates to the classification of diversification strategies.

It is worth pointing out that classifications of diversification strategies proposed in the literature are criticized on the grounds of being based on subjectivity and therefore not being appropriate for the study of small and medium-sized private companies. I devised my own taxonomy to overcome these shortcomings, distinguishing between intra- versus inter-industry diversification, rather than related versus unrelated diversification.

I also drew on the business model literature, as the business model is a reflection of the actual strategy that is implemented (Casadesus-Masanell and Ricart, 2010). This implies that there are as many business models as there are strategies. Furthermore, as suggested by Teece (2010) and Baden-Fuller and Morgan (2010), there is only a handful of business models in an industry. This confirms the possibility of a taxonomy. The chapter ends with the classification of firms on the basis of the intra- and inter-industry diversification distinguishing four possibilities. Chapter 5 lies the basis on which I will test my first hypothesis on classification.

Having presented the taxonomy of industrial diversification strategies, I was able to highlight commonalities and divergences between business models and resources of the panel, in [Chapter 6](#). Hypotheses 1 to 5 are addressed in this chapter.

Note that, as the main focus of this thesis is the impact of turbulence on companies' strategy and positioning, exiting companies and the industrial strategy type (and therefore its respective business model) that is the most independent of the PV market evolution (i.e. inter-industry diversifiers in more than two industries) have been excluded. A total of 70 firms corresponding to three business model types are analyzed.

I have proposed my own criteria inspired by the Business Model Canvas of Osterwalder et al. (2010) to describe the business model of the three remaining types. This results in a clearer picture of the observed abundance of actors in the downstream segment of the PV value chain. Some criteria have proved to be more relevant than others, depending on the business model type.

The question of the performance of a business model or of diversification strategies remains unanswered. It is to this point that the last chapter is devoted. In [Chapter 7](#), I quantitatively analyze the strategic performance growth of the companies in the three most PV market-dependent types. Specifically, five accounting performance indicators and their respective growth between 2010 and 2015 are studied. The evolution of performance sheds light on four different performance scenarios which I first describe, before seeking to link strategies, business model, and performance growth.

Part 1 – Analytical framework

Chapter 1: The overlooked topics in the global value chains framework: the governance of multipolar, modular chains and of fragmented segments

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Résumé

Chapitre 1 : Les zones d'ombre dans l'étude des chaînes de valeur mondiales : la gouvernance des chaînes multipolaires et modulaires et des segments atomisés

Les chaînes de valeur mondiales (*global value chains* en anglais) sont notre point de départ dans ce travail de thèse. Elles proposent un cadre d'analyse de l'organisation des industries au niveau mondial et de leurs évolutions. Plus précisément, elles s'intéressent au pouvoir, à la gouvernance et aux dynamiques des chaînes dans un contexte international. Ce cadre d'analyse prend tout son intérêt dans un contexte de fragmentation des chaînes de valeur remarquée depuis les années 1980. En d'autres termes, ces chaînes sont devenues plus géographiquement dispersées et l'organisation de la production et de la distribution plus fragmentée.

La littérature propose cinq modes de gouvernance : par le marché, modulaire, relationnel, captif et hiérarchique. Chaque mode a son ou ses "gouvernant(s)". Il est important de préciser que dans une chaîne de valeur modulaire où les différents maillons évoluent indépendamment des autres, plusieurs modes de gouvernance peuvent coexister.

Un état de l'art des recherches précédentes permet de mettre en lumière l'attention quasi-exclusive portée sur des industries, certes variées, mais dont le point commun est le pouvoir détenu par une poignée d'acteurs, nommées firmes motrices (*lead firms* en anglais), sur l'ensemble de la chaîne de valeur. Cette configuration fait référence aux situations de monopole et d'oligopole. Ces firmes motrices jouent le rôle de chef d'orchestre et définissent ainsi la division du travail.

Il est important de souligner que ces firmes motrices peuvent partager leur pouvoir de gouvernance avec des acteurs tant internes (tels que des fournisseurs) qu'externes (tels que des institutions ou gouvernements) à la chaîne de valeur. Dans ce cas on qualifie ces chaînes de multipolaires, à opposer à unipolaire quand seules les firmes motrices tiennent les rênes.

Cependant, les chaînes de valeur multipolaires ou celles marquées par l'absence des firmes motrices sont peu abordées par la littérature. Or, elles sont bien plus complexes à étudier que les chaînes unipolaires. De plus, les situations de forte compétition sont également négligées par les chercheurs. Ce chapitre propose donc de mettre en lumière ces lacunes et l'importance de les combler.

Ce chapitre attire donc notre attention sur la gouvernance de chaînes de valeur modulaires caractérisées par un marché très concurrentiel sur au moins une partie de la chaîne, autrement dit sans firme motrice comme gouvernant. Pour illustrer cette situation, nous nous intéresserons à la chaîne de valeur du photovoltaïque. Ce sera le sujet du Chapitre 2.

The individual has always had to struggle to keep from being overwhelmed by the tribe.
Nietzsche

Introduction

Competition is no longer confined within national boundaries but, instead, is spreading across country boundaries. The trend is not new, as internationalization has been observed since at least the 17th century (Gereffi et al., 2001, p. 1). Interestingly, what differentiates the current era of 'globalization' from the earlier era of 'internationalization' is the functional integration of internationally dispersed activities (Ponte and Sturgeon, 2014, p. 197). Technology transfers (through acquisitions, importation of manufacturing equipment, and talent recruitment) have modified a lot the industry structure, with new market entrants from developing countries (Gallagher and Zhang, 2013, p. 15;19). It is worth pointing out the significant, yet still increasing, participation in manufacturing activities from Asia.

This geographic spread implies long-distance business relationships with legally independent firms. The Global Value Chain (GVC) literature is very insightful to examine the ease with which companies establish and manage such business relationships (Humphrey and Schmitz, 2001, p. 20; Ponte and Sturgeon, 2014, p. 198). Specifically, its interest is in the governance of globally dispersed and organizationally fragmented production and distribution networks over time.

Prior research of GVCs illustrates the wide variety of interest regarding the industry: e.g. automobile (Sturgeon et al., 2008), electronics (Sturgeon, 2002), apparel (Schmitz and Knorringer, 1999), horticulture (Dolan and Humphrey, 2000), garments (Gereffi, 1999), and coffee production industry (Fitter and Kaplinsky*, 2001). These industries are characterized by a handful of powerful companies, namely lead firms, which determine the division of labor. It follows that the GVC studies mainly analyze the power exercised by these powerful actors. In other terms, the literature pays scant attention to the governance of GVCs with no lead firm. This first chapter aims to underline this gap and highlighting the importance of filling this gap.

For this purpose, Section 1 analyzes and traces back the origin of the concept of GVC. Particularly, I present related pieces of literature to clarify the notion of GVC along with the 'upgrading' concept. Section 2 describes the different types of GVC structure resulting from the changes in the organization of global industries over time, notably the chain structure shifts into buyer-like one. Particularly, I will steer the attention on the most disaggregated chain structure, which is the modular value chain. Modular value chain is of particular interest as it implies the independence of each stage of a value chain and then enables some linkages to be governed without a single lead firm. Reckoning that actors are at the heart of the governance issue, lead firms, along with the other players impacting the GVC, are exposed in the following section. Considering that the GVC structure variety discussed in Section 2 implies governance variety, I address the governance topic in Section 4. Finally, I establish the conclusions that can be drawn from the chapter.

1. Globalization and Production: Global Commodity Chains (GCC), Global Value Chain (GVC) and Global Production Networks (GPN)

1.1. Origins of GCC

In past decades, some phenomena resulted in an increasing globalization of value chains in general (Organisation for Economic Co-operation and Development, 2008, p. 21). Among others, there are three well-acknowledged factors. Firstly, an increasing number of low-cost suppliers come from emerging countries with significant industrial capacity, especially China and India. Secondly, technological progress, in particular, the development of information and communication technologies (ICTs), coupled with market deregulation, offers significant possibilities of offshoring services. Thirdly, improved transport facilities make the economic question of geographical distances more easily surmountable (Organisation for Economic Co-operation and Development, 2008, p. 22). These changes have resulted in an international expansion and geographical fragmentation of supply chains.

To grasp these world economy changes and the dynamics of new power games, a direct tie was missing between the concept of value-added chain and global organization of industries (Gereffi et al., 2005, p. 82). Aiming at filling this gap, in their seminal book, “Commodity chains and global capitalism”, Gereffi and Korzeniewicz (1994), generate an analytical framework: Global Commodity Chains (GCCs)¹. A commodity chain designates “a network of labor and production processes whose end result is a finished commodity” ((Hopkins and Wallerstein, 1986, p. 159). “The whole range of activities [is] involved in the design, production, and marketing of a product” (Gereffi, 1999, p. 1).

A notion that is at the heart of GCC is upgrading. Upgrading studies focus on the strategies used not only by firms and groups of firms but also countries, regions, individual localities and other economic stakeholders to maintain or improve their relative competitive positions in the global economy (Gereffi and Fernandez-Stark, 2011, p. 12; Ponte and Sturgeon, 2014, p. 196). The notion of ‘upgrading’ is intrinsically related to the first reason for the development of GCC literature. Indeed, initially, while it is always the case, the focus of research work was on how and why developing countries and economies in transition integrate the GCC. That is why the GCC topic aroused such great excitement among researchers and international organizations in connection with economic development, encompassing the WTO, the World Bank, and the OECD (Gereffi and Lee, 2012, p. 24).

¹ Their work drew on the multiple works of Wallerstein and Hopkins on the world-system theory.

These strategies result in a shift between different stages of the chain. This change aims at increasing either value creation or value learning, or both. Gereffi et al. (2001, p. 6) distinguish various types:

1. Product upgrading designates a move made by firms into more sophisticated product lines.
2. Process upgrading is achieved through superior technology or reorganizing the production systems leading to a more efficient transformation of inputs into outputs.
3. Intra-chain upgrading encompasses the functional upgrading (i.e. the acquisition of new functions in the chain), the upgrading via vertical integration (i.e. the move upstream or downstream to different stages in a supply chain) and, the network upgrading (i.e. the diversification of buyer-supplier linkages).
4. Inter-chain upgrading refers to a competence acquired in a particular function of a chain, which has been applied to a new sector.

1.2. From GCC to GVC

Since the book of Gereffi and Korzeniewicz (1994), numerous contributions have been made to the GCCs literature, whose name has evolved to 'global value chains' (GVCs). The name change occurred due to numerous critics about the name (Ponte and Sturgeon, 2014, p. 202; Vind and Fold, 2007, p. 70). Indeed, the term 'commodities' leads to misunderstandings due to popular connotations with undifferentiated products. Ponte and Sturgeon (2014, p. 202) specify that this confusion is particularly observable with primary commodities, including crude oil and bulk agricultural goods.

The term 'value' is preferred as it refers to the 'value added' concept and refocuses to the main sources of economic development, that are of human effort and capital². Furthermore, Gereffi et al. (2001, p. 2) spotted 'incomplete' firms that have specialized in certain value chain functions, to be opposed to complete firms which are vertically integrated within the chain. Thus, GVC is defined as "a full range of activities that firms and workers perform to bring a specific product from its conception to its end use and beyond" (Gereffi and Fernandez-Stark, 2011, p. 4).

² It is of utmost importance to distinguish GVC literature from related concepts, including the "value chain" of (Porter, 1998a). On the one hand, (Porter, 1998a) defines the value chain internal to a company. This is to say that it takes into consideration 'complete' firms that internalize all the business functions. On the other hand, a series of articles use the term 'value chain' preceded by global (Gereffi et al., 2001; Gereffi and Fernandez-Stark, 2011) to describe a broader situation than the one proposed by Porter.

1.3. Similarities and differences

Undoubtedly, GVC and GCC have a common theoretical background, which is the world-systems theory of Wallerstein but differ in their approach (Vind and Fold, 2007, p. 70). To a lesser extent, another related strand of literature is also of interest for this comparison work: 'global production network' (GPN). A production network is defined as "a set of inter-firm linkages that bind a group of companies into larger economic groups (Sturgeon, 2001). Therefore, it seems that the framework of both GVC and GPN is an extension of the GCC's one. Precisely, there is a gray line between the GCC, GVC, and GPN pieces of literature. The following table should allow the reader to grasp the similarities and differences between them easily.

It is evident from Table 1.1 that when observing the definitions, the researchers are all talking about the same thing. However, a few differences emerged between the three strands of literature along four criteria.

First, Gereffi et al. (2001, p. 2) shed light on the difference of the unit of analysis: the firm for GCC and the chain or organizational network for GVC. Specifically, Gereffi and Lee (2012, p. 25) state that the new framework evolved and now focuses on "globally expanding supply chains and how value is created and captured therein." This focal point refers to the 'business model' concept, as value creation and value capture are the two dimensions of business activity that help to build and sustain a competitive advantage (Teece, 2010).

Second, while the GCC framework pays particular attention to the internal explanatory factors for industry dynamics, GVC and GPN frameworks take into consideration all influences from the exterior, in addition to the internal actors and factors to the chain. Precisely, the GVC literature took a bold step in taking a broader interest in the contextual, developmental and strategic issues than the GCC approach did, and raised interest in the characteristics of inter-firm relationships (Ponte and Sturgeon, 2014, pp. 202–203; Vind and Fold, 2007, p. 70).

A similar extension was applied to production networks on both the unit of analysis (shift from the firm to the production network) and the limit of the framework (the inclusion of the external environment). On the one hand, Borus, Ernst and Haggard (2000 in Vind and Fold, 2007, p. 70) define the international production network of a transnational corporation as "the set of relationships (across national borders) through which the firm organizes its entire range of business activities: R&D, product definition and design, procurement, manufacturing, distribution, branding, marketing, and support services". On the other hand, Sturgeon et al. (2008) propose an alternative definition, under the name of global production networks (GPN), to include the wider institutional framework with non-corporate actors. These actors include Governments and labor unions.

	Global Commodity Chains (GCCs)	Global Value Chains (GVCs)	Global Production Networks (GPNs)
Definition	“A network of labour and production processes whose end result is a finished commodity” (Hopkins and Wallerstein, 1986, p. 159).	“A full range of activities that firms and workers perform to bring a specific product from its conception to its end use and beyond” (Gereffi and Fernandez-Stark, 2011, p. 4).	A set of inter-firm linkages that bind a group of companies into larger economic groups (Sturgeon, 2001).
Framework	Internal explanatory factors for industry dynamics	GCC + external factors to the chain (contextual, developmental and strategic issues)	Internal and external to the network.
Focus	Actors, i.e. drivers of the chain (developed in Section 3)	Chain dynamics	Inter-firm relationships’ nature and extent
Governance question	Who governs?	How is it governed? (developed in Section 4)	How is it governed?
<p><i>Table 1. 1.: Comparative table of GCC, GVC, and GPN literature</i> <i>Source: Compiled by author from Hopkins and Wallerstein (1986), Gereffi and Fernandez-Stark (2011) and Sturgeon (2001)</i></p>			

Third, another evolution is observable on how the pieces of literature address the governance issue: it moves from “who governs?” (GCC) to “how is it governed?” (GVC and GPN). While GCC has a strong focus on the chain drivers, GVC and GPN are interested on the mechanisms of the chain governance. Put simply, the governance structure explains how value chains are controlled. Governance is defined as the “authority and power relationships that determine how financial, material, and human resources are allocated and flow within a chain” (Gereffi and Korzeniewicz, 1994, p. 97). Governance in the context of GVC lays on the idea that governance dynamics do not occur spontaneously, automatically or even systematically. Rather they are the consequences of strategies and decisions of specific actors (Gibbon et al., 2008, p. 319; Ponte and Sturgeon, 2014, p. 200). Indeed, the question of governance arises when some firms set up parameters under which others in the chain operate (Humphrey and Schmitz, 2001, pp. 20–22).

Finally, GVC and GPN pieces of literature are interested in different aspects of the governance question. Sturgeon (2001, p. 10) proposes the following distinction between them. On the one hand, GVC literature highlights the chain dynamic side, as GVC are reused and reconfigured on an ongoing basis, and as some economic

actors bypass them. On the other hand, GPN researchers focus on inter-firm relationship's nature and extent that bind sets of firms into larger economic groups.

Beyond these points, it seems that these three frameworks are all pointing the same issue at least for this doctoral research: the chain governance. Consequently, I combine the three pieces of literature, and I use the term GVC that encompasses GCC and GPN. For a better understanding of the issue of governance, I believe that a presentation of the various GVC types is needed. That is the topic of the following section.

2. Global Value Chain evolution

The context has changed over time. So do GVC configurations. This section is dedicated to highlighting a specific change, that is the outsourcing trend, along two axes: (1) the activities endeavored by the most powerful actors in the chain (Section 2.1.); and (2) the consequences of the disaggregation of a GVC (Section 2.2.).

2.1. Producer or buyer-driven chains: From a strict dichotomy...

Relating to the issues raised by governance in GVC, Gereffi (1999, 2001) proposes as a starting place to distinguish two distinct types of international chain configurations: producer-driven and buyer-driven chains³. Both types of chain require coordination from powerful actors, namely lead firms. The Organisation for Economic Co-operation and Development (2008, p. 47) defines lead firms as “enterprises (major players) that consistently operate value adding processes on both sides of the focal point, i.e. both in production and in marketing/distribution”. The tabular comparison below provides us a fairly accurate idea of the similarities and differences between the two types of interest in this study.

The classical form of GVC is producer-driven. Here, a handful of transnational corporations (TNC) and final product manufacturers govern the chain and have the role of lead firms. In this situation, the key parameters are set by these lead firms that control key product and process technologies (Humphrey and Schmitz, 2001, pp. 21–22). Thus, companies take advantage of economies of scale and technological advances to earn money. Indeed, in capital-, technology- and, skill-intensive industries, such as electronics (e.g. Sturgeon, 2002) and automobile industries (e.g., Sturgeon et al., 2008), technology and production expertise are core competencies that require to be developed and deployed either in-house (i.e. vertically integrated chain), or by “closely affiliated ‘captive’ suppliers that can be blocked from sharing them with competitors” (see Section 4.5.; Ponte and Sturgeon, 2014, pp. 201–202). Thus, actors evolve in a vertically integrated chain.

³While Gereffi (2001) introduces the electronic commerce leading to a third category, that is of ‘internet-oriented chains,’ I do not present it here.

	Producer-driven chain	Buyer-driven chain
Chain coordinator	Transnational Corporations (TNC) and final product manufacturers. They belong to global oligopolies.	Large retailers, marketers and branded manufacturers of the final product.
Characteristics of the market	Capital-, technology-, and skill-intensive industries.	Labor-intensive, consumer goods industries. These companies design or market or do both, but do not make, the branded products they order.
Type of coordination	Coordinating value chains; Vertically integrated chain	Spatially dispersed/ disintegrated/ decentralized chain
Profits	Profits from scale, volume, and technological advances.	Profits from unique combinations of high volume research, design, sales, marketing, and financial services.
<p><i>Table 1. 2.: Comparative table of producer-driven and buyer-driven chains</i> <i>Source: Compiled by the author from Gereffi et al. (2001) and Gereffi and Lee (2012)</i></p>		

Turning to buyer-driven chains, the powerful actors are global buyers, which operate in labor-intensive industries. Global buyers were spotted in GVC literature, whereas particularly neglected by academics in other literature streams. Starting with the apparel industry (Gereffi and Korzeniewicz, 1994), the list was expanded to include large retailers (e.g. JC Penny, Sears and, later, Wal-Mart, Tesco and Carrefour) and highly successful branded merchandisers and agri-food processors (e.g. Nike, Liz Claiborne, Nestle, and Kraft). It is worth noting that in 2001, Sturgeon (2001, p. 17) reckoned that it is rare that large retailers hold power.

Intriguingly, the role of a global buyer is not confined to place orders. Rather they are involved in the creation, shaping, and coordination of their supply chain. Indeed, they focus largely on design and marketing (Humphrey and Schmitz, 2001, pp. 21–22). It can be done directly from their headquarters or “overseas buying offices” (Ponte and Sturgeon, 2014, p. 201). Surprisingly, it could also be achieved through intermediaries, essentially while not limited to international trading companies (Ponte and Sturgeon, 2014, pp. 201–202).

2.2. To a fading one due to outsourcing

Appeared in the 1980s (and had accelerated since) is the increasing outsourcing of non-core activities undertaken by technology-intensive firms resulted in deverticalization of lead firms in contested and fast-moving industries, such as electronics (Sturgeon, 2002, p. 452, 2001, p. 17), and therefore the disaggregation of chains. The decision to undertake an activity in-house or to outsource it has been intensively discussed (e.g., Choi, 2007; Dedrick et al., 2010; Jacobides et al., 2006).

Consistent with this deverticalization trend, dominant firms get rid of a significant share of their manufacturing activities – and consequently, they free a part of their

capital (previously used for investments in plant and equipment or the purchase of materials and inventories) (Sturgeon, 2002, p. 470). This is to say that producer-driven chains shifted into buyer-driven chains.

In link with the characteristics of buyer-driven chains, innovation is directed toward product design and marketing rather than in manufacturing know-how (Ponte and Sturgeon, 2014, pp. 201–202). (Sturgeon, 2002, pp. 465–466) noted that product innovation gains importance as competitive outcomes highly depend on the product-level innovation such as product strategy, definition, development, design, and marketing⁴⁵. In such chains, profits are generated from unique combinations of high volume research, design, sales, marketing, and financial services (Gereffi, 1999, p. 2). Obviously, their role is wide. It encompasses product strategy, product definition, product design, but also end-user sales and marketing (Sturgeon, 2001, p. 16). Such role implies a great deal of power that they wield in the value chain.

Sturgeon, 2002 (pp. 456–458) offers an example: the case of Apple. Think of how Apple transformed its business model in the late 90s. In 1996, the company started to outsource its manufacturing facilities, consistent with its will to improve its ‘upside flexibility’. Far from being its death knell, outsourcing has been its savior. Since then the firm was clearly able to “quickly ramp production volumes upward to meet unexpected surges in demand.” Less obvious is the fact that as its contract manufacturers, i.e. turn-key suppliers, provided to a large number of clients (e.g. SCI Systems had more than 50 clients at that time), Apple benefited from economies of scale.

2.3. And the consequences of outsourcing

2.3.1. Possible multiplication of drivers

Most of the studies explored unipolar GVC chains (Ponte and Sturgeon, 2014, pp. 197;215-216). A unipolar chain describes the case when powers are concentrated in one functional position in the value chain. To the best of my knowledge, in unipolar chain studies, the unique drivers are lead firms.

However, the dramatic outsourcing trend of lead firms has undeniably led to a deverticalized industrial landscape (Hitt et al. 1999, in Sturgeon, 2002, p. 451). Some researchers use the term disaggregation of activities (e.g., Asmussen et al., 2009; Beugelsdijk et al., 2009) or “a process of fine-slicing activities” (Hernández and Pedersen, 2017, p. 140). Either way, this new situation resulted in the introduction of new drivers in the value chain, as seen in the previous example of Sturgeon (2002, pp. 456–458). Indeed, the outsourcing tendency makes room for other actors, in particular for a handful of large and highly functional ‘turn-key suppliers’ (cf. Section 3.2.).

⁴ It is worthwhile specifying that a split between innovation and production in the electronic industry occurred as “certain kinds of knowledge have become increasingly codified” (Sturgeon, 2002, p. 467). Related to this are de facto and de jure standards.

⁵ Interestingly, brand-name companies ask for contract manufacturer having a ‘global footprint.’ In some cases, it resulted in the internalization of the largest contract manufacturers in the mid-1990s.

Indeed, unipolar chains are not the only possibility. Ponte and Sturgeon (2014, pp. 215–216) start from the dichotomy producer- and buyer-driven chains to suggest a continuum of polarity, ranging from unipolar to multipolar governance. In between, there are bipolar chains. In bipolar or multipolar chains, multiple forces are in play. These chains are based on the construction of a plurality of drivers and driving mechanisms (Ponte and Sturgeon, 2014, pp. 215–216). The role and power of the various drivers will be developed in Section 3.

2.3.2. *Possibility of modular value chains*

Actually, the Apple example discussed earlier enables (Sturgeon, 2002, pp. 456–458) to introduce not only turn-key suppliers but also modular value chain. According to Langlois (2002, p. 19), “modularity is a very general set of principles for managing complexity.” The modularity concept has been developed in social sciences in general with Smith (1976 in Langlois, 2002, pp. 19–20), in technological design (Simon, 1962), and more recently in organizational design.

In the GVC framework, a modular chain is a new form of an industrial organization developing among U.S. firms in large industries, and in particular in the electronic equipment industry (previously hierarchical) (Sturgeon, 2002). Far from being the only sector to engage in such transformation, apparel, toys, offshore oil drillings also made this move.

What is essential in the modularity design literature is the notion of decomposability. It is possible thanks to standardization. It deals with the idea that internal workings in a module are highly independent with the inner workings of other modules (Langlois, 2002, p. 22). Such interdependencies reduce the costs of communication across the modules. Based on the parable of the watchmakers, Simon (1962, p. 470) argues that in an evolutionary selection environment, a decomposable system is preferable as, in the case of a damaged or incomplete subsystem(s), the entire system is not challenged. Such conclusion could be applied in organizational design, and more precisely in the context of buyer-supplier relationships (cf. Section 4.3).

In addition to the essential role of standardization, two features of such a value chain stand out. First, it is required to delink the manufacturing from product innovation (Sturgeon, 2002, p. 468). It is related to modular innovation, which designs innovation that takes place through changes in the modules (Langlois, 2002, p. 22). As argues Sturgeon (2002, p. 468), R&D, be it product or process, remains a vital function for each corporation evolving in the modular chain. Far from denying the important role played by tacit knowledge and face-to-face contacts, what links modules “must be a swift electronic transfer of codified information” (Vind and Fold, 2007, p. 71).

Second, the equipment production should not only be increasingly standardized and highly automated but also, be easily reprogrammed and switched to a new product based on codified product specifications on short notice (Sturgeon, 2002, p. 467; Vind and Fold, 2007, p. 71).

To sum up, value chain modularity can arise when product architecture modularity is pairing with technical standards and information technology and standards for

exchanging information (Gereffi et al., 2005, p. 83; Gereffi and Fernandez-Stark, 2011).

2.3.3. Increasing complexity of coordination

Another consequence of the outsourcing trend is that lead firms become more increasingly organizationally and geographically flexible. Lead firms outsource to smaller regional contract manufacturers in Asia, Europe, and North Africa (Sturgeon, 2002, p. 461). It is worth noting that the more a supply chain is unbundling, the more a lead firm has to coordinate its partners. Accordingly, the more activities are outsourced all around the world, the more the complexity of managing a multiplicity of relationships with suppliers based in multiple locations is high (Sturgeon, 2002, p. 461). Gereffi et al. (2005, p. 82) specify that global buyers can and do exert a high degree of control over spatially dispersed value chains even when they do not own production, transport or processing facilities. Indeed, thanks to the high volume of their purchase, they exert a great deal of power over suppliers (Ponte and Sturgeon, 2014, pp. 201–202).

A telling example is the case of Cisco Systems. Its strategy to gain a wide market share lies in a worldwide chain of highly proficient contract manufacturers for its core manufacturing, except for few manufactured in-house (Sturgeon, 2002, p. 466). The case of Tesco in Zimbabwe is also illustrative (Humphrey and Schmitz, 2001, p. 20): the company owns neither the farms nor the packing facilities; yet, Tesco has a strong influence on what happens at earlier points in the chain.

The example of Tesco steers the attention to the concept of upgrading discussed earlier in Section 1.1. It is worthwhile noting that upgrading - and governance structure - raises controversies. On the bright side, it is indisputable that be part of GVCs bring opportunities to developing countries. Indeed, lead firms “transmit best practices and provide hands-on advice on how to improve layout and production flows and raise skills” (Humphrey and Schmitz, 2001, p. 20). Notably, upgrading studies explain how relatively developing regions become major export producers in a short period. On the dark side, it is also argued that a high level of pressure (e.g. quality raise, speed increase, cost reduction⁶) from lead firms may make local producers locked into physical activities (i.e. manufacturing).

Acknowledging that these manufacturing activities are usually characterized by low entry barriers and create low returns, it seems unlikely for these actors to move towards intangible activities (e.g. R&D, design, branding, marketing). A well-known counterexample includes China. Yet, among others, Gereffi et al. (2001, p. 1) and Kaplinsky (2000 in Humphrey and Schmitz*, 2001, p. 21) reckon that the chain governors, generally located in developed countries, own and master intangible competencies characterized by high barriers of entry and command high returns. Thus, upgrading has a double edge sword effect: such governance structures that foster acquisitions of production capabilities can lock these firms in function and

⁶ As for price concessions, suppliers’ answer to these pressures tends to locate more of their operations in low-cost locations and to apply the same pressure to their suppliers and workers (Ponte and Sturgeon, 2014, pp. 201–202).

prevent them from the acquisition of design and marketing capabilities (Schmitz and Knorringer, 2000 in Humphrey and Schmitz*, 2001, p. 20).

Beyond these points, I cannot deny that all actors are not included in GVC, as GVC deals mostly with the question of exclusion and integration. While some are part of the process, others are excluded, marginalized or expelled from it, or even worse, as witnessed an increase of inequality and social polarization (Ponte and Sturgeon, 2014, p. 196)⁷. Notably, a previous work (cf. the case of Tesco in Zimbabwe) showed that marginalization of small growers in the UK-Africa horticulture is more due to lead firms' sourcing strategies than efficiency advantage of large growers (Humphrey and Schmitz, 2001). These strategies are influenced by the expectations of customers, NGOs, and government agencies, complying with safety and environmental and labor standards (Dolan and Humphrey, 2000, pp. 165–169). While I do not deepen this issue, I am nevertheless aware, in the word of Ponte and Sturgeon (2014, p. 197), of this 'inclusivist' bias to GVC-related work.

3. The diversity of chain drivers

Section 3 addresses the question 'who governs?'. Specifically, in this section, I present the various actors having a power in shaping the value chains in global industries. In addition to the key role of lead firms and some key suppliers⁸, I stress the importance of the regulatory and institutional framework as companies are embedded in an environment, for which the countries' specific characteristics are highly influential in the day-to-day operations.

3.1. Lead firms

The concept of 'lead firm' dates back to before the GVC literature. Indeed, it has been introduced by the growth pole theory and the notion of lead industries, and precisely by François Perroux in the 1950s⁹ (Erickson, 1972, p. 426). In this context, lead firms supposedly impact directly and indirectly on economic growth and structural change (Erickson, 1972, p. 427).

Within the GVC framework, lead firms specify what to produce, how and by whom (Gereffi et al., 2001, p. 0). Indeed they "help drive the organization and geography of their production networks by demanding that their suppliers engage in new activities and invest in new places" (Sturgeon, 2001, p. 17). Hence, the role of lead firms is of utmost importance in the value chain analysis.

Such power is exercised deliberately and through suppliers' coordination and without any direct ownership of the firms (Gereffi and Lee, 2012, p. 25). In doing so, actors play the role of an orchestra conductor to maximize the industry's profits

⁷ For further insights on this issue, see for example Ponte and Gibbon (2005, p. 3).

⁸ It is worthwhile noting that supplier power is an exception in GVCs and it is not dependent on the type of chain governance (Ponte and Sturgeon, 2014, p. 205).

⁹ Actually, Perroux used the French words 'firme mortice' and Erickson translated them into 'lead firm'.

in general and, to “develop and manufacture an innovative product and to maximize the market value of its innovation” for its own (Dedrick et al., 2010). Accordingly, the industry’s profit is distributed according to what lead firms have decided between them and their partners and suppliers (Dedrick et al., 2010). Hence, there is an “asymmetric influence between a ‘leader’ firm and ‘follower’ firms” (Erickson, 1972, p. 428). Considering the exerted power, lead firms are either monopolies or form an oligopoly (Erickson, 1972, p. 428; Gibbon et al., 2008, p. 14; Phillips, 2017, p. 432;435; Selwyn, 2016). In short, the ‘lead firm’ concept is tightly linked to the theory of economic domination and imperfect competition.

3.2. Turn-Key Suppliers

Turn-key suppliers are qualified as turn-key because they provide a full-package service and manufacturing solution to the brand-name firms (Sturgeon, 2001, p. 17; Vind and Fold, 2007, p. 71). Indeed, these capabilities are not limited to basic manufacturing but rather go beyond to include design-for-manufacturability, sourcing and process innovation. Despite the high degree of control by lead firms through instructions over what to make, the decisions, regarding how and where products are made, are widely made by suppliers (Sturgeon, 2001, p. 17).

A linked result of this relative freedom is that rather than having just one client, these suppliers can address the needs of a vast and diverse pool of customers as the equipment can effectively be shared across the supplier's customer base (Sturgeon, 2002, p. 466). Indeed, standardized and highly automated production equipment lead to an easy and quick (re)programmation (Sturgeon, 2002, p. 467; Vind and Fold, 2007, p. 71). Such generic manufacturing capacities allow the supplier to produce a large variety of products and to propose a broad range of combinations. It makes money thanks to the exploitation of economies of scale.

Let us return to the example of Apple and its strategy of outsourcing. In 1996, SCI Systems, a contract manufacturer and electronic manufacturing service provider, bought the largest computer factory of Apple in Colorado (Sturgeon, 2002, pp. 456–458). As part of the deal, an agreement that obliges SCI Systems to continue to manufacture Apple products for at least three years. However, SCI Systems was free to provide to any other clients, be they competitors or not of Apple, with outputs from these production lines. In 1996, SCI Systems counted more than 50 clients in its portfolio. This enabled SCI Systems to exploit economies of scale.

Sturgeon (2002, pp. 466–467) believed that to achieve such goal, rather than specializing in “processes or services that are idiosyncratic or highly customer-specific,” it is preferable to specialize their offer in a cross-cutting base component, base process or, base service.

1. Base process deals with a process used to manufacture products sold in a broad range of end-markets (e.g. semiconductor wafer fabrication, printed circuit board assembly, apparel assembly, plastic molding, pharmaceutical manufacturing).
2. Base component designates products usable in a wide variety of end-products (e.g. memory chips, electric wires, automotive braking systems).

3. Finally, base service refers to services needed by a broad range of end-users (e.g. accounting, data processing, logistics).

This assumption is backed by the article of Gambardella and McGahan (2010), who oppose dedicated technologies to general technologies.

3.3. Platform Leader

Platform leader designates very powerful component suppliers (Ponte and Sturgeon, 2014, p. 204). Specifically, these actors wield lots of power to set de facto standards influencing the lead firm's actions (Ponte and Sturgeon, 2014, p. 204). In some industries and products, this position may arise.

One of the most telling examples is offered by Kawakami (2011), with the personal computer industry. Here, Intel is qualified as a powerful platform leader. Despite its role of supplier, it has the power to shape both “linkages mechanisms at key nodes in the chain and also to influence the power distribution between lead firms” (e.g. Dell) and first-tier suppliers (e.g. Quanta, a Taiwanese contract designer, and manufacturer).

3.4. Institutions and upgrading willing

Undoubtedly, GVCs are embedded in “a complex matrix of institutions and supporting industries”. It follows that agents external to the chains also have the power to set product and process parameters (e.g., Humphrey and Schmitz, 2001, p. 22; Sturgeon, 2001, p. 11). These agents encompass standard-setting bodies, international NGOs, social movements, certification agencies, labor unions, and consumer associations. They define standards and norms, whether on the product or process. Specifically, the analysis of power relations is not limited to relations between firms, but also includes the impact of regulation, institutions and business cultures in shaping GVC governance (Ponte and Sturgeon, 2014, p. 216).

Despite the acknowledgment of the importance of considering them in the study and construction of GVCs, GVC researchers have paid scant attention to these external actors. Admittedly, some studies are interested in the power exerted by politics and therefore states (e.g., Levy, 2008; Mayer and Phillips, 2017). But as far as I know, they investigate the power or role of politics or states in GVC along with the role of other actors. That is to say, at best they study multipolar chains. But this manuscript is interested in situation where politics are the only driver, i.e. unipolar chains without lead firms. This situation refers to a highly competitive marketplace (at the opposite of the monopolies and oligopolies characteristics of the position of lead firms). However, at the best of my knowledge, no study addresses a perfect competitive market whose sole driver is politics.

4. The diversity of chain governance

Having presented the various actors having the power to impact a GVC, I am now poised to discuss governance. Put differently, I address in this section the following

question: 'how is it governed?'. For this purpose, in line with Powell¹⁰ (1989), GVC proposes a more complex situation than the simple opposition of market and hierarchy, as suggested by Coase (1937) and Williamson (1983) in the transaction costs literature, in which a firm face the decision of make-or-buy (Gereffi et al., 2005, p. 85; Hernández and Pedersen, 2017, p. 140).

It is worth noting that governance patterns within a value chain can vary from one linkage (i.e. relationship between two stages of a value chain) to another. While each business partners may lead to a different type of linkages, I do not deny that the type of governance in key nodes may have a significant influence on the governance of the entire value chain (Ponte and Sturgeon, 2014, p. 206). Precisely, an analysis of the dominant linkage mechanisms and conventions situated at the key node between lead firms and first-tier suppliers may be sufficient to explain the overall governance (Ponte and Sturgeon, 2014, p. 196).

Equally important, the governance of a value chain and more precisely of a node may evolve over time. There are several conditions, be they external or internal to the firms, that affect the governance structure. Hernández and Pedersen (2017, p. 141) offer a literature review of these conditions. Consequently, it would be hard not to consider the dynamics underlying the governance of GVC. However, in this doctoral thesis, I do not consider the fluctuating dimension of GVC governance.

4.1. Criteria

To grasp this complexity, Gereffi et al. (2005, p. 85) propose three criteria to get a more detailed analytical type of value chain governance constituting a scale:

1. Complexity of transactions: “The complexity of information and knowledge transfer required to sustain a particular transaction, particularly with respect to product and process specifications”. The more the transaction is complex, the higher the likelihood the activity will be internalized.
2. Codifiability of information: “The extent to which the information and knowledge can be codified and, therefore, transmitted efficiently and without transaction-specific investment between the parties to the transaction”. The more the information is codifiable, the higher the likelihood the activity will be externalized.
3. Capability of suppliers: “The capabilities of actual and potential suppliers in relation to the requirements of the transaction.” It deals with the capacity of suppliers to make the product in question with little input from buyers. It is related to the asset specificity, one of the three independent variables in Williamson (1981)'s framework (the other are frequency and uncertainty): the degree that capital assets (e.g. machinery, routines or skills) are specific to the transaction in question (Sturgeon, 2002, p. 473). In other words, it designates the degree that these assets are specialized, dedicated or customized to make a specific asset. The higher the asset specificity, the higher the likelihood the activity will be internalized.

¹⁰ He proposes the 'network' structure in between.

For each criterion, a simple 'high/low' answer is required, offering several possible combinations¹¹. It follows a classification of five supply relationships, which do not cover all the possible combinations (Gereffi et al., 2005, p. 83). The explanation of not presenting the three remaining cases in the categorization has been explained in the article of Ponte and Sturgeon (2014, p. 204)¹².

So, in addition to the market and hierarchy (i.e. vertical integration), which form the ends of the spectrum, Gereffi et al. (2005, p. 73) propose three intermediate levels: 'modular,' 'relational,' and 'captive.' These five various forms of GVC governance reflect different degrees of power exercised by lead firms. Nevertheless, one may remark that lead firms are recurrent as chain drivers in most of the chain types discussed in this section. Even for some, lead firms are the only drivers. Such chains are characterized as unipolar. For a better understanding, Table 1.3. sums up the position of each characterized type of governance.

4.2. Market governance

This type of governance suits relatively simple transactions, and simple product specifications (i.e. easily codified transactions) and requires low supplier's capability. Then, in arm's length market, suppliers can make products with little input from buyers and little explicit coordination with them (Gereffi et al., 2005, p. 83; Gereffi and Lee, 2012, p. 25). In other words, little or no formal cooperation between actors is required. Moreover, switching cost is low for both partners. Here, market linkages are governed by price rather than by a lead firm (Gereffi and Fernandez-Stark, 2011; Gereffi and Lee, 2012, p. 25). It is the governance that is the more assimilated to a situation of perfect competition market.

4.3. Modular governance

As Table 1.3. shows, the modular relationship requires a high level of each variable. Modular governance can be expected when suppliers (i.e. turn-key suppliers) have the competence to make a complex product, yet with relative ease to codify customer's specifications (i.e. the one of the lead firms), and when codified information of products specifications are easily transmitted through standardization between distinct modules (Gereffi et al., 2005).

The degree/intensity of relationships is higher than in simple markets due to the high volume of information flowing across buyers and suppliers (Gereffi and Fernandez-Stark, 2011, p. 9). However, the switching cost to new partners remains low as

¹¹ While I acknowledge the help of this categorization, I also critic the arbitrary notions of high and low.

¹² Specifically, two cases (corresponding to the two first lines of Table 1.3.) deal with low transactions complexity pairing with low codification ability. Such configurations are unlikely. Thus they are automatically eliminated. Turning to the last non-studied combinations (the third line of Table 1.3.), Ponte and Sturgeon 2014, p. 204) claim that a situation wherein the transaction complexity is low, the codification ability is high, and the supplier capability is low, leads to the exclusion of suppliers from the value chain. Such situation "does not generate a buyer-supplier relationship. Therefore, no governance type is assigned" (Ponte and Sturgeon, 2014, p. 204).

codification has the benefit of lowering costs for both business partners. Indeed, codification makes exchanges of complex information easy with little explicit coordination. The aim is to reduce asset specificity through codifying very complex information, complying with standard protocols.

Interestingly, the question of the driver(s) of modular governance cannot be answered simply. Indeed, this form of value chain may imply more than one driver, including lead firms and turnkey suppliers. Here, “lead firms concentrate on the creation, penetration and defense of markets for end products” (Sturgeon, 2002, p. 451). Intriguingly, unique to the modular governance is the possible existence of platform leader.

4.4. Relational governance

This type of relationships involves transactions relying on complex information not easily transmitted or learned and, not codifiable. The knowledge of this type of information drives to mutual dependence. Yet, this situation does not preclude the possibility of a lead firm to exert some level of control over its partners. This issue can be handled by, instead of codification, frequent interactions and knowledge sharing between actors. This kind of linkages is largely based on mutual trust and social ties, which could be regulated through reputation, social and spatial proximity, family and ethnic ties and so on (Gereffi et al., 2005; Poppo and Zenger, 2002). Given the time required to set up relational linkages, this type of governance deals a lot with switching costs, which can lock an actor into its current system or brand.

4.5. Captive governance

Captive governance emerges when a high complexity of transactions and codifiability of information are pairing with low supplier capabilities (Gereffi et al., 2005). Unsurprisingly, these buyers (i.e. lead firms) have the power to set up conditions/parameters under which suppliers operate. This governance type implies close ties and high switching costs for both actors. This situation requires from lead firms a greater commitment, monitoring, and control and implies a greater dependence of suppliers. Indeed, most of the time, captive suppliers are restricted to a narrow range of tasks. It describes a group of small suppliers. So, these small suppliers are in the grip of lead firms for complementary activities (e.g. design, logistics, component purchasing, and process technology upgrading), resources, and market access. Such situation leads to a power asymmetry and makes exit an ‘unattractive option’ as buyers tend to lock-in suppliers. That explains why the literature described these suppliers as ‘captive.’ Here, lead firms rule alone captive relationships.

4.6. Hierarchical governance

Characterized by vertical integration and managerial control by the lead firm(s), hierarchical governance exists when codification is not possible to achieve for complex product and when highly qualified suppliers are rare (Gereffi and Fernandez-Stark, 2011). Here, lead firms have a more significant involvement. Thus, lead firms develop and manufacture products in-house (cf. producer-driven chains).

This governance mode has the benefit of controlling resources including intellectual property. Management hierarchy is the ‘governor’. While I cannot deny the impact of this kind of structure on a market, I can neither deny that this governance type tends to dwindle over time.

Complexity of transaction	Codifiability of information	Capability of suppliers	Type of governance	Requirement of explicit control	Tolerance of distance	Supplier switching costs	Driver	
Low	Low	Low	Non-characterized governance type					
Low	Low	High						
Low	High	Low						
Low	High	High	Market	Low ↓ High	High ↓ Low	Low ↓ High	Price	
High	High	High	Modular				Lead firms and others	
High	Low	High	Relational				Lead firms and others	
High	High	Low	Captive				Lead firms	
High	Low	Low	Hierarchy				Lead firms	
<p><i>Table 1. 3.: Characteristics of governance types</i> Source: Compiled by author from Gereffi et al. (2005) and Ponte and Sturgeon (2014)</p>								

Conclusion

The outsourcing trend appeared in the 1980s resulting in the globalization and disaggregation of value chains (Hitt et al. 1999, in Sturgeon, 2002, p. 451). In this chapter, I underscored the importance of the GVC framework to enable a better understanding of this new situation. GVC issues deal with governance, power, and the chain dynamics within an international environment while considering external actors of the chain such as institutions. Specifically, the GVC framework raises two questions: ‘who govern the chain?’ and ‘how is it governed?’.

The first question leads us to the study of a particular actor: lead firms. Lead firms are defined as powerful actors defining the division of labor. As such, they are the orchestrator of value chains (Dedrick et al., 2010). Domination is therefore of key relevance in the GVC framework. It is only possible in imperfectly competitive

markets (Erickson, 1972; Gibbon et al., 2008, p. 14; Phillips, 2017, pp. 432; 435; Selwyn, 2016).

Admittedly, their activities and positioning have evolved over time. Lead firms nowadays operate more in soft activities (e.g., R&D and marketing). They moreover tend to occupy only a limited number of segments of a value chain, while they were highly vertically integrated.

Definitively, the GVC studies are overwhelmingly attached to the study of lead firms. However, these dominant firms are not the only ones who exert power on value chains. There are possibly other forces involved in the governance of a GVC. They may be internal to the value chain (i.e. turn-key suppliers and platform leaders) or external (i.e. institutional actors). In the situation of multiple forces in play, the chain is defined as bipolar or multipolar (Ponte and Sturgeon, 2014). It is as opposed to a unipolar chain, where there is only one driver, usually lead firms.

What is certain is that the GVC literature has paid scant attention to other actors than lead firms. Indeed, rare are the exceptions that focus on bipolar (or ‘twin-drivers’) and multipolar chains. This is unfortunate because unlike in unipolar chains that are relatively simple to examine, in bipolar and multipolar chains, dynamics and the nature of linkage mechanisms are more complex. Also neglected are value chains with a low concentration of actors, whose situation can be compared to perfectly competitive markets. This leads to the second question.

The second question is crucial as it deals with the governance of internationally dispersed activities. The literature proposes to distinguish five governance modes (Gereffi et al., 2005). They are placed along a continuum ranging from market to hierarchy; both extremes are well-known thanks to Coase and Williamson. The three options in the middle are modular, relational, and captive. Specifically, this chapter aimed at acknowledging the variety of chain and therefore of chain governance. All but one governance form involves lead firms. In captive and hierarchical chains, the only drivers are lead firms; in modular and relational linkages, lead firms are a driver, but others may be involved; in market governance, the price is the only driver.

Having said this, the GVC framework and prior research are deficient in explaining the governance of certain chains, especially in modular value chains, where each segment evolves independently from the others. Indeed, particularly for chains characterized by modularity, it may be not untrue that, more than one value chain governance exists. Therefore, I admit the possibility that lead firms are not the only drivers or are even inexistent for the governance of specific nodes. It poses the question of what happens in some chain segments of a GVC characterized by a perfectly competitive market and therefore without lead firm to govern. The next chapter is an attempt to fill this gap in analyzing the PV value chain. Precisely, Chapter 2 will shed light on the modularity of the PV value chain with the upstream segment governed by lead firms and the downstream without lead firm.

Chapter 2: The upstream segment of the photovoltaic value chain is illustrative of the overlooked topics in the global value chains framework

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Résumé

Chapitre 2 : La chaîne de valeur aval du photovoltaïque illustre les zones d'ombre dans l'étude des chaînes de valeur mondiales

La technologie photovoltaïque et les activités composant sa chaîne de valeur sont au cœur du Chapitre 2. Les possibilités sont nombreuses au regard des technologies, des applications, et des marchés. Considérant que la technologie à base de silicium est la plus répandue (utilisée à 90%), et en particulier le poly-silicium, le reste de la thèse se concentre uniquement sur cette technologie.

La chaîne de valeur du photovoltaïque est composée de huit maillons. Les activités évoluent indépendamment les unes des autres, en particulier dans la partie aval. En d'autres termes, la chaîne de valeur est modulaire. En considérant cette spécificité, j'ai examiné la chaîne de valeur du photovoltaïque sous l'angle des barrières à l'entrée, la concentration des marchés, et les dynamiques de l'industrie (en particulier l'intégration verticale et les mouvements géographiques).

Les quatre maillons en amont, toutes fortement technologiques, érigent d'importantes barrières financières à l'entrée. Cela implique qu'un nombre restreint d'acteurs détient le pouvoir sur chaque nœud. Les acteurs produisent et délivrent leurs produits au niveau international. Il est à noter que les firmes tendent à être intégrées verticalement et aujourd'hui sont majoritairement chinoises. Ces particularités permettent de conclure que la partie amont est un archétype des chaînes de valeur unipolaires.

Tel n'est pas le cas des quatre maillons de la partie aval de la chaîne de valeur. Deux d'entre eux sont nettement moins technologiques que les activités en amont et les deux autres sont des activités de service. Du fait des faibles barrières à l'entrée, un plus grand nombre d'acteurs sont présents sur ces maillons. Ces acteurs sont pour la très grande majorité de petite ou moyenne taille et non-publics. Aucune "firme motrice" ne domine donc la partie aval. Dans cette partie, la chaîne est gouvernée par des acteurs externes : les institutions publiques. En effet, les réglementations régissent la partie aval de la chaîne de valeur, et par conséquent le développement du marché photovoltaïque. La littérature sur les chaînes de valeur mondiales ne permet donc pas d'expliquer le cas de la partie aval de la chaîne du photovoltaïque. C'est une limite théorique.

Afin de mieux comprendre le pouvoir exercé par les institutions dans la partie avale, le Chapitre 3 s'intéressera à l'impact institutionnel sur le marché du photovoltaïque.

You may be deceived if you trust too much, but you will live in torment if you do not trust enough.

Frank Crane

Introduction

Chapter 1 emphasized the usefulness of the global value chain (GVC) framework for analyzing the governance of a GVC. This framework focuses mainly on the role of specific technological and economic drivers of a GVC: lead firms. This first work provides us with the groundings to assess the extent of its applicability to a value chain not governed entirely by lead firms, at least to a part of this value chain. For this purpose, in the present chapter, I use the value chain of photovoltaic (PV) technology which, in short, converts solar radiation into electricity at the atomic level (REN21, 2015, p. 248).

The PV value chain is of particular interest because of its modularity enabling more than one governance of its value chain. Precisely, its governance in the upstream segment differs from that in the downstream segment. In this chapter, I show that the drivers at the key node in the upstream segment are lead firms (modular governance) and, to a lesser extent, prices (market relationship). In the downstream segment, the drivers are regulations (market governance). I highlight the characteristics of the PV value chain and demonstrate the limits of the GVC framework for this particular chain. For this purpose, I analyze the PV value chain through the lens of the GVC framework as presented in the first chapter and consider the proliferation of actors in the downstream segment.

To this end, Section 1 provides an overview of the main features of PV technology. In particular, I focus on the exploitation of solar power, the diversity of PV technologies, and PV market growth through its various end-use industries. After discussing the various technologies underlying a PV module, I look at PV systems based on poly-silicon. Section 2 analyzes the crystalline silicon-based PV value chain (i.e. the series of activities carried out to generate PV power), providing the reader with an overview of the characteristics of each activity leading to the PV energy supply. Sections 3 and 4 investigate the PV value chain through the lens of the GVC literature. They provide an overview of the characteristics of the value chain segments considered in this section. They highlight the relative applicability of the global value chain framework to the upstream segment (Section 3) and the limit of this framework for the downstream segment (Section 4).

1. What makes PV PV?

This first section stresses the main features of PV technologies. Their characteristics are grouped into three categories: (1) solar power exploitation (Section 1.1.); (2) solar material diversity (Section 1.2.); and (3) PV growth and market diversity (Section 1.3).

1.1. Solar power exploitation characteristics

1.1.1. *The sheer abundance of sun*

As Löf (1973, p. 53) stated, the dominant energy source for the Earth is solar. To see this *sheer abundance*, one only has to note that one hour of solar energy hitting the earth's surface is equivalent to a year's energy consumed by all human activities (International Energy Agency, 2014a, p. 13). Solar energy is uniquely potent precisely because of this great potential. But to use it directly, the energy has to be converted into useful forms. PV technology is one possibility of conversion.

1.1.2. *PV, a variable source of power*

The foremost feature of solar energy is that, like wind power, it is *based on variable resources*. Obviously, sunray intensity varies depending on the season (summer or winter), the weather (clear or cloudy) and, the time of the day (day or night). However, as the electricity system requires that supply meet demand at all times, the variability of this clean energy is clearly an economic drawback (Löf, 1973).

To overcome this problem, its storage could be improved (Löf, 1973, p. 54). Electricity storage is indeed the key, as it would allow the energy flows between supply and demand to be controlled¹³, and would result in a higher contribution of clean energies in the electricity mix. The bottom line here is that such additional technological developments (i.e. storage facilities) add to the price attached to the use of PV. An alternative would be to consider using a variety of electricity sources (e.g. a mix of solar, wind, and nuclear), rather than a radical shift from a dominant source to another. The variability of solar power is not the last feature that makes PV technology stands out.

1.1.3. *The newness of PV exploitation*

Compared to these other renewable energy sources (RES) (i.e. wind power, hydropower, Concentrated Solar Power, geothermal, ocean power, and biomass), the exploitation and commercialization of solar energy is *a recent phenomenon*. The commercialization of solar PV cells started in 1954, whereas the exploitation of the other RES is centuries old (Craddock, 2008).

Admittedly, the history of PV technology goes back more than half a century: that of solar cells is even older (i.e. the first device that converted sunlight into electrical power). In 1839 Edmund Becquerel, a French physicist, discovered the PV effect, defined as “the basis of the conversion of light to electricity in PV, or solar cells” (Parida et al., 2011). The conversion of solar radiation into electricity at the atomic level is possible owing to certain light-absorbing or solar materials (REN21, 2015, p. 248). They absorb photons and generate free electrons via the PV effect. Solar materials are thus the feedstock for the PV panels industry. A more in-depth

¹³ <http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-new-economics-of-energy-storage>

understanding of PV would be useful here, and I will consider this aspect in the following subsection.

Becquerel's scientific discovery laid the technological foundation for solar energy production when, 34 years later, Willoughby Smith, an English electrical engineer, used solid selenium to create photoconductivity (ADEME, 2015a, p. 125). In 1883, Charles Fritts, an American inventor, created the first PV cell based on selenium (Craddock, 2008, p. 42; Green, 2009; Platzer, 2015, pp. 26–27). Selenium is, however, a poor conductor, which has an energy conversion yield of only 1%. The year 1954 was crucial as it marked the introduction of the first practical PV cell by David Chapin, Calvin Fuller and Gerald Person of Bell Labs, based on crystalline silicon with a 4% conversion efficiency (Craddock, 2008; Haley and Schuler, 2011, p. 18). Crystalline silicon subsequently supplanted selenium as a light absorbing material.

1.2. Solar material diversity but predominance of crystalline silicon

It is noteworthy that while crystalline silicon is the dominant solar material thanks to its first-mover advantage, it is not the only one commercialized. Currently, five commercial technologies, considered below, compete in the global PV market (as well as those not yet commercialized). Each one evolves within its own sphere of application. They are part of three kinds of technology generation that coexist: (1) the first is based on crystalline silicon (c-Si), (2) the second is based on thin-film (TF) and, (3) a third group is still under development (e.g., IEA-ETSAP and IRENA, 2013, p. 1; International Energy Agency, 2010, p. 7; van de Kaa et al., 2014). This subsection provides a description of the various solar materials used. Table 2.1. summarizes the technologies' characteristics.

1.2.1. Crystalline silicon, the first category of solar materials

Crystalline silicon (c-Si), based on sand, is the first group of PV semi-conductors. This includes polycrystalline silicon (or multi-crystalline silicon) (mc-Si or poly-Si) and mono-crystalline silicon (sc-Si). Each technology has its own supporters. Multi-crystalline silicon has been used primarily by Soltech Inc. and Suntech; while mono-crystalline silicon, for example, has been developed by BP Solar. Interestingly, some companies opt for developing both technologies, such as Sharp (cf. Box 2.1), Sunpower (cf. Box 2.6.), and Canadian Solar.

While crystalline silicon is by far the most mature technology, R&D spending remains significant and is focused on improving cell efficiency. It is measured in terms of generation as a percentage of cell capacity. Overall, the current conversion efficiency remains disappointing. Depending on whom you ask, their cell conversion efficiency varies from 13 to 22% (SETIS, 2013) or 15% to 20%. At the time of writing, the best commercial mono-crystalline silicon modules efficiency reached 25%, and 18% for poly-crystalline silicon modules (IEA PVPS, 2016b, p. 5). In other words, the mono-crystalline silicon PV module is able to convert to electricity 25% of the solar energy (sunlight) it is exposed to.

Box 2. 1.: Sharp's solar story

Electronics is the core business of the Japanese group Sharp. More than 50 years ago, the group diversified its activities into solar energy production under the name of Sharp Solar. Sharp Solar was the first to use PV on the ground by powering hundreds of lighthouses along the Japanese coast in 1966 thanks to mass production. But at that time, this was the only identifiable application for which PV was cost-competitive (Platzer, 2015, p. 26). Since then, the range of applications has grown, to encompass satellites, lighthouses, and both industrial and residential applications¹⁴. The company is involved in the development of mono-, polycrystalline and thin-film modules.

In 2013, Sharp established its European head-office in London and then set up in Wales the division Sharp Energy Solution Europe, its manufacturing facility. In 2013, the production was running at full capacity (400MW) and was able to meet not only the European demand (mainly residential) but also the Japanese one.

To be closer to the market, Sharp decided to establish its own training academy and a learning center for installers of both solar products and LED. Backed by its electronics activity, Sharp has not been disturbed as much as its competitors were by PV market variations.

Crystalline silicon is the most widespread raw material used to manufacture the semiconductors that convert sunlight into electricity (Platzer, 2015, p. 3). In 2016, mono- and poly-crystalline silicon together accounted for more than 94% of the PV system market in IEA-PVPS countries¹⁵, and 90% overall. This predominance is largely due to its first-mover advantage and its widespread use in China and Asia-Pacific countries (e.g., IEA PVPS, 2016, p. 5; International Energy Agency, 2014, p. 9; SETIS, 2013; SolarPowerEurope, 2016). As poly-silicon is more affordable than mono-silicon, albeit less efficient, it is not surprising that poly-silicon is dominant at 75% of the crystalline cell market, and 55% of the total PV cell market, all technologies combined. Based on the fast-moving pace of the PV market, it is hard to do accurate projections beyond five years (SolarPowerEurope, 2016), but it is likely that crystalline silicon technologies remain leaders in the coming years.

1.2.2. Thin-film solar cells for the second category of solar material

Thin-film solar cell technologies represent the second generation of light-absorbing materials. They are thin layers of semiconductor materials applied to a solid backing material. The category encompasses three technologies, plus some variants that I am not going to look at here.

¹⁴ <http://www.sharp.co.uk/cps/rde/xchg/gb/hs.xsl/-/html/solar-modules.htm>

¹⁵ The IEA PVPS counts 27 countries Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and United States.

Invented in 1972, cadmium telluride (CdTe) has attractive features for large-area applications; i.e. for ground-mounted power plants (cf. Section 2.3.2.4.; Ferekides et al., 2000). Its market share is 5% at the time of writing. This technology is known to be able to squeeze energy at a lower cost than silicon does but less efficiently. In 2016, its cell conversion efficiency reached 16.3% in commercial applications and 22% in lab (IEA PVPS, 2016b, p. 5). FirstSolar is by far the most eminent proponent of this technology (cf. Box 2.2.).

Then comes copper indium gallium selenide (CI(G)S), invented in 1975. In 2016 its best module conversion efficiency in lab reached 19.2% (Fraunhofer ISE, 2017a, p. 25), and its market share was 2% (IRENA and IEA PVPS, 2016, p. 37). Among others, FirstSolar and Q-Cells are heavily involved in the development of this solar material.

Box 2. 2.: FirstSolar's story

Created in 1999, the U.S. firm FirstSolar is one of the world's two largest thin-film solar energy solution provider. The other is Sunpower. Headquartered in Tempe, Arizona, it has installed over 10 GW worldwide. Its biggest PV construction plant is located in California, and its two biggest utility-scale power projects are Desert Sunlight and Topaz (cf. Section 2.3.6.).

Unlike most competitors, it provides second-generation solar panels, i.e. thin film, made with cadmium telluride. Its R&D efforts have enabled it to increase its panels' energy output to reach the highest efficiency rate for thin film. Solar modules are produced in-house in automated manufacturing facilities located in the US and Malaysia.

The last thin-film technology is amorphous (uncrystallized) silicon (a-Si), introduced in 1976. In 2011 its efficiency ranged from 5% to 7% and could be increased to 8% to 10% thanks to double- and triple-junction designs (Parida et al., 2011; Vasseur et al., 2013). According to IEA PVPS (2016, p. 5), it was still 7% in 2014. Among the most well-known companies that have opted for this technology are Bosch Solar and Mitsubishi Heavy Industries (MHI). It is worth pointing out that its market share is decreasing over time, mainly because, according to IEA PVPS (2016, p. 5), it "failed to follow both the price of crystalline silicon cells and the efficiency increase of other thin-film technologies" (cf. Section 1.3.1. for the evolution of crystalline silicon prices). However, in spite of its relative newness and its low efficiency, among thin-film technologies, it is popular for specific applications (Deng and Schiff, 2003, p. 506; Parida et al., 2011). Precisely, because of its low-efficiency rate, it is particularly well-suited to small devices that do not require a lot of energy (e.g. pocket calculators).

Overall, the total thin film market share was expected to grow. In reality, it has decreased from 13% in 2010 to 10% in 2014, and then to 8% in 2016 (REN21, 2016, p. 65, 2011, p. 41). These technologies are lagging behind silicon-based solar materials mainly because they suffer from lack of a proven track record of performance, due to their relative newness. To compensate for their lower efficiency

compared to crystalline silicon, thin film technologies offer a lower PV cell cost as they use a smaller amount of semiconductor material.

This category furthermore benefits from limited synergies with mature industry to promote it, unlike crystalline silicon-based technologies that rely on the semiconductor industry research and, in particular, on the producers of silicon, as its name (i.e. crystalline silicon) suggests (FRINNOV, 2009; Su, 2013, p. 3). Hence, for thin films, there is no possible spin-off from other industries accelerating the development; improvements can only come from the producers and researchers of these technologies.

1.2.3. A third category not yet commercialized

The *third group* of PV technologies is on the way but is not yet commercially available. These technologies are currently on the way from pilot and demonstration plants to commercial applications. To be sure, they are different from conventional PV system.

These technologies, based on active, organic layers (i.e. conductive organic polymers or small organic molecules) and on very low-cost materials and manufacturing processes, with low energy input and easy up-scaling, differ from conventional PV systems and are expected to be price-competitive. The downside is their efficiency as they lag far behind that of the more mature PV technologies, with a maximum lab module efficiency of 11% in 2015. Two technologies fall under the umbrella of organic cells:

1. Dye-sensitized solar cells (DSSC) were introduced in 1988. They are a hybrid of an organic cell with an inorganic component. The DSSC technology has barely reached the commercial production stage and is therefore used only for niche applications. KONARKA is one of its main promoters.
2. Fully organic photovoltaic cells (OPV) introduced in 2006 (Fraunhofer ISE, 2017a, p. 26).

The most recent technologies, introduced in 2015 (Fraunhofer ISE, 2017a, p. 26) is perovskite. Over the past few years, perovskite solar cells have reached efficiencies superior to 20% in labs (IEA PVPS, 2015, p. 5), despite its very late introduction. These efficiency improvements are expected to continue (REN21, 2016, p. 66) but have not yet been commercialized. This technology is expected to be cost-competitive with the other PV technologies.

A fourth technology falls into this category but is not organic-based: Concentrating Photovoltaics (CPV), the most mature emerging technology of this third generation. It benefits from the concentrator systems, which capture and focus direct sunlight from a wider area, using lenses. Its high commercial conversion efficiency, up to 36%, reduces the need for costly active materials (IEA PVPS, 2016b), although this barely offsets the total cost, which remains high. R&D efforts are therefore still required to make it more efficient. The 2012 to 2014 period was particularly interesting in the CPV development market, with some remarkable installations (REN21, 2016, p. 64; cf. Section 2.3.2.4.). Yet, in 2015, many projects were canceled, resulting in little-added capacity. With a global CPV total capacity of 360MW over 227GW, or 227,000MW total PV world capacity by the end-2015, its

market is still young and remains marginal (IEA PVPS, 2016b). Soitec was one of the most important supporters (cf. Box 2.3.).

Box 2. 3.: Soitec's Solar story

Soitec, a worldwide semiconductor specialist, was founded in 1992. It stayed true to its original core business, i.e. electronics, but decided to benefit from its expertise/core competencies to vary its activities, including solar power. It has been operating in the solar industry under the name of Soitec Solar, one of the rare companies involved in CPV. In 2014 it proposed a four-junction CPV module with an efficiency of 38.9%.

Soitec ceased its solar business in January 2015, following the announcement of a new delay in completion of San Diego's project for a solar plant of 150MW. In May 2015 the company sold its solar assets and production sites (Freiburg in Germany and San Diego in the USA) to ConcenSolar. It has nevertheless kept its financial participation in solar plants and is still developing its four-junction solar cell, the most efficient in the world. Put differently, Soitec decided to refocus on its core business: electronics.

Generation	Cell material category	Cell material	Best lab module efficiency (%)	Market share in 2015	Producers supporting the technology ¹⁶	Year of Introduction	Specific application
1 st Generation	Crystalline Silicon	Multi-crystalline silicon (mc-Si)	19.9	54,86%	Soltech Inc.; Suntech	1954	
		Mono-crystalline silicon (sc-Si)	24.4	36%	SolarWorld Sunmodule 230/220; BP; Sharp	1954	
Large r2 nd Generation	Thin-Film	Cadmium telluride (CdTe)	18.6	5,14%	First Solar	1972	Large area
		Copper indium (gallium) selenide (CI(G)S)	19.2	2%	First Solar; Q-Cells; Global Solar; ITN Energy Systems; Ascen Solar; WürthSolar	1975	
		Amorphous silicon (a-Si)	10.9	2%	United Solar Ovonic; Kaneka; Bosch Solar; EPV; Mitsubishi;	1976	Small devices
3 rd Generation	Thin film	Concentrating photovoltaic (CPV)	38.9	1%	Soitec	mid 1970s	Large area
		Dyes-sensitized (DSSC)	11		Konarka		
		Organic photovoltaic (OPV)	10				

Table 2. 1: Solar material characteristics
Source: Compiled by author from Fraunhofer ISE (2017), IEA-ETSAP and IRENA (2013), IEA PVPS (2015, p. 5) and, various web research.

¹⁶ During the last decade, for the project of NREL, the focus was on three large thin-film manufacturers: First Solar in CdTe, Global Solar in CIGS, and United Solar Ovonic (Uni-Solar) in a-Si (http://www.nrel.gov/pv/thin_film_partnership.html).

1.3. PV market: growth and diversity

1.3.1. Impressive growth

Since 2006, despite its variability, limited cell efficiency, need for storage, and technological variation, PV technology experienced the fastest growth of all modern renewable technologies during the periods end-2010-2015 and end-2006-2011, with respectively an annual average of 42% and 58% operating capacity growth (cf. Figure 2.1. and Annex for more details on growth, costs, and market share).

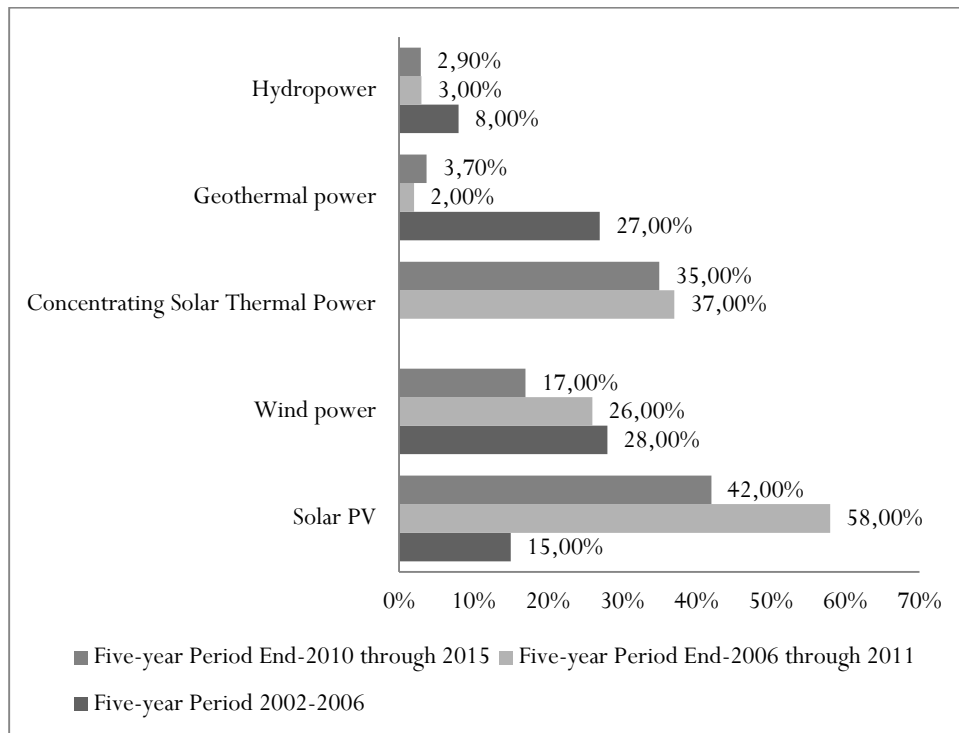


Figure 2. 1.: Average annual growth rates of renewable energy capacity, 2002-2015
Source: Compiled by author from REN21 (2008, p. 10), REN21 (2012, p. 22), REN21 (2015, p. 28), and REN21 (2016, p. 29)

It grew from 7GW in 2006 to 277GW in 2016 (REN21, 2016 and earlier years; Figure 2.2.). The result was that, in 2015, the contribution of PV power to the electricity demand reached 2.1% at the global level (REN21, 2016, p. 32), with big regional differences. For example, it accounted for 3.5% at European level (SolarPower Europe, 2015, p. 26), 8% of the German electricity demand and 1.6% of the French demand (IEA PVPS, 2016b, p. 27). To get an idea, 3.5% of the European energy consumption is equivalent to over 105 TWh of electricity, or the annual production of 17 GW coal-fired power plants (SolarPower Europe, 2015, p. 26). Admittedly, its market share remains low at 4% in 2014.

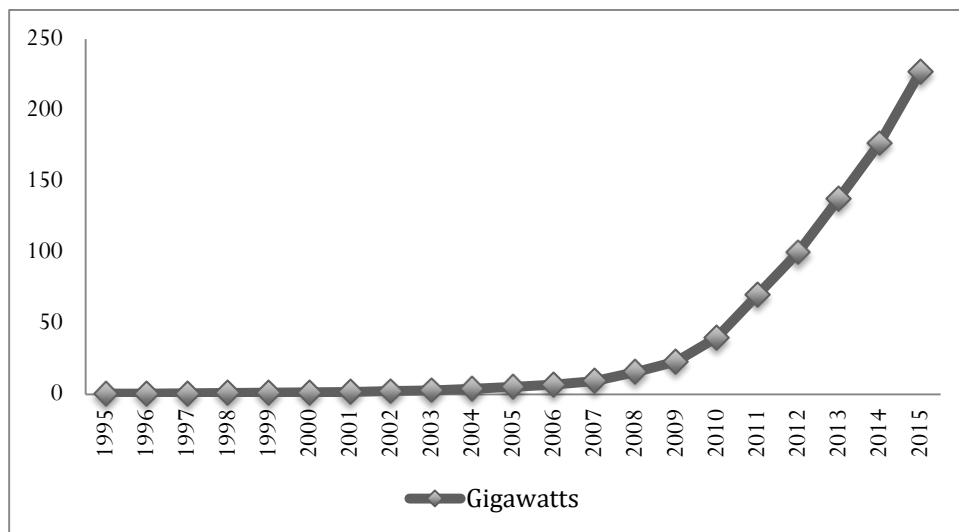


Figure 2. 2.: Solar PV total world capacity, 1995-2015

Source: Compiled by author from REN21 (2016) and earlier years

Two major factors led to this growth. The first one is policies. The market has benefited largely from demand-pull policies and subsidies. This is the topic of Chapter 3.

The second obvious reason for this dramatic PV penetration growth is cost reduction. Specifically, from 1998 to 2014, module (i.e. the most technological part of the PV value chain) prices dropped by \$4.4/W (85%), and non-module costs, i.e. costs independent of the module such as installation, by \$3.7/W (52%) (Barbose et al., 2015, pp. 16–18). There were many reasons for this collapse.

It was primarily due to declining silicon prices. The fluctuation is significant as crystalline silicon is the feedstock for PV panels. Due to silicon shortages, the price peaked at \$3.88/W before decreasing to \$2.00/W in December 2009 (Bazilian et al., 2013, p. 331), and then to \$0.6/W in 2014 (REN21, 2015, p. 62; cf. Box 2.4.). As polysilicon accounted for about 20% - 25% of the total module cost in 2013, silicon price fluctuations unquestionably had a huge influence on the entire crystalline silicon PV value chain (Bazilian et al., 2013, p. 331; Platzer, 2015, p. 3). The silicon price drop is a significant reason for PV cost reduction leading to PV growth, but it is only one reason.

Technological progress has also played a major role. As cost reduction and technological progress are tightly entangled with each other, improving module efficiency allows producers to reduce costs related to PV systems. On average, module efficiency has increased steadily from 2010 through 2014 in the U.S. sample, to reach a median module efficiency of 16% in 2014 (Barbose et al., 2015, pp. 16–18). Based on cost modeling by Goodrich et al. (2012, in Barbose et al., 2015, pp. 16–18), an efficacy increases from 15.5% in 2013 to 16% in 2014 reduces the non-module costs by \$0.06/W, comparable to 15% of the period drop.

Cost decreases also have multiple other reasons, notably continued progress in the production processes and reductions in the use of consumables (International Energy Agency, 2014a, pp. 28–29). Efforts are also dedicated to extending the technical life of cells and modules (International Energy Agency, 2014a, pp. 28–29), and

increasing potential energy outputs (Platzer, 2015, p. 4). The size increase of PV plants has also driven the price per watt down (cf. Section 1.3.2.3.1.).

Box 2. 4.: Silicon price variation

The great excitement in the PV market in the second half of the 2000s led to an insufficient supply to meet demand, leading to an unmanageable price. The period 2008 to 2012 witnessed sharp price fluctuations from \$400/kg in 2008 to \$20/kg in 2012 (Barbose et al., 2015, p. 2; Fu et al., 2015, p. 515). This downward trend continued in 2014 with multi c-Si spot prices down about 14% from 2013 to reach \$0.6/W (REN21, 2015, p. 62).

The increase was due to the impossibility to satisfy the demand, due to a strong and sustained increase in the PV industry. The price collapse is due simultaneously to over-capacity in silicon production and lower manufacturing costs in China and Taiwan. For example, in 2013, poly-silicon production was up to 227,000 tons, an increase of 16% over the previous year (Bloomberg Finance L.P., 2014, p. 2).

These supply-demand imbalances impacted the profit margin of operators. Unsurprisingly, gross margins were very high during the shortage period and exceptionally astronomical at 83%, before decreasing sharply to reach 45-49% by May 2009 (PwC, 2009, p. 37).

Interestingly, during the first decade of the 21st century, a strong demand for silicon from the PV industry led to a demand shift from the semi-conductor industry to the PV industry. While over 80% of the silicon industry was dedicated to the semiconductor industry before the 2000s decade, 80% is now consumed by the PV industry (Fu et al., 2015, p. 515).

1.3.2. Market diversity, where do PVs shine?

Having described PV growth and its main drivers, I will now turn to its market. Given that the PV market does not evolve in the same way, depending on the place and the system size, in this subsection, I examine this disparity. Specifically, I show that PV power can be produced through a centralized or distributed system. Furthermore, considering the lack of homogeneity in distributed systems, I go deeper to distinguish three different types of distributed system (off-grid, residential, and commercial).

1.3.2.1. PV dual production mode

PV power is ***produced through two energy production models***: centralized and distributed. With centralized production, it is generated on a large scale and is mainly managed by highly integrated corporations, typically large utilities and large organizations. DESERTEC, one of the world's biggest generation programs, is a perfect example of centralized generation (cf. Section 1.3.2.5.). It is based on the idea of large-scale utilization of PV and other RES (from water, wind, and geothermal) in deserts and arid regions, where solar power is abundant and constantly available (cf. Box 2.5.).

In distributed production, energy is generated in a multitude of small places. Thus, to be considered as distributed, the energy systems should be either: (1) relatively small and dispersed compared to the centralized production systems; or (2) distributed independently of a centralized network (REN21, 2015, p. 246).

It is noteworthy that all clean energy sources are produced on a large scale (i.e. centralized). Only PV, wind power and hydropower can also be produced on a small scale (REN21, 2015). Yet distributed wind power and distributed hydropower (i.e. small-scale) remain marginal, being used only in the U.S. and in developing countries, respectively. Hence, PV power stands apart from other renewable energy sources because PV technology is the sole technology for which distributed production is not a niche; it accounted for 35% of all installations in 2015 (Figure 2.3; IEA PVPS, 2016).

Overall, distributed PV systems are the main mode of production. Yet the situation is going to change soon because the centralized mode has been prevalent in new installations since 2013, representing 65% of all new installations worldwide in 2015 (Figure 2.3; IEA PVPS, 2016, p. 12). A centralized mode of production is preferred because it allows for rapid development of PV. The impressive growth of centralized PV plants is therefore expected to continue, especially in light of the growing interest by developing countries. The fast growth of centralized PV is mainly driven, in addition to the U.S.A., by China and by emerging countries whose policy support focus is on electricity generation, the availability of cheap capital for financing this kind of installation, and highly competitive calls for tenders (cf. Chapter 3; IEA PVPS, 2016, p. 14).

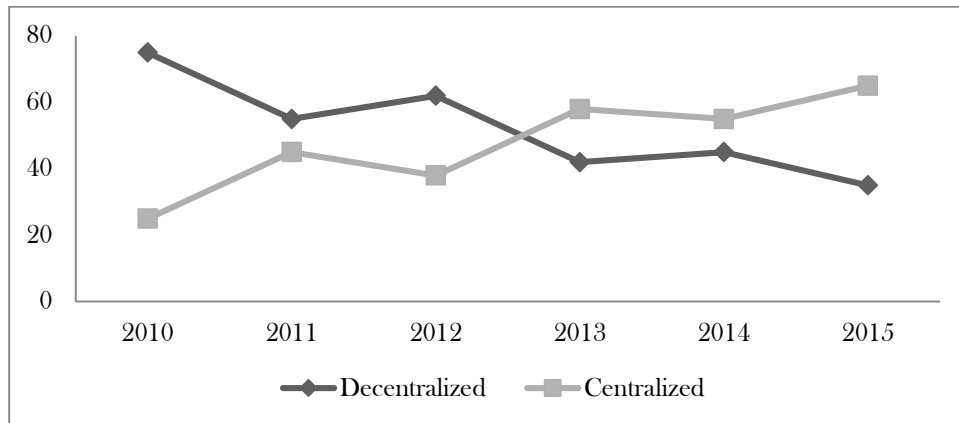


Figure 2. 3.: Ratio of decentralized versus centralized Solar PV installation
Source: IEA PVPS (2016a, p. 12)

Yet the question of producing distributed or utility-scale energy is not just a matter of choice, but also of population density. This difference across countries could be partially explained by the significant land use required to generate PV power. One must also bear in mind that the current conversion efficiency remains disappointing. As discussed earlier, PV technology can convert to electricity up to no more than 25% of the solar energy (sunlight) it is exposed to (IEA PVPS, 2016b, p. 5). Because of this relative inefficiency, the technology requires large areas of land. Furthermore, population density has a significant influence on the PV plant size (IEA PVPS, 2015,

p. 27). The higher the population density, the more likely it is that distributed PV generation will be chosen. In densely populated European countries, such as France, Germany, Belgium, the Netherlands, and Austria, it is not surprising that policymakers prefer distributed PV rooftop installation. As a result, the distributed proportion of solar PV total capacity in 2015 rose to around 65% in France and 75% in Germany. Conversely, in countries with large areas of free land, utility-scale plants may be preferred over rooftop projects, notably to accelerate PV integration. For example, in Romania and Bulgaria, the percentage of centralized solar plants respectively reached approximately 95% and 90% (SolarPowerEurope, 2016, p. 28).

To be sure, a general repartition between distributed and centralized is provided in most government and expert reports. But the distributed system is a heterogeneous group. I, therefore, believe that a detailed categorization will provide the reader with deeper insights into the PV market. Actually, nowadays there is *not one market but four* end-use sectors (International Energy Agency, 2010, pp. 10–11): (1) off-grid, (2) residential, (3) commercial and industrial, and (4) utility plant.

It is worth noting that, both the residential and the commercial and industrial rooftop systems together formed the grid-connected distributed system. Grid-connected distributed PV systems denote systems installed behind the customer meter, that is, on the demand side of the electricity meter. The power is generated and sent either to a grid-connected customer or directly to the electricity network (IEA PVPS, 2015, p. 6). Their size varies widely. Until 2013, they were the most widely used applications within the overall PV market (cf. Figure 2.3.).

The grid-connected distributed system can be contrasted with the utility-scale systems forming the centralized system. These distinctions are of particular importance, as behind seemingly simple metrics, wide disparities, notably in price and size, appear. The following table summarizes the key features of the four end-sectors.

1.3.2.2. Off-grid systems

The first of the end-use sectors deals with *off-grid (or stand-alone) PV power systems*. They are autonomous and self-sufficient applications, not connected to a network of high-tension cables and power stations. The size of these applications varies widely and is typically up to 5kW (IEA PVPS, 2015, p. 6).

Off-grid applications are used where PV is cost-competitive with other small generating sources (IEA PVPS, 2015, p. 6). In some cases, they offer an economic alternative to extending the electricity distribution network. Off-grid applications are used to provide electricity to households, isolated villages and rural communities for remote facilities and for recreational and communication devices in specific cases (e.g. in the mountains) not connected to the utility grid(s) because the existing infrastructure would make that too costly. Interestingly, they are also used to power large-scale telecommunication systems (IEA PVPS, 2015, p. 6; SolarWorld, n.d.).

A distinction can be made between off-grid domestic and non-domestic installations (IEA PVPS, 2015, p. 6). With off-grid domestic installations, electricity is installed for providing lighting, refrigeration and other low-power loads to users via a ‘mini-

grid'. This mini-grid is often hybrid, that is, composed of more than one source of energy.

Turning now to off-grid non-domestic installations, interestingly they were the first commercial application for PV systems (IEA PVPS, 2015, p. 6). Specifically, the first serious use of PV technology was governmental: to power satellites during the space race between the USA and the Soviet Union (Platzer, 2015, p. 26) (cf. Chapter 3). This was not long after the introduction of the first PV cell, in 1958. Since then, almost all satellites have been powered by PV cells owing to their long-lasting operability with virtually no maintenance. Sharp was the first company to use PV for a terrestrial application by powering hundreds of lighthouses along the coast of Japan (cf. Box 2.1.). Thus, these non-grid-connected applications address a broad range of needs, including powering satellites, telecommunications, pumping water for agriculture, vaccine refrigeration and navigational aids.

Despite the off-grid system's significant share in the mid-1990s, it currently accounts for a small portion of total systems: from 70% of the total world installations in 1994 to 20% in 2000, and to less than 5% nowadays with significant disparities across regions (IEA PVPS, 2015, p. 11; IRENA, 2015, p. 13). In most European countries they account for less than 1% of the installed PV capacity, as opposed to the USA, where they account for about 10% (EPIA, 2014, p. 13; International Energy Agency, 2014a, p. 10). Off-grid applications remain particularly important in nations that lack electricity infrastructures and in remote areas, including Australia, China, and South Korea. For example, in 2015, 25 MW, up to 16 in 2014, were installed in Australia and 20 MW in China, down from 40 (IEA PVPS, 2015, p. 11; IRENA and IEA PVPS, 2016, p. 12).

1.3.2.3. Residential systems

The first of the on-grid distributed systems involves *residential systems*, which are implemented on the rooftops of individual buildings/dwellings, typically single-family residences and multi-family housing. Here, the PV installed capacity is usually limited to 10 kW.

The increase of system size has been noteworthy in residential systems. It has allowed for reductions in the fixed project costs per installed watt (Barbose et al., 2015, pp. 16–18). Over the 2013-2014 period alone, the median size of U.S. residential systems grew by 0.3 kW. Relying again on the modeled PV cost relationships developed by Goodrich et al. (2012, in (Barbose et al., 2015, pp. 16–18), the impact is estimated at a non-module cost decrease of approximately \$0.04/W, equivalent to 10% of the non-module price drop from 2013 to 2014 (Barbose et al., 2015, pp. 16–18).

1.3.2.4. Commercial (and industrial) systems

The second grid-connected distributed end-use sector concerns *commercial (and industrial) (rooftop) systems*. As the name suggests, they are mounted on commercial office buildings, schools, hospitals, retail outlets, and so on so forth. The capacity is more significant as they are up to 1MW.

Two types can be distinguished, based on the installation size: small (<500 kW) and large commercial systems (>500 kW up to 1 MW). While the larger class has risen in median system size over time, the opposite is true for the smaller category. The vast majority is considerably smaller with an average of 20-30 kW over the past decade (Barbose et al., 2015, pp. 16–18).

1.3.2.5. Centralized (utility-scale) systems

This leaves us with the last end-use sector: the *utility-scale systems* dealing with centralized production. These systems are mainly mounted directly on the ground, or exceptionally on top of buildings. Typically, their generation capacity ranges from 1 to 10 MW. As such they fulfill the function of centralized power stations to supply bulk power and are not associated with a specific customer (IEA PVPS, 2015, p. 6).

Box 2. 5.: Importance of deserts and arid regions

Deserts and arid regions are particularly well-suited to the exploitation of solar and wind power, for three reasons. First, the sunlight and the wind are freely available in endless supply. It is estimated that the PV exploitation of an area corresponding to 1% of the desert surface would be enough to satisfy the world's energy demand. According to Dr. Gerhard Knies, “within 6 hours, deserts receive more energy from the sun than humankind consumes within a year”. However, it is still under-utilized.

Second, most desert areas benefit from scattered human and animal populations, and sparse vegetation, which is compatible with the land use required for a large-scale RES facility.

Last but not the least, technologies are now available to transport the converted electricity from sunlight and wind over long distances at minimum loss to centers of demand (Desertec Foundation Flyer). This is made possible thanks to High-Voltage Direct Current (HVDC) transmission. In contrast to the conventional transmission (i.e. alternative current), HVDC can carry electricity from RES over long distances with losses limited to 3 percent per 1,000 kilometers. This is even more attractive, knowing that 90% of the world's population lives within 3,000 km of these places.

Interestingly, considering their size, these systems are independent of any nearby development (IEA PVPS, 2015, p. 6). Therefore, large-scale PV plants are mainly implemented in desert and arid regions. Further information on opportunities offered by deserts and arid regions to the development of PV use are set out in Box 2.5. It was not until the 1980s (i.e. two decades after the first commercialization of PV) that the idea of such exploitation was considered, thanks to Dr. Gerhard Knies, German Physicist and Member of the Supervisory Board of the DESERTEC Foundation (DF), a private industrial initiative (source: The Desertec Concept). The DF intends to offer a solution to the challenge of satisfying the growing global energy demand in a sustainable way by exploiting power plants in sun-rich deserts. Describing itself as “a global civil society initiative”, the DF has the objective of shaping a sustainable future by promoting not only the systematic use of renewables

in deserts and arid regions but also the electrification of the world with clean electricity as a way to achieve positive, further developments of global society. In other words, it is committed to improving living conditions and defusing the battle for limited fossil fuel energy resources and scarce drinking water resources.

The first 1 MW solar plant was inaugurated by Arco Solar in 1982 at Lugo, California. Since then, a large number of utility-scale plants have been set up. The year 2014 witnessed the utility-scale projects boom in dozens of new countries around the world (IEA PVPS, 2015, p. 10). It is worth pointing out that, in 2016, more than 120 solar PV plants larger than 50 MW were operating, up from 70 projects in 2015¹⁷. As of February 2016, the top 50 plants alone have a total capacity exceeding 13.5 GW (REN21, 2016, p. 64). These large plants are running in 23 countries, nine more than in the previous year. The ten largest PV plants are in China, India and the U.S. (REN21, 2015, p. 61).

Let us have a closer look at just how big these projects are. Our first example consists of two utility-scale power projects: Desert Sunlight and Topaz, generating 550 MW each, located in central California (Sanburn, 2015). They went online respectively in early 2015 and late 2014 (REN21, 2015, p. 61). Built by FirstSolar, they are the first utility-scale projects that are really on the scale of a conventional coal or nuclear power plant. Desert Sunlight Solar Farm totalizes on its own more than 8 million solar panels of cadmium telluride, a PV technology appropriate for large-scale plants (cf. Section 1.), while Topaz has 9 million. Desert Sunlight project alone delivers enough electricity to power about 160,000 homes and to reduce carbon emissions at the same time. The ecological impact is comparable to taking 130,000 cars off the road.

Another example is the world largest solar installation: Solar Star Projects (formerly Antelope Valley Solar Projects), in Kern and Los Angeles counties in California (Sunpower 2014). While SunPower (cf. Box 2.6.) built it, BHE Renewables is the current owner¹⁸. The projects went online in 2015, adding 579 MW to the existing global PV capacity. With its 1.7 millions of mono-crystalline silicon modules (cf. Section 2.2.1), it can provide power to about 255,000 homes.

¹⁷http://www.dii-eumena.com/fileadmin/Daten/press/Dii%2014_10_14_eng%20Press%20Release%20-%20AC%20Roma.pdf and <https://www.db.com/cr/en/concrete-desertec.htm>

¹⁸ https://www.bherenewables.com/include/pdf/fact_sheet_topaz.pdf

Box 2. 6.: SunPower

Based in San Jose, California, SunPower Corp is the 2nd biggest US PV maker. The company bought Tenesol, the French solar subsidiary of Total for \$165.2M in February 2012. In the same time, Total bought 66% of SunPower for \$18.6M.

The yield of its solar products is 24%, much better than the 15% average of its rivals. But, SunPower faced competitive issues leading to the announcement of restructuring plans at the end of 2016.

Considering that FirstSolar and SunPower are two major US PV producer, it is worth comparing them. Like FirstSolar, SunPower is in charge of a large solar plant in California, named Solar Star, providing 700MW. It is comparable to half of a nuclear power plant with the new generation of reactors.

But, unlike FirstSolar, SunPower has a geographically diversified pipeline of utility-scale power projects. For example, the company is also involved in non-subsidized projects, such as in Chile. With a capacity of 75MW, it is unique. The company is also committed for a 50-year period in South Africa, where it provides solar energy solutions for ground-based solar farm and off-grid applications. In the context of the Independent Power Producers Procurement Program, following a call for tenders, the South African Department of Energy selected SunPower for the engineering, procurement, construction, operation and maintenance of an 86MWc-solar plant in Prieska: Oasis Power Blocks. It aims at providing 210GWh a year, the equivalent domestic consumption of 450,000 people.

Numerous noteworthy initiatives in other parts of the world come to mind. Admittedly, the DF concept's implementation is not limited to the U.S.A. Indeed, as explained above, since 90% of the population lives within 3,000 km of deserts, it is possible to carry out the project where suitable deserts are within reach of the centers of demand, i.e. in the Sahel and Southern Africa, the Americas, Australia, India and East Asia.

What is certain is that the southern Mediterranean region is relevant regarding renewable energy sources (RES), solar and wind mainly (Cambini and Rubino, 2014, p. 209). The following example relates to the Moroccan Solar Plan involving five mega-scale solar power projects: Laayoune (Sahara), Boujdour (Western Sahara), Tarfaya (south of Agadir), Ain Beni Mathar (center) and, Ouarzazate. The Plan aims at producing 500MW of generation capacity by a combination of solar thermal power plants, CSP, PV, and wind power (Dii, 2013). Together they will be able to produce approximately 1.4 to 1.6 TWh per year. The first phase went live at the end of 2015. The Moroccan Solar Plan plays an exemplary role, and as such the International Energy Agency (IEA) welcomed it¹⁹. To supervise, coordinate, and implement the different projects, the Moroccan Agency for Solar Energy (MASEN), a public-private

¹⁹ <http://www.iea.org/newsroomandevents/pressreleases/2014/october/review-highlights-morocco-progress-towards-energy-transition.html>

venture, was created in March 2010²⁰. The capital is held in equal proportions by the Moroccan State, the Hassan II Fund For Economic and Social Development, the Energetic Investment Company (SIE), and the *Office National de l'Eau et de l'Electricité* (ONEE).

Yet such ideas do not always yield the promised results. A counterexample may be found in the industrial consortium Dii GmbH, standing for DESERTEC Industrial Initiative, launched in 2009. Previously located in Munich, Dii's offices are now in Dubai since Dii's repositioning as a consulting firm, in February 2015 (for further details, cf. Box 2.7.), in the framework of cooperation between many renowned firms and DF. Its body of shareholders is characterized by its composition, which includes the industrial and financial sectors. The founding shareholders are DF, ABB, ABENGOA Solar, Cevital, Deutsche Bank, E.ON, HSH Nordbank, MAN Solar Millennium, Munich Re, M+W Zander, RWE, SCHOTT Solar, and Siemens²¹. Dii describes itself as a facilitator of the whole process (Dii, 2013, p. 6). The main purpose of this initiative was to accelerate the creation of a market for renewables in EU-MENA regions by creating an interconnected pan-European and cross-Mediterranean grid based essentially on clean energy generation²² (Bardolet, 2014, p. 96). For now, except for few success stories, the DESERTEC concept "remains a dream, a vision."

Box 2. 7.: Rise and Fall of the Desertec Foundation

As stressed in 2010 by Dr. Angela Merkel, German Chancellor, DESERTEC "has the potential to be a connecting project between the European and the African continent" (Press conference in Berlin 05.12.2010)²³. As the years went by, there were doubts about the ability to deliver tangible and timely results. In particular, there were many doubts as to whether megaprojects such as DESERTEC would be able to prevail in the future of electricity generation over other solar energy sources using both solar thermal power and PV (Scheer, 2009 in Bruns et al, 2011).

Hence, the idea of exporting clean power from MENA to EU has been abandoned by Dii due to: (1) the excessive budget; (2) technical issues; (3) years of bickering about future strategies, obligations and managerial style²⁴ (DESERTEC Foundation, 2013); (4) the fact that the EU has experimented with its own renewable energy sources since DESERTEC's creation; and (5) an EU directive (Directive 2009/28/EC) limiting energy importation from non-EU countries.

²⁰ <http://www.eurosunmed.eu/partners/masen-moroccan-agency-solar-energy>

²¹ <http://www.desertec.org/press/press-releases/091030-01-formation-dii-gmbh/>

²² <http://www.desertec.org/press/press-releases/130701-desertec-foundation-is-leaving-the-industrial-consortium-dii/>

²³ <http://www.desertec.org/concept/endorsements/>

²⁴ <http://www.desertec.org/press/press-releases/130701-desertec-foundation-is-leaving-the-industrial-consortium-dii/> and http://www.globalenergyworld.com/news/8422/DESERTEC_Foundation_is_leaving_the_industrial_consor_tium_Dii.htm

That is why Dii wished to refocus on the local market. Since then, both entities (i.e. DF and Dii) have evolved separately.

The cessation of the DF membership of Dii GmbH was announced on July 1st, 2013, following an extraordinary board meeting on the June 27th. As a result, forced to lower its objectives, the Dii had to reinvent itself as a consultancy firm. Its purpose is now limited to providing services to its shareholders and supporting the implementation of projects in the MENA area²⁵. Its office has moreover moved from Germany to Dubai to get closer to the “clients”. Dii CEO Paul van Son described this repositioning as follows: “Frankly, four years ago DESERTEC was all about bringing energy from North Africa. We abandoned that one-dimensional thinking. It's now more about creating integrated markets in which renewable energy will bring its advantages... That's the main objective”²⁶.

1.4. Conclusion

This first section highlighted the uniqueness of PV as a renewable energy source. Specifically, PV technology stands out for numerous reasons, including its newness compared to the clean energies, its significant proportion of distributed production, and its explosive growth during the last ten years through its four end-use sectors.

This section has also emphasized the fact that the industry has been experimenting with a wide variety of technological options. For the remainder of this Ph.D. thesis, since the large majority of the market is dedicated to a specific light-absorbing material, i.e. the multi-crystalline poly-silicon (poly-Si), I focus on it, and to a lesser extent on mono-crystalline silicon. I do not deny that the other two technology generations (i.e. thin-film and third category of PV semi-conductor device) are gaining interest, but their market share remains limited albeit not negligible.

I have discussed light-absorbing materials, but PV technology is not limited to this component, which actually requires much more manufacturing processes. I include here not only the conversion of metallurgical-grade silicon to the (mono- and) poly-silicon that can be used for solar cells but also all the processes required for the manufacturing module. All the non-module activities are all taken into consideration. That is the topic of the next sections. Specifically, the following section aims at improving our understanding of PV through its manufacturing processes, enabling me later to analyze the PV value chain within the GVC framework.

²⁵ <http://www.dii-eumena.com/fr/presse/news/dii-is-moving-on-from-its-new-basis-in-dubai.html>

²⁶ <http://www.forbes.com/sites/christophercoats/2014/10/30/tunisia-follows-solar-supplier-dream-for-europe/>

2. Photovoltaic value chain

In this Section, I examine a segmentation of the value chain, which will enable us to pool activities into eight categories, inspired by the model used by EPIA and Gallagher and Zhang (2013). Furthermore, in line with the OECD and others (e.g., International Energy Agency, 2010), it is possible to group actors operating in the PV industry into two main segments: those operating *upstream* (focusing on the PV modules), and those *downstream* (dealing with the services and system components forming a PV system). The description of the value chain starts with the upstream segment (Section 2.1.) and ends with the downstream one²⁷ (Section 2.2.).

2.1. Upstream activities, focus on module

The upstream segment of the PV value chain deals with the solar panel manufacturing activities. Specifically, production of a crystalline silicon module involves four stages (Platzer, 2015, p. 4). It is worth noting that the production and distribution are done at the global level.

2.1.1. Poly-silicon manufacturing

Poly-silicon is the raw material used for the solar materials. Poly-silicon manufacturers produce highly purified silicon. The level of purification is at least at 6N equals to 99.999999% purity (NREL, 2010, p. 30). This implies not only a significant standardization of the process but also significant technical capabilities.

2.1.2. Wafer manufacturing

Once the silicon is produced, wafer companies use traditional semi-conductor manufacturing equipment to shape the light-absorbing material into ingots (i.e. molds in which relatively pure material, here poly-silicon, is cast). The ingot is sliced into thin wafers (i.e. a slice). The wafers are further “cut, cleaned and, coated according to the specifications of the system manufacturers” (Platzer, 2015, p. 4).

The wafers are cut into specific dimensions and shapes according to the client’s needs (i.e. those of cell makers), to form a cell (Platzer, 2015). The typical dimensions are 5x5 and 6x6 inches. Their shape is variable: round, square, or long and narrow.

2.1.3. Cell manufacturing

This thin wafer is then treated to form an electric field, positive on one side and negative on the other²⁸. That is the purpose of a solar cell. In other words, the semi-conductor device generates direct current electricity. Hence, “solar cells are the basic building blocks of a PV system” (Platzer, 2015, p. 4).

²⁷ Over the years, the proportion of the production of cell and module costs decreases, allowing the downstream part to increase its weight in the value added. It is worthwhile noting that the PV modules’ contribution to total PV cost of installation shrank from around 70% in 2007 to 48% in 2012, depending on the technology and the type of installation (EPIA, 2012).

²⁸ <http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/>

2.1.4. *Module manufacturing*

When 60 to 72 PV cells are covered by a solar glass and are assembled together to form an electric circuit, the end result is a module (Platzer, 2015, p. 4). The function of the glass is to protect the module from elements (i.e. wind and rain) and to maximize the efficiency conversion. A module weighs between 34 and 62 pounds. This is the last step in the upstream segment.

2.2. *Downstream activities*

This section is dedicated to the study of activities independent of the module manufacturing activities. I understand that grid-connected systems require more than the PV module. These non-module activities are situated in the downstream segment. They can be grouped into four categories: (1) balance of system (BOS) component making; (2) system manufacturing; (3) project development (and installation); and (4) operations and maintenance (O&M).

Therefore, manufacturing activities are also present in the downstream segment, through BOS and system manufacturing. They generate non-module hardware costs (e.g. fixed supports or tracking systems, cables, inverters) (Barbose et al., 2015, pp. 2; 16; International Energy Agency, 2014a, pp. 30–31). The other two activities relate to soft costs, including marketing and customer acquisition, connection, financing, system design, installation labor, and inspection costs.

It is worth noting that downstream activities, including inverters, are subject to national codes and regulations (IEA PVPS, 2016b, p. 52). Indeed, country particularities have undoubtedly had an impact with regard to taxes, license fees, and geographic issues (e.g., Barbose et al., 2015; REN21, 2015; cf. Chapter 3). That explains why the companies are close to the end-markets and produce locally.

2.2.1. *BOS manufacturing*

BOS manufacturing activity relates to the manufacturing of inverters, electrical engineering equipment (cables and wiring, connectors), structural components (solar panel mounting equipment), monitoring system, and so on (Gallagher and Zhang, 2013; International Energy Agency, 2014, p. 11; SER-SOLER, 2013, p. 6).

The inverter is the most important element here. Acknowledging that a PV module produces direct current electricity, to convert it into alternative current, an inverter is required. Indeed, an inverter makes the power generated by PV modules compatible with grid and home use by converting direct current to alternate current (Platzer, 2015, p. 5). Interestingly, new inverters are under development to provide sophisticated control and interactive communications features. These functions enable inverters to better support grid management and grid protection (IEA PVPS, 2015, p. 44).

2.2.2. *System manufacturing*

I also include in front-end manufacturing activities *system manufacturing*, dealing with fixed supports or tracking systems applied on building rooftops or facades, above parking lots, or on the ground (International Energy Agency, 2014a, p. 11).

Two system types are proposed for rooftops:

1. With standard rooftop systems, the module is only attached to the construction materials of a building. As such it is not part of the construction materials.
2. Building-integrated photovoltaic (BIPV) are the most expensive systems (International Energy Agency, 2014a, pp. 30–31). The PV module is integrated into the envelopes or with the construction materials of a building. In other words, for this application, the module replaces the roof elements.

Other solutions are under development, including PV materials for roads and similar surfaces (International Energy Agency, 2014a, pp. 30–31). However, they are not considered in the manuscript.

2.2.3. *Project development*

This activity deals with the implementation of a solar plant: development, construction, financing, inspection, installation, and various administrative tasks, including the permit.

2.2.4. *Operations and maintenance (O&M)*

This relates to the exploitation of the solar plant, by the energy producer or for the customer, and encompasses a wide variety of maintenance contracts and costs (IEA PVPS, 2015, p. 49). Therefore, supervision and monitoring of PV plants are part of this stage. Some companies offer a software for this purpose. This activity gains in importance as the PV market grows (IEA PVPS, 2016b, p. 53).

2.3. **Conclusion**

The description of the PV value chain sheds light on eight distinct stages: four in the upstream segment and four in the downstream. Upstream activities are highly technological and dependent on each other. Contrariwise, the downstream activities include low-technological manufacturing activities and services. What is important is that the downstream activities evolve independently from the evolution of those in the upstream. The mix offers a wide variety of combinations. This results in the modularity of the PV value chain. The modularity is particularly glaring in the downstream segment, as there is no communicating vessel between these activities.

Having described the activities, I outline their characteristics inspired by the GVC framework in the following sections. Annexes 2.1. and 2.2. will provide an overview of the characteristics of value chain segments that are developed in this section. In doing that, I will be able to highlight (1) in Section 3 the relative applicability of the global value chain framework to the upstream segment and, (2) in Section 4 the limit of this framework for the downstream segment. Upstream Industry Structure

3. The upstream industry structure

I am interested in the industry structure and the governance at key nodes. To this end, I pay particular attention to barriers to entry, market concentration, vertical integration, and geographical dynamics. This section focuses on the upstream segment.

3.1. The predominance of financial barriers to entry

The primary barrier to entry in the upstream segment is by far financial. While technical barriers do exist, they can reasonably be overcome. To give an idea of the financial barriers, according to Sontakke (2015, p. 9), the capital outlays are high, with \$100 million required to set up a poly-silicon plant producing 1,000 tons annually. Platzer (2015, p. 3) estimates that it could require up to \$1 billion to build a plant. The financial barriers are also high for cell manufacturing, albeit less than that for poly-silicon manufacturing. In 2011, it is estimated that building a cell manufacturing plant with a capacity of 120 MW a year costs \$40 million, according to the U.S. Department of Energy (NREL, 2011a). While I do not have any estimate as to the cost of building a plant producing wafers and ingots, as well as modules, financial barriers to entry are much lower than those associated with the other stages of the value chain.

Interestingly, the various profitability levels reflect the degree of the various financial barriers. Studies (PwC, 2012, p. 22, 2009, p. 37) show that the more capital intensive the activity, the higher the Earnings Before Interests and Taxes (EBIT; also referred to as operating profit) will be. Accordingly, in 2010, poly-silicon production was the most profitable activity, with an EBIT of 27%, followed by cell manufacturing (20.1%), far ahead of module manufacturing (7.2%) and activities dealing with systems (5.9%) (PwC, 2012, p. 22). Obviously, this margin was an incentive for many firms to operate specifically in silicon and cell production.

Rank	2007	2008	2009	2010	2011	2012	2013	2014
1	Sharp (Japan)		First Solar (USA)	Suntech Power and JA Solar	Suntech Power (China)	Yingli (China)	Yingli (China)	Trina Solar (China)
2	Q-Cells (Germany)	Sharp (Japan)	Suntech Power (China)	JA Solar (China)	First Solar (USA)	First Solar (USA)	Trina Solar (China)	Yingli (China)
3	Suntech Power (China)	First Solar (USA)	Sharp (Japan)	First Solar (USA)	Yingli Green Energy (China)	Trina Solar (China)	Sharp Solar (Japan)	Canadian Solar (Canada)
4	First Solar (USA)	Yingli Green Energy (China)	Q-Cells (Germany)	Yingli Green Energy (China)	Trina Solar (China)	Canadian Solar (Canada)	Canadian Solar (Canada)	Jinko Solar (China)
5	Solar World (USA)		Yingli Green Energy (China)	Trina Solar (China)	Canadian Solar (Canada)	Suntech Power (China)	Jinko Solar (China)	JA Solar (China)
6	Sanyo (Japan)		JA Solar (China)	Motech Industries (Taiwan)	Sharp (Japan)	Sharp (Japan)	ReneSola (China)	Sharp Solar (Japan)
7	BP Solar	Trina Solar (China)	Trina Solar (China)	Q-Cells (ML)	SunPower (USA)	Jinko Solar (China)	First Solar (USA)	ReneSola (China)
8	Kyocera (Japan)		Gintech (Taiwan)	Gintech (Taiwan)	Tianwei New Energy (China)	SunPower (USA)	Hanwha SolarOne (China)	First Solar (USA)
9	Moser Baer Photovoltaic	Canadian Solar (Canada)	Motech Industries (Taiwan)	Sharp (Japan)	Hanwha-SolarOne (China)	REC Group (U.S.A.)	Kyocera (Japan)	Hanwha SolarOne (China)
10	Motech Industries		Canadian Solar (Canada)	Canadian Solar (Canada)	LDK Solar and Hareon Solar (China)	Hanwha SolarOne (China)	JA Solar (China)	SunPower (USA) and Kyocera (Japan)

Table 2. 2.: Top 10 solar module manufacturers by installed capacity (2007-2014)

Source: Compiled by author from various websites (pv-tech.org; <https://www.renewableenergyworld.com>)

3.2. Market concentration

Despite financial barriers to entry, new competitors with significant financial capacities continue to enter the fray. For example, since 2005, between 60 and 80 emerging small and medium-size players have entered the global poly-silicon market (Fu et al., 2015, p. 515).

While the ENF Solar database does not provide an exhaustive list of the actors operating in the upstream segment, it enables us to have an idea of its population. At the time of writing, 79 companies are listed as polysilicon manufacturers, 150 wafer makers and 112 ingots producers, 66 cell and module manufacturers²⁹. These figures are consistent with the level of financial barriers discussed above.

It is noteworthy that, despite the introduction of new competitors, a handful of manufacturers capture the bulk of the market (Platzer, 2015). Between 90% and 93% of the market share during the 2011-2013 period was concentrated in the hands of the top ten poly-silicon producers (Bloomberg Finance L.P., 2014, p. 2; Fu et al., 2015, p. 515). In particular, the top five players supplied more than 60% of the 260,000 tons of polysilicon produced³⁰ (IEA PVPS, 2015, p. 38). Based on this figure, the poly-silicon industry could be considered as highly concentrated and driven by an oligopoly (Bloomberg Finance L.P., 2014, p. 2). However, this estimate is contradicted by Fu et al. (2015, pp. 515–516), who claim that the market is still considered as un-concentrated, with a 13.9% at Herfindah-Hirschman-Index (HHI)³¹.

The lower down I go in the PV value chain, the less concentrated the market is. The silicon cell industry is much less concentrated than the poly-silicon industry: the market share of the top ten cell producers is 46% and is stable over time (Bloomberg Finance L.P., 2014, p. 2). The module industry is as fragmented as the top 10 PV module manufacturers in 2014 produced 51% of all shipments³². Hence, the higher the financial barriers, the weaker the competition.

It should also be mentioned that the top cell and module manufacturers, irrespective of their segment, change over time (cf. Table 2.3). These changes could partly be explained by business fragility following price fluctuations (cf. Box 2.4.), which have caused some companies to go out of business, including big actors. SunTech, one of the top 10 cell manufacturers, is a case in point, as it went bankrupt due to default on bond payment in 2014.

²⁹ <http://www.ensolar.com/directory/material>

³⁰ 5.7g of poly-silicon are required for 1W of solar cells (IEA PVPS Trends 2015: 38).

³¹ The index is defined as the sum of the squares of the market shared of each firm in the industry.

³² It seems that at least since 2011, the industry tends to be more concentrated as the top ten captured 51% of the market share in 2014, up from 45% in 2011 and 48% in 2013 (Bloomberg Finance L.P. 2014:2; REN21 Renewables 2011; Global Status Report, 2011: 41) the BNEF (2014: 2) and Mints (2015).

3.3. Vertical integration

Another noteworthy feature of the upstream industry structure is the vertical integration trend (also called ‘intra-chain upgrading’ within the GVC framework). Significantly, this trend affects the value chain unevenly and is highly dependent on the level of capital outlay for building a production facility³³. Studying vertical integration is particularly useful for determining the drivers in the upstream segment.

According to Eric Westerhoff of Soitec, usually, when a company manufactures its modules, it is also in charge of the cell production, and vice versa (cf. interview). Indeed, vertical integration in the PV upstream segment is particularly common between cell and module manufacturers. While three of the ten leading module producers are pure-players, the seven others are vertically integrated into cell production (Bloomberg Finance L.P., 2014, pp. 4; 6).

Still, it is worth pointing out an undeniable upward trend of outsourcing poly-silicon cell production (ADEME, 2014a, p. 19). Interestingly, some module manufacturers are not able to meet demand even though they are running at very high capacity. This is particularly true for tier-1 module makers, who outsource production to tier 2 and even tier 3 (Bloomberg Finance L.P., 2014, p. 1).

Such outsourcing is possible because of the high complexity of the transaction, the high level of codification of transactions (i.e. the ease with which clients’ specifications can be codified), and the high capabilities of suppliers (i.e. whether the equipment production is easily reprogrammed). Indeed, little information is required such as the conversion efficiency and the size of the cell. Hence, the cell makers are able to produce for more than one module manufacturers. As such, cell makers are turnkey suppliers and module manufacturers are lead firms in the upstream part of the PV value chain.

Unfortunately, outsourcing history is full of stories that do not end well. Soitec is a case in point (Box 2.3.). This firm outsourced the cell manufacturing of its CPV module. Its R&D efforts provided interesting outcomes with great commercial promises, but unfortunately, it relied on the wrong supplier, leading to two significant delays in the delivery of its San Diego solar plant of 150 MW. This finally resulted in giving up the solar activity at the beginning of 2015.

Besides, ingot and wafer manufacturers tend to be dominated by cell manufacturers, most likely because this activity is fairly standardized and the barriers to entry are relatively low. It is estimated that 40% of all cell producers have integrated wafer activities³⁴. Considering that they integrate downstream, this vertical integration is called forward integration by economists (Harrigan, 1985, p. 399).

In 2011, when comparing the top ten producers of poly-silicon, only three top poly-silicon producers were integrated downstream into ingot and wafer manufacturing:

³³ http://www.greenrhinoenergy.com/solar/industry/ind_02_wafers.php

³⁴ http://www.greenrhinoenergy.com/solar/industry/ind_02_wafers.php

GCL, REC, and MEMC³⁵ (Bloomberg Finance L.P., 2014). This could be explained by the significant investments required for establishing a new production facility.

3.4. Geographical manufacturer dynamics

The podium changes discussed in Section 3.2. reflect the dynamics of the geography of manufacturers. It comes as no surprise that I am witnessing an increasing trend to shift production to low labor cost countries over just a few years, in industries ranging from poly-silicon to module production (Bloomberg Finance L.P., 2014; International Energy Agency, 2010, p. 10). Specifically, there is an increasing availability of a large base of low-cost suppliers, especially from China and India, in the upstream segment (cf. Figure 2.4.). These countries are qualified as net exporters as they have increased their business value in exports through the PV market (IEA PVPS, 2015, p. 49).

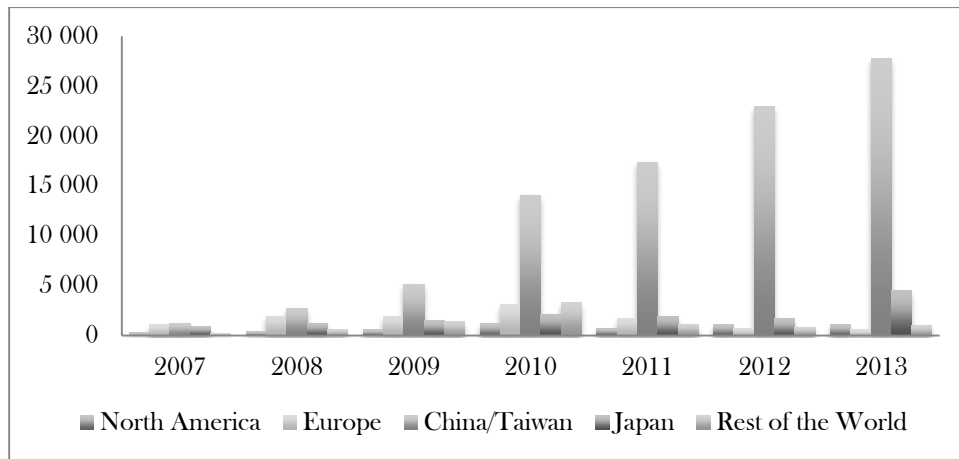


Figure 2. 4.: Global cell production by region (2007-2013)

Source: Compiled by author from Bloomberg Finance L.P. (2014, p. 5) and NREL (2011b, p. 21)

In particular, since 2009 Chinese companies have conquered the cell and module segments of the value chain, pursuing an aggressive low-cost strategy (REN21, 2015, p. 62). At the time of writing, they account for almost half of the actors³⁶, and in 2013 and 2014 they alone accounted for 64% of the world's cell production. The trend is expected to continue.

Some studies (e.g., Fu et al., 2015, p. 517; REN21, 2015, p. 21) claim that the manufacturing cost differences that do exist are most likely a result of different quality based on silicon purity, different facility locations, and labor rate variations. However, the low labor cost impact is marginal as production is highly automated. That is why the International Energy Agency (2014a, p. 11) suggests that the historical price advantage of Chinese factories over American ones (and by extension

³⁵ <http://www.greenworldinvestor.com/2011/03/01/list-of-worlds-top-solar-wafer-companies-growing-bigger>

³⁶ <http://www.enfsolar.com/directory/material/cell>

European plants) is due not so much to country-specific factors as to scale, supply-chain development, and access to finance. Specifically, the origin of this shift would thus most probably be the result of huge investments in production capacity.

Similarly, a comparative analysis over time shows that not so long ago industrialized countries were leaders in poly-silicon production, and now new competitors with significant financial capacity have entered the fray (NREL, 2010). Almost half of all production comes from Chinese or South Korean firms. The podium of the top five polysilicon players in 2014 reflects this diversity: GLC Poly Energy (China), Wacker-Chemie (Germany), OCI (Korea), Hemlock Semiconductor (U.S.A.), and REC Silicon (U.S.A.).

This trend could also be explained by the fact that many patents relating to the crystalline-silicon light-absorbing material have fallen into the public domain (Mathews, Hu and Wu, 2011 in Su, 2013, p. 3). This is meaningful when I understand that competition is primarily based on price, as poly-silicon is traded on commodity exchanges (Sontakke, 2015, p. 9). This price war has caused many firms to exit the segment. A case in point is Emix (owned by Grupo FerroAtlantica since 2012), one of the two companies involved in the processing of silicon in mainland France.

3.5. Conclusion

I conclude from the analysis of the upstream segment that the first two nodes (between poly-silicon and wafer, and between wafer and cell manufacturing activities) are characterized by simple transactions and product specifications (i.e. high level of standardization) and high capability of suppliers. On the basis of the governance forms of GVC considered in the first chapter, the governance of these two nodes is essentially market-like. Therefore, the main driver is the price.

As regards to the node between cell and module manufacturing, the relationship is essentially modular, despite the significant trend towards vertical integration. Here the main drivers are undoubtedly lead firms. Specifically, I conclude that lead firms occupy the module making stage as they provide specifications to turnkey suppliers (i.e. cell manufacturers). Admittedly, the capability of suppliers is high, enabling them to be 'independent' from the lead firms and to have some power.

4. A heterogeneous downstream segment

As I did for the upstream part of the PV value chain, I am going to analyze the downstream segment and specifically its barriers to entry (Section 4.1.), its market concentration (Section 4.2.), its vertical integration trend (Section 4.3.), and its geographical repartition (Section 4.4.).

4.1. Technical barriers to entry

While upstream manufacturing activities require huge cash investments that most firms do not have, this is not the case for downstream activities, in both

manufacturing and service provision. In fact, the primary barriers are technical-like, as they are linked to the skills of the workforce³⁷.

Admittedly, “conceiving and building PV systems requires a variety of skills, some very specific to PV” (International Energy Agency, 2014a, pp. 16–17). However, it is worth specifying that actors in the downstream segment have diverse origins. IEA PVPS (2016, p. 53) counts “subsidiary of utility companies, subsidiary of PV module or PV material companies, companies involved in conventional or oil-related energy business and pure-players.” That is to say, that diversification towards PV market of companies is common in the downstream part of PV value chain.

4.2. Market concentration

Unsurprisingly, because of this low barrier to entry, the market is more prone to competition by new entrants. Su (2013, p. 3) qualifies the downstream part of the PV value chain as a perfect competition market. Hence, starting from the system manufacturer, the number of actors is multiplying. Indeed, the inverter industry is becoming “increasingly crowded and markets more fragmented” (REN21, 2014, p. 50). In particular, specialized components (e.g. tracking systems, monitoring systems and PV connectors) represent a significant business opportunity for some large electric equipment makers (IEA PVPS, 2015, p. 44).

Service-based stages are particularly fragmented. Installation (part of ‘project development’ stage) is a telling example of this proliferation of actors. At the time of writing, the database of ENF Solar listed 18,843 solar system installers in the world³⁸. This is by far the most fragmented activity, with 646 installers in France alone, 1,445 in Germany, and 2,480 in the UK.

Interestingly, in France, the installation sector is occupied by a broad and heterogeneous group of companies (ADEME, 2014a, p. 21). It is possible to group installers into three categories. Most independent France-based professional installers set up very few solar panel systems; in fact, about 80% of them get to set up only one or two solar installations per year. Then come a thousand other installers who manage to install between 10 and 20 systems a year. In the latter group, there are a handful of large companies, estimated at a few dozens, that are taking sole charge of the installation of one-third of all systems.

4.3. Vertical integration

In particular, as soft cost activities only deal with skills, that training can provide, the porosity between the stages is very high. I evoked in Section 4.1. the entrants from non-PV markets. Upstream players also enter the downstream segment through services. That is to say, competition also comes from the upstream segment of PV value chain (IEA PVPS, 2016, p. 53). They may produce PV modules or polysilicon in addition to providing O&M services for example.

³⁷ As a result, labor costs keep minimal costs high, for they are an expenditure that cannot be compressed to any significant degree. Accordingly, in 2010 these activities generated low profitability (5.9%) (PwC, 2012, p. 22).

³⁸ <http://www.enfsolar.com/directory/installer>

This is not the case for manufacturing activities. Indeed, Platzer (2015, p. 5) claims that vertical integration between BOS component manufacturing and system manufacturing is not common. Rather BOS components are sourced from external suppliers.

Service providers that also distribute PV modules or inverters of their suppliers are called EPCs, standing for Engineering, Procurement and Construction (IEA PVPS, 2016b, p. 53).

4.4. Geographic dynamics

PV systems can be manufactured locally (Weber, 2015), to better match local particularities. It also holds true for most of BOS components, whose value is created mainly locally³⁹. But, when it comes to inverter manufacturing, the competition is now essentially from China (Bloomberg Finance L.P., 2014; International Energy Agency, 2014a, p. 10). Specifically, this situation results from a 25% lower production by the leader SMA Solar Technology (Germany) over the years, combined with a preference for local products in the Chinese market. It follows that the market share of German manufacturer eroded from 47.2% in 2011 to 21.1% in 2013 (Bloomberg Finance L.P., 2014, p. 9). SMA alone held 16.3% of the market in 2013 (Bloomberg Finance L.P., 2014, p. 11). This situation has led to a geographical shift of production, from Germany to China (Bloomberg Finance L.P., 2014, p. 8).

Some studies have reported the unbalanced contribution of countries to the GVC (EPIA, 2012), and French politicians have not denied this. Jean-Claude Andreini has clearly pointed out that manufacturing activities are not a source of employment⁴⁰. To be sure, most jobs are indeed created in services, especially with regard to project development, installations and O&M activities (EPIA, 2012, p. 1; PwC, 2009, p. 35). That could explain partially why policies focus their effort more on downstream than on upstream activities. EPIA (2012, p. 1) reckons that “a large part of the value of PV systems is created locally, regardless of where the cells have been made and the modules have been assembled”. Indeed, companies close to the end market typically supply most of the downstream activities (PwC, 2009, p. 35).

4.5. Conclusion

The downstream segment is characterized by the fragmentation of the market. In particular, a significant number of small actors occupy the service-based activities. None of them plays the role of the orchestrator. The situation is close to perfect competition market. As such, in the downstream segment, powerful actors (i.e. lead firms) do not govern the nodes. Rather, considering that the downstream activities are marked by country-specificities and energy is a regulated market, it seems that this segment is governed by regulations.

³⁹ EPIA (The PV Value Chain, 2012) estimates that approximately 80% of the EU BOS manufacturing market is created in Europe, equivalent to €5.7 billion.

⁴⁰ 6th parliamentary meeting on renewable energies held on the April 1st, 2015.

Conclusion

This chapter has emphasized the promises it offers as for solar materials but also the market and technological variation the industry is facing. Indeed, PV technology stands out for numerous reasons; among them, its newness compared to the other renewable energy sources, its significant decentralized proportion, and its explosive growth since the mid-2000s. It is also developing through various markets and technologies. Precisely, four end-markets can be distinguished: off-grid, residential, commercial and industrial and, centralized plant. Turning to the technologies, there are three distinct generations of light-absorbing material: crystalline silicon (c-Si), thin-film and, a third one including organic and CPV. To the extent that crystalline silicon is dominant in the PV market (e.g., IEA PVPS, 2016, p. 5; International Energy Agency, 2014, p. 9; SETIS, 2013; SolarPowerEurope, 2016), I only consider it for the remaining of this doctoral research.

But, the PV value chain is not limited to the light-absorbing material. Indeed, it encompasses eight stages, split in two between the upstream and downstream segments: poly-silicon, wafer, cell, and module manufacturing in the upstream segment; BOS and system manufacturing, project development, and O&M in the downstream.

In this chapter, I have seen that the PV value chain is illustrative of a modular chain. Indeed, the evolution of the downstream segment is largely independent of that of the upstream part. Furthermore, activities within the downstream part evolve independently from the other. It is this independence that makes possible a greater variety of combinations (EPIA, 2012, p. 1; PwC, 2009, p. 35). For example, a module could be matched with a tracker to be installed on the ground or on a rooftop system, and then the PV system could be off-grid or on-grid. These are only a few possibilities.

From the point of view of PV value chain modularity, I examined the PV value chain, along with barriers to entry, market concentration, and the industry dynamics (vertical integration and geographical moves). Some oppositions were revealed.

First, undeniably, the worldwide division of labor is changing quickly. Indeed, the relative regional shares of world PV production are expected to keep changing significantly over time (International Energy Agency, 2014; cf. Figure 2.3.). In particular, the part of OECD countries is expected to decrease, although the relative production share will vary by country and according to each nation's particular market framework. Conversely, in Latin America and Asia, the production share will probably continue to grow. There is little doubt that the offshoring trend will continue.

Second, conversely to the upstream segment, where operations are situated at international level, the downstream actors are very close to the end-markets. In other words, they tend to create value locally (EPIA, 2012, p. 1; PwC, 2009, p. 35). It is worth noting that this local-sensitivity results in wide variations across countries and end-use sectors.

Third, as described by PwC (2009) and Weber (2015), the activities in the PV upstream segment are characterized by manufacturers and are capital-intensive, highly standardized, profitable and, technical. The main barrier to entry is subsequently capital. Conversely, the downstream segment contains labor-intensive activities, with a low level of standardization and low profitability. It implies a low level of barriers to entry, which can be overcome by training.

Moreover, what is striking and deserves to be mentioned is that in the upstream segment, most of the value created is captured only by a handful of firms, namely lead firms, occupying the module manufacturing stage. Thus, by far the greatest proportion of manufacturers is left with slim margins. Turnkey suppliers are also important in the upstream. Contrariwise, the downstream segment is disaggregated, fragmented, and stamped by the absence of lead firms. The main driver is rather institutional. To be specific, regulations are the driver. The relatively low barriers to entry explain the fragmented nature of the downstream segment to a large degree.

In short, the GVC framework concerns only the upstream situation and provides very few keys, if any, for gaining insights on a segment led by institutions and characterized by a proliferation of actors and competitive marketplace. I conclude this chapter by highlighting the limits of the GVC literature in explaining the downstream situation. Considering that PV deployment is led largely by regulations, the question of the impact of government policies on the PV industry structure and on the proliferation of actors in the downstream segment arises. The following chapter will attempt to provide answers to this question.

Chapter 3: The public policy role, from state support to disengagement in the photovoltaic

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Résumé

Chapitre 3 : Le rôle des politiques publiques, du soutien au désengagement de l'Etat dans le photovoltaïque

Ce troisième chapitre s'attache à décrire l'impact des politiques sur l'évolution du marché photovoltaïque. Les gouvernements disposent de plusieurs outils pour promouvoir le développement électrique issu du photovoltaïque. Un type en particulier nous intéresse : les politiques gouvernementales en direction du marché, tels que les tarifs de rachat, les crédits d'impôt, et les appels d'offre. Les tarifs de rachat sont de loin la mesure la plus importante puisqu'ils ont été massivement utilisés pour soutenir le développement du photovoltaïque. Cependant ce chapitre montre aussi les fortes différences entre les pays quant aux outils utilisés et à leurs modalités de mise en œuvre.

Pour autant, l'analyse va montrer que le déploiement du marché, mesuré par la demande d'installations photovoltaïques et l'emploi en aval, est passé par trois périodes distinctes mais communes pour la majorité des pays de l'OCDE. Les cas de l'Allemagne et de la France illustrent nos propos.

La première commence dans le début des années 1990s et s'arrête en 2005. Dans les deux pays, les mesures offertes par leurs gouvernements respectifs ne permettent pas de compenser les coûts élevés des panneaux photovoltaïques. Elles ont donc un très faible impact sur le développement du marché et de l'emploi.

La seconde période concerne les années 2005-2010. Cette phase voit une explosion du nombre d'installations et de l'emploi grâce à des aides très avantageuses combinées à une chute des coûts de production des panneaux.

Cette croissance exponentielle impacta fortement les dépenses publiques et conduisit les gouvernements à un arrêt brutal des aides étatiques à partir de 2010. Il s'ensuit une période de « vache maigre » pour les entreprises. Cela a eu pour implication une chute du nombre des entreprises, et de l'emploi, dans la partie aval de la chaîne de valeur.

Ce constat pose la question du comportement stratégique de ces entreprises pour faire face à cette période de turbulence. La thèse se concentre donc sur les stratégies déployées par les entreprises en période de turbulence. Le chapitre 4 étayera notre nouveau positionnement.

Experience is a brutal teacher, but you learn. My God, do you learn.

Clive Staples Lewis

Introduction

Chapter 1 concluded that global value chain (GVC) studies mainly paid attention to GVCs that were led by lead firms and, as a result, neglected GVCs not driven by these actors. Interestingly, lead firms sometimes do not dominate the whole chain but rather only a part of a GVC. Exploring photovoltaics (PV) is interesting as it is an industry whose downstream segment is not dominated by lead firms. Specifically, I demonstrated in Chapter 2 that, on the one hand, the upstream segment is based on imperfect competition market as it is oligopolistic, driven by lead firms in the module manufacturing stage. On the other hand, it was shown that the downstream segment is similar to perfect competition market as it is highly fragmented, encompassing a large number of actors with no lead firm dominating the arena.

It is not unheard of that public authorities have a strong impact on the energy industry. Hence, to understand this proliferation of actors, investigating the role of public authorities will provide some insights into this issue. Studies showed that PV benefited particularly from governmental interventions both for technology and market developments. What is certain is that demand, along with scientific and technological progress, is crucial in the process of innovation (Mowery and Rosenberg, 1979). However, this issue falls beyond the scope of this doctoral thesis. Rather, I am chiefly interested in the influence of public authorities upon employment in the PV downstream value chain.

Insofar as this manuscript focuses on the downstream segment, this chapter will only center on policies driving PV deployment. It is to these policies that this chapter now turns. Precisely, I will shed light on demand-pull policies, as opposed to supplier-focused and technology-push policies driving the technology development (cf. the categorization of Breitschopf, 2015a). Put differently, I aim to demonstrate the positive relationship and dynamics between demand-focused policies and the number of actors in the downstream segment.

Undeniably, previous studies have already investigated the impact and effectiveness of support schemes on the overall demand for renewable energy sources (RES), and more specifically PV (Breitschopf, 2015a; Fulton et al., 2009). One is of particular interest in this manuscript: in the PV industry, Breitschopf (2015a, p. 11) asserted that the higher the profit per unit of kW sold by the power producer to the grid operator⁴¹, the higher the demand for new PV installation. That is to say, the expected profit of an investment has a positive bearing on market development and PV diffusion. Other research attempted to address the impacts of the renewable energy growth upon the gross labor market (Breitschopf, 2015a; Fulton et al., 2009; van Mark and Nick-Leptin, 2010).

⁴¹ The difference between the revenues (i.e. FiT) and the Levelized cost of electricity generation (LCOE) minus the potential discounted support policies (e.g. interest subsidies).

Still, to the best of my knowledge, the topic of employment in the PV downstream segment, and the link between energy policies, market demand, and direct employment are largely eschewed from the literature. To fill this void, and to shed light as to why there is a proliferation of actors in the downstream segment of the PV industry, the present chapter proposes to look at the influence of demand-focused policies on the evolution of the PV market development, which in turn influence the employment growth of this industry.

A point is made that the governmental direct support policies started only in 1991 on the demand side with the implementation of feed-in tariff (FiT) in Germany. Therefore, the study centers on the period from 1991 onwards. Admittedly, Governments' interest on solar power dates back to a few decades for a political reason. It dealt with the key role of PV for powering satellites in the space exploration race opposing the United States to the former Soviet Union (Arrighi, 2016, p. 177; Haley and Schuler, 2011, p. 18; Platzer, 2015, p. 26). But a fresh impetus to the PV exploitation was given by the oil crisis of 1973 and 1979⁴². Notably, the energy crisis led the German Government to consider RES, including solar power, as an alternative to fossil fuels and nuclear power (Huber, 1997).

Recall that Chapter 2 has underlined the wide disparities in the development of PV industry across and within regions. It is noteworthy that industrialized nations (e.g., Germany and France) and developing/transitional economies (e.g., Romania and Bulgaria) differ substantially in terms of socio-economic situations, free land capacities, government interventions, and PV market segmentation. Consistently, this chapter, to outline support schemes for PV deployment, will only pay attention to two similar European countries (France and Germany) within one region (that is the EU). I choose these two nations as they scored in the top three places in Europe in 2015⁴³, regarding added PV capacity; the third country is the United Kingdom (IEA PVPS, 2016a, p. 11). They have the benefit to be similar in numerous dimensions, while different (starting from their energy production choices), thus representing two distinct starting points. I aim to demonstrate that despite their differences, both state policies impact in a similar way the demand and at the same time the number of actors in the downstream segment.

The chapter is organized as follows. Section 1 outlines the main governmental interventions harnessing the development of the PV market, through public procurement and policies. It includes a short description of support schemes, as well as direct and indirect measures. In Section 2, the policy framework of Germany and France will be discussed. In Section 3, using a historical perspective (from the 1990s onwards), I will demonstrate that annual installed capacity and, as a result, the number of direct jobs created (largely in the downstream segment⁴⁴) heavily depend on demand-focused policies. This chapter ends with the conclusion.

⁴² <http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/>

⁴³ At the global level, they are positioned behind China, Japan, and the USA.

⁴⁴ It is worth noting that studies give information mainly on gross employment. However, considering that project development (i.e. engineering, studies, and administration), installation, and operation and maintenance (O&M) employed 86 % of the gross employment in EU28 in 2014, from 67% in 2008 (EY Global

1. Governments and PV

Governments around the world appeared to have a key position in creating PV demand through policies (Section 1.1) and public procurement (Section 1.2). I present them in turn.

1.1. Support measures

The PV deployment, at least in the EU, relied mainly on direct support policies, be they national or regional. Policies mainly deal with national measures. Regional measures and indirect support policies only play a complementary role in the PV deployment.

1.1.1. Direct support measures

Direct measures directly impact the PV development by “incentivizing, simplifying or defining adequate policies” (International Energy Agency, 2015, p. 13). As noted earlier, direct energy policies can be categorized into four groups (Breitschopf, 2015a): (1) demand-focused policies, aiming to harness demand for PV technologies; (2) technology-push policies, striving for knowledge and networking improvement; (3) supplier-focused policies, dealing with manufacturers; and (4) policy mixes, incorporating “the effect of several instruments or policies to capture interactions of these policies on technological changes”. While technology-push, supplier-focused, and policy mixes were of utmost importance in the PV deployment (Nemet, 2014), they are not the topic of this doctoral thesis as they address largely the upstream activities and do not directly impact the PV demand. For simplicity, future mentions of policies refer exclusively to demand-focused policies.

The main direct support policy is FiT. Germany was the first to set up FiT in 1991. The idea is that power producers receive payment from grid operators (e.g., EDF in France and E.On in Germany) in exchange for the electricity exported to the grid. Nowadays, the FiT contract guarantees a fixed compensation for 20 years (International Energy Agency, 2017, p. 15).

In Germany, the FiT is financed by an EEG surcharge (EEG-Umlage), paid by electricity consumers, except industrial companies classified as power intensive (International Energy Agency, 2015, p. 14). The rationale for the exception is not to damage the German company competitiveness on the international market.

In France as well, electricity operators have to bear the additional costs resulting from the obligation of distribution grid operators to purchase the electricity at price

Cleantech Centre and SolarPower Europe, 2015, p. 26), the figures provided give a glimpse on the number of actors in the downstream segment. While these figures are general to the EU28, I assume that the same proportion applies to all these countries.

fixed by law (i.e. the FiT)⁴⁵. Precisely, the Contribution to Electricity Public Services (CSPE) was created to put the burden of the cost on the electricity consumers. That is to say, the CSPE is a levy to fund FiT remunerations, totally financed by residential electricity consumers (ADEME and IEA PVPS, 2016, p. 26). The more electricity they consume, the more they will contribute.

In the beginning, the FiT was the only direct supporting measure. It applied to all PV systems, not depending on the system size nor application. The differentiation according to system size and application type was introduced later. The FiT was replaced by calls for tenders for grid-connected installations since 2011 in France for systems above 100kW (ADEME and IEA PVPS, 2016, p. 17) and since 2014 in Germany for systems above 750kW (International Energy Agency, 2015, p. 14). A call defines both the total volume of the installation and the maximum funding level. The winners of the bid are the one with the lowest funding level. Admittedly, other criteria than cost may apply.

1.1.2. Indirect support policies

Turning to indirect support policies, they contribute to pushing PV development by changing the regulatory environment (ADEME and IEA PVPS, 2016). They deal with national and regional initiatives favoring the implementation of RES in general, and of PV in particular. Numerous initiatives spring to mind. Mention may be made, amongst other, of COP21, professional trade unions, the Research & Innovation program Horizon 2020, as well as its Energy Directives and financing tools (EIB, EBRD, European Regional Development Fund) proposed by the E.U. (ADEME and IEA PVPS, 2016).

Another initiative type is worth detailing: standardization bodies. The PV industry is facing two important issues resulting from the quick development of the PV markets in the second half of the 2000s (International Energy Agency, 2014a, pp. 16–17): (1) there are a lot of local installers who lack the required skills and (2) initial design is poor. Hence, to get a clearer picture, professional bodies set up quality labels, standards, and norms. PV-related standards and codes are established at the European level (CENELEC) and international level (IEC, standing for International Electricity Commission).

Standards established by IEC (IEC 61215 for crystalline silicon modules) have demonstrated their efficiency to prevent from early failure – or “infant mortality” – of PV modules but International Energy Agency (2014a, pp. 16–17) still reckons the lack of quality standards for both PV modules and PV systems. For example, modules pass qualification tests are not developed enough to be relevant to the customers in their choice. To cite another example, customers need to be informed about the behavior, performance, and longevity of various PV products in specific environments.

⁴⁵ <http://www.res-legal.eu/search-by-country/france/tools-list/c/france/s/res-e/t/promotion/sum/132/lpid/131/>

For tackling the local installer proliferation issue, in France, numerous bodies were developed (ADEME, 2015b, p. 32). Founded in 2006, Quali'EnR certifies installation operators for RES systems. QualiPV is specialized for PV installation operators only. It works with QualiPV Bât, which focuses on the integration of the building, and QualiPV Elec, in charge of the electrical part and the grid connection. It is noteworthy that “homeowners must call on qualified professionals stamped with the RGE label (Recognized guarantor of the environment)” (ADEME, 2015b, p. 32). These labels are a way to leverage the highly skilled and trained professionals. For example, the strong expertise of European companies can enable them to export project management to emerging markets (EPIA, 2012).

1.2. Public procurement policy: Role model as local demand

Public procurement also impacts on the development of the PV market. Precisely, public procurement goes through community-owned systems with the engagement of local communities. The community-owned systems designate systems owned by a group of individuals or companies (that is to say, not all involve local communities). They are becoming increasingly significant and emerge in a growing number of countries (REN21, 2015, p. 61). The phenomenon has spread to Australia, Japan, the United Kingdom, and Thailand. There is not one model but a great variety of models. The three most important ones are utility-sponsored (cf. Chapter 2 with DESERTEC and the Moroccan Solar Plan), special purpose entity, and non-profit models. The last one is the one of interest here.

Variety could also be observed inside each model. For example, in France, the local communities (i.e. non-profit model) have three levels of engagement in a PV plant (ADEME, 2014b, pp. 30–32). At the minimum level, local communities just provide the operator with the land. At the middle level, in addition to providing the land, their participation is restricted to partially finance the plant. At the top level, not only do the local communities own the property but also, they are fully engaged from the design to the exploitation of the PV plant. Indeed, I acknowledge that the deployment of the PV technology is partially led by some rare (but still relevant) cases of local conservation and renewable energy initiatives. These local communities, which enable more than one RES to be placed on their territory, play the crucial role of facilitator. In other words, they are pivotal in the deployment of RES in general, and of PV energy in particular.

The point is best made by one illustrative example. In 2012, in addition to PV (45,830 kW), Perpignan Méditerranée, a French agglomeration, generated power from wind power (14,250 kW), biogas (14,687kWe and 2,220 kWt) and thermal solar (5,000 m²) plants for its population of 257,000 inhabitants (RES League, 2013). Not only has it achieved energy independence since 2015 but it also generates revenues by selling the excess back to the national grid.

It is noteworthy that, projects of French local communities towards the energy transition benefit from specific funds in billions of euros from the Caisse des dépôts, BpiFrance, and the Energy transition financing fund (*Fonds de financement de la Transition énergétique*) (ADEME, 2017, p. 26). At the end of 2016, almost 500 local authorities already benefited from the Energy transition financing fund (ADEME, 2017, p. 26). They were 260 at the beginning of 2015.

Having said this, smaller communities also have their place in this category. That is to say, even small actors can be involved in a deep structural change that favors green technologies deployment. For example, the *Communauté des Communes du Thouarsais*, a group of French municipalities of 36,000 inhabitants, is involved in PV (2,237 kW in 2013), solar thermal (991 m²), wind power (36,000 kW) and biomass power (4,090 kW) production (RES League, 2014).

In the same vein, the Bavarian village Wildpoldried mainly produced PV (4,700 kW), solar thermal (2,100 m²), wind power (12,100 kW) and, biomass (4,800 kWt) (RES League, 2013; WILDPOLDSRIED, 2017). In 2012, its power production represented 321% of the energy consumed, thanks to the green initiatives of the village council undertaken since 1997. It self-consumes the energy generated, and it makes \$5.7 million per year by selling the production surplus to the national grid. Now this village is considered a textbook case of green initiative.

What is certain is that the public market size is negligible and came at a relatively late stage. Hence, it marginally drove the PV industry growth. Against this backdrop, I conclude that the role of public procurement is rather as a role model.

1.3. Conclusion

Public authorities were of utmost importance in the development of PV markets. Their involvement was manifested not only on the demand-side with local consumption (i.e. public procurement) but also as policies, be they direct or indirect. Considering that policies are tricky as they evolve over time and can encompass various measures, the rest of this manuscript is interested largely in measures impacting directly the PV demand.

Undeniably, there is a significant disparity of regulatory context across countries. For illustrating this variety, the following section compares the policy framework of France and Germany (IEA PVPS, 2016a, p. 11).

2. Policy frameworks

2.1. The German energy framework, triggered by its leadership in climate change policy

Since the early 1980s, Germany aspires to take the lead in climate change policy (Huber, 1997). To tackle the climate change issue, the nation opted for a different path from the UK (toward gas) (Collier, 1997) and France (toward nuclear power) (Giraud et al., 1997). A switch from coal to gas in electricity generation, as it happened in the UK, was discarded, as it would result in another energy dependency.

Intriguingly, nuclear power was considered as an important option for the post-coal era. Indeed, the Enquete Commissions asserted that nuclear power has the double benefit of achieving energy independence and reducing carbon dioxide emissions. However, the energy supply industries were reluctant to invest in nuclear plants regarding uncertainties on costs and safety, problems with licensing procedures, and political feasibility. A similar opposition came from the Social Democratic Party (SPD), the opposition party. Yet, “despite considerable support from the

environment minister and the governmental coalition, nuclear power has not regained public credibility” (Huber, 1997, p. 73). Hence, this debate about nuclear power limited its development, as evidenced by the small 15.9% of the German gross electricity generation supplied by nuclear power in 2014⁴⁶ (International Energy Agency, 2015, p. 9). Rather, Germany favored the deployment of RES⁴⁷.

Specifically, in 2015, PV (39.22 GW) is second after wind energy (41.3 GW onshore and 3.28 offshore GW) in terms of RES generation capacity⁴⁸. PV generation covered 8% of the German electricity demand (IEA PVPS, 2016b, p. 27; SolarPower Europe, 2016, p. 34). It is expected to rapidly rise as PV contributed for about half of the increase of clean energies generation (International Energy Agency, 2015, p. 4). Admittedly, its share is declining as only 1,6 GW were installed in 2015, far behind the 7.5 GW annually installed in 2011 and 2012 (cf. Table 3.7.; IEA PVPS, 2016b, p. 10).

Definitively Germany's will for leadership in environmental policy resulted notably in being the champion of cumulated PV installed capacity for a decade in a row. Recently China overtook Germany regarding both annually installed capacity (since 2013) and cumulative capacity (since 2015). At the end of 2015, Germany cumulated 40 GW equivalent to 17.3% of the global market share, compared to 43.5 GW in China (IEA PVPS, 2016b, pp. 9–10; SolarPower Europe, 2016, p. 16). Nevertheless, Germany still remains strongly involved in deploying PV across its soil.

Based on Table 3.1., it is obvious that the on-grid PV applications were increasing rapidly, whereas off-grid PV systems growth can be barely noticed (International Energy Agency, 2003, p. 7;9; cf. Table 3.1.). Actually, off-grid systems are more than negligible in the cumulative installed PV power since the beginning. Hence, German policies addressed in particular grid-connected PV system. In details, in 2015, about 10% of the German solar PV cumulative capacity is residential, 25% is utility scale, and the remaining is commercial or industrial (SolarPower Europe, 2016, p. 28).

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Off-grid	20	23	26	29	32	35	40	45	50	unknown				
On-grid	296	435	1,105	2,056	2,899	4,170	6,120	9,914	17,320	24,820	33,000	36,300	38,200	39,800

Table 3. 1.: Cumulative installed PV power in Germany in MW
Source: Compiled by author from International Energy Agency (2017, 2015, 2012)

⁴⁶ Following Fukushima, the end of the nuclear power production is expected in 2022 (International Energy Agency, 2015, p. 4).

⁴⁷ Considering that coal is the only domestic fuel, simultaneously of renewable energies development, the German government opted for increasing the coal technologies efficiency and exploiting the potential for combined heat and power (Huber p.75).

⁴⁸ https://www.energy-charts.de/power_inst.htm

2.2. The French energy framework, marked by the dominant nuclear power generation.

Nuclear power is anchored in the French energy system since the first oil crisis. It has been set to take over fossil fuels' share in electricity generation. This solution allowed the nation to achieve a greater degree of energy independence: from 22,5% in 1973 to 51,6% in 1994 (Giraud et al., 1997). The upward trend kept going on as, in 2014, 75% of the energy consumed comes from nuclear power through 19 nuclear plants⁴⁹. Such reliance on nuclear power is unique in Europe. As the production of nuclear power is carbon free, one may consider it as a “good” energy source. The dark sides are the nuclear waste process and nuclear risks as proven by Fukushima and Chernobyl. It follows that the French Government aims to reduce its part to 50% till 2025⁵⁰. This decision will let room for RES and notably PV.

The relative growth of PV over the other RES is exponential as in 2015, 43% of newly installed generation capacities in metropolitan France are PV (ADEME and IEA PVPS, 2016, p. 10). Still, the PV share remains insignificant as PV power production is estimated to less than 2% (ADEME, 2017, p. 9). With 7.4 TWh out of a total of 476 TWh in 2015, PV is the third source of clean energy power generation capacities, far behind hydroelectricity (53.9 TWh) and wind power (21.1 TWh).

The profile of the PV installation evolved over time. In the beginning, the main PV system application was off-grid. This holds true until 2007 (cf. Table 3.2.). Admittedly, the part dedicated to self-consumption is negligible. Since, the decentralized on-grid is the most widespread system. It represented 65% in 2015, equivalent to 4,257 MW (ADEME and IEA PVPS, 2016, p. 11; cf. Table 3.2.). It is worth noting that about 20% of the French solar PV cumulative capacity is residential, 45% is commercial or industrial (SolarPower Europe, 2016, p. 28). However, its share decreases from 70% in 2014. Contrariwise, the centralized production increases its share significantly since its beginnings in 2008 to reach 35% of the cumulative installed PV systems in 2015. The introduction of call of tenders played an undeniable role in its development. Hence, like Germany, the development of each end-sector results from the policies implemented by the French Government.

⁴⁹ <http://www.la Tribune.fr/entreprises-finance/la-tribune-de-l-energie/10-chiffres-a-connaître-sur-la-france-et-le-nucléaire-479263.html>

⁵⁰ <http://www.la Tribune.fr/entreprises-finance/la-tribune-de-l-energie/10-chiffres-a-connaître-sur-la-france-et-le-nucléaire-479263.html>

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Off-grid	13	15	17	19	20	21.5	22.5	23	29.2	29.3	29.4	29.6	29.7	29.8	30.2
Centralized connected	0	0	0	0	0	0	0	7	42	242	702	1,012	1,264	1,709	2,302
Distributed connected	1	2	4	7	13	16	53	150	300	938	2,242	3,052	3,454	3,963	4,257

Table 3. 2.: Cumulative installed PV power in France in MW
Source: Compiled by author from ADEME (2007, 2003) and ADEME and IEA PVPS (2016)

3. PV growth and deceleration

The history of PV policy, market and, employment can be split into three phases. I discuss them in turn.

3.1. From the beginning to the mid-2000s: PV market for innovators and early adopters

During the early phase of the energy transition policy, in both countries, the market introduction instruments were not enough to compensate the significant cost of installing a PV system. Based on Breitschopf (2015a, p. 11), it resulted in a negative margin. Hence, it was not appealing to drive massive demand. I present their story in details.

3.1.1. Germany

The German concrete involvement started early with the Electricity Feed-in-Act law (StrEG, standing for *Stromeinspeisungsgesetz*) on the 1st January 1991 (Fulton and Mellquist, 2011). The law established the first FiT scheme in the world designed for clean energies (wind power, PV, biomass, hydroelectricity and, geothermal energy). However, the nascent PV industry benefited marginally from this law due to low incentives.

Specifically, under the Electricity Feed-in-Law, the FiT rate varied between 8.45 and 8.84 cents €/kWh (Fulton and Mellquist, 2011). It was equivalent to 90% of the retail electricity price and thus far from being able to compensate the high PV price system (Fulton and Mellquist, 2011, p. 13).

It is worth noting the contribution of the 1000 Roofs Program at the beginning of the German PV experience installations. It provided subsidies “to individuals to cover the cost of installing a PV rooftop system”. It lasted from 1991 to 1995. During this

period, 2,000 on-grid PV systems were installed on rooftops⁵¹. Hence, at that time, PV systems remained mostly a curiosity. Put differently, it was seen as unlikely that it gained widespread use⁵².

As the date of the 1st April 2000, the Renewable Energy Sources Act (the EEG law, standing for *Erneuerbare-Energien-Gesetz*) replaced the Electricity Feed-in-Act law. Fulton and Mellquist (2011, p. 16) In a nutshell, the EEG “determines the procedure of grid access for renewable energies and guarantees favorable Feed-in-Tariffs (FiT) for them” (International Energy Agency, 2015, p. 4). The EEG also set the renewable targets. Specifically, the German 2010 Energy Concept's goal is that the renewable energies share supplies 40-45% of the electricity in 2025 and 80% in 2050 (previously 20% for 2020 under the amendment of 2004; Altenhöfer-Pflaum, 2015, p. 4). Their share represented 27.8% in 2014, from zero in 1990 (International Energy Agency, 2015, p. 4; Weiss, 2014, p. 7). In determining ambition goals of PV installation at long and middle-term, the EEG provides certainty in planning investments for the whole PV sector.

The initial EEG of 2000 has forecasted a review every four years (Fulton and Mellquist, 2011, p. 16). Since then, it was modified five times in 2004, 2008, 2012, 2014 and, 2016. Each version brought further refinements.

The replacement of the Electricity Feed-in-Law by the EEG in 2000 was marked by the FiT rate rise to be closer to the PV system generation cost and the introduction of national tariffs (Fulton and Mellquist, 2011). In 2001, the FiT rate was established at approximately 51 cents €/kWh (cf. Table 3.3.). At the top, the FiT rate reached 57.4 cents €/kWh in 2004.

Additional market introduction instruments were proposed to drive market growth, however modest: rebates equal to 70% of PV system cost, and, municipal PV FiT in over 50 cities (e.g. Hammelburg, Aachen, and others) (Fulton and Mellquist, 2011, p. 15).

I draw the attention on the 100,000 Roofs Solar Power Programme. It is an extension of the 1,000 roofs programme⁵³. It started in 1999 to end in 2003 as it ran out of funds (Fulton and Mellquist, 2011, p. 13). It provided low-interest loans at 1.91%, i.e. 4.5% below market conditions⁵⁴ (International Energy Agency, 2003, p. 6). The funding conditions of these programs targeted systems superior to 1 kW but inferior to 5kW⁵⁵. Under this programme, 65,700 PV systems were built representing a total volume of 345.5 MW (International Energy Agency, 2007, p. 7).

⁵¹ https://thebreakthrough.org/archive/soaking_up_the_sun_solar_power

⁵² <http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/>

⁵³ <https://www.iea.org/policiesandmeasures/pams/germany/name-21000-en.php>

⁵⁴ <https://www.iea.org/policiesandmeasures/pams/germany/name-21000-en.php>

⁵⁵ <https://www.iea.org/policiesandmeasures/pams/germany/name-21000-en.php>

	2001	2002	2003	2004	2005
FIT (cents €/kWh) (roof-mounted systems up to 10kW)	51	48.1	46	57.4 ⁵⁶	54.5
PV system price (€/kWp) (roof-mounted systems up to 10kW) Q4 for each year	6.400	5.600	5.080	5.300	5.600
Annual installed capacity (MW)	119	120	139	665	1,000
Cumulative installed capacity (MW)	176	296	435	1,100	2,056
Number of companies (in thousands)	unknown				
Number of full-time jobs (in thousands)		7	10-12	25	

Table 3. 3.: Evolution of feed-in-tariff for building integrated PV and number of jobs in the downstream segment in Germany from 2001 to 2005
Source: Compiled by author from Fulton and Mellquist (2011), International Energy Agency (2017, 2015, 2014, 2008, 2003), IEA PVPS (2016a), and van Mark and Nick-Leptin (2010)

Even with these more favorable measures, incentives were too low to support PV installation costs on its own. While these measures barely offset the cost, they were much more efficient than the previous law as the cumulative capacity reached 2,056 MW at the end of 2005 from 176 MW in 2001 (and 9MW in 1999) (International Energy Agency, 2015, p. 7; cf. Table 3.3). It is obvious that despite a significant growth in Germany (more than 11 times), the PV share remained negligible when comparing to the total 39,800 MW in 2015 (about 5%).

Having said this, the impact of such measures were strong enough to attract new entrants in the PV sector and increased fivefold the number of full-time jobs. There were 35 thousand people to work directly or indirectly in the PV sector in 2006 (International Energy Agency, 2007, p. 17). It is important to specify that companies largely focus on grid-connected PV systems as policies addressed only this category.

3.1.2. France

Conversely to Germany, in the beginning, French public decisions triggered the development of off-grid systems over grid-connected. The measure of interest is FACÉ (standing for Fund for rural electrification), which started in February 1993 (ADEME, 2003, p. 12). It is based on a collaborative agreement between ADEME (the French Environment and Energy Management Agency) and EDF (the main French electricity utility); it benefited PV, wind power, and micro hydroelectricity sources.

⁵⁶ One may note an increase of FiT in 2004, following years of slight decrease. It is a compensation of the end of the 100,000 Roofs Solar Power Programme (International Energy Agency, 2003, pp. 24–25).

The measure supported the supply of electric energy to off-grid sites⁵⁷ (ADEME, 2015b, p. 7). These targeted sites encompass telecom relays and remote homes, where a RES option is economically more feasible than grid extension (ADEME, 2003, p. 12). In remote areas, PV off-grid system was more economical financially than “pulling and maintaining a line [...] since cost of an electric line might reach up to 90 000 euros per kilometer” (ADEME, 2003, p. 12). Hence, the reason for such policies is purely financial.

Interestingly, FACÉ financing fund combining with a contribution of ADEME and the Government may cover 95% of residential PV investment costs (ADEME, 2015b, p. 18, 2007, p. 7, 2003, p. 14): 65% from FACÉ; 13% from ADEME, 17% from Finance Ministry through an indirect participation; and 5% from the owner (in addition to the annual rent). All in all, 1,315 off-grid PV power systems benefited from the measure, totalizing 1,253 kW and costing 23.7 million of euros. 56% of these systems were installed in continental France and the remaining 44% in French overseas departments.

Interestingly, installations in the overseas departments and territories of France (both on and off-grid) had and continue to have a meaningful impact on the French added capacity (IEA PVPS, 2015, p. 23): around 300MW out of the 939MW added in 2014. It could be explained by the significant irradiation, the attractive fiscal conditions and the convenience of installing decentralized production in islands.

Admittedly, there were a few private initiatives directed towards the installation of grid-connected distributed PV systems, notably Hespul and HIP-HIP. See ADEME (2003, p. 14) for further details. But the first national measure, that is FiT, was only introduced in 2002. It follows that the introduction of FiT redirected the support measures towards the grid-connected power supply (ADEME, 2015b, p. 15). The FiT was then established at 15.25 cent €/kWh for systems up to 1MW in France mainland and 30.50 cents €/kWh in Corsica and overseas departments (ADEME and IEA PVPS, 2016, p. 17; Markvart and Castañer, 2003, p. 916). Considering the gap between them, I only consider FiT mainland as it is the ‘normal’ one. The FiT then decreased slowly to 14.125 cents €/kWh in 2005⁵⁸.

The income tax credit of 50% also played a role in the PV deployment. It was set in 2004 to residential BIPV roof owners (ADEME and IEA PVPS, 2016, p. 21). It was appealing as it amounts to 50% of PV modules and other equipment costs, up to 8,000€ per income-tax paying person (ADEME, 2007, p. 7).

It results in a mild growth of the PV capacity over the period: from 13.9 MW in 2001 to 17.2 MW in 2002, to 33 MW in 2005 (cf. Table 3.4.). Comparing to the

⁵⁷ Self-consumption is difficult to promote due to the low retail prices for electricity in continental France. It is widely explained by the lack of prosumers’ incentives. While there are some calls for proposals, from regions for financing self-consumption, there was no premium for self-consumption until recently. The first national calls for self-consumption appeared in 2016 (ADEME and IEA PVPS, 2016, pp. 20–21). Tertiary buildings are the main targets of this measure. The call for proposals from regions and the call for tenders at the national level may foster self-consumption.

⁵⁸ http://www.photovoltaique.info/IMG/png/tableau_v11_20160418.png

6,605 MW cumulated in 2015 and to the Germany situation in 2005 (2,056 MW), the contribution of this period is negligible.

	2001	2002	2003	2004	2005
FIT (cents €/kWh)⁵⁹	15	15.250	14.793	14.529	14.125
PV system price (Residential rooftop up to 9 kW, existing building) (€/W)	15.05	14.33	13.65	13.00	11.60
Annual installed capacity (MW)	2,525	3,385	3.832	4.950	7.020
Cumulative installed PV power (MW)	13.856	17.241	21.072	26.023	33.043
Number of companies	unknown				
Number of direct jobs⁶⁰		580			< 1,000

Table 3. 4.: Evolution of feed-in-tariff for building integrated PV and number of jobs in the downstream segment in France from 2001 to 2005
Source: Compiled by author from ADEME (2017, 2015, 2013, 2011, 2009, 2007, 2003), ADEME and IEA PVPS (2016), and International Energy Agency (2009)

Considering the significant proportion of off-grid systems over the cumulative installed PV capacities during that period, most of the new entrants in the PV market focused on the rural electrification (ADEME, 2003, p. 12). Having said this, it is not surprising that actors in the downstream segment of the PV value chain are pretty rare. Despite a near doubling of the number of jobs in five years, the level of direct employment in French PV sector does not exceed one thousand for the whole value chain, including production and installation in 2005 (International Energy Agency, 2009, p. 31). It is noteworthy that the number of jobs and cumulative capacity evolved in parallel.

3.2. Second mid-2000s: the fast-paced growth

In France, as well as in Germany, it took time to see the first significant effect of the FiT policy. Indeed, while public support schemes hesitantly began in the 1990s, market introduction instruments have been particularly effective since the mid-2000s.

3.2.1. Germany

This period is characterized by two trends. First, the PV system price has been halved: starting at 5.600€/kWp in 2005 to end at 2.842 at the end of 2010 (cf. Table

⁵⁹ http://www.photovoltaique.info/IMG/png/tableau_v12_20170516.png

⁶⁰ “Direct jobs and GVA are related to the PV industry specifically (e.g. manufacturing of PV modules, installation, and maintenance of PV systems...) while indirect jobs and GVA stem from supplying industries (e.g. transport, manufacturing of certain materials, professional services...)” (EY Global Cleantech Centre and SolarPower Europe, 2017, p. 11).

3.5.). Meanwhile, the FiT remained high, albeit decreasing from 51,8 to 39,14 cents €/kWh between 2006 and 2010 (International Energy Agency, 2014b, p. 16). The FiT decreased due to an increasing PV installation. Yet, this trend is slower than the one of the system price.

Consistent with the reasoning of Breitschopf (2015a, p. 11), it results that, from 2008, the FiT was sufficiently high to compensate the declining PV system cost along with the other support measures. The two trends combined led to the increase in demand. Over the period, the cumulative capacity jumped from 2 GW at the end of 2005 to 10.6 GW at the end of 2009, and to 17.9 GW at the end of 2010 (International Energy Agency, 2017, p. 7). It is equivalent to an increase of nine-fold from 2005 to 2010. It is worth noting that there was no limit to annual installed capacity with FiT. Therefore, at the time when the margin was attractive, significant new installations popped up.

This sharp proliferation of PV power impacted the number of jobs: in 2010 the PV sector hired 98,000 more people to address the explosive demand on PV installation, in addition to the 35,000 estimated in 2006 (International Energy Agency, 2017, p. 27; van Mark and Nick-Leptin, 2010, p. 18). That is to say, from 2006 to 2010, the photovoltaic-labor force increased fourfold in Germany. Admittedly, the sector grew exponentially, yet a slower pace than did the PV demand. The increasing PV plant size definitively played a role in this disconnection between the two curves.

	2005	2006	2007	2008	2009	2010
FIT (cents €/kWh) (roof-mounted systems up to 10kW)	43-60	51.8	49.2	46.75	43.01	39.14
PV system price (€/kWp) (roof-mounted systems up to 10kW) Q4 for each year	5.600	4.906	4.458	4.359	3.255	2.842
Annual installed capacity (MW)	1,000	843 ⁶¹	1,271	1,930	4,500	7,300
Cumulative installed capacity (MW)	2,056	2,899	4,170	6,100	10,600	17,900
Number of full-time jobs (in thousands)		35	42	48	80.6	133
<i>Table 3. 5.: Evolution of feed-in-tariff for building integrated PV and number of jobs in the downstream segment in Germany from 2005 to 2010</i> <i>Source: Compiled by author from Fulton and Mellquist (2011), International Energy Agency (2017, 2015, 2014), and van Mark and Nick-Leptin (2010)</i>						

3.2.2. France

It is worth noting that a specificity of the French regulatory framework is to prioritize the development of building-integrated PV applications (BIPV) systems over

⁶¹ 2006 was an exception in the upward trend of annual installed capacity. The reasons are twofold: (1) the shortage of silicon supply; and (2) the interdependency between system prices and feed-in tariffs (International Energy Agency, 2007, p. 22).

conventional building-attached applications (BAPV) systems notably through a bonus since 2006 (for further details read ADEME, 2015, p. 18 and IEA PVPS, 2016b, p. 27). Indeed, in 2006, the basic FiT for PV-generated electricity is 0,30 EUR per kWh, while the bonus was of 0,25 EUR per kWh (ADEME and IEA PVPS, 2016, p. 17). This measure confirms the governmental and ADEME's policy of promoting the BIPV concept. From now on, any reference to FiT shall be understood as FiT for BIPV installations only.

At the top, the FiT for installations below 9 kW has jumped to 60.176 cents €/kWh in 2009 for a PV system cost of 6.9€/W (ADEME and IEA PVPS, 2016, p. 14). It is worth noting that a yearly revision is scheduled on the basis of a specific inflation index (ADEME, 2007, p. 7). Meanwhile, the PV system price was divided by two over the period. It was 11.6€/W in 2005 and ended at 5.9 in 2010 (cf. Table 3.6.).

	2005	2006	2007	2008	2009	2010
FiT (cents €/kWh)⁶²	14.125	55	55	57.187	60.176	57.753
PV system price (Residential rooftop up to 9 kW, existing building) (€/W)	11.6	8.12	8.4	8.2	6.9	5.9
Annual installed capacity (MW)	7.020	10.89	38	104.4	191.3	838.1
Cumulative installed PV power (MW)	33	43.9	75.5	179.9	371.2	1209.3
Number of companies in the downstream segment (estimated)			735	2,760	5,080	6,074
Number of installation companies			630	2,500	5,000	6,000
Number of direct jobs⁶³	<1,000	1,238	1,970	4,500	8,500	24,300

Table 3. 6.: Evolution of feed-in-tariff for building integrated PV and number of jobs in the downstream segment in France from 2005 to 2010
Source: Compiled by author from (ADEME, 2017, 2015b, 2013, 2011, 2010, 2009, 2008, 2007), ADEME and IEA PVPS (2016), and International Energy Agency (2009)

To conclude, based again on Breitschopf (2015a, p. 11), the FiT coupled with the income tax credit (rebate still at 50%) and, decreasing PV system price generated tremendous returns on investment for energy producers⁶⁴. Thus, this state support enabled a rapid development of the PV market. Specifically, the annual added capacity rose at break-neck speed from 10.89 MW in 2006 to 838.1 MW in 2010 (ADEME, 2013, p. 7; cf. Table 3.6.). The most impressive difference is between

⁶² http://www.photovoltaique.info/IMG/png/tableau_v12_20170516.png

⁶³ The figures include PV energy sales, system installation, and equipment manufacturing.

⁶⁴ <http://www.photovoltaique.info/Chiffres-cles.html>;

http://www.photovoltaique.info/IMG/png/tableau_v11_20160418.png

2008 and 2010. The cumulative capacity then rose over the period from 43,9 MW to 1,209.3 MW (ADEME, 2017, p. 10; cf. Table 3.6.).

Also, an important move for the development of the French PV market is to increase the life of the contract to 20 years (ADEME, 2007, p. 7). Hence, the new measures were not only more attractive for investors but also provided a long-term perspective for both investors and companies (ADEME, 2007, p. 7).

In line with the explosion of the demand level, the supply followed the same curve. Specifically, the number of direct jobs exploded from 1,000 in 2005, to 1,970 in 2007, to 24,300 in 2010 (cf. Table 3.6.). Likewise, the number of companies in the downstream evolved from 735 in 2007 to 6,074 in 2010, composed largely of installers.

3.3. The 2010s: the age of industry purification

The boom experienced in the second period was unsustainable primary for economic reasons. Due to the financial windfall, which occurred in 2008-2010 following the sharp drop in PV costs, the support costs rise dramatically (Fulton and Mellquist, 2011). Therefore, the following phase is marked by a will to restructure and to better master PV expansion in both countries.

3.3.1. Germany

As a response to these changing market conditions, the German Government implemented the PV Act in 2010. The 2012 and 2014 EGG intended to propose further refinements for better supporting and limiting the annual added PV capacity. Specifically, the Government implemented an increasing number of limitation measures on new PV installations through the PV Act and EEG. Among others:

1. The PV Act established two unscheduled downward adjustments of the FiT in 2010 and 2011 (Fulton and Mellquist, 2011). The FiT was reduced drastically to reach 12.31 cents €/kWh in 2015 for roof-top system smaller than 10 kWp (International Energy Agency, 2017, p. 12;14; cf. Table 3.7.). It is equivalent to a third of the level of 2010 (at that time 39.14 cents €/kWh).
2. Also, as a response to the quick growth of PV installations in 2008, the Government implemented a corridor or “flexible” degression system with the 2009 amendment of the EGG for better controlling new installations. Actually, the cap was implemented at the EGG's very inception but was soon discarded in 2004.

The update period was reduced from six to one month. This programmed reduction of FiT depends on the volume of MW installed during the previous year (Fulton and Mellquist, 2011; International Energy Agency, 2015, p. 4). The FiT evolves in an inverse manner to the market evolution. Concretely, if the newly installed PV capacity is more important than the corridor, the degression rate will rise from 0.5% to up to 2.8%⁶⁵ (Fraunhofer ISE, 2017b).

⁶⁵ <http://www.res-legal.eu/search-by-country/germany/single/s/res-e/t/promotion/aid/feed-in-tariff-egg-feed-in-tariff/lastp/135/>

Conversely, if it is under the target-corridor, the degression rate will go down.

For example, in 2010 alone, 7.3 GW were installed, far more than the 6 GW forecasted. Hence, consistent with the system of the corridor, the FiT decreased from 39.14 to 29.74€ cents/kWh. Conversely, in 2015, the annual installed capacity of 1.6 GW is below the target. Indeed, the target corridor was between 2.4 and 2.6 GWp per year. Hence, consistent with the corridor system, the FiT decreased slightly from 13.68 in 2014 to 12.31€ cents/kWh in 2015.

3. Appeared with the EGG 2012, market premium⁶⁶ spurs PV energy producers of new PV systems between 100 and 750kWp to sell electricity on the electricity market, instead of benefiting of the fixed tariff through the FiT system (Fraunhofer ISE, 2017b). In choosing the market, the energy producer receives an additional premium on the top of the market price. This incentive aims to cover the costs of their installations and ensuring their profitability. As with the FiT, the market premium is recalculated every month.
4. Since 2014, a system of call for bids is put in place for ground-mounted and rooftop PV systems, whose installed capacity are larger than 750 kW⁶⁷. The winners of the call are the investors with the lowest price. The average price proposed by the winners at the first tender under the EEG 2017 was 6.58 cents/kWh⁶⁸.

Following these new measures, the number of new installations in Germany has plummeted. At the top (from 2010 to 2012), more than 7 GW were connected to the grid every year. The following years, the figures were less breathtaking as the market went down progressively to reach 1,6 GW in 2015 (International Energy Agency, 2017). This is equivalent to a drop of 80% of new installations from 2012 to 2015. This downward trend certainly contributed to losing its leadership to China, regarding both cumulative and annual installed capacity. For the sake of comparison, during the same period, new installations have doubled worldwide (Wirth, 2017, p. 12).

Like the two previous periods, the number of jobs has followed the curve of the market demand. As the annual installed capacity was divided by nearly five from 2012 and 2015, the number of jobs were divided by three over the period. Specifically, there were 113,900 in 2012. In 2015, only 42,200 of them remained (International Energy Agency, 2017, p. 27). It is important to note that financial difficulties due to the combination of the decreasing annual installation with the decreasing system price and margins led companies to bankruptcy (International Energy Agency, 2014b, p. 14).

⁶⁶ While most energy producer can interchange the option unlimitedly, the market option is compulsory for all new installations above 100kW since 2016.

⁶⁷ <https://www.cleanenergywire.org/factsheets/eeg-reform-2016-switching-auctions-renewables>

⁶⁸ <https://www.pv-magazine.com/2017/02/08/lowest-price-in-germanys-pv-bidding-e0-06kwh-say-eeg/>

	2010	2011	2012	2013	2014	2015
FIT (cents €/kWh) (roof-mounted systems up to 10kW)	39.14	28.74	24.43	17.02	13,68	12.31
PV system price (€/kWp) (roof-mounted systems up to 10kW) Q4 for each year	2.842	2.147	1.751	1.698	1.640	1.456
Annual installed capacity (MW)	7,300	7,500	7,600	3,300	1,900	1,600
Cumulative installed capacity (MW)	17,900	25,400	33,000	36,300	38,200	39,800
Number of companies including installers and suppliers (in thousands)		10		5		
Number of full-time jobs (in thousands)	133	128	113.9	68.5	49.3	42.2
<p><i>Table 3. 7.: Evolution of feed-in-tariff for building integrated PV and number of jobs in the downstream segment in Germany from 2010 to 2015</i> <i>Source: Compiled by author from Fulton and Mellquist (2011), International Energy Agency (2017, 2015, 2014), and van Mark and Nick-Leptin (2010)</i></p>						

3.3.2. France

France, as well as other large European countries, faced the same challenges, as did Germany. However, it faced them differently. Following years of robust growth, the French Government has constrained the PV development to 800 MW a year (cf. the multi-annual investment plan⁶⁹) (ADEME and IEA PVPS, 2016, p. 23) and has set up a moratorium on the obligation to purchase. In specific terms, the French ministry of ecology issued a decree (n°2010-1510) on 9^h December 2010 running for three months with the purpose of temporarily suspending the obligation of EDF and local distribution companies to purchase electricity generated from solar sources for systems greater than 3kW⁷⁰. Moreover, no more new PV projects superior to 3 kWc could be permitted during this period, except for residential installations. This policy shift contributed to regulatory uncertainty (Haley and Schuler, 2011). While regulatory uncertainty is of utmost importance, it is not the core of this work. Rather, it provides the context of this doctoral thesis.

It seems that the reason the moratorium was put in place in the first instance was to avoid the imminent catastrophe that could happen when firms are engaged in a price war. For this purpose, the Government grouped different actors in the PV industry (elected representatives, and representatives of consumer groups and,

⁶⁹ <http://www.res-legal.eu/search-by-country/france/tools-list/c/france/s/res-e/t/promotion/sum/132/lpid/131/>

⁷⁰ <http://legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000023212761&categorieLien=id>

environmental associations). They notably debated the lowering of FiT and the implementation of a quotas system. The expected result was the implementation of a new regulatory framework which aimed to ensure visibility for the players in the PV industry (ADEME, 2011, p. 13).

As a result, some changes applied to state subsidies. Not only have FiT fallen from 57 in 2010 to 40 cents per kWh in 2011, to reach 25.39 cents at the end of 2015 (cf. Table 3.8.), but also the income tax credit decreased from 50% to 22% in 2011, to 11% in 2013 (ADEME, 2015b, p. 16). The latter finally ended on the 1st January 2014.

Also, call for tenders were introduced. Specifically, the FiT was restricted to systems below 100 kW, with a quarterly adjustment. For PV systems above 100 kW, the FiT was replaced by calls for tenders since 2011, be it on- or off-grid, with or without storage. They aim to reach the target capacity set by the multi-annual investment plan (Programmation Pluriannuelle des Investissements PPI)⁷¹. An independent French institution manages national calls for tenders, namely *Commission de Regulation de l'Energie*, on behalf of the Ministry of Environment. Calls for tenders are an appeal for very cost-competitive projects. Yet, the submitted electricity price is not the only criteria: while the cost counts for two third of the decision, the remaining one-third deals with the assessment of the carbon footprint of the PV module manufacturing process (ADEME, 2015b, p. 16).

It follows that in the years following the moratorium, one may notice that the annual installed capacity has been halved: from 1,764.1 MW in 2011 to 903 MW in 2015 (ADEME and IEA PVPS, 2016, p. 12).

Considering that demand for PV plunged, so did the offer. Over the same period, the number of direct jobs fell from 27,400 to 7,400 (ADEME, 2012, p. 15; ADEME and IEA PVPS, 2016). Put differently, 73 % of the people who worked in the PV industry for manufacturers, operators or service companies were no more engaged in the industry in 2015.

The difference between the annual installed capacity and the number of direct jobs evolutions can be explained by the larger size of PV plants. It is due to the increasing importance of centralized PV plants in the newly installed capacity from 2011 representing 23.8% to reach 35% in 2015 (cf. Table 3.2.). Yet, considering that most of the jobs were linked to the grid decentralized plants, the strong impact on the fall of job number is unsurprising.

⁷¹ <http://www.res-legal.eu/search-by-country/france/tools-list/c/france/s/res-e/t/promotion/sum/132/lpid/131/>

	2010	2011	2012	2013	2014	2015
FIT (cents €/kWh)⁷²	57.753	40.63	34.15	29.1	26.97	25.39
PV system price (Residential rooftop up to 9 kW, existing building) (€/W)	5.9	3.9	3.7	2.7	2.6	2.5
Annual installed capacity (MW)	838	1,764	1,120	654	954	903
Cumulative installed PV power (MW)	1209	2,973	4,093	4,747	5,701	6,605
Number of direct jobs	24,300	27,400	18,460	12,130	8,500	7,400

Table 3. 8.: Evolution of feed-in-tariff for building integrated PV and number of jobs in the downstream segment in France from 2010 to 2015
Source: Compiled by author from ADEME (2017, 2015, 2014, 2013, 2012, 2011), ADEME and IEA PVPS (2016), and International Energy Agency (2009)

Conclusion

Governments have various tools to influence the PV market evolution. Government policies, direct and indirect, along with public procurement. The latter is manifested by local initiatives and only played a marginal role. Hence, the chapter centers on policies.

Despite a certain interest in the RES in the quest for energy independence, government policies came at a relatively late stage. Following the description of Germany and France' characteristics regarding the policy and market segmentation, the chapter concludes on significant institutional discrepancies.

Despite these differences, a historical review demonstrated that their government policies impacted in a similar way not only PV market development but also employment. Indeed, this chapter has proven that policy measures have a strong influence on the evolution of demand for installing PV plants and number of actors. Considering that the vast majority of jobs are in the downstream segment, I focus on them. The demonstration lies in the evolution of the number of new annual installations and on the number of jobs through three distinct periods.

The first period spans from the early 1990s to the mid-2000s. Germany showed the lead at the beginning of the 1990s. But at that time, subsidies towards PV were shy compared to the other clean energies. More significant efforts to promote PV started in many countries in the early 2000s. Yet, subsidies were not enough to compensate the huge amount of investment to install a PV system.

Then came the second period characterized by an exponential growth. The favorable policies coupled with the decreasing installation cost led to the ebullient growth performance in the second part of the 2000s. Specifically, in France, the FiT raised from 14.125 cents €/kWh in 2005 up to 60 cents €/kWh in 2009 while the PV system price fell from 11.6 €/W in 2005 to 5.9 in 2010. It pulled the cumulative installed PV

⁷² http://www.photovoltaique.info/IMG/png/tableau_v12_20170516.png

power from 33 MW to 1,209 MW. It, in turn, led to increasing number of jobs: from less than 1,000 in 2005 to 24,300 in 2010. A similar evolution is observable in Germany.

A decreasing annual installed capacity and a drop of job employment marked the restrictive period experienced since 2010. Following the popularity of PV technologies, FiT, along with other market introduction instruments, resulted in being a financial burden for Governments. As a response, they stopped, or at least reduced, their respective policies in favor of PV. It resulted in a dramatic drop of actors in the downstream part of the PV value chain. Precisely, the number of jobs sharply dropped from 24,300 in 2010 to 7,400 in 2015.

These stop-and-go policies, also called policy inconsistency, resulting in a period of turbulence for actors. This, in turn, impacted companies' business choices and survival. This doctoral thesis turns on these topics. That is to say, I have to investigate the strategic behavior of actors operating in the PV downstream value chain. For this purpose, I have first to elaborate hypothesis and explain how I investigated on the subject. This is the topic of Chapter 4.

Part 2 – Methodology

Chapter 4: The Design Methodology for studying the strategic choices of SMEs after the State disengagement in the photovoltaic: Combining qualitative and quantitative methods

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Résumé

Chapitre 4 : Le design méthodologique pour l'étude des choix stratégiques des petites entreprises après le désengagement de l'Etat : une combinaison de méthodes qualitatives et quantitatives

Les trois premiers chapitres nous mènent à notre problématique : Quelles stratégies sont les plus fructueuses pour la survie et la croissance des entreprises privées de petite taille et de technicité moyenne ou faible dans un contexte de turbulence ?

L'objectif de la thèse est d'enquêter sur les capacités de survie des acteurs opérant dans un segment fragmenté d'une chaîne de valeur, en l'occurrence celui du photovoltaïque, dont la partie aval subit des turbulences. En particulier cette étude porte sur un type de firmes souvent négligé : les entreprises privées de petite taille et de technicité moyenne ou faible.

Une revue de la littérature nous a conduit à privilégier les stratégies de diversifications des firmes et à élaborer les six hypothèses suivantes. L'**Hypothèse 1** porte sur la possibilité d'identifier un nombre restreint de business models génériques dans une industrie. L'**Hypothèse 2** présume que dans un contexte de turbulence et dans une chaîne de valeur fragmentée, les entreprises tendent à s'intégrer verticalement principalement dans les services. L'**Hypothèse 3** suppose que dans un segment de chaîne fragmentée marqué par les politiques gouvernementales et orienté services, les entreprises auront tendance à se limiter au territoire national. L'**Hypothèse 4** prédit que les entreprises auront tendance à étendre leurs offres au plus grand nombre dans un contexte de turbulence. L'**Hypothèse 5** met en exergue l'importance des ressources sur les marges de manœuvre des entreprises. Enfin, l'**Hypothèse 6** pose le postulat selon lequel les business models suivent des trajectoires de performance distinctes à moyen terme suite à des turbulences.

Le chapitre est également consacré à la méthodologie et au design de recherche mis en place pour traiter les hypothèses. Ainsi, il détaille comment nous avons collecté et analysé les données. Pour répondre à notre problématique et tester nos six hypothèses, nous utilisons une méthodologie de recherche en deux étapes. Par une série d'entretiens auprès de dirigeants d'entreprise et de responsables de projets énergétiques de villes, nous soulignons l'importance de la stratégie de diversification dans la lutte pour leur survie. Nous réalisons ensuite une étude quantitative sur des entreprises. L'échantillon de départ compte 276 entreprises. Elle sera réduite à 103 entreprises opérant en 2010 sur le sol français et dans la partie aval de la chaîne photovoltaïque.

A problem well put is half solved.

John Dewey.

Introduction

Chapter 3 concludes on the undeniable impact of policies on photovoltaic (PV) market evolution and employment. Specifically, policies led to market turbulence and the significant drop of jobs in the first half of the 2010s. Hence, Chapter 3 leads the research to investigate the strategic capabilities of enterprises to survive when facing a market turbulence.

What is specific to regulated markets, such as energy and in particular PV, is that companies are embedded in an environment, for which the countries' specific characteristics are fundamental in the day-to-day operations. Hence, Chapter 3 also sheds light on the difference of regulatory and institutional framework between two relatively similar countries: France and Germany. To limit biases linked to the difference of framework, I solely focus on companies operating on the French soil. I chose France instead of Germany as it is the country that was the most impacted by market turbulence.

Considering that market turbulence is a kind of situation that “moves away from everyday phenomena” (Eisenhardt and Graebner, 2007, p. 28), my research is an exploratory study. In this chapter, explanations will be provided on how I investigated on the firm survival capabilities and the rationale for my methodological decisions. For that purpose, the research design and methodology will be exposed.

Precisely, I combined qualitative and quantitative methods. I recognize that both methods have different strengths. For my research, I believe that I need both. To be sure, it is not a new methodology. Numerous previous studies have already done this for diverse reasons⁷³. Here, I opted for combining these methods for their complementary.

In line with the research design identified by Morgan (1998, p. 367), I considered a division of labor between the qualitative and quantitative methods. Based on his ‘Priority-Sequence Model,’ the present doctoral thesis is in the situation of qualitative preliminary (i.e. cell 1 of the model). That is to say, the qualitative method comes as an initial step to the principal method, which is quantitative. The purpose of such qualitative preliminary research is to improve the effectiveness of the quantitative research. As such, the study involves two distinct phases. The procedures for the two stages of this study are discussed in turn.

Specifically, Section 1 discusses the procedures of the qualitative phase. In particular, I explain why and how I made the interviews. I deduce from this first step my hypotheses, that are exposed in Section 2. Then comes the quantitative phase in Section 3. Precisely, I outline the various steps resulting in the database development. The chapter ends with the conclusion.

⁷³ It is worth noting that this design has been sharply criticized. One of the most significant critics is that doing so violates basic paradigmatic assumptions for each method (Morgan, 1998:363).

1. Phase 1: The qualitative phase through interviews

The first phase is qualitative. I start by exposing the objective of this first step (Section 1.1.). Then I describe the tool used, that is interviews (Section 1.2.). I continue with the data collection (Section 1.3.) and the main results of the exploratory phase (Section 1.4.).

1.1. Objective of the qualitative phase

This first step aims at providing us with useful hints on the survival strategy and positioning of companies. Most importantly, the primary objective was to reduce the possible scope of the investigation. In other words, by understanding their positioning, their stake in the PV industry, their strategy and, their business, I hoped that the first step would ease the quantitative work. For this purpose, I aimed at formulating hypotheses at the end of this first step. These hypotheses should lead us to answer the research question, that is the performance of survival firms in a fragmented value chain in a context of market turbulence.

1.2. Interviewees description

According to Eisenhardt and Graebner (2007, p. 28), interviews form a good starting point for an exploratory study. Accordingly, my first source of data is interviews with actors and specialists of the question of PV market development.

Following Eisenhardt and Graebner (2007, p. 28)'s suggestion, to limit bias related to interviews, I proceeded to interview various actors having different stories and points of view on the focal phenomenon. As Shah and Corley (2006, p. 1823) noted, “multiple social realities can exist around a phenomenon because those involved interpret the phenomenon differently”. This should lead us to obtain diverse interpretations of the focal phenomenon and consequently to “mitigate retrospective sense-making and impression management” bias (Eisenhardt and Graebner, 2007, p. 28).

Accordingly, the study draws upon 19 interviews with representatives of companies operating in the French upstream and downstream segments of the PV value chain (eight CEO or founders, three directors, four managers and one commercial engineer) and representatives of local communities (two project managers and one director).

1.3. Data collection

I began each interview with a brief explanation of my research to expose the interview's purpose and to raise the interviewee's interest. Then the discussion started based on a set of open-ended questions. The covered subjects are:

1. Their business in general, including the size and the ranking of their PV market segments in their turnover.
2. The way the company generates revenues.
3. The activities that generate revenues.
4. The PV technologies used.

5. The funding and requirements of the PV projects.
6. Their evaluation of the slowdown of the PV market
7. Their difficulties in their business and how they overcome them.
8. The (political) measures that could help their business.

Although a framework of questions has been determined in advance, I have not ruled out introducing a certain degree of freedom in order not to disrupt the natural flow of the conversation. Hence, the interviews were neither wholly opened nor strictly guided. Instead, they were semi-structured narrative interviews. This type of interview offers the interviewee the advantage of answering freely to the questions but also topics that the interviewee considers relevant. Hence, the interviewee can elaborate on his point of views. It is consistent with the exploratory nature of the study. It is noteworthy that significant deviations will be avoided.

It is worth specifying that the interviews were face-to-face or by telephone. The average duration of each interview was 40 minutes. As requested by some interviewees, the interviews have not been recorded. That did not prevent me from noting down their answers and transposing them on a report.

Importantly, aware of context and country specificities and consistent with my desire to provide conclusions that go beyond national borders, I use the German case to achieve generalization, to some extent, of my research. Specifically, while there was not a formal interview, I validated the preliminary results from the first set of interviews with Heiko Schwarzburger, the editor in chief of *Photovoltaik*, a German magazine, whose headquarter is in Berlin.

1.4. Diversification: the main conclusion

As written earlier, my primary objective of this first step is to understand the companies' strategy for survival. I realized how diverse the firms are. Indeed, based on the interviews, it seemed that they differ in their history, their overall strategy, and their positioning in the PV market. That is to say that the interviewed companies reacted to the market turbulence in sharply different ways. What is certain is that they sought for strategies conducive to survival. Nevertheless, it seems that diversification towards other markets is the backbone to survive market turbulence.

Indeed, the most outstanding result is that their willingness to integrate various activities seemed to be the first option to survive. It could be inside (i.e. vertical diversification) or outside the PV value chain (i.e. industrial diversification). This move could also be towards different countries (i.e. global diversification). Undoubtedly, diversification is not the only factor impacting one's survival capacity.

2. Formulation of hypotheses

The interviews and the literature review led us to formulate five hypotheses.

2.1. Diversification classification hypothesis

What is certain is that firms are not all alike, as they differ regarding their behavior and performance in the industry and country contexts in which they operate (Nelson, 1991, p. 61). Management scholars have proposed that these differences largely reflect different choices made by firms.

I do believe that investigating the firm's strategic behavior would be easier if it is possible to organize the companies into a few categories. In line with the interviews, the categorization had to be based on diversification strategies. Considering the porosity of the PV downstream activities with other industries (IEA PVPS, 2016, p. 53), and that among the various forms of diversification, the one that is the most studied is industrial diversification, this hypothesis focuses on it. The next two hypotheses address the other forms: vertical and global diversification.

Having said this, previous studies shed light on the link between strategy and business model (e.g., Casadesus-Masanell and Ricart, 2010). Interestingly, Teece, (2010) and Baden-Fuller and Morgan (2010) presume that, in an industry, there are only a handful of business model possibilities. Hence, I propose to elaborate the hypothesis on business model. As far as I know, this assumption has not been tested. This leads us to the first hypothesis:

Hypothesis 1: There are only few business models in an industry.

Considering that a classification only generates generalities, I need to go further to respond the research question. Hence, the following hypotheses enable us to provide a deeper understanding of these business model possibilities. Specifically, I consider the two most important strategic decisions in relation to marketing function (Zahay and Griffin, 2010, p. 85): the positioning (Hypotheses 2 and 3) and segmentation (Hypothesis 4).

2.2. Value chain-related hypothesis – Positioning (1)

As Harrigan (1985, p. 397) wrote, vertical integration is one of the first diversification strategies a company considers. Previous studies shed light on the many strategic benefits of vertical integration (Harrigan, 1985, 1984; Porter, 1998b, p. 306). The one of interest here is that it may reduce the effects of market turbulence. It is argued that the number of integrated stages for manufacturing corporations will be low when demand is uncertain, and higher when demand is more certain. The reasoning lies in the capacity of the downstream activity to absorb the output of the upstream activity (Harrigan, 1985; Porter, 1998b, p. 306). This rationale applies to manufacturing companies and to industries with interconnected vessel activities, such as the upstream segment of the PV value chain.

It is not the case in the PV downstream segment. Hence, the fear of not being able to absorb the output of the upstream activity does not apply. Indeed, the activities are mainly in services and more importantly, the downstream segment is disaggregated as the various stages are independent of the other. Moreover, the significant fragmentation of the PV downstream value chain is particularly glaring for the most service-related activities, which are project development and operations and maintenance (O&M), compare to the manufacturing activities, which are system and balance of system (BOS) manufacturing. As such, they are service providers, manufacturers, or both.

Undeniably, the level of barriers to entry plays a role in vertical integration. Indeed, previous studies shed light on the significant technical barriers to entry for services and the high level of financial barriers to entry for manufacturing activities (e.g., Platzer, 2015; PwC, 2012; Sontakke, 2015). It is worth noting that technical barriers to entry can be easily overcome thanks to training. However, it is much harder for financial obstacles.

Against this backdrop, I predict that in a fragmented value chain with independent and mainly service-like stages, vertical integration is appealing to reduce the effects of market turbulence. Therefore:

Hypothesis 2: In a context of market turbulence, in a fragmented value chain, the number of integrated stages in services will be high.

A company is mono-stage if it is involved only in one stage of the value chain. Specifically, I considered that there are four possible specializations, corresponding to the four stages of the PV downstream value chain. A company is multi-stage otherwise.

2.3. Global diversification-related hypothesis – Positioning (2)

Global diversification is another diversification strategy. It is defined as a diversification of a company's activities across multiple national markets. Undeniably, companies in the upstream segment of the PV value chain are global (e.g., Bloomberg Finance L.P., 2014; Weber, 2015). As such they are engaged in such global diversification.

Turning to the downstream part, it is another story. Indeed, one feature highlighted in Chapter 2 is the market closeness of companies in the downstream segment of the PV value chain. Weber (2015) and PwC (2009) specify that this geographical closeness of activities particularly applies to services, and to a lesser extent to manufacturing activities. It is unsurprising when considering the significant variations of legislation from one country to another (cf. Chapter 3). These variations are particularly striking when dealing with installation and project development. Based on this information, I make the following prediction:

Hypothesis 3: In a fragmented segment driven by national policies and service providers, it is highly likely that the firms are limited to national borders.

Notably, I have collected geographical information on the localization of the companies and their offices and subsidiaries, and the geographic coverage of their exports. I found them on their companies' website, mainly when looking at the references. I limit the number of possibilities to four:

1. 'Regional' coverage is selected when the activity is limited to a specific region.
2. 'National' coverage is the case when the activity is limited to the national frontier but covers more than one region.
3. The enterprises that do have activities worldwide without any physical presence are designated as 'export.'
4. In case of a mention of subsidiary or office on foreign soil, I consider that the company has an 'international' coverage. I include in this category overseas departments based on the difference of regulation with mainland France.

2.4. Segmentation-related hypothesis

One may note that Hypothesis 2 and Hypothesis 3 deal with positioning, one of the two strategic decisions linked to marketing function (Zahay and Griffin, 2010, p. 85). The other strategic decision involves segmentation. Segmentation is about determining the set of customers that best fit with the chosen position. These are the two pillars in service-based companies to achieve firm performance. This is a brief introduction to business model elements. I will have a closer look at them in Chapter 5.

In line with Zahay and Griffin (2010, p. 86), the customer segmentation criterion distinguishes broad from focused orientation. A firm serves a broad customer segment when there is selection for neither the type of PV applications nor the type of customers. I selected focused customer segment for a company if the information leads us to understand that the company targets a specific category of customers or type of application.

Past attempts to link customer segmentation and market turbulence have dealt with market orientation (e.g., Davis et al., 1991; Wilden and Gudergan, 2015). In a stable market, in general, the offering serves a particular set of customers. When market conditions change, companies are invited to be more market-oriented (i.e. focused on meeting their customer needs). In other terms, they serve a focused customer segment. This leads to the following hypothesis:

Hypothesis 4: In a context of market turbulence, the companies tend to address their offer to a public as specific as possible

I reckon that numerous companies may have as much customer segments as business lines they are involved in. However, in this manuscript, I only considered the PV business unit and not the firm unit.

2.5. Resources-related hypothesis

Undeniably, diversification strategies imply significant resources, be they financial, physical or human (Chatterjee and Wernerfelt, 1991; Kor and Leblebici, 2005; Penrose, 2009). The rationale behind diversification strategy is mostly linked to the

resource-based view of the firm (Li and Greenwood, 2004, pp. 1134–1135; Park and Jang, 2013, p. 53). This perspective considers the firm as a bundle of resources. But, some of these resources overly abundant are in oversupply. Unused resources (or slack resources) are viewed as costs and “signal inefficient resource management” (Park and Jang, 2013, p. 53). Hence, Penrose (1959 in Li and Greenwood, 2004, p. 1134) suggests that some enterprises diversify to realize benefits from exploiting the excess resource. It is particularly true for resources that are rare, inimitable, valuable and non-substitutable (e.g., Barney, 1991; Wernerfelt, 1989). This should lead to synergies in general and economies of scope in particular. Hence, the first four hypotheses have to be adjusted regarding the resources at the disposal of the company. It results in:

Hypothesis 5: The classical criteria of resources-constraints play a significant role in the strategic capacities of the enterprises.

Of particular interest are:

1. The ownership control (dependent or independent);
2. The partner network: I consider it as high if there is any explicit mention of its partners or operation involving at least one partner; the level is low otherwise;
3. Equity capital;
4. Total asset;
5. And the number of employees. For the sake of simplification, I have categorized the firm size based on the number of employees. In accordance with OCDE⁷⁴, I distinguished the small from the medium from the large companies in the following way: small firms have a staff between 20 and 50 persons; medium-sized companies have more than 51 employees but less than 250; and large corporations employ more than 251 persons.

2.6. Performance- related hypothesis

The last hypothesis deals with the performance of diversification strategies. It is one of the most researched topics in various disciplines, spreading from strategic management and industrial organization to finance (e.g., Christensen and Montgomery, 1981; Datta et al., 1991). There is no consensus on the subject: some results have shown that diversification strategies may outperform other possible strategies, while others are inconclusive. What is certain is that diversification strategies impact performance but do not guarantee favorable performance (Dubofsky and Varadarajan, 1987, p. 597).

In the context of turbulence, what is of particular interest is the evolution of firm performance. Following the most widespread hypothesis on diversification performance, the last hypothesis is as follow:

⁷⁴ <https://stats.oecd.org/glossary/detail.asp?ID=3123>

Hypothesis 6: Diversification strategies lead to a better performance over time.

3. Phase 2: Testing the hypotheses quantitatively.

One may realize that the interviews only provide examples of strategies. To ensure that they are not exceptions, I aimed at testing them quantitatively. In other terms, this further step provides the statistical robustness of my research. Hence, in this section, I describe the construction of the dataset.

The dataset was built in three steps. I start with the scope of the quantitative study (Section 3.1.). I continue with the identification of the relevant companies (Section 3.2.).

3.1. The perimeters of the quantitative research

3.1.1. A six-year post-moratorium period

Traditionally, time is not particularly relevant when studying strategy (Eisenhardt and Brown, 1998, p. 788). It is not the case when firms are facing a market turbulence and are struggling to survive, notably by engaging in changes. That is why I considered a period instead of a year.

Specifically, I tracked information over the six-year period between 2010, i.e. the year of the moratorium, and 2015. The reasons for considering a six-year period lie in three points. Firstly, as Bergh and Lawless (1998) assume, the effects of product-market uncertainty develop over time. Accordingly, I believe that the effects of the French moratorium on the strategy of firms may be visible after a period spanning from few months to years. Secondly, it provides the study with a long-term perspective. Thirdly, it does not consider year-to-year fluctuations that may create any possible noise.

3.1.2. Data types

My research relied on diverse types of quantitative data. I employed quantitative data such as the year of foundation, the number of employees, the turnover, and the operating profit. While quantitative data are particularly common in quantitative methods, I am not confined to this choice. I also employed qualitative data, encompassing legal status, CEO name, and activity-related data. Numerous researchers underline the benefits from combining the two data types (Eisenhardt, 1989, p. 538; Eisenhardt and Graebner, 2007, p. 28).

If I go beyond the qualitative-quantitative data cleavage, it is possible to classify the type of information according to the purpose of collecting these data:

1. data linked to the company classical information (including corporate ownership, inception date, and their link to a parent or subsidiary company);
2. data related to the activity of the firm (such as business lines, the offering, and the geographical coverage).

3. company performance (including the equity capital, the total asset, and other financial information to assess companies' performance).

3.2. The identification of relevant enterprises for the purpose.

3.2.1. The selection of a listing of enterprises.

I collected data for 276 firms operating in France on Microsoft Excel®. These firms are derived from a listing provided by two significant French professional associations: (1) *Syndicat des Energies Renouvelables* from the directory of 2013-2014 edited in early 2013; and (2) *Enerplan*, on its website at the date of September 2014. An update has been done from the 2017-2018 directory of *Syndicat des Energies Renouvelables*. The choice of these two associations lies in the fact that they provide a representative sample of the actors along the PV value chain, while others are specialized only in one segment.

3.2.2. Refining the listing

The second step was to identify the relevant population for my doctoral research. It contains all enterprises operating in the downstream segment of the PV market with more than ten employees in at least one year over the six-year period (2010-2015). In other words, to be part of the final sample, I established a protocol of selection that excludes:

1. Firms that do not have direct activities in the PV industry. For example, companies producing solar energy only for their consumption are not selected.
2. Firms that do not operate at least partially in the downstream part of the PV value chain (i.e. system manufacturing, BOS component manufacturing, project development, and O&M). Indeed, I do not exclude companies that are operating upstream as long as they also operate downstream.
3. Firms whose staff never outnumbered ten employees during at least one year over the period 2010-2015. Indeed, diversifications studies only focus on SME or large companies. It is more likely that these companies engage in diversification or internationalization strategies than micro-companies (Horta et al., 2016, p. 177).

These three screenings pulled out 150 companies from the initial listing. Consequently, 126 enterprises composed the final list. After confirming that these 126 businesses met all these criteria, I proceeded to the next step.

Besides, the vast majority of the remaining companies are non-listed firms. It implies that the limiting factors in drawing on materials that I faced were availability and confidentiality. For reducing the flaws and enhancing the robustness of the research, I operated a triangulation of data collection. Particularly, I computed the data from four different source types to be sure to have as much information as possible and to

ensure the data validity. For collecting their data, I used (1) the websites of enterprises, (2) the world-level paid database of businesses named ORBIS, (3) three free business directory websites (societe.com, verif.com, and infogreffe.com) that provide information publicly available, (4) press releases, and press articles. Therefore, the documents that were at my disposal were heterogeneous. It is worth noting that due to the private nature of the firms, I had no way of determining the percentages of revenues generated from each business lines. At the end of this step, I also excluded 23 firms for which I did not succeed to collect enough data to assess the performance. Therefore, the list was reduced to 103 companies.

Conclusion

Survival is the foremost objective of firms. To study a firm's survival capacities in a period of turbulence, I set out six hypotheses related to diversification strategy and business models. The particularity of these hypotheses is that they are about low or no-tech companies. I am not aware of any study addressing the relative impact of various diversification strategies on the survival of low or no-tech companies. Each of these hypotheses will be considered in turn.

The first three hypotheses relate to firms' positioning inside the value chain. The assumption is that service providers, in case of turbulence, are vertically integrated. Hypothesis 4 is based on the segmentation of the customer base. Hypothesis 5 takes into consideration the resources available to companies. Finally, Hypothesis 6 addresses the question of the performance of a diversification strategy and business model.

Despite the exploratory nature of my study, I did not want to confine myself to a descriptive approach (which we find in Chapters 5 and 6). That is also why I engaged in quantitative research, enabling notably the investigation of the performance of diversified companies, mainly SMEs, in a turbulent market context (Chapter 7).

Part 3 - Results

Chapter 5: A characterization proposal of strategies in an industry through its ideal business models

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Résumé

Chapitre 5 : Proposition de caractérisation des stratégies dans une industrie par ses business models génériques

Dans ce chapitre nous présentons et discutons les concepts de stratégie de diversification industrielle et de business model. Nous changeons de niveau d'analyse en descendant au niveau microéconomique. Le chapitre se concentre sur deux dimensions : (1) une nouvelle taxonomie de diversification industrielle, et (2) les modalités de caractérisation des business models génériques.

La première concerne notre proposition d'une nouvelle taxonomie de diversification industrielle. Alors que les taxonomies existantes reposent sur le concept de proximité des secteurs d'activités d'une entreprise, la nôtre repose sur les frontières d'un marché et d'une industrie. Nous retenons cette approche pour trois principales raisons. La première est que la notion de proximité est toujours utilisée de manière ad hoc et est donc subjective puisqu'elle dépend de l'analyste. La deuxième raison est liée à l'importance de la transposabilité des résultats. Enfin la dernière raison tient à la disponibilité des informations des entreprises privées de petite taille qui ne sont pas accessibles facilement, contrairement aux entreprises cotées en bourse. L'analyse par les frontières d'un marché et d'une industrie met en exergue quatre familles de situations possibles : (1) entreprises non-diversifiées ; (2) entreprises diversifiées au sein d'une même industrie ; (3) entreprises diversifiées dans deux industries ; et (4) entreprises diversifiées dans plus de deux industries.

Notre deuxième contribution est de construire les fondements nécessaires pour tester l'hypothèse de Teece (2010), pour qui les nombreux business models existants dans une industrie sont des variations de business models génériques (cf. Hypothèse 1). Pour ce faire, se basant sur Casadesus-Masanell and Ricart (2010), pour qui le business model traduit la stratégie d'une firme, nous faisons l'hypothèse que les quatre stratégies exposées dans le paragraphe précédent mènent à quatre business models distincts. Ainsi, nous utilisons le « *business model canvas* » de Osterwalder et al. (2010) afin d'identifier les caractéristiques de ces business models génériques, et en particulier six composants : la proposition de valeur (produits ou services), les activités clés (cf. les activités aval de la chaîne), les canaux de distribution (l'espace géographique d'activité), la segmentation de la clientèle (large ou réduite), les ressources clés (le nombre d'employés, les actifs, et les capitaux) et les réseaux de partenaire (important ou non).

The most authentic thing about us is our capacity to create, to overcome, to endure, to transform, to love, and to be greater than our suffering.
Ben Okri.

Introduction

Chapter 2 shed light on the large number of enterprises, mainly new entrants and small and medium, that occupies the downstream segment of the photovoltaic (PV) value chain. Specifically, the chapter highlighted the inability of global value chains (GVCs) theories to address the downstream situation which, as I pointed out, includes the following activities: systems manufacturing, balance of system (BOS) component manufacturing, project development, and operation and maintenance (O&M). Chapter 3 then showed that the PV industry is of particular interest because the industry is economically and technologically driven by government policies. It demonstrated, in particular, that policy turbulence also led to market turbulence, which, in turn, has affected the survival of French companies. Interestingly, in 2016, six years after the moratorium imposed by the French Government, over 600 PV installation companies were still operating in France alone (cf. Chapter 2)⁷⁵. These companies are highly differentiated, in terms not only of size but also, notably, of strategy.

While the GVC literature provides a holistic view of global industries, the strategy literature draws the analysis to the company level. Looking at the issue from this standpoint should allow me to deepen my understanding of the diversity and proliferation of actors on this segment of the PV value chain.

One strategy is central in my doctoral research: diversification - one of the most widely studied themes in the strategic management literature (Park and Jang, 2013, p. 51). Remarkably, it is also of interest to researchers from various fields, including industrial organization economics, financial economics, organization theory, and marketing (Ramanujam and Varadarajan, 1989).

Before going further, it is important to distinguish industrial diversification from global and vertical diversification. A company can diversify its operations across its lines of business, namely industrial diversification, or across multiple national markets, namely global diversification, or across stages on the same value chain, namely vertical diversification (Ansoff, 1957; Boons and Lüdeke-Freund, 2013; Denis et al., 2002; Harrigan, 1985, 1984; Porter, 1998b). Even though global and vertical diversification deserves my attention, I have chiefly dedicated this chapter to industrial diversification. The reason behind this choice is that previous studies on the PV value chain acknowledge that some activities are cross-industry (cf. Chapter 2; IEA PVPS, 2016, p. 53). Therefore, in this chapter, any mention of diversification, from here onwards, refers only to industrial diversification, except where otherwise noted. To be specific, this chapter lays the groundwork for testing Hypothesis 1.

Having said this, the chapter also centers on a related concept: business model. In a nutshell, it describes the internal mechanism of a company. Over the three last

⁷⁵ <http://www.enfsolar.com/directory/installer>

decades, we have witnessed strong enthusiasm for strategy and business-model concepts, from academics, practitioners, and investors. However, these notions remain unclear. As Magretta (2002, p. 91-92) pointed out, strategy and business model are two terms that are often stretched to mean everything – and end up meaning nothing. Furthermore, the link between them remains blurred. Yet there is indeed a strong relationship between these two notions⁷⁶.

Acknowledging that a company's business model is a reflection of its actual strategy (Casadesus-Masanell and Ricart, 2010), I use business model components to go deeper into the analysis of strategy at the corporate level. It is noteworthy that the business model literature tends to focus either on its components (Zott et al., 2011) or on the story of role models such as Google, Disney, South-West Airlines and Amazon (i.e. "ideal cases to be admired" in the words of Baden-Fuller and Morgan, 2010, p.157). Scholars thus pay close attention to the firm's business model but neglect its strategic and competitive dimensions. It follows that a comprehensive view of the industry is missing.

As Teece (2010, p. 176) pointed out, there is moreover "a plethora of business model possibilities." As Baden-Fuller and Morgan (2010) and Teece (2010) put it, despite the heterogeneous nature of firms within a particular industry, some common characteristics and patterns emerge from studying their business models. As such, they are only variations of ideal business models. Ideal business models play the role of 'scale models' or 'nutshell models' in the PV sector, as they are "representations or short-hand descriptions" of existing businesses (Baden-Fuller and Morgan, 2010). This is the basis on which I will test my first hypothesis.

Hence, the objective of this chapter is twofold. The first and foremost goal of this chapter is to determine the criteria that will help me to characterize ideal business models and then to test the arguments of Teece (2010) and Baden-Fuller and Morgan (2010). This chapter may also be seen as an attempt to fill the gap due to the lack of a strategic view of business models.

The chapter is structured as follows. Section 1 defines diversification along with other strategies identified by Ansoff (1957) and discusses the objectives of diversification. I moreover examine the categorizations of diversification, and in particular of Wrigley (1970) and Rumelt (1974, 1982). In Section 2, I set out my taxonomy. Section 3 is devoted to business model. Notably, departing from the nine building blocks of the business model framework developed by Osterwalder et al. (2010), I determine which building blocks will serve me to identify the characteristics of an ideal business model. It provides the basics required to analyze companies' business model and then to make comparisons. Finally comes the conclusion.

⁷⁶ "In simple competitive situations, there is a one-to-one mapping between strategy and business model, which makes it difficult to separate the two" (Casadesus-Masanell and Ricart, 2010, p. 195). However, this overlap is unfortunate when there are strong contingencies on which a well-designed strategy must be based. In this situation, the two concepts differ (Casadesus-Masanell and Ricart, 2010, p. 195). For further distinctions between strategy and business model, see for example Casadesus-Masanell and Ricart (2010, p. 205) and Chesbrough and Rosenbloom (2002, p. 535).

1. Diversification strategy

1.1. Strategy possibilities

One of the foremost challenges of a company is to survive in a competitive environment. To do so, a company has to grow and change through four basic product-market alternatives which are not mutually exclusive but can be pursued in parallel (Figure 5.1.; Ansoff, 1957, pp. 113–114). These strategies are presented below and in Figure 5.1.:

1. Market penetration. A company applying this strategy aims at selling more of its current products. It could either increase the volume of its sales with its existing customers or find new customers for its existing products (Ansoff, 1957, p. 114).
2. Market development. Market development is about adaptations of its current product line to new missions. It does not exclude modifications of the product characteristics.
3. Product development. This is the opposite of market development as the idea is to develop products with new and different characteristics to cater to the current mission.
4. Diversification. This strategy requires the departure from both the current product line and the current market structure to enter into new markets with new products. Diversification is unquestionably the most challenging strategy as it means an increase in the number of industries in which a company operates (Berry, 1971). That is why I focus on it here.

		Products	
		Present	New
Markets	Present	Market penetration	Product development
	New	Non-Market development	Diversification

Figure 5. 1.: The product-market growth matrix
Source: Adapted from Ansoff (1957)

1.2. Definition(s) of diversification

Simply defined, a diversified firm has listed “two or more business economic sector entries” (Robson et al., 1993, p. 38). Each of them should generate at least 10% of a company’s turnover (cf. Box 5.1. for the most commonly used methods to assess the degree of diversification). In this sense it is the opposite of undiversified firms, also called focused or single business firms, which have only one business lines.

Box 5. 1.: Assessing the degree of diversification

Typically, researchers assess the degree of diversification (i.e. how much?) through a business/product count or a continuous measure (Datta et al., 1991, p. 531).

Researchers have traditionally used business/product count measures, and especially standard industrial classification (SIC) codes (Bergh and Lawless, 1998; Tanriverdi and Lee, 2008) and US Census Bureau information, which enable them to identify the various businesses of a company and to measure their diversity (Datta et al., 1991, p. 531). The bright side of SIC is unquestionably its concreteness and replicability (Rumelt, 1982, p. 360). However, “the varying degrees of breadth in the SIC classes and the implicit assumption of equal ‘dissimilarity’ between distinct SIC classes” (Rumelt, 1982, p. 360) must be noted.

The Hirschmann Index (Hirschman, 1964), the Entropy Index (Bergh and Lawless, 1998; Jacquemin and Berry, 1979; Park and Jang, 2013) and stock market-based indices (Barnea and Logue, 1973) are examples of continuous measures (Datta et al., 1991).

For some researchers, diversification is a multidimensional process and thus implies a more comprehensive view of the company structure. Some researchers, therefore, provide a definition intended to better encompass its multidimensional nature and thus to broaden the scope. Ramanujam and Varadarajan (1989, p. 524), for instance, include “the administrative linkages and process aspects of diversification”, defining diversification as “the entry of a firm or business unit into new lines of activity, either by processes of internal business development or [by] acquisition, which entail changes in its administrative structure, systems, and other management processes” (cf. Box 5.2. for details on the mode of diversification). This definition excludes “simple product line extensions that are not accompanied by changes in administrative linkage mechanisms” (Ramanujam and Varadarajan, 1989, p. 524). Put differently, it involves not only new markets, products or services, new customer segments, or new geographic markets, but also broader changes in the structure of an enterprise. Whatever the definition, it should be recognized that changes are at stake.

Box 5. 2.: Choice of mode of diversification

The mode of diversification refers to how a company diversifies into different business lines. The two main options for a company, which are diametrically opposed to each other, are internal development and mergers & acquisitions (Datta et al., 1991, p. 532; Ramanujam and Varadarajan, 1989, p. 527). The former “exploits internal resources as a basis for establishing a business new to the firm and involves issues related to the management of innovation” (Datta et al., 1991, p. 532), while the latter involves “strategy assessments of target firms in terms of their strengths and weaknesses and their value to the acquiring firm” (Datta et al., 1991, p. 532). Clearly, there are points in between. So, they can be depicted on a continuum, and many modes of diversification fall somewhere in the middle of the spectrum. These include joint ventures, strategic alliances, and licensing agreements (Booz et al., 1985; Ramanujam and Varadarajan, 1989, p. 527).

1.3. Goals of diversification

Such changes are certainly challenging. Yet they might be worth their while. They consist of either an offensive/proactive or a defensive move (Ansoff, 1957, p. 114; Datta et al., 1991, p. 530; Kirkwood and Srni, 2011, p. 771; Ramanujam and Varadarajan, 1989, p. 525; Reed and Luffman, 1986).

On the proactive side, the motivation involves greater market power, better top management, high economies of scale and scope, and synergies that concern the sharing of complementary skills or utilization of excess productive capacity.

On the defensive side, reducing risk is one of the most basic reasons for a company to engage in a diversification process. However, is diversification the answer to environmental uncertainty? Environmental uncertainty, defined as “the degree to which future states of the competitive environment cannot be anticipated or accurately predicted” (Bergh and Lawless, 1998, p. 89), notably occurs when a market experiences turbulence. The studies of Ansoff (1957) and Bergh and Lawless (1998) are interesting as they opt for two different points of view.

Whereas Ansoff (1957) compared companies in a stable industry that were willing to diversify to enterprises in a less stable industry, Bergh and Lawless (1998) looked at companies that were already diversified and had at least one subsidiary in a stable industry and another one in a less stable industry. The results are somehow similar: in a stable environment, a company may be interested in expanding its scope (i.e. diversifying); in an unstable one, it will tend to focus on or expand toward a more stable industry. Hence, diversifications result in portfolio restructuring, defined as “a change in the firm’s configuration of lines of business through acquisition and divestiture transactions” (Bergh and Lawless, 1998, p. 92).

1.4. Choice of direction for diversification

Are all diversifications the same? Until now, I have spoken about diversification strategy as though diversifications are all alike. Yet diversification strategy is complex and has been studied under numerous dimensions (Datta et al., 1991). Many researchers use ‘diversification strategy’ in its plural form and have attempted to describe, dissect, and categorize different types. I have discussed the mode (i.e. how?) earlier in this section (cf. Box 5.1). Actually, the core of this manuscript is the type of diversification (i.e. which direction?). It is to this subject that I now turn. Broadly speaking, two perspectives on the question of diversification type stand out.

1.4.1. Related versus unrelated diversification

The most common distinction was initially proposed by Wrigley (1970). It relies on the nature of relatedness between the various business lines of an enterprise (Datta et al., 1991, p. 532). Specifically, its proponents take into account not only the number of business lines composing a firm's portfolio and the relative size and importance of each line but also the relations among the lines as the way to distinguish between types of diversification (Bergh and Lawless, 1998, p. 90). It follows an opposition between related and unrelated diversification.

Related diversification denotes “expansions within a firm’s primary product line” (Stern and Henderson, 2004, p. 493), implying the transferability of core resources, i.e. skills and capabilities, common technologies, or shared customers in the new industry (Kirkwood and Srari, 2011; Zahavi and Lavie, 2013). That is to say, in related businesses, common skill, market or resource apply to each (Rumelt, 1974, p. 29). One can envision a company which newly introduced products or services have significant interaction with the offering of the existing markets, largely because they entail similar skills and resources.

Conversely, unrelated diversification refers to expansions outside a firm’s primary product line (Stern and Henderson, 2004, p. 493). One can envision companies whose products or services have little or nothing in common with the products or services of the existing markets and require a different set of skills and resources.

Having described the two possible directions for diversification, I now consider the most commonly mentioned classifications in the literature according to Datta et al. (1991, p. 532): those of Rumelt (1974) and Wrigley (1970), which deepen the simple opposition of related versus unrelated diversification. Indeed, while this dichotomy is insightful, it is more appropriate to consider related and unrelated diversification as two points on a continuum. A spectrum is indeed required to consider all the nuances and subtleties of the relatedness between business lines. For this purpose, notably Wrigley (1970) and Rumelt (1974) propose a categorization to include some possibilities between the two extremes for large companies. Wrigley (1970) was the first to offer a nominal scale of four major degrees of diversification strategies. The distinction is based on the relation among the various businesses in a firm’s portfolio and the percentage of sales generated by the main product line. These categories are presented in the following table.

Diversification strategies	Percentage of sales generated by the main product line
Single	At least 95%
Dominant	At least 70%
Related	Up to 70%
Unrelated	

Figure 5. 2.: Classification of industrial diversification of Wrigley (1970)
Source: Adapted from Wrigley (1970)

Turning to Rumelt (1974), his book *Strategy, Structure and Economic Performance* marks a milestone in the diversification strategy literature (Christensen and Montgomery, 1981; Varadarajan and Ramanujam, 1987)⁷⁷. Rumelt (1974) notably proposed a finer-grained analysis in deriving a nine-category scheme from Wrigley (1970)’s four types: (1) single business; (2) dominant vertical; (3) dominant constrained; (4)

⁷⁷ In addition to the categorization, another noticeable contribution of this book was to prove the relationship between diversification and economic performance statistically. This linkage will be analyzed in Chapter 7 along with my taxonomy of diversification strategy.

dominant linked; (5) dominant unrelated; (6) related constrained; (7) related linked; (8) unrelated-passive; and (9) acquisitive-conglomerate. The objective of this new categorization is to identify the link between the core and peripheral businesses.

Rumelt (1982) later proposed a variant of this categorization, reduced to seven possibilities: 'dominant linked' and 'dominant unrelated' categories merge, resulting in 'dominant linked-unrelated' category; 'unrelated-passive' and 'acquisitive-conglomerate' merge too to form 'unrelated business.' The original and the variant have both been widely used (Bergh and Lawless, 1998; Christensen and Montgomery, 1981).

1.4.2. Limits of related/unrelated diversification categorization

While researchers recognized the importance of the seminal work of Rumelt (1974, 1982) and Wrigley (1970), their classifications have raised critical voices (Christensen and Montgomery, 1981; Datta et al., 1991; Park and Jang, 2013; Varadarajan and Ramanujam, 1987; Venkatraman and Grant, 1986).

First, I, along with numerous authors, consider that the criterion of relatedness is too subjective and dependent on the environment (Datta et al., 1991, p. 549; Park and Jang, 2013, p. 52). As such, studying relatedness, in general, is tricky.

Second, for assessing the relatedness between two business lines, one has to know the percentage of revenue generated by the various business lines of the company (Varadarajan and Ramanujam, 1987) and what the relevant core skills to transfer are (Klein and Lien, 2009, p. 291). Unfortunately, these pieces of information are on easy access only for publicly traded companies. Therefore, access to information is a significant limitation when a research centers on private enterprises.

Furthermore, in my opinion, the categorization of Rumelt (1974, 1982) implies a stabilized situation at the corporate level, whereas diversification is a time-consuming process, taking up to 12 years before any rewards are reaped (Park and Jang, 2013, p. 51). Considering that my study spans only a six-year period, it is unlikely that a stabilized situation will be observed for all the companies in my panel.

In light of the above considerations, considering that my doctoral thesis mainly focuses on private companies, classifications based on relatedness in general, and those of Rumelt and Wrigley in particular, are not appropriate. Admittedly, many alternatives based on relatedness have been proposed (e.g., Palepu, 1985; Varadarajan and Ramanujam, 1987) but they are all unsatisfactory for the study of private and small and medium-sized firms and regarding the subjectivity of the relatedness criterion (Park and Jang, 2013, p. 52). Therefore, my attention turns to another type of diversification that is based more on objectiveness and requires less in-depth information: the one based on the boundaries of an industry or market.

1.4.3. Intra versus inter-industry diversification

Contrary to the distinction based on relatedness, the one based on the boundaries of an industry or a market implies a strict dichotomy and not a continuum. As such, it is more an objective tool. Moreover, it requires less in-depth knowledge of firms.

Hence, I prefer to use the intra/inter-industry diversification distinction here as it fits the objective and characteristics of this doctoral thesis.

So far, intra versus inter-industry diversification has received limited attention compared to the first one (Park and Jang, 2013, p. 51). For this second distinction, academics focus on the boundaries of an industry to qualify a diversification.

Corporate diversification is mainly conceptualized across industries, i.e. inter-industry diversification. The definition of Berry (1971), as well as those of Ansoff (1957) and Bergh and Lawless (1998), for instance (cf. Section 1.1.), excludes the possibility of diversification inside the same industry. Yet diversification also occurs within industries (Stern and Henderson, 2004, p. 488), namely intra-industry, or within-industry diversification, where firms have more than one product line within industry boundaries (Tanriverdi and Lee, 2008; Zahavi and Lavie, 2013).

1.5. Conclusion

What is certain is that changes are at the heart of the diversification concept. To grasp the complexity of diversification strategy, many researchers have proposed a more complex conception of diversification. To do so, the mode and the type (or direction) of diversification are considered. The latter is of particular interest in this manuscript.

Interestingly, a mixture can be observed between within-industry diversification and related diversification, while, initially, the two categorizations appear distinct (Park and Jang, 2013, p. 51). Within-industry diversification is “a form of related diversification that is especially prevalent in high-tech industries” (Tanriverdi and Lee, 2008). As such, it is possible to link a distinction based on the frontier of an industry and the relatedness of business lines.

Numerous researches address the question of the type of diversification, mainly from the perspective of relatedness. Yet, I prefer to build my taxonomy of industrial diversification based on the boundaries of an industry and a market. The choice overcomes the limitations of the existing classifications based on relatedness: access to restrict information and subjectivity. The following section presents the taxonomy.

2. Presentation of the taxonomy

In line with other popular strategy models such as the product-market growth matrix (Ansoff, 1957), the BCG Growth-Share matrix, and the regimes of appropriability matrix (Teece, 1986), I propose to build my taxonomy around a two-by-two matrix, along two axes:

1. Intra-industry diversification: I am interested to know whether the firm operates in the PV market only or in the energy industry in general.
2. Inter-industry diversification: I am interested to know whether it operates in the energy industry only or also in other industries.

On that basis, four diversification strategies are derived from the intersection of intra- and inter-industry diversification (cf. Figure 5.2.):

1. Single-business enterprises. These correspond to the ‘non-diversified firm’ or ‘single business’ in the classifications of Wrigley (1970) and Rumelt (1982).
2. Intra-industry diversifiers;
3. Inter-industry diversifiers in two industries;
4. And inter-industry diversifiers in more than two industries.

		Inter-industry diversification	
		Mono-industry (Energy)	Multi-industry (Non-energy)
Intra-industry diversification	Mono-market (PV)	Single-business enterprises	Inter-industry diversifiers in two industries
	Multi-market (Energy)	Intra-industry diversifiers	Inter-industry diversifiers in more than two industries

Figure 5. 3.: What is your strategy?
Source: Author

Having said this, what is of interest in my doctoral thesis is the characterization of these strategies (cf. Hypothesis 1). Yet, the level of analysis to understand how companies survived through strategies provides a general understanding. Hence, I propose to have a more nuanced understanding of the diversification question through business models. Having discussed diversification strategy categorizations, it is now possible to focus on the business model concept.

Based on the assertion of Casadesus-Masanell and Ricart (2010), that the business model is a reflection of the strategy which the company has implemented, four possible ideal business models present in the downstream segment can be considered:

1. Companies that focus solely on PV implement the PV specialized-based business model (BM1). They are single-business firms.
2. The energy sources-based business model is employed by companies specialized in energies, including (but not solely) solar energy (BM2). They are intra-industry diversifiers.
3. The complementary function-based business model is set up by diversified companies whose core competencies come from mature industries, and that integrate PV panels into another structure (BM3). They are inter-industry diversifiers in two industries.
4. Companies proposing products or services not specific to one market or industry apply a general-purpose technologies business model (BM4). They are inter-industry diversifiers in more than two industries

These ideal types are mutually exclusive and jointly exhaustive. These four possibilities are best seen in the matrix chart below.

		Inter-industry diversification	
		Mono-industry (Energy)	Multi-industry (Non-energy)
Intra-industry diversification	Mono-market (PV)	BM1 The PV specialized-based strategy	BM3 The complementary function-based strategy
	Multi-market (Energy)	BM2 The energy sources-based strategy	BM4 The general-purpose technologies strategy

Figure 5. 4.: What is your business model?
Source: Author

I acknowledge that this is by no means the only way to classify diversification strategies and associated business model in the PV industry. Rather than constituting prescriptive criteria, my taxonomy describes ‘ideal-types’ of business model and is, therefore, a tool for my research to put order into the seeming chaos of social reality. Ideal business models are “representations or short-hand descriptions” of existing businesses (Baden-Fuller and Morgan, 2010). These business models are ‘ideal types’ in that they are based on certain elements and characteristics common to most cases of each category. By no means do they correspond to all of the features of any one particular case. In other words, this taxonomy aims at validating my first hypothesis, that the multitude of business models in any one industry is the variation of a handful of ideal business models.

The following section presents the business model concept and outlines the various business model elements selected that help me determine the characteristics of each ideal business model defining my taxonomy.

3. Business model

Section 3.1. provides an overview of the business model concept. Section 3.2. outlines the building blocks of a business model, which will allow me to highlight the distinguishing features for identifying the business model ideal types.

3.1. Business model definition(s)

Business model is a relatively recent term, which can be traced back to 1954 - when Peter Drucker published *The Practice of Management*. The book’s readership grew in the mid-1990s, coinciding with the Internet boom and e-commerce (Chesbrough and Rosenbloom, 2002; Demil and Lecocq, 2010; Magretta, 2002; Teece, 2010; Zott et al., 2011). There has been an increasing interest in the business model construct since then (Zott et al., 2011). This growing trend is evidenced in the numerous academic conferences and management workshops (e.g., EGOS, EURAM

and R&D Management), and in special issues on business model and business model innovation (e.g., *Long Range Planning* in 2010, *M@n@gement* in 2010, *International Journal of Innovation Management* in 2013, *R&D Management* in 2014, and *Strategic Entrepreneurial Journal* in 2013 and 2015).

Even though many contributors have proposed their own definition of business models, no consensus has yet emerged. Succinctly defined, business models refer to “stories that explain how enterprises work” (Magretta, 2002, p. 87). A more accurate definition of business models would be, for example, “the logic of the firm, the way it operates and how it creates value for its stakeholders” (Casadesus-Masanell and Ricart, 2010). Similarly, a business model defines “how the enterprise creates and delivers value to customers, and then converts payments received to profits” (Teece, 2010, p. 173). The lack of consensus concerning a definition of business model requires further research. While I do not intend to contribute to the clarification of this term, for the purpose of my work, I have opted for the definition provided by Teece (2010).

Teece moreover argues that a business model has to depict the mechanisms that help companies to link two dimensions of a firm’s activity (i.e. value creation and value capture) in order to create and sustain a competitive advantage⁷⁸. That is to say, these two dimensions measure the coherence of a business model (Casadesus-Masanell and Ricart, 2010, p. 200)⁷⁹. Value creation deals with the way a company generates value for its customers. As stressed by Chesbrough and Rosenbloom (2002, p. 534) and Teece (2010), creating value is not sufficient for a firm to profit from its business model. Value capture (or value appropriation), i.e. *how the firm captures some of this value as profit*, must be considered. As such, a business model should answer the following questions: “Who is the customer and what does the customer value?” and “What is the underlying economic logic that explains how I can deliver value to customers at an appropriate cost?” (Drucker, 1954).

But not all firms are doing so in the same way. It is achieved through a combination of business model components, also called ‘building blocks,’ which are articulated in a way “to produce a proposition that can generate value for consumers and thus for the organization” (Demil and Lecocq, 2010). As they will enable me to identify an ideal business model, the following section is dedicated to the description of these components.

3.2. Identifying the selected business model elements

The most common three elements, even if they are named differently, depending on the author, are the most basic and important ones (Chesbrough, 2010; Chesbrough

⁷⁸ While value creation “provide the volume and structure of revenues,” value captures (i.e. the internal and external organizations) “provide the volume and structure of costs.” The difference results in margins.

⁷⁹ This point is of interest particularly in basic investment research and in the production of scientific knowledge (Teece, 2010: 185). As spillovers are too large, and as strong intellectual property protection for scientific knowledge is nearly impossible to satisfy, it is hard to profit from discovery. That explains why few firms invest in basic knowledge.

and Rosenbloom, 2002; Johnson et al., 2008; Teece, 2010). They are: (1) value proposition, (2) revenue model, and (3) internal infrastructure. Yet the business model literature does not restrict the list of its components to these three dimensions. The list goes on and on. As Dmitriev et al. (2014, p. 308) point out, “the variety of elements identified reflects the multi-dimensional nature of business models in the literature.”

Some researchers propose a business model tool encompassing various building blocks. The development of these business model tools could be interpreted as an attempt to reach a common definition of the business model concept. Among them are the Business Model Canvas (BMC) of Osterwalder and Pigneur, the Lean Canvas of Maurya, the Resources, Competences, Organization, and Value (RCOV) of Demil and Lecocq, and the Value Model Canvas (VMC) of Kraaijenbrink. When I compare citation frequency in Google Scholar, BMC is by far the most oft-cited, with 10,500, as opposed to 790 for the Lean Canvas, 237 for the RCOV, and 16 for the VMC, as of March 27th, 2018. Based on these figures, I choose to depart from the BMC for detecting the components leading to the identification of ideal business models.

The BMC is a good starting point to fulfill one of the two purposes of this chapter, as it proposes a common language to describe firms. Of particular interest is the fact that it helped me to determine the criteria used to characterize the strategy of companies, through their business model. Nevertheless, it is far from being perfect. Among other things, it excludes strategic purposes, and its building blocks have different levels of abstraction.

Bearing these caveats firmly in mind, I reviewed the nine building blocks for characterizing ideal business models. However, not all of them are selected to define ideal business models. For defining them, based on the hypotheses discussed in Chapter 4, I consider the most salient business model components that define the categories. I also have to go down to a level of detail sufficient to distinguish one firm from another, but not so deep as to examine all the minutiae. I describe them below as presented in the literature.

3.2.1. *Value proposition*

Value proposition identifies “*what the offering is*”. Chesbrough and Rosenbloom (2002, p. 533) define value proposition as the value created for a specific customer segment by the offering, based on technology. Some values created for a customer segment are (Osterwalder et al., 2010, pp. 23–25): newness, performance, customization, ‘getting the job done,’ design, brand/status, price, cost reduction, risk reduction, accessibility, and convenience/usability. This is a non-exhaustive list.

Considering the possibility to combine various value propositions, as presented by Osterwalder and Pigneur, I do not consider the component as such. Admittedly, a simplified view with no ambiguity of ‘value proposition’ is also put forward: the offering could be delivered in the form of products or services (Demil and Lecocq, 2010, p. 231). Hence, for the purpose of characterizing ideal business model, I prefer to limit the value proposition to the simple product-service distinction. I add a third option that is a mix of both.

3.2.2. *Target market segment or market segmentation*

The offering aims at serving different groups of customers (people or organizations, large or small) that may not belong to the same customer segment. As such, the question asked here is “*to whom is the offer addressed?*” To be part of the same customer segment, customers should share common needs, behaviors, or other attributes (Osterwalder et al., 2010, p. 21). Thus, customer groups belong to separate segments, notably when a company needs to use different distribution channels (cf. Section 3.2.2.2.) or propose a distinct offer. Below are five examples of customer segmentation (Osterwalder et al., 2010, p. 21):

1. Mass market. The company makes no distinction between different customer segments. They form one large group which has broadly similar needs and problems. This is the case for example in the electronics sector.
2. Niche market. The company identifies and targets specific and specialized customer segments. It may create a dependent situation. This is common in supplier-buyer relationships. It is true notably for car part manufacturers who have a dependent status from major automobile manufacturers.
3. Segmented. The company distinguishes different market segments with similar but varying needs and problems. The retail arm of a bank which distinguishes the normal from wealthy clients exemplifies this situation.
4. Diversified. When a company targets two or more unrelated customer segments with very different needs and problems, it applies a diversified customer business model.
5. Multi-sided platforms (or multi-sided markets). Two or more interdependent customer segments are served. This means that companies may propose offers to various kinds of customers (e.g., end-consumers, suppliers, competitors, and sponsors) (Demil and Lecocq, 2010, p. 231). A free newspaper company is a case in point, as it serves both advertisers and readers, simultaneously.

As for value proposition, I believe that a simplification is welcome for this component. I consider only two options: broad and focused (Zahay and Griffin, 2010, p. 86). A firm serves a broad customer segment when there is selection for neither the type of PV applications nor the type of customers. I select focused customer segments for a company if it targets a specific category of customers or type of application.

3.2.3. *Channels*

Here, I am interested in the way an enterprise communicates with its customer segments and delivers to them a value proposition (Osterwalder et al., 2010, p. 26). Channels deal with communication (i.e. awareness and evaluation of the value proposition), distribution, and sales (i.e. purchase and after-sales).

Channels can be direct or indirect. While direct channels such as in-house sales force or web sales are necessarily owned channels, indirect channels are either owned or provided by partners. For example, own stores are indirect and owned by the

company; partner stores and wholesalers are indirect channels and are owned by the partner.

Considering that the localization of the firms' operations and offices is the point of interest, I only considered owned channels, be they direct or indirect. The difference between direct and indirect is considered when dealing with foreign operations: if it is direct (no offices nor subsidiaries), the 'export' option applies; otherwise, the 'international' option is chosen.

3.2.4. *Key activities*

To create and offer a value proposition, reach markets, maintain customer relationships, and earn revenues, a company has to undertake some key activities (Osterwalder et al., 2010, p. 36). These activities could be classified as follow:

1. Production activities. These deal with designing, making and delivering a product in substantial quantities and/or of superior quality. They are manufacturing firms' main activities.
2. Problem-solving. This is about proposing new solutions to individual customer problems. It is particularly appropriate for service organizations, including consultancy firms and hospitals.
3. Platform/network activities. This is the case when a platform is a key resource in the company's business model. The platform could be a network, matchmaking platforms, software or brands. These activities relate to platform management, service provisioning, and platform promotion.

Instead of the proposition offered by Osterwalder et al. (2010), I consider the value chain stages in the downstream segment of the PV value chain. Specifically, there are: balance of system (BOS) component manufacturing, systems manufacturing, project development, and operations and maintenance (O&M).

3.2.5. *Key resources*

The 'key resources' building block describes "the most important assets required to make a business model work" (Osterwalder et al., 2010, p. 34). Interestingly, a company could mobilize the resources through its networks, either internal (i.e. owned or leased by the enterprise) or external (i.e. acquired from key partners). I present the four categories below:

1. Physical resources. This category encompasses machines, buildings, vehicles and distribution systems. These assets are mainly capital-intensive.
2. Intellectual resources. They include patents, proprietary knowledge, copyrights, and brands. Intellectual resources are known to be difficult to develop. However, they are also known to potentially offer substantial value.
3. Human resources. While they are used in every company, they are particularly significant in knowledge-intensive and creative industries, such as biotechnologies.

4. Financial resources. Some business models use financial resources and/or guarantees as leverage. For example, they could be cash, lines of credit, or stock option pools.

This component is as crucial as key activities (Osterwalder et al., 2010, p. 35). Hence, it is used in this doctoral study but not exactly in the way presented by Osterwalder and Pigneur. Rather I merge physical and intellectual resources into the total asset. As for human resources, I prefer to consider the number of employees. Finally, equity is studied for financial resources.

3.2.6. Partner or value network

As it is unusual for a single firm to possess all the resources it needs, or to perform every activity by itself to create value for its customer segment, it relies on its partners. It could involve different actors: non-competitors (i.e. strategic alliances), competitors (i.e. cooptation), suppliers, and buyers (Chesbrough and Rosenbloom, 2002, p. 534; Osterwalder et al., 2010, p. 38). The objectives for creating alliances include (Osterwalder et al., 2010, p. 39):

1. Optimizing and achieving economies of scale: this partnership aims at optimizing the allocation of resources and activities, and consequently at reducing costs. It often involves outsourcing or sharing infrastructure.
2. Reducing risk and uncertainty: when companies face uncertainty, they could set up a partnership. Sometimes they could be competitors in one area while cooperating in another.
3. Acquiring particular resources and activities: some partners provide particular assets or resources or execute certain activities. The purpose of such partnership could be to acquire knowledge, licenses, or access to customers.
4. Developing new businesses (i.e. joint ventures).

Intriguingly, to a large extent, these examples echo the objectives of diversification discussed earlier in Section 1.

This component reflects the competition and strategic dimensions often obliterated in the business model literature. Therefore, it is a crucial element for the development of ideal business models. For my purposes, the study stresses the relative importance of partnership in one company's business instead of the numerous possible motives: either high or low.

3.2.7. Customer relationships, cost structure, and revenue model.

I gather the three last components as none of them are kept in the analysis for the identification of ideal business models. While I do not deny the importance of these three building blocks when depicting a sole company, I consider that it offers a detailed level that makes it not appropriate for the identification of ideal business model. However, I believe that a short description of each of them is useful to support their exclusion.

1. The 'customer relationships' building block describes the type of relationships a company establishes with specific customer segments. It is a spectrum with

at one end personal relationships and at the other end automated relationships. Here are five examples of customer relationship categories: personal assistance; dedicated personal assistance; self-service; automated services; co-creation. It is noteworthy that for a specific customer segment, many types of customer relationship can co-exist.

2. Turning to the 'cost structure' building block, it refers to the operating costs, i.e. all the costs required to create, deliver the value proposition, maintain customer relationships, and generate revenue. It considers not only the fixed and variable costs but also the economies of scale and scope. Broadly speaking, there are two extremes with possibilities in between. At one end of the spectrum, there are companies whose cost structure is qualified as cost-driven, i.e. their objective is minimizing costs. Firms that emphasize value creation instead of cost sit at the opposite end of the continuum.
3. Having said this, I still do not know how a company generates revenue. This is where the revenue model comes into play. Revenue models answer the question: "*what is the source of each revenue stream?*" As such they reflect how "revenue streams can be manifested in a business model" (Hamermesh et al., 2002, p. 3). More specifically, revenue models refer to a mechanism of pricing and charging money (Chesbrough and Rosenbloom, 2002; Johnson et al., 2008; Zott and Amit, 2010). They determine "how and per which unit of products or services money can be charged" (e.g., per pack or unit for a product, per hour for a service) (Dmitriev et al., 2014). Here are some examples of such mechanisms provided in Hamermesh et al. (2002) and Osterwalder et al. (2010):
 - Volume or unit-based (or asset sale). A company sells a product or service at a fixed price per unit. This is the most widely understood revenue stream. It corresponds for example to retail operations such as in a restaurant, clothing shop, or beauty parlor.
 - Usage fee. Here, the company derives revenues from use of a particular service. The fee increases with the use. A prime example is the number of hotel nights or the number of minutes spent on the phone.
 - Advertising. Revenue is generated by the advertising of a particular product, service, or brand. Usually, the fee is not paid by end-users, who at worst may pay only a fraction "of the true value of the product or service." Network television stations and content-based websites use this revenue model.
 - Licensing and syndication. This occurs when a company gives customers permission to use protected intellectual property in exchange for licensing or syndication fees. It is usually observable in the media industry for copyright and in the technology sector for patents.
 - Brokerage or transaction fees. The company generates revenue by intermediation services aimed at facilitating the transaction performed on behalf of two or more parties. The customer pays a fixed fee or a percentage of the transaction's total value. Credit card providers, brokerage firms, auction houses and real estate agents are good examples.

- Lending/renting/leasing. During a fixed period, a company grants to another the exclusive right to use a particular asset. In contrast to the above revenue streams for which there is a one-time payment, this one generates recurring revenues.
- Subscription/ Membership fees. A company derives income from the sale of continuous access to a product or service. This revenue stream also provides recurring revenues to the company as customers pay a fixed amount at regular intervals.

Conclusion

In this chapter, I drew the level of analysis to the microenvironment in discussing firm strategy and business model, as well as the link between these concepts. Specifically, the chapter's contributions are threefold.

First, the above discussion contributes to the strategy literature in proposing a new taxonomy of diversification. Taken into consideration the boundaries of the PV market and energy industry, I have proposed a categorization of diversification strategies. Four possibilities derive from the intersection of intra- and inter-industry diversification: (1) single-business enterprises; (2) intra-industry diversifiers; (3) inter-industry diversifiers in two industries; and (4) inter-industry diversifiers in more than two industries.

This categorization is therefore intended to overcome the shortcomings of prior diversification classifications, largely relatedness-based. Indeed, two important factors drive this classification proposed in this chapter: (1) restricted access to information and (2) objectiveness. In other words, not only is this taxonomy usable for the study of private companies, but also the results of the categorization are replicable because they are not based on an interpretation of data.

The second contribution of this chapter is the first step for testing the statement of Teece (2010), for whom the many business models in an industry are variations of generic business models (cf. Hypothesis 1). To be specific, I assume that the four diversification strategies leads to respectively four ideal business models: the PV specialized-based business model (BM1) for single-business enterprises; the energy-based business model (BM2) for intra-industry diversifiers; the complementary function-based business model (BM3) for inter-industry diversifiers in two industries; and the general-purpose products business model (BM4) for inter-industry diversifiers in more than two industries. I expect that each quadrant displays some specificities. To test the Teece's hypothesis, I have made a selection of business model components derived from the BMC of Osterwalder et al. (2010) that affords deeper insight into each ideal business model and the population characteristics (cf. Table 5.1.). In Chapter 6, these differentiating factors will be identified by means of these selected components.

Hypotheses	Criteria	Possibilities
Positioning (Hypothesis 2)	Value proposition	Services; production; mix service-production activities
	Key activities (Value chain segment)	Systems manufacturing; balance of system (BOS) manufacturing; project development (and installation); and operation and maintenance (O&M).
Positioning (Hypothesis 3)	Channels	Regional; National; Export; International
Segmentation (Hypothesis 4)	Customer segmentation	Focused; Broad
Resources (Hypothesis 5)	Key resources	Amount of asset and equity, and number of employees
	Partner network	Crucial or not.
<i>Table 5. 1.: Selected business model building blocks</i>		
<i>Source: Author</i>		

The final contribution is the following: the categorization can be seen as an attempt to integrate the strategic dimension in the business model concept. Admittedly, the enumeration of business model building blocks sheds light on the variety of the elements that a company has to consider when designing a business model. Most of them are limited to the firm-based level of analysis, consisting of suppliers, customers and competitors (Armstrong and Kotler, 2011; Vignali et al., 2003). By considering the strategic behavior of firms at the industry level in taking into account that actors can work in several different markets or industries simultaneously and can move between the four quadrants, I incorporate the strategic dimension in ideal business models. Hence, the taxonomy addresses the general lack of consideration of the strategy dimension in the business model literature, in providing a holistic view of an industry structure through the business model of its actors.

Chapter 6: Characterization of ideal business models

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Résumé

Chapitre 6 : Caractérisation des business models génériques

Le chapitre se centre sur les entreprises toujours en activité en 2015. Il a pour objet de tester les cinq premières hypothèses. Il va le faire en enlevant les entreprises pour qui le photovoltaïque n'est qu'un de leurs multiples marchés (qui sont dans plus de deux industries). Ainsi, nous comptons dans notre échantillon final 70 firmes.

Les **Hypothèses 3 et 4** ne sont pas validées. Nous avons émis l'hypothèse que les différences de réglementations restreindraient les entreprises à l'espace national. Or 49% de notre échantillon opère à l'étranger. De même, l'Hypothèse 4 prévoyait une tendance des entreprises à ne pas segmenter leur clientèle, en d'autres termes, à diversifier au maximum leur clientèle (*broad segmentation*) pour faire face aux turbulences. Or seul 49% des 70 firmes a fait ce choix.

L'**Hypothèse 2** selon laquelle les firmes opérant dans une chaîne de valeur fragmentée et dans un contexte de turbulence tendent à être verticalement intégrées dans les services est validée. En effet, 70% de l'échantillon occupe deux maillons de la partie aval de la chaîne de valeur du photovoltaïque. Les faibles barrières à l'entrée des activités de services ont permis cette forme d'expansion. Plus précisément, 41 entreprises sont positionnées sur les deux activités de service : le développement de projet et, l'exploitation et la maintenance. Le développement de projet est l'activité la plus prisée avec 61 firmes la proposant. Mais l'exploitation et la maintenance sont particulièrement intéressantes en période de turbulence puisqu'elles garantissent des revenus réguliers.

L'**Hypothèse 1**, qui vise à tester l'argument de Teece (2010) selon lequel les business models individuels des firmes ne sont que des variations de business models génériques dans une industrie, est validée. En effet, nos trois business models génériques exhibent des caractéristiques très différentes.

Les entreprises diversifiées mais n'opérant que dans l'industrie de l'énergie (BM2) ont des spécificités très particulières : elles sont verticalement intégrées (78%) et sont prestataires de services (95%) ; et elles sont de petite (70%) ou moyenne taille (27%).

Les entreprises non-diversifiées (BM1) et les entreprises qui se sont diversifiées dans deux industries (BM3) ont des caractéristiques opposées. Les premières sont verticalement intégrées (75%), orientées services (70%), et visent une segmentation large de la clientèle. A l'inverse, les dernières n'occupent qu'un maillon de la chaîne (62%), sont plutôt manufacturières (54%), et visent un type de clients en particulier (85%).

La même opposition est observable quand il s'agit des ressources : les entreprises non-diversifiées (BM1) reposent beaucoup sur leurs partenaires (80%) et sont de petite taille (75%), alors que les entreprises diversifiées dans deux industries (BM3) n'ont pas un réseau de partenaires fort (77%) et sont de moyenne (23%) ou grande (39%) taille.

Cette différenciation entre les business models par rapport aux ressources permet de valider l'**Hypothèse 5**.

Sometimes even to live is an act of courage.
Seneca

Introduction

The previous chapters lead us to the investigation of the companies operating in the downstream part of the photovoltaic (PV) value chain. Specifically, Chapter 2 shed light on the disaggregated and fragmented structure of this segment. Chapter 3 showed how many actors there are and how much they are struggling as a consequence of the French moratorium. Most of them have left the PV market, and the survivors have adopted varying diversification strategies and business models. In Chapter 5, I proposed a diversification strategy taxonomy based on the boundaries of the PV market and the energy industry as a tool to analyze the business models. Indeed, considering that a business model can be seen as the reflection of a strategy, I assume that a diversification strategy features some common characteristics that enable me to identify an ideal business model. Hence, I also selected some business model components that may be of interest in describing the characteristics of ideal business models.

In the present chapter, based on descriptive statistics of various corporate characteristics over the period 2010-2015, I highlight the commonalities and divergences that can be found between and within each business model. This will help me to get a closer look at the strategic behaviors of the actors in the downstream segment of the PV value chain, and to test Hypotheses 1 to 5. Precisely, I develop a model of ideal business models based on industrial diversification distinction.

For this purpose, I describe the panel through the four cases defined by the taxonomy and distribute the 103 France-based companies operating in 2010 as shown in Figure 6.1. In the BM1 type, they all focused exclusively on PV activities. There were 32 companies in that period. Turning to the BM2 category, their operations dealt with energy only, including at least PV power. For example, they may have concerned wind power or methanization, in addition to PV power. 34 intra-industry diversifiers composed this sub-panel. As for the BM3 group, the 20 inter-industry diversifiers had their core activities in a mature industry, including building and electricity, and offered PV as an added value to their clients. Finally, the last category, BM4, groups together 17 companies. They were involved in various energy markets and industries, thanks to their generic products. For the sake of argument, a company of the BM1 type is designated as a BM1 company, so on and so forth.

		Inter-industry diversification	
		Mono-industry (Energy)	Multi-industry (Non-energy)
Intra-industry diversification	Mono-market (PV)	32 BM1 The PV specialized-based strategy	20 BM3 The complementary function- based strategy
	Multi-market (Energy)	34 BM2 The energy sources-based strategy	17 BM4 The general-purpose technologies strategy

Figure 6. 1.: Sample allocation of the 103 companies in 2010
Source: Author

I proceed as follows. Section 1 discusses exits from the PV market. I then deepen my understanding of the BM4 type in Section 2. Based on its characteristics, I justify why I exclude this business model type from the final analysis. Section 3 is devoted to the evolution of business model types, as companies may shift their business model during their life cycle. Sections 4 and 5 describe the commonalities and differences of the panel along six criteria. All criteria are business model components. Section 4 focuses on three strategies of expansion: (1) vertical integration (linked to the ‘key activities’ and ‘value proposition’ components); (2) the geographical expansion (in relation to the ‘channel’ component); and (3) the spectrum of the customer segmentation. In Section 5 I discuss the incidence of three structural factors in the definition of their strategy, focusing specifically on: (1) the importance of the partner network; (2) size; and (3) capitalization. The last two points deal with the ‘key resources’ component. I finally establish the conclusions that can be drawn from the chapter.

1. The non-survivors

In this first section, I am interested in the businesses that exited the PV market. I focus on the nature of their death (Section 1.1.), their link to the size in terms of jobs number (Section 1.2.) and their business model (Section 1.3.).

1.1. Dead? Not all!

In Chapter 3 I discussed the consequences of the moratorium. The primary output was the high mortality rate of companies. It is therefore not surprising that among the panel a handful of companies exited the PV business. Yet their fates were not all equal. The literature on survival often equates exit to death, but exit also relates to

the companies that stopped their PV activity but survived (Stern and Henderson, 2004). All in all, 17 firms have exited the PV market since 2011 (cf. Table 6.1)⁸⁰.

	Total		BM1		BM2		BM3		BM4	
	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Total Non-survivors	17	17	3	9	4	12	9	45	1	6
Liquidated	10	10	3	9	3	9	3	15	1	6
Stopped PV activities	7	7	0	0	1	3	6	30	0	0
Total companies in 2010	103	100	32	100	34	100	20	100	17	100

Table 6. 1.: Analysis of non-survivors by business model
Source: Author

Ten out of the 17 companies went bankrupt (cf. Table 6.1.). This did not, however, preclude other companies from buying one of their business lines. The case of Marchegay is illustrative of a BM3 liquidated company whose PV activity was rescued through an acquisition (cf. Box 6.1.). After its bankruptcy in 2015, the PV activity was sold to Dome Solar.

Box 6. 1.: Marchegay, a moving out BM3 company

Founded in 1948 in Vendée department, Marchegay, a manufacturer, bears the name of its founder, Roland Marchegay. After belonging to Richel, a French group specialized in greenhouses, for ten years, in 2011, it bought back its independence to become SAS Marchegay Technologies. In 2015, the firm employed 105 persons and operated over 30 countries. During the same year, it went bankrupt. Since then, the PV activity has been sold to Dome Solar, and the other activities were acquired by MTECH SAS, by a decision of the Commercial Court.

Initially, Marchegay was focused on the production of frames and metal structures. Therefore, it is part of BM3. Its diversification to the solar industry started in 2007, i.e. during the ten-years of belonging to Richel. In 2012, a fourth activity rounded out the range of its offer by promoting the building of quality greenhouses, facades, and sustainable buildings.

Focusing on its solar activity, Marchegay is positioned in two stages of the PV value chain: systems manufacturing and project development. Precisely, the company also designed, built, and installed roof-integrated PV panels, commonly called Heliossystems. They are particularly known for the speed at which they can be installed, in particular, HELIOS B² (Avis Technique n°021/13-33). HELIOS RC3 is specific to solar shade structures. Here is something else too: the Helios RP+ system is compatible for integration on a greenhouse. Their Easy Clip and user-

⁸⁰ It is worth remembering that the panel was built from a list dating back to 2012. This means that there was probably a prior selection to eliminate the companies that did not survive.

friendly systems (for installers) make them interesting. Indeed, installers from other companies can easily install the roof-integrated PV panels.

The PV applications are various, encompassing the residential, agricultural, tertiary and industrial industries. The modules used could be crystalline, laminated, or double glass, depending on the client's wish.

The remaining seven were all diversified firms that operated a portfolio restructuring. In Chapter 5 I discussed portfolio restructuring in a context of a market crisis. The idea is that in case of difficulties in a specific market, a diversified company focuses on its strongest market(s). Hence, these seven enterprises preferred to focus on stronger markets and to jettison the unstable PV market. Put differently, these companies stopped their PV activity but remained active in other markets.

1.2. Middle-sized firms exit the most from the PV market

Typically, the size of companies that exit the market is variable (cf. Table 6.2.). Large companies (more than 250 employees) are the ones that exit the least from the PV market. They account for only 8%⁸¹ of their category. The small-sized companies (fewer than 50 employees) did quite well as they weathered the storm of the post-moratorium crisis of 2010 better than did their medium-sized counterparts (between 51 and 250 persons). To be specific, 15%⁸² of all small companies exited the PV market, which was much less than the 25%⁸³ of the medium-sized businesses. Marchegay (Box 6.1.) illustrates the exit of a medium-sized company, with its 124 employees in 2010.

This confirms my intuition that the intermediate group would be the worst performing group in the panel. In Hypothesis 5, I assume that this group lacks what the smaller and larger groups have vis-à-vis their survival capacities in a turbulent context. In short, medium enterprises do not benefit from the flexibility of their smaller counterparts (Fiegenbaum and Karnani, 1991 in Raju et al., 2011, p. 1324; Cohen and Klepper, 1996 in Laforet, 2008, p. 754), nor the resources of the larger ones.

In particular, in accordance with previous studies, the director of FranceWatts explained in an interview that his company, a systems manufacturer, keeps its staff small on purpose. According to him, remaining small allowed them to exploit their flexibility and ability to move fast. Turning to large companies, their large size enabled companies to reach economies of scale. They moreover had easier access to money and had greater human resources.

⁸¹ 8%=1/12

⁸² 15%=(4+6)/(4+2+25)

⁸³ 25%=6/24

1.3. Most of the companies that exited were in the BM3 class

Whatever the nature of their exit, the non-survivors are split up as follows: three BM1, four BM2, nine BM3, and one BM4 company (cf. 6.2.). Overall, they account for 9% of all BM1, 12% of BM2, 45% of BM3 and, 6% of BM4. At first sight, the BM3 type is by far the most exiting business model in the PV market and the BM4 the most resistant one.

An analysis under the light of the dead nature sheds light on a different conclusion. BM1 and BM4 companies are all liquidated. It is an expected end for BM1 as liquidation is the only possible way out for them, as they have no other market to fall back on. The only BM4 non-survivor suffered the same fate. Intriguingly, the only exit is not due to the PV market crisis, as its business started to experience difficulties before the moratorium. Therefore, I can conclude on the insensitivity of BM4 to the PV market crisis. This observation draws my attention to the BM4 type (cf. Section 2).

Besides, some of BM2 and BM3 companies also were liquidated, respectively three and three. The other one BM2 and six BM3 companies opted for securing their business by leaving the PV market (i.e. portfolio restructuring). It was possible thanks to their diversified activities.

Companies alive in 2010	Total		All non-survivors		Liquidated		Stop PV activities	
	Nb	%	Nb	%	Nb	%	Nb	%
=<20	42	41	4	24	3	30	1	14
20<x=<50	25	24	6	35	3	30	3	43
50<x=<250	24	23	6	35	3	30	3	43
>250	12	12	1	6	1	10	0	0
Total	103	100	17	100	10	100	7	100
Median	28		48		48		48	
Mean⁸⁴	265		126		161		75	

Table 6. 2.: Analysis of non-survivors by type of exit
Source: Author

2. Presentation and exclusion of the BM4 group

In accordance with the definition of generic products, the 17 BM4 cases are involved in multiple markets through a product of general applicability (Gambardella and

⁸⁴ A BM4 company, Kayserberg Plastics, experienced difficulties a long time before the PV market crisis. It is the only large company among the market exit in general, and liquidated companies in particular. Its staff was composed of 1,060 persons in 2010. The mean excluding its size would be significantly different. Indeed, instead of 161 for the liquidated companies, it would be 62. Similarly, the mean for all non-survivors would be 67 without this company, instead of 126.

McGahan, 2010). In other words, their offer is deployed in multiple downstream markets.

For example, AEG Power Solutions (cf. Box 6.2.), previously Saft Power Systems Group, is a transnational corporation involved in power supply systems and services for various industries. It targets customers operating not only in renewable energy markets but also in industrial, infrastructure and telecommunications markets, such as transportation and petrochemical companies. As for the solar market, it is positioned in the balance of systems (BOS) manufacturing stage. It proposes, for example, central hybrid power, energy storage, solar inverters, power supply module inverters and monitoring services for solar power plants, utility-scale applications, and off-grid for PV technologies based on silicon or concentrated solar power.

Silec Cable, to cite another example of a BM4 company, is a cable and wire company. It is involved in many industries, such as renewable energy, construction, military, oil, gas, and petrochemical cable. In the solar industry, it develops, manufactures and distributes wires and cables for the generation, transmission and distribution of electricity.

Another illustrative case is GrafTech France. It is a graphite product manufacturer and service provider for numerous industries and markets. Its products range from aerospace and defense to chemical processing, energy storage, and solar technology.

For all these examples, it is hard to know with certainty the importance of the PV market in their business. What is certain is that the solar market accounts for only a fraction of the sales. As such, the PV market is absorbed into the mainstream. Therefore, the main conclusion is that the BM4 companies are far less dependent on the success or failure of any specific market than their counterparts are. Specifically, BM4 companies do not experience the same difficulties in dealing with the PV market crisis as do the companies from the other quadrants. Section 1.3. has introduced this point.

As a reminder, I am interested in the impact of the moratorium on the survival capacities of companies. Considering the negligible effect of a single market in the growth or survival of a BM4 firm, I exclude this type from the study from here on. As a result, a total of 86 companies remain in this doctoral research.

Box 6. 2.: AEG Power Solutions, an example of BM4 enterprise

AEG Power Solutions, previously Saft Power Systems Group is a transnational corporation specialized in energy conversion, belonging to 3W Power Holdings S.A. The French part of the company was created in 1997.

It is a designer, provider, and manufacturer of power supply systems and service for various industries. As such, AEG Power Solutions is a prime example of a BM4 enterprise. Specifically, not only does it target customers operating in industrial, infrastructure and telecommunications markets, such as transportation and petrochemical companies, but also in the renewable energy markets.

Focusing on the latter, their products aim at supporting “integration of the renewable energies into the grid, solutions for energy storage and solar solutions.”

Hence, it is a mono-stage enterprise in the PV value chain, positioned in BOS manufacturing. Especially, it deals with all activities connected to energy management. It proposes, for example, central hybrid power, energy storage, solar inverters, power supply modules inverters and monitoring services for solar power plants, utility-scale applications, off-grid for PV technologies based on silicon or concentrated solar power. It aims at serving groups of customers with different needs and problems (i.e. broad customer segmentation).

At the time of writing, production, installation, and maintenance of BOS components are operated in Germany, France, Spain, and Malaysia. Located near Tours, the French offices' activity is now only limited to look after all R&D activity connected to direct current. Yet, the firm operates worldwide.

3. Movement analysis: toward intra-industry diversification

The diversification literature stresses the importance of portfolio restructuring in a context of turbulence. Portfolio restructuring involves not only a shift of focus onto its stronger business lines (cf. Section 1 with companies that stopped their PV activity), but also the diversification of a company's business lines toward a more stable activity. It is to the latter that this section now turns. Indeed, exiting the PV market was not the only change that occurred from 2010 to 2015; there was also a change of business model. Hence, in the middle of difficulty lie opportunities.

Most of the 86 enterprises either stuck to the same business model or exited the PV market. Yet, in this study, only a minority of companies changed their business model. That was the choice made by 12 corporations. (cf. Table 6.3.). All of the newly diversifiers but two⁸⁵ were part of the BM1 quadrant in 2010. Interestingly, nine out of these 10 BM1 companies evolved to become of BM2 type. The most noteworthy changes or unchanged cases are described successively in the following section.

BM in 2015		BM in 2010		
		BM1	BM2	BM3
BM1	20	19	1	0
BM2	37	9	28	0
BM3	13	1	1	11
Exit	16	3	4	9
Total	86	32	34	20

Table 6. 3.: Trajectories of business model types
Source: Author

⁸⁵ I presented the exceptions, which are SETA Energies and Apex Energies, in Section 3.1.1.

3.1. The stable business models

3.1.1. *BM2: stay and fight*

The overwhelming majority of the BM2 cases have not changed their business model. A total of 28 out of the 34 BM2 companies in 2010 did not evolve in any other respect. This is equivalent to 82% of the sub-panel. The percentage rises to 93% if I do not take into consideration the exit companies.

A case in point of a BM2 company that stayed BM2 is UNITE, a systems manufacturer (cf. Box 6.3.). This company resulted from a merger between HYDROWATT (hydro-electricity) created in 1985 and ALTECH (wind power) created in 1999. In addition to these two markets, UNITE diversified its activities the following year through the creation of a third engineering office, SOLUNITE. The latter makes PV roof framing, namely Solar K®, in St Girons. Specifically, in collaboration with Rigidal Systems (a metal roofing and cladding systems manufacturer), it produces a PV system for silicium amorphous modules produced by UNISOLAR.

Box 6. 3.: UNITE, a BM2 company

HYDROWATT, a hydro-electricity firm created in 1985, changed its name into UNITE holding in 2007, subsequent to its combination with ALTECH, a wind power company created in 1999. The new corporation entered the solar market the following year through the creation of a third engineering office: SOLUNITE. As such, UNITE exemplifies the BM2 type.

All activities included, UNITE is in charge of more than 80MW of renewable installed capacity in France mainland and employed 10 persons in 2015 (down from 38 in 2010). To date, the company operates 45 hydraulic power stations, has developed over 10% of the wind farms authorized in France and makes its own PV panels.

Overall, UNITE covers from the project development to realization to exploitation. SOLUNITE, in addition to being project developer, is a systems manufacturer (PV value chain). Specifically, it makes PV roof framing, namely Solar K®, for silicium amorphous modules produced by UNISOLAR in St Girons. Put differently, it is a multi-stage company.

Such production was made in collaboration with Rigidal Systems, a metal roofing and cladding systems manufacturer (partner network).

While based in Lyon, the group UNITE nevertheless has local operations in most of the French regions through its 5 engineering, technical and maintenance centers (channels).

Yet there are exceptions: two BM2 companies moved to another quadrant. The first one is SETA Energies that started as an intra-industry diversifier (i.e. BM2) in 2010 and ended as an inter-industry diversifier (i.e. BM3) in 2015. The added activity of SETA Energies is electrical installation.

The second one is Apex Energies that was a BM2 type in 2010 and moved into the BM1 box during the study period. This is the story of APEX-BP Solar (cf. Box 6.4.).

In 1999, it was bought by BP Solar, a former wholly owned subsidiary of British Petroleum (BP). It became APEX-BP Solar. Following the decision of BP to stop its solar activity worldwide, BP Solar closed in December 2011. Five former employees decided to buy up the French solar business to gain back independence. The company is currently operating under the name Apex Energies.

Box 6. 4.: Apex Energies, Transformation of business model from BM2 to BM1

Apex Energies, created in 1991, is a French PV service-based firm (i.e. BM1). It was acquired in 1999 by BP Solar, to penetrate the French market. BP Solar was created in 1981 and was a former wholly owned subsidiary of British Petroleum (BP), one of the top oil and gas multinationals. Following the decision of BP to stop its solar activity worldwide, BP Solar closed in December 2011. Before turning BM1 type again, in France, five former employees decided to buy up the French solar business to gain back independence. That is to say that between 1999 and 2011, Apex Energies, under the company name Apex-BP Solar, was a BM2 company. It follows that Apex Energies is an example of a transformation of business model from BM2 to BM1 type.

Nowadays, the company is still operating under the name of Apex Energies and employed 25 persons in 2015 (from 73 in 2010). It is a multi-stage company as it operates in 'project development' and 'O&M' stages of the PV value chain. Precisely, it is involved in the following activities:

1. *Development and construction.* The company designs and builds grid-connected and off-grid PV plants. All in all, it has installed more than 600 on-grid and 5,000 off-grid plants. Self-production is also proposed for businesses, communities, and individuals. At the time of writing, the installations totalize 455 KWc over 72 solar plants.
The following project dating back to 2016 exemplifies this business activity. The company was in charge of a 31.2KWp production project, with a storage system, in the industrial area named Sables de l'Etang Salé located on Reunion Island. It should provide with the energy security needed at least for the computer server (the data center alone represents 25% of the building's energy consumption). The overflow is for self-consumption. The project also planned to include shade structure and shelters to recharge the electric service vehicles.
Also in the phase of project development, Apex Energies proposes to audit solar plants, technically, financially, administratively, and legally. Over 350 solar plants are analyzed annually.
2. *Operation.* Operation is its core activity, be it as energy producer or operator for its clients. As of March 2018, the company exploited more than 24MWp of PV energy, including 15MWp held in equity. It aims at exploiting 40MWp as energy producer by 2018. It is possible through external growth. Indeed, the firm is highly active in the second-hand market for PV plants. This strategy allows a quick growth of its solar park. Thanks to the operation of its solar plants, it guarantees a significant level of revenues.

The Thézan project is a telling example of its financing role. Apex Energies was the sole investor in this project, located in the land of the former landfill site of Crès de Laouzino. As mounted on trackers, a part of the land could be used as a grazing ground. It involves 9,408 PV panels installed over 4.5 hectares. It should cover three times the energy consumption of Thézan-des-Corbières village.

3. *Maintenance.* What is of interest in the maintenance activity is that, in 2015, the company increased its supervision and monitoring performance for its 7,000 clients, through the acquisition of S4E, a software company specialized in energy management. Specifically, PVSoft, of the S4E's software, allows remote monitoring for small PV installations. This software is the first one that is not dedicated to large PV plants.

Besides, its PV solutions encompass sloping roofs, with or without building integration, terrace roofs with all types of waterproofing, ground plants, and parking shelters. It targets various types of clients, including investors, industrials, local communities, farmers, individuals and, plant builders. As such Apex Energies serves a broad customer segment.

As for the geography, it is worth specifying that it operates in France mainland and French overseas departments and territories (channel). Moreover, it is on the latter that its activities are the most significant. It began to extend its operations to reach Europe since 2014 (mainly Italy) and Mexico since 2015.

3.1.2. *BM3: should I stay or should I go?*

It is noteworthy that only the BM3 companies have not changed into another type: they have either kept their business model or exited the market. I noted in Section 1.3. that BM3 is the category that witnessed the most market exit, with 45% of the 20 BM3 companies leaving during the study period. However, aside from the exit cases, this category is the most stable business model.

The main reason is that they were operating in a mature industry before entering the PV market. These companies include, among others, builders of car park shelters with PV shade panels (e.g. GagnePark), roof covering companies that install PV roof tiles (e.g. Imerys Toiture), and electrical installation firms proposing an electrical installation of solar modules (e.g. Rosaz Energies). This is not an exhaustive list; far from it. Hence, in a period of market turbulence, BM3 companies just needed to focus more on their core activities.

Clearly, the survival or growth of these companies was not wholly based on the PV market, which accounts for additional revenue only. For example, GagnePark (BM3; cf. Box 6.5.), a company involved in the construction of parking lots, extended its offer to include PV technologies to its shade structure, in response to requests from its customers. Its solar activity accounted for 50% of its turnover before the moratorium, which put it at the top of the PV market growth. Since the moratorium of 2010, its solar activity has been halved. In 2014, it accounted for only 20%. Yet

the company is still in good shape. Better than that, it experienced growth regarding its sales, employees, and total asset.

Box 6. 5.: GagnePark, a BM3 firm

GagnePark is another prime example of a small-sized BM3 corporation (25 employees in 2015 and 14 in 2009). Located in Lyon, GagnePark was founded in December 2006 by Montauroux Group, a specialist in metal construction.

Its originating business line is the conception, engineering and, construction of parking lots. The company undertakes R&D programs aiming at patenting innovative solutions for construction systems. The GAGNEPARK® construction process for multi-storey parking lots is illustrative. GagnePark proposes to its clients new patented solutions combined with mass customization. What makes its patents so unique is that it allows a simplified and rapid on-site assembly procedure and a customization of its solutions. Specifically, it offers non-standardized products, enabling it to reap advantages of economies of scale and to deliver a custom product in taking account of the specifications of its clients and the characteristics of the land and budget (i.e. mass customization).

Considering the specificities of its clients, it is possible to say that GagnePark targets a focused customer segment. Indeed, the clients are supermarkets and commercial centers or industrials requiring parking lots for their employees. Among its clients are Carrefour Group, Auchan, and EFFIA Stationnement.

Quickly after its first successes, its clients asked GagnePark to diversify its offer to include PV. Then, backed by its research on the construction process and experienced on parking construction, in 2008 the firm satisfies its existing clients by extending its offerings to PV shade structures, also called carports. Solar PV panels are simply put on a shade structure for parking. The power generated is either resold or self-consumed. Hence, GagnePark is a multi-stage manufacturer in the PV value chain. Indeed, it operates in 'project development' and 'systems manufacturing' stages of the PV value chain.

R&D endeavors are also significant in its solar activity: the firm had patented its building system under the name of OMBRAPARK. It is applicable, for example, to single-storey or terrace level of multi-storey parking lots. As of 2015, this patented building system was implemented across France (channel) to over 280,000m², cumulating 50MWc and 16,500 car parking spaces.

At the time of writing, its latest PV project dates back to September 2016. It involved the 13.5MWp grid-connected shade structure of the Walon-Rivesaltes solar plants, located in the city of Rivesaltes in the Pyrénées Orientales department. All in all, more than 48,000 PV panels were installed, equivalent to over 80,000 m² of shade structures.

Yet, since the decree of 2010, its solar activity has been halved. Indeed, in 2009-2010, more than 50% of its sales were generated from its solar activity. During the interview, the CEO admitted that the percentage was reduced to 20%. However, the company added in 2012 a new solar activity: *solar-powered shelters* (i.e. for charging electric vehicles) and still makes a multi-thousand-euro

investment each year in R&D focused on building system, be it for solar plants or not.

3.2. BM1, an unstable business model

3.2.1. *Those who stayed solely on PV activities*

Compared to the other two business models, the BM1 type is unstable. Only 59%⁸⁶ of the 32 companies in the BM1 box in 2010 were still in this box in 2015. Even after excluding the non-survivor BM1 firms, the percentage remaining in the BM1 category increases to barely 66%. It is far behind the BM2 (93%) and BM3 (100%) groups.

Definitively, the majority of the BM1 companies in 2010 remained in their category. Their survival strategy was therefore not industrial diversification. To gain some insight on these different strategies, consider a BM1 stable case: kiloWattsol. kiloWattsol (Box 6.6.) is a leading European independent technical advisor (cf. Box 6.6.). It is a single business positioned in one stage of the PV value chain: the project development phase. It chose to target a focused customer segment but to reach out to foreign markets.

Box 6. 6.: kiloWattsol, a BM1 company that stayed BM1

Located in Lyon, kiloWattsol is a leading European independent technical advisor in PV power (BM1). Set up in 2007, kiloWattsol is a spin-off of ENTPE (Ecole Nationale des Travaux Publics de l'Etat) and LASH (Laboratoire des Sciences de l'Habitat). Specifically, it was founded by Xavier Daval and Dominique Dumortier. Xavier Daval is the former European Director of OK International, a world-leading tools manufacturer for the electronics industry and a subsidiary of Dover Corp (an American conglomerate manufacturer of industrial products). Dominique Dumortier is a former professor at ENTPE Engineering School and is also one of the leading European specialists in daylight and solar radiation characterization, and modeling.

kiloWattsol is a small-sized (8 persons in 2015 while 11 in 2010), mono-stage service provider as it is involved solely in project development (PV value chain). While it is feasible to offer a wide variety of services based on the software, one may consider that kiloWattsol generate revenues from a single revenue stream: the generation of surveys.

Broadly speaking, on the basis of its internally developed software, it proposes to reduce the level of incertitude in pricing risk and determine the project's return on investment. Hereafter are two examples of its services:

- Risk assessment. Siemens Bank and Commerzbank mandated KiloWattsol in 2012 for doing a risk assessment of disconnection for the San Martino and Pietralba PV plants (4 MWp), located in the French island of Corsica.

⁸⁶ 59%=19/32

- Capacity audit: in 2012, Dutch Infrastructure Fund (DIF), the Finsterwalde II and III power plant owner, commissioned kiloWattsol to assess the power plant's future yield for its remaining lifetime. The survey took into account the specific climatic conditions of the location to be as close as possible to the reality.

The year 2015 alone, 300 projects were assessed cumulating over 1GWp. The project size varies from 100kWp on rooftop to the biggest worldwide projects. That is to say that kiloWattsol works on sizeable projects. The company moreover targets a focused customer segment: most of its clients are banks and investment funds. To a lesser extent, project developers or installers also ask for their services. Also, some companies having its own internal technical advisor service request counter-expertize.

Meanwhile, the enterprise has an expanding global portfolio of operations in countries such as Burkina Faso, Turkey, Japan, Thailand, the United States and Italy (channel). To meet the expectations of its international clientele, its team speaks six languages: English, French, German, Dutch, Spanish and Romanian. The profile of its team member is varied. It encompasses Ph.D. and engineers.

3.2.2. *Those who changed their business model*

Considering that diversification is one of the two possible ways out for a single business company in a context of turbulence (the other is liquidation), it is not surprising that ten out of the 29 BM1 companies alive, approximately one-third of the category, diversified over time. Specifically, nine out of the ten BM1 firms evolved to become BM2 and only one BM1 changed to become BM3. Hence, only the BM2 group had significantly more companies in 2015 than in 2010: 37 as opposed to 30.

Arkolia Energies (cf. Box 6.7.) is a telling example of a BM1 enterprise that evolved between 2010 and 2015 into an intra-industry diversifier. Its survival strategy was notably to diversify its activities, notably toward wind power and biomass. One piece of information that struck me during the interview was that, according to Laurent Bonhomme, the CEO, Arkolia Energies chose this biomass market because in that field the company would not be conflicting with the interests of EDF, the French main utility. Their success would, therefore, be more likely. Furthermore, Arkolia Energies engaged in two other diversifications: (1) it diversified its offer in the PV market as it operated in the project and development, and operations and management (O&M) stages (i.e. vertically integrated); (2) it also targeted a wide range of customers.

Box 6. 7.: *Arkolia Energies, Transformation of business model from BM1 to BM2*

Arkolia Energies is a small-sized (31 workers in 2015 from 11 in 2010), Montpellier-based company founded in 2008 by Laurent Bonhomme and Jean-Sébastien Bessière. The former is a former banker, specialized in real estate market. The latter is a former financial auditor and corporate financing advisor.

The firm is a multi-energy service provider (PV value chain). Specifically, it is involved in project development and O&M of power plants. The maintenance of its clients' PV plants generates little monetary value. As such it has limited impact on Arkolia Energies' profitability.

Project development of solar plants constitutes its originating business lines. In 2011, it extended its activity of project development to other energy sources: methanization, wind power, and biomass. Put differently, it turned into BM2 type.

Also, the company diversifies its revenue sources in the PV market in becoming energy producer in 2012. At the time of writing, the company has developed a portfolio of more than 373MWp of PV rooftop and shade structure. In 2015, this sole activity generated €38 million, equivalent to roughly 90% of its €44 million of annual total revenue. They are majority owner at 51% of four large ground-mounted PV power plants, named Arkolia Solar Park (ASP), for a total of €75M and 70MW in 2015. Depending on the projects, the remaining 49% belongs to Groupe Caisse des Dépôt, Green City Energy or Acofi. In other words, its partners bring the needed money to the projects (partner network). The resale of electricity generates €6 millions of turnover in 2015. The founders consider that this activity is a proof of their expertise in financial engineering and project funding.

The latest project inauguration owned partly by the enterprise dates back to June 2016. Located in the city of Soler (near Perpignan, in the Pyrénées-Orientales department), this solar plant required €16 millions of investments. At the time of writing, it was the largest French solar plant on trackers. Based on 60,000 PV modules and 2,500 trackers, this 45-hectare solar farm is capable of powering 15,3MWp for 24GWh of annual production. It is equivalent to powering the 7,000 households of the city.

It is worth pointing out that as for PV, Arkolia Energies targets farm building (its initial application), warehouses, solar shade structures, offices, industrial or commercial buildings on behalf of farmers, landowner, industrials, investors, or local communities. Considering the wide range of its clients, it is possible to say that Arkolia Energies targets a broad customer segment.

It also operates across France with three agencies located in Rodez, Toulouse, and Nantes (channel). Furthermore, it is involved in a joint venture in Ghana.

3.3. Conclusion

At the end of the study period, I identified four main trajectories: (1) the BM1 companies that remained BM1; (2) the BM2 companies that remained BM2; (3) the BM3 companies that remained BM3; and (4) the BM2 companies derived from the BM1 box. As I assume that the latter group had characteristics that may be different from those of both BM1 and BM2 types, I named this new group 'New BM2'.

It is worthwhile to check the characteristics of each case. Considering that the moves between business models represent a minority, to survive the companies had to use

other strategies. The examples of kiloWattsol and Arkolia Energies exemplify three different strategies that differ from industrial diversification: (1) diversifying the geographic scope (i.e. global diversification); (2) integrating other PV activities (i.e. vertical diversification); and (3) broadening the customer base (i.e. customer segmentation). In both examples, they implemented a form of expansion. It is about either the positioning (cf. Hypothesis 2 and 3) or the segmentation (cf. Hypothesis 4). The question of whether they are exceptions has to be considered. The next section is devoted to these three strategies.

4. Positioning and segmentation criteria

As a reminder, 103 companies operating in 2010 composed my starting sample. From that point, I focus solely on the survivors of the BM1, BM2, and BM3 categories as the moratorium impacted their businesses. Putting aside the companies that had gone out of business (17 companies) and the surviving BM4 companies (16), the sample studied is now 70 companies, that I spread over the three remaining business models. I thus had 20 BM1, 9 New BM2, 28 BM2, and 13 BM3 companies. For my purposes, I consider the information about the year 2015, unless otherwise specified.

In this section, I investigate the companies' expansion strategies in the three dimensions highlighted in the cases of kiloWattsol and Arkolia Energies. Interestingly, they refer to four business model components discussed in Chapter 5:

1. The positioning and number of occupied stage(s) in the PV value chain identified as key activities and value proposition.
2. The spatial coverage: the geographical scope of its activities, referring to the 'channel' business model component.
3. The clients: the width of its customer segment(s).

Analyzing the panel through these three dimensions leads us to verify the validity of the Hypotheses 2, 3, and 4.

4.1. Vertical diversification in the PV value chain especially towards project development and for actors in energy (Hypothesis 2)

The first criterion concerns the value proposition and key activities along the PV value chain. I consider the nature and scope of activity in the PV market. This sub-section aims at validating Hypothesis 2.

4.1.1. *Predominance of service-based vertically integrated suppliers*

In this sub-section I am interested in one specific type of diversification: the diversification of activities within a value chain, namely vertical diversification (cf. Ansoff), or intra-chain upgrading (cf. GVC literature), or commonly referred to as vertical integration. The idea of vertical integration is that a company goes through an increasing number of stages in a value chain. For this purpose, I distinguish the companies that operate in only one stage from those that are in more than one stage. The first are said to be mono-stage; the second multi-stage (i.e. vertically integrated).

The sample is operating in the PV industry, either in services, or in products, or in both. As a reminder, services include project development and operations and maintenance (O&M), as opposed to manufacturing activities encompassing systems and balance of systems (BOS) manufacturing.

		Number	%
Multi-stage	Service only	41	59
	Pure manufacturing	0	0
	Service & Product	8	11
	Total	49	70
Mono-stage	Service	14	20
	Manufacturing	7	10
	Total	21	30
Total		70	100
<i>Table 6. 4.: Summary statistics of positioning in the PV value chain</i>			
<i>Source: Author</i>			

All in all, 49 companies are vertically integrated along the PV value chain, equivalent to 70% of the panel (cf. Table 6.4.). Intriguingly, all these 49 vertically integrated companies have a service in their PV offer (Table 6.4.).

It is worth noting that some activities are more inclined to go together. Intra-service integration, i.e. project development combined with O&M, is the most widespread activity combination, with 41 out of 49. Apex Energies (BM1; Box 6.4.) exemplifies a vertically integrated company in services. At the time of writing, in addition to designing and building over 600 on-grid and 5,000 off-grid PV plants (i.e. project development), Apex Energies exploited more than 24 MWp of PV energy and supervised and monitored the performance of the solar plants for its 7,000 clients (i.e. O&M). As for the remaining enterprises, only eight provide services and products in the PV value chain. As such, they are less significant quantitatively.

Analyzing the PV activity scope through the nature of the activity highlights the predominance of service providers among the multi-stage enterprises. Actually, the same predominance of services applies to mono-stage companies. Specifically, two-thirds of the mono-stage firms operate either in project development or O&M. kiloWattsol (BM1; Box 6.6.) exemplifies a service-based supplier positioned in only one stage of the PV value chain: project development. Overall, this leaves the manufacturers in a minority position.

The result is predictable, as posited in Hypothesis 2 and Chapter 2, considering that manufacturing activities require capital that is much more difficult to raise. Previous studies shed light on technical difficulties as the only barriers to entry in the service-related PV downstream segments (e.g., Platzer, 2015; PwC, 2012; Sontakke, 2015). Such technical difficulties could potentially be overcome through training, which is not the case of manufacturing activities. This barrier to entry explain the

predominance of services in the downstream segment of the PV value chain, and notably, a vertical diversification of an industrial company towards a service, is much more likely than towards another manufacturing activity. Hence, Hypothesis 2 on the impact of turbulence on vertical integration is validated.

4.1.2. Project development, the most attractive activity, but an increasing importance of O&M

Table 6.5. displays the distribution of companies according to the activities in which they are involved. What is striking from the table is that companies overwhelmingly (87%) operate in project development (61 out of 70 companies). Of these, 41 are intra-service integrated firms, as discussed in the previous subsection. Then comes the 12 project developers not vertically integrated, accounting for 57%⁸⁷ of the mono-stage companies. To this is added all the vertically integrated manufacturers in services. In other words, project development is the activity present in all multi-stage companies; they always involve project development in addition to either BOS or systems manufacturing. Considering that installation (incorporated in the project development stage) is the most common activity as noted in Chapter 3, the result is unsurprising.

	Total	Systems manuf.	BOS manuf.	Project development	O&M
Systems manufacturing	11	5	0	6	0
BOS manufacturing	4	0	2	2	0
Project development	61	6	2	12	41
O&M	43	0	0	41	2
Total		11	4	61	43

Table 6. 5.: Combination of activities

Source: Author

An example of manufacturers also offering project development in the PV value chain is Imerys Toiture (BM3; Box 6.8.). The company is a roof tile developer and manufacturer. Specifically, it offers the engineering, construction, and installation of roof tiles. As such, it operates in the 'project development' and 'systems manufacturing' stages of the PV value chain.

Box 6. 8.: Imerys Toiture, a BM3 company that proposes a mixed offer

Imerys Toiture is another firm that initially operated in a mature industry but subsequently decided to enter the PV market. Hence, it is a typical example of a BM3 corporation. This is its story.

Created in 2008, Imerys Toiture, the French leader in innovative clay tiles, is a joint venture between EDF ENR, a French utility, and Imerys Terre Cuite, the French leader of terracotta tiles and bricks. In addition to its traditional clay tiles

⁸⁷ 57%=12/21

activity, it operates in the PV building integrated rooftop market for residential and industrial applications at the national level (channel). Especially, the company is a PV roof tiles developer, manufacturer, and installer. Hence, Imerys Toiture is a multi-stage firm as it is involved in systems manufacturing and project development in the PV value chain.

PV tiles are an alternative to PV panels installed on top of a roof. The installation process is rather identical to its original core competencies, even though the PV roof tiles are a bit bigger. Thus, by taking the place of clay tiles, PV roof tiles intend to ensure the tightness of the roof. Furthermore, it is also argued that it preserves integrity (i.e. waterproof) and aesthetics: the used installation process and the colors (i.e. slate-grey and silver) enable the tiles to disappear in the roof.

Furthermore, their PV roof tiles aim at being easy to use for installers. Hence, their PV-related offering aims at two types of clients: PV roof tile installers and end-users (i.e. energy producers in the case Imerys Toiture is in charge of the installation). Considering that the application, i.e. PV roof tiles, is specific, it is possible to assert that Imerys Toiture targets a focused customer segment.

One remarkable project was to install PV panels on the sailboat 'Green.' The panels provide green energy to the boat during the competition Transat Bakerly, linking Saint-Malo, to Plymouth and New York in 2016.

In second place comes O&M with 43 enterprises represented. In addition to the two companies operating solely in O&M, it is possible to count the 41 intra-services vertically integrated companies. Interestingly, the importance of O&M activity is increasing over time among these 41 intra-service multi-stage companies. The main reason is that O&M generates recurring revenues, unlike project development. Ensuring regular revenues is crucial, especially in a period of turbulence.

The interview with Brian Boulanger, the managing director of Gensun (BM1; cf. Box 6.9.), illustrates this reasoning. Gensun was initially involved solely in project development. But the construction activity of solar power plants generates irregular revenues. As such, its core activity is uncertain, especially after the French moratorium. Therefore, as compensation for this inconvenience, the firm looked for periodic sources of revenue. The answer was found in the maintenance of its clients' solar plants. In other words, maintenance activity enables a company to recoup part of the investment. At the time of writing, Gensun is in charge of the maintenance of 450 MWp. Following the acquisition of Juwi ENR by its parent company, maintenance became its core activity.

Box 6. 9.: Gensun, a BM1 company whose O&M activity is crucial

To cite a different example of a small BM1 service supplier, Gensun (40 persons in 2015 from 23 in 2010) is specialized in PV. It was created in Montpellier in 2007 by Michel Erbs, who hold experience in managing major technological projects. At the time of writing, Gensun belongs to Neoen (the third largest renewable energy producer in France, after EDF and Engie) up to 60% of the capital.

Nowadays, it is positioned along two stages of the downstream PV value chain: O&M and project development. In particular, it is a service-based company specialized in the development, construction, operation, supervision, and maintenance of PV plants of all sizes. It is worth noting that Gensun was initially solely on project development. To cite an example of industrial roof project development, CS Pistole hired Gensun to develop a project involving 7,360 modules over 13,500 square meters. The solar plant is supposed to generate 1,729kWp.

It later engaged in vertical integration because, according to the deputy CEO, Brian Boulanger, Gensun considered its core activity as uncertain, especially after the French moratorium. Thus, as compensation for this inconvenience, the firm diversified its revenue sources with maintenance contracts. In other words, maintenance activity enables to recoup part of the investment.

Furthermore, thanks to the acquisition of Juwi EnR by Neoen at the end of 2014, Gensun retrieved Juwi EnR solar park and, hence, sharply increased its solar park maintenance to 300MW. It is equivalent to a multiplication by ten over one year. Hence, the maintenance activity became its core activity.

GenSun may work on various projects on behalf of its clients, i.e. power producers: on regular roof, flat rooftop with crystalline silicon or thin films, or ground-mounted power plants, with or without solar trackers. So, the company targets a broad customer segment.

At first sight, nothing, in particular, distinguishes Gensun's offer from its competitors, except its geographic accessibility (channel). Indeed, GenSun owns five agencies in France (Montpellier, Aix-en-Provence, Toulouse, Pau, and Pessac) and four subsidiaries in Portugal and India. While Gensun does not have offices in Central and South of America, GenSun expects to expand its business in these regions. It is made possible thanks to the knowledge and activity of Neoen. Therefore, Neoen, as mother company, also plays a significant role in the business expansion.

Another noteworthy recurring revenue that is part of the O&M value chain stage comes from being an energy producer. As an energy producer, companies are involved in operations but for their own power plants and not for their customers. Specifically, they generate revenues from the sales of the energy produced from these PV plants. The main advantage, in addition to generating recurring revenue, is that of being independent of clients, and thus less dependent on market fluctuation. It is therefore unsurprising that this activity is growing in importance. A total of 28 companies that became energy producers are identified in the panel: Arkolia Energies, Apex Energies, Générale du Solaire, Urbasolar, and Voltalia, to name a few. Interestingly, none of them are part of the BM3 group.

The case of Arkolia Energies (New BM2; cf. Box 6.7.) clearly illustrates the importance of this new revenue. Laurent Bonhomme, the CEO, made no secret of the reason behind Arkolia Energies' growth. I discussed earlier its strategy of industrial diversification towards other renewable energy sources. The reason of

interest here is the revenues generated from the energy produced from its own energy solar farms. According to him, it is a strategic business as it generates recurring cash flow. Specifically, €6 million out of €44 million were generated from this activity in 2015, compared to €2.1 million out of €23 million in 2012⁸⁸. As a consequence of this new activity, the company increased its equity and assets significantly, to reach respectively €5,423,900 and €30,280,800 in 2015, from €2,268,400 and € 6,145,600 in 2010.

4.1.3. *The more a company relies on the PV market, the more likely it is to be multi-stage in the PV value chain*

Having described all these generalities, I am now poised to analyze the vertical integration strategy per business model. By doing so, I distinguish three different groups, starting with the most homogeneous group and ending with the most heterogeneous one.

4.1.3.1. New BM2 enterprises, entirely service providers

Let us begin with the New BM2 group. The main profile characterizing eight out of the nine companies is that of vertically integrated service-providers (cf. Table 6.6.). The exception is Solaridis, a multi-stage company proposing project development and manufacturing PV systems.

Arkolia Energies (Box 6.7.) exemplifies a BM2+ intra-service firm as it is involved both in project development and in O&M of PV power plants. The vast majority of its revenues come from project development and the operations of its own and customers' solar power plants. Interestingly, the maintenance of its customers' PV plants generates little monetary value, compared to its other activities. As such it has a limited impact on Arkolia Energies' profitability.

Categories		Total		BM1		New BM2		BM2		BM3	
		Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Multi-stage	Service only	41	59	12	60	8	89	19	68	2	15
	Pure manuf.	0	0	0	0	0	0	0	0	0	0
	Service & Product	8	11	3	15	1	11	1	3	3	23
	Total	49	70	15	75	9	100	20	71	5	38
Mono-stage	Service	14	20	2	10	0	0	8	29	4	31
	Manuf.	7	10	3	15	0	0	0	0	4	31
	Total	21	30	5	25	0	0	8	29	8	62
Total		70	100	20	100	9	100	28	100	13	100

Table 6. 6.: Summary statistics of positioning in the PV value chain
Source: Author

⁸⁸ The year 2012 marks the beginning of the company's activity as an energy producer.

4.1.3.2. BM2 companies, largely service providers

The two main profiles of the BM2 group cover 97% of the sub-panel. Interestingly, these 97% are all pure service suppliers.

The foremost profile concerns integrated suppliers in services. It is shared by 19 out of 28 BM2 companies, equivalent to 68% of the group (cf. Table 6.6.).

Then comes the eight mono-stage service providers (29%). It appears that they are not evenly distributed in terms of activity: six are project developers, as opposed to two in O&M. Hence, at this stage of the analysis, I have established the attractiveness of project development. This confirms the general trend towards project development discussed in Section 4.1.2.

To conclude, whatever the reason for a company to occupy a service-related stage in the PV value chain, the BM2 is a relatively homogeneous group. The factors that distinguished the BM2+ mono from multi-stage service providers are to be found in other criteria.

4.1.3.3. The BM1 companies, half-way between BM2+ and BM3

The third group encompasses the BM1 companies, which tend to be like the BM2. The mono- to multi-stage ratio is much the same. In terms of the service to manufacturing ratio, the BM1 type does admittedly lean towards services, as does the BM2 category. But it is far behind the latter, with only 70% of service providers, as opposed to 96% in the BM2 group.

In this category, only one profile stands out⁸⁹: multi-stage service providers dealing with 60% of the BM1 group. To cite an example, GenSun (BM1; Box 6.9.) is a service-based company specialized in the development, construction, operation, supervision, and maintenance of PV plants of all sizes. As such, not only is it specialized in services but is also vertically diversified as it is positioned in two stages of the downstream PV value chain: O&M and project development.

Besides, all in all, five BM1 companies, equivalent to 25% of the BM1 type, are mono-stage. kiloWattsol (Box 6.6.) is an example of this minority yet intriguing situation. They are evenly distributed between services and products. Being mono-stage implies that they have a different strategy to survive, other than vertical integration and industrial diversification. I will deepen this investigation in the following sections.

4.1.3.4. BM3 companies are manufacturers

I end with the BM3 companies. Overall, BM3 companies are predominantly manufacturers (57%, which is seven out of 13). Only four of the 13 companies are pure manufacturers in the PV value chain. Furthermore, while most of them (62%) are mono-stage, only half of them are in manufacturing. Based on these figures, I conclude on a significant variation of profiles. Specifically, I count four different

⁸⁹ The other BM1 firms are almost equally split between three profiles out of four. Therefore, I do not consider them further here.

profiles but none of them separately reflects more than one-third of the group. The first two groups deal equally with four mono-stage service providers or four mono-stage manufacturers. The third are three multi-stage actors providing services and products. The last one consists of two intra-service suppliers. Their respective proportion is 31%, 31%, 23%, and 15%. As such, the BM3 category is the most heterogeneous one.

Clearly, it is not the nature of the activity that determines the number of PV activities a BM3 company is involved in. Whatever the activity in the PV value chain, a BM3 business limits its efforts to enter and survive in this market, as the number of exit BM3 companies attests. In other words, they just transfer their existing capabilities to the PV market. Hence, all the PV-related activities they are involved in require capabilities very close to those of their core competencies.

It is important to keep in mind that this business model category is set up by diversified companies whose core competencies come from mature industries and integrate PV panels into another structure (cf. Section 3.1.2.). Building upon the knowledge they gained in other industries, these firms propose new services or products as a complement to their traditional offer. As Roberts and Berry (1985) have pointed out, diversification into new products and markets should be guided notably by the company's degree of familiarity with the new technology and the new market. Considering the variety in the original activities of BM3 companies, it is unsurprising to find the same variety of activities in their PV activities.

Let us go back to the case of Imerys Toiture (BM3; Box 6.8.). This roof tile developer and manufacturer is illustrative of the manufacturing capability of the BM3 companies. As noted above, it operates in the 'project development' and 'systems manufacturing' stages of the PV value chain. Specifically, it proposes PV roof tiles as an alternative to PV panels installed on a roof. By replacing clay tiles, PV roof tiles are designed to ensure the impermeability of the roof. Interestingly, the installation process is very similar to its original core competencies, even though the PV roof tiles are a bit bigger. In other words, it was a relatively easy transfer of capabilities.

The case of Gagnepark (BM3; Box 6.5.) also illustrates this transfer capability. Building parking lots is its original business line. Soon after its first successes, its clients asked GagnePark to diversify its offer to include PV technologies. Then, backed by its research and experienced in parking construction, in 2008 the firm satisfied its existing customers by extending its offer to PV shade structures (or carports), which have solar PV panels installed on them. R&D is significant in this company's solar activity: it patented its building system under the name of "OMBRAPARK." The system is applicable, for example, to single-story parking lots or to the terrace level of multi-story parking lots. The power generated is either resold or self-consumed.

4.1.4. Conclusion

Overall, the largest part of the panel faces the turbulence in being vertically integrated at 70%. Most of them are in services. This supports Hypothesis 2.

Regarding the contribution to Hypothesis 1, the foremost conclusion is the distinction between the BM1, New BM2, and BM2 companies overwhelmingly multi-stage on the one hand, and the BM3 cases mainly mono-stage on the other.

The dividing line is the degree of importance of the PV market in a company's business. What distinguishes BM3 companies from their counterparts is that their survival does not fully rely on the PV market. PV is only a source of additional revenue for them. These companies can afford not to develop their PV activities and thus stay mono-stage in the PV value chain. It is noteworthy that the PV stage a BM3 firm occupies is the same stage it is engaged in its mature industry. Hence, the ease of transfer capacities is a significant criterion for BM3 companies for entering the PV market. That is to say, they engaged in a related diversification.

Conversely, the common thread of BM1 and BM2+ companies is that they rely to a greater degree on the PV market, which has a greater impact on their profits. Hence, to stabilize their financial situation, many of them have opted for vertical integration. In other words, the more a company relies on a turbulent market, the more it operates in multiple stages of the value chain.

One may argue that BM2 companies are independent of the PV market. It is important to bear in mind however that PV activity represents a significant portion of most of these actors' activity, and that operating in energy is a tricky business because it depends heavily on policies. Hence, PV activity influences the overall financial security of BM2 businesses.

Interestingly, there is still one-third of single businesses (i.e. BM1 companies) that continue to operate only in one stage of the PV value chain. Building on the case of kiloWattsol (Box 6.6.), I assume that these companies have found other ways to secure their business. In the following sections, I examine two other directions of expansion: (1) geographical diversification; and (2) broader customer segmentation.

4.2. Mainly domestic companies (Hypothesis 3)

This sub-section exposes the geographical expansion of the companies' solar activities over the French borders (Hypothesis 3). For this purpose, I chose four different degrees of spatial coverage: (1) regional; (2) national; (3) export; and (4) international.

It is worth noting that I distinguished the companies that operate overseas through their subsidiaries or offices (i.e. international) from those that restrict their activity to exports. The latter do not have a physical presence outside the French soil.

Also, I consider that operations in overseas departments and territories deal with either international or export trade. Despite their belonging to the French state, these areas have different regulations. These differences and details on the characteristics of these overseas departments and territories have been discussed elsewhere (cf. Chapter 3; e.g., Jacobs, 2012, p. 61). That is why I distinguish them from the national scale.

Based on Table 6.7., none of the four degrees distinguish themselves from the others. Nevertheless, a conclusion can be drawn: 68% of the sample have their physical presence solely in mainland France. But geographical diversification is not about the physical presence or not; export is also a form of geographical diversification. Based on this definition, 34 companies are geographically diverse; that is, equivalent to 49% of the panel. Therefore, Hypothesis 3 on geographical diversification is not validated.

A quick look at Table 6.7. sheds light on a similar proportion across the various business models. Therefore, the geographic expansion is not a determining factor for any business model. Hence, instead of presenting the diversity of the panel, I propose to depict in turn the four levels of spatial coverage.

For each business model type, only a minority of companies has confined their activities to a single region. The proportions vary: 10% for the BM1 group, 7% for BM2, and 38% for BM3 (cf. Table 6.7.). None of the ten New BM2 companies are concerned.

	Total		BM1		New BM2		BM2		BM3	
	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
International	22	32	6	30	3	33	10	36	3	23
Export	12	17	4	20	2	22	5	18	1	8
National	26	37	8	40	4	44	11	39	4	31
Regional	10	14	2	10	0	0	2	7	5	38
Total	70	100	20	100	9	100	28	100	13	100

Table 6. 7.: Spatial coverage
Source: Author

Turning to a larger scale, overall, more than twice as many businesses cover the whole national territory or at least a couple of regions. The proportion of national enterprises is slightly different from that of regional companies for the BM3 type, with 31%. The difference grows with the BM1 and BM2 groups, as their numbers are up to five times higher, with respectively 40% and 39%. Turning to the New BM2 companies, four out of nine of them cover the entire country. Among others, the group UNITE (BM2; Box 6.3.), based in Lyon, has local operations in most of the French regions through its five engineering, technical and maintenance centers in Lyon, Nantes, Charézier, St Girons, Poses, Ajaccio and Grenoble. Likewise, GagnePark (BM3; Box 6.5.) developed 26 projects all over France, from Le Mans to Marseille, Belfort, and Paris. But there is no regional agency, apart from its headquarters in Montpellier.

The part of the panel operating worldwide is significant (see Table 6.7.): 34 companies, equivalent to 49% of the panel, have expanded geographically.

Interestingly, 12 out of 34 enterprises are located only on French soil but reach beyond the country's borders. Many interviewees claimed that the future is not in the French market, but overseas. "Exporting is the future of SMEs," claimed David

Dejean-Servières, founder and CEO of Kogys, a French systems manufacturer. He nevertheless expressed reservations on SMEs' product exports, pointing out that their export capacity is limited in so far as they are not able to produce at a competitive price. However, exporting is not only a matter of manufacturing products but also of services. A case in point is kiloWattsol (BM1; Box 6.6.), as it operates worldwide without opening foreign offices. This is true across all business models.

The vast majority of these 34 companies (65%) actually goes further than exporting, by having subsidiaries⁹⁰ or agencies all around the world. For example, Apex Energies (BM1) set up five agencies in the French overseas departments and territories (cf. Box 6.4.). They are located in Guadeloupe, Martinique, Guyana, Polynesia, and the Indian Ocean for a better local anchoring. These choices were certainly driven by the specific characteristics of these territories.

The following examples clearly illustrate the willingness to improve the local anchoring despite international operations. Gensun (BM1; cf. Box 6.9.) is a telling example with its five agencies in France (Montpellier, Aix-en-Provence, Toulouse, Pau, and Pessac) and four subsidiaries in Portugal and India (cf. Box 6.7.). The case of Arkolia Energies (New BM2) is also illuminating, with its headquarters in Montpellier and its three agencies in France (Rodez, Toulouse, and Nantes), in addition to one in Ghana through a joint venture (cf. Box 6.7.).

Whether there is a physical presence overseas or not, Europe is a top destination. Francewatts (BM1) is a convincing example as it exports its PV systems notably to the Benelux countries, Germany, and Italy. Africa also seems to be one of the most appealing areas for the France-based companies. A case in point is Kogys, which is operating in Morocco, Senegal, and Madagascar, while Arkolia Energies prefers English-speaking Africa (New BM2; cf. Box 6.7.). Some companies are established on both continents, such as Adiwatt (BM1), which has offices in Europe (Spain and Switzerland) and Africa (Morocco, the Democratic Republic of the Congo, Benin, Algeria, Togo, Rwanda, and Chad). Others work across the globe on the model of kiloWattsol (BM1; cf. Box 6.6.). This firm was involved in projects in countries as diverse as Burkina Faso, Japan, Thailand, Peru, and the United States.

It is however also worth noting that the cases I reported here exemplify the fact that most companies have opted for developing a robust local base through the creation of local agencies, be it on French soil or overseas. This is consistent with the fact discussed in Chapter 2 that the activities in the downstream segment are close to the market.

4.3. Broad customer segmentation for BM1 and specialization for BM3 (Hypothesis 4)

The last axis of expansion deals with customer segmentation. I classified the companies according to the narrowness of their customer base. While I acknowledge that it is rather a continuum, for the sake of simplification, I consider only the ends

⁹⁰ Obviously, having a real international presence is possible mainly because they belong to a larger group.

of the spectrum: focused or broad (Zahay and Griffin, 2010, p. 86). The former deals with one or more highly specific customer segment(s); the latter addresses all types of customers.

There is roughly a balance between the two options in the sample as a whole (cf. Table 6.8.). Out of the 70 companies composing the sample, 34 make no or little distinction between customers; they target a broad customer segment. The remaining 36 companies focus on one or more distinct groups of customers, that is, on what I have called a focused customer segment. Therefore, findings do not support my Hypothesis 4, stating that in a period of turbulence, companies aim to target a public as focused as possible.

Based on the numbers in Table 6.8., I note that the distribution of actors in the BM2 and New BM2 groups is similar. Hence, I consider that they behave in the same way, and group them in the BM2+ type for the analysis of the customer segmentation. The BM2+ group respects the parity, with 18 enterprises for broad customer segmentation and 19 for focused. Hence, the type of customer segmentation is not a determining factor for the BM2+ type.

		Total		BM1		New BM2		BM2		BM3	
		Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Customer segment.	Broad	34	49	14	70	4	44	14	50	2	15
	Focused	36	51	6	30	5	56	14	50	11	85
Total		70	100	20	100	9	100	28	100	13	100

Table 6. 8.: Statistics per customer segmentation type
Source: Author

Conversely, I find a strong relationship between broad customer segmentation and the BM1 type. Indeed, 14 of the 20 BM1 cases opted for targeting as broad a public as possible. For example, GenSun (BM1; cf. Box 6.9.), a vertically integrated service provider, targets all energy producers (i.e. broad customer segmentation). For this purpose, it does not confine itself to a specific PV technology or PV installation type but works on various projects on behalf of its customers: on regular roof, flat rooftop with crystalline silicon or thin films, or ground-mounted power plants, with or without solar trackers, to name but a few.

Finally, focused customer segmentation applies largely to the BM3 business model. A full 85% of this type of business targets a specialized customer segment. Gagnepark (BM3; cf. Box 6.5.) is an excellent example, as it aims at companies requiring parking lots for their employees or clients, such as supermarkets and shopping malls. Its customers include the Carrefour Group, Auchan, and EFFIA Stationnement. Considering the specific characteristics of its customers, it is possible to say that GagnePark targets a focused customer segment. Interestingly, this does not prevent the firm from benefiting from economies of scale. GagnePark offers its customers new patented solutions combined with mass customization. What makes its patents so unique is that they allow for a simplified and rapid on-site assembly procedure and a customization of its solutions. Specifically, the company offers non-standardized

products, which enable it to reap the benefits of economies of scale and to deliver a customized product that takes into account its customers' specifications and the characteristics of the country and budget (i.e. mass customization).

4.4. Conclusion

The section has shed light on three different strategies of expansion, in addition to industrial diversification: vertical integration inside the PV value chain; the extent of spatial coverage; and the width of the customer segment.

This section highlights the tendency of the panel to be vertically integrated and especially in services. I moreover observe no majority on either side of the global diversification topic. The same observation applies to customer segmentation. Therefore, the results are not statistically relevant for the two last hypotheses. I conclude from this general study on the validation of Hypothesis 2 but not on Hypotheses 3 and 4.

Besides, it is interesting to see that some strategies are found more with one specific business model than with another. It is more likely for a BM1 to be multi-stage and target a broad customer segment; for a BM2+ to be multi-stage in services; and for a BM3 to be a mono-stage manufacturer and focused in its customer segment. As for the spatial coverage, it is not a distinguishing feature for any of them.

Having said this, I believe that beyond their market or industry origin, their resources impact the choice of their strategies (Li and Greenwood, 2004, pp. 1134–1135; Park and Jang, 2013, p. 53; cf. Hypothesis 5). This impact is the subject of the following section.

5. Firm-based/resources criteria (Hypothesis 5)

This last section examines the prediction regarding resources (Hypothesis 5). Specifically, I study three features that may impact the positioning of companies: the strength of the partner network (Section 5.1.), the company size in terms of employees (Section 5.2.), and the capitalization choice (Section 5.3.).

5.1. Large partner network for BM1 companies; small for BM3

As I did for the 'customer segmentation' criterion, I opt for a binary choice for the level of importance of the partner network in companies' PV operations, instead of considering the entire spectrum. It is considered 'high' if the enterprise relies heavily on its partners for its PV activity, and 'low' otherwise.

		Total		BM1		New BM2		BM2		BM3	
		Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Partner network	High	38	54	16	80	4	44	15	54	3	23
	Low	32	46	4	20	5	56	13	46	10	77
Total		70	100	20	100	9	100	28	100	13	100

Table 6. 9.: Partner network
Source: Author

Table 6.9. shows that, overall, there is an equal share between the two options. If I take into consideration the business model, I conclude that the partner network is particularly crucial for 80% of the BM1 companies. For example, Urbasolar (BM1; Box 6.10.) holds a financial interest in five investment funds in partnership with banks and other financial institutions, including the BPCE Group, OMNES Capital, the Crédit Agricole, and the LA POSTE Group. The partners provide either the money or the land for the projects. To date, the company and its partners directly own a power plant portfolio generating more than 100MW.

Box 6. 10.: Urbasolar, a BM1 corporation that relies on its partner network

The company was founded in 2006 by two experienced persons in the solar industry: Arnaud Mine, a former president of SOLER (a professional association of the PV industry), founder and former CEO of Apex Energies and of SOLELEC Caraïbes (a subsidiary of TENESOL), and by Stéphanie Andrieu, former COO of Apex Energies.

Urbasolar is a BM1 company and a multi-stage service provider (PV value chain). Its activities involve PV power plant development, sales, design, construction, and O&M.

It notably invests in the PV power plants it develops and builds with the intention of becoming an energy producer. As an energy producer, Urbasolar has developed a financial capacity of more than €300 million. Specifically, the company holds a financial interest in five investment funds in partnership with institutions, including the BPCE Group, OMNES Capital, the Crédit Agricole and, the LA POSTE Group (partner network). To date, the company and its partners directly own a power plant portfolio generating more than 100MW.

It is a medium-sized company (83 workers in 2015 from 47 in 2010) which builds plants across the world involving recently Kazakhstan, East Africa, and the Philippines (channel).

Contrariwise, the partner network is unimportant for the BM3 cases. Only three companies of the 13 composing the BM3 set rely heavily on their partner(s). Their independence from partners might be due to the strength of their non-PV business line(s).

Here again, as for customer segmentation, the division of both New BM2 and BM2 groups is close to parity. Therefore, partner network is not a determining factor for characterizing the BM2+ group. Nevertheless, let us consider how the partner network is crucial for some of them, notably Arkolia Energies (New BM2; cf. Box 6.7.). It is essential mainly for its energy-producing activity, as it is for Urbasolar (BM1; Box 6.10.). In 2015 Arkolia Energies owned 51% of four large ground-mounted PV power plants, totalizing €75M and 70MW. Its partners (Groupe Caisse des Dépôt, Green City Energy, or Acofi) brought the needed money to the projects.

Note that a similar proportion of each business model applies to both partner network and customer segmentation. It is therefore legitimate to wonder if these criteria are repetitive. To test, I analyzed the link between these two features for the BM2+ type (Table 6.10.). The choice of the BM2+ group is justified by its neutrality for both criteria.

	BM2+	Partner network	
		High	Low
Customer segmentation	Broad	7	11
	Focused	12	7

Table 6. 10.: Linking customer segmentation to partner network
Source: Author

The results are a strong inclination in companies targeting a focused customer segmentation to have a strong partner network, while those with a broad customer segmentation tend to pair with a weak partner network. 62% of the 37 BM2+ companies match this pattern. In other words, there is a robust but not perfect correlation. I do not conclude on the perfect match between the two criteria, and therefore keep these two criteria separate.

5.2. Small and medium-sized BM1 and BM2, large BM3

As I did for the non-survivor companies in Section 1, I study the size of the survivors. What is striking is the relatively small size of the panel (cf. Table 6.11.). 66% of the panel has fewer than 50 workers. All in all, 91% of the 70 companies are small-and-medium enterprises (i.e. fewer than 250 employees).

The small numbers of the median and mean of the BM1, New BM2, and BM2 groups confirm the small size and concentration of these groups. 72%⁹¹ of these groups are small (i.e. fewer than 50 workers), and 26%⁹² are medium-sized (i.e. between 51 and 250 employees). FranceWatts (BM1) had 16 employees in 2015. According to Sylvain Robillard, the Sales Manager, the company stays small on purpose, as this represents an advantage by offering flexibility and rapidity, two critical ingredients to success. Likewise, UNITe (BM2; cf. Box 6.3.) had only 10 employees in 2015

⁹¹ $72\% = (8+7+6+3+11+6)/(20+9+28)$

⁹² $26\% = (5+10)/(20+9+28)$

despite the wide variety of its energy markets. It operates in the following markets: hydropower, wind power and, solar power.

	Total		BM1		New BM2		BM2		BM3	
	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
=<20	28	40	8	40	6	67	11	39	3	23
20<x=<50	18	26	7	35	3	33	6	21	2	15
50<x=<250	18	26	5	25	0	0	10	36	3	23
>250	6	8	0	0	0	0	1	4	5	39
Total	70	100	20	100	9	100	28	100	13	100
Median	29		28		14		37		60	
Mean	224		45		17		102		492	

Table 6. 11.: Frequency of size
Source: Author

Interestingly, the BM1 and BM2 types, and to a lesser extent the New BM2, have a similar distribution of the population regarding the number of employees, up to their respective ninth decile mark. From that point, their paths diverged. The maximum number of employees for the BM1, New BM2, and BM2 types in 2015 were respectively 176 with Solairedirect (BM1), 31 with Arkolia Energies (New BM2), and 1,484 with Compagnie Nationale du Rhone (BM2). Therefore, there is no large firm in the BM1 and New BM2 groups, and the New BM2 is the smallest group. It is worth noting that Compagnie Nationale du Rhone is the only large company in the BM2 type. Even without it, between the BM1 and BM2 groups, the BM2 type is the one with larger companies, as there are two with more than 176 workers, which is the maximum size in the BM1 group.

Unquestionably, the larger companies of the sample are in the BM3 type. Unlike the other business models, the vast majority of BM3 companies (i.e. 62%) has over 50 employees. This is not the most significant difference. Most notably, the big gap between the median and the mean of BM3 suggests the occurrence of a few extreme data points. Among the 13 companies, five are large. Precisely, three of them employ more than 1,000 persons, and the maximum size is 2,520 employees at SMAC. This results in a wide dispersion in the last quartile. Again, it may be induced by the fact that the companies exist by themselves through their core activity and market.

5.3. Capitalization choice

For characterizing the capitalization of business models, I have considered three different data: (1) the corporate ownership, (2) the equity capital, and (3) total asset.

Corporate ownership is an important criterion, as shown in the literature (Zahra et al., 2000, p. 937). It has been demonstrated that ownership may impact the

resources available to certain firms, and therefore their strategy. I, therefore, controlled for ownership.

Consider the case of GenSun (BM1; cf. Box 6.9.). The company relies on Neoen, its parent company, the third largest renewable energy producer in France, after EDF and Engie in particular for its geographical business expansion. At the time of writing, GenSun expected to expand its business in Central and South of America thanks to the knowledge and activity of Neoen. Therefore, Neoen plays a significant role in the business expansion. Furthermore, owing to the acquisition of Juwi EnR by Neoen in 2015, Gensun retrieved the Juwi EnR solar park and thereby sharply increased its solar park maintenance to 300MW. That is a tenfold increase over one year.

Overall, the corporate ownership analysis informs us of the high proportion of companies belonging to a bigger entity. All in all, it is true for 64% of the panel (cf. Table 6.12). The proportion is particularly large for BM1 and BM2 companies, of which over 60% are part of a group.

		Total		BM1		New BM2		BM2		BM3	
		Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Corpor. Owner.	Depend.	45	64	12	60	5	55	21	75	7	54
	Independ.	25	36	8	40	4	44	7	25	6	46
Capital (in €K)	Median	590		228		0.763		1,257		4,300	
	Mean	11,924		1,698		7,617		14,898		24,235	
	Median per empl.	12		6		70		13		12	
	Mean per employee	260		126		323		427		64	
Total Asset (in €K)	Median	12,949		6,530		19,594		6,809		16,414	
	Mean	121,554		14,574		65,481		162,862		167,977	
	Median per empl.	242		182		979		302		179	
	Mean per employee	941		649		2,092		985		554	
Total		70	100	20	100	9	100	28	100	13	100
<p><i>Table 6. 12.: Capitalization</i> <i>Source: Author</i></p>											

While I have considered the equity and total asset for qualifying resources, they have to be put aside for the analysis of the business models. Specifically, the equity capital has to be withdrawn from the analysis due to the impact of corporate ownership. Indeed, the equity does not reflect the real financial capacity of a dependent firm. Similarly, total asset is not a good indicator to characterize a business model as the diversification strategy, the nature of its activities and depreciations distort the analysis.

5.4. Conclusion

I put forward Hypothesis 5 on the impact of resources on businesses' strategic capabilities. The results led us to conclude only on the impact of some variables on BM1 companies: the number of employees, partner network, and capital ownership (cf. Table 6.13).

Turning to BM2 cases, solely the partner network criterion was found not to be a distinctive feature. Finally, it appears that only one of the selected resources is determinant for a New BM2 or a BM3 firm. Specifically, the small size is characteristic to New BM2. In other words, it is neither a partner network nor the dependence on another structure that enables a BM1 company to evolve into a BM2. To conclude, it is possible to validate Hypothesis 5.

	BM1	New BM2	BM2	BM3
Partner network	High	/	/	Low
Size	Small and medium	Small	Small and medium	/
Corporate ownership	Dependent	/	Dependent	/

Table 6. 13.: Overview table on the main resources
Source: Author

Conclusion

This chapter enabled me to describe the reduced panel, i.e. 70 companies, in terms of strategies and business model. This study leads to few conclusions regarding the hypotheses.

I expected to find an overwhelming proportion of companies vertically integrated in a period of crisis, even though the value chain is highly disaggregated: 70% of the panel occupies two stages of the PV downstream value chain. I therefore validated **Hypothesis 2**. This was possible thanks to the predominant place of services in the downstream segment, whose barriers to entry can be overcome through training. Indeed, the most common combination of activities is project development and O&M (41 out of the 70). Although project development is the most popular stage, as 61 companies operate at least at this stage, O&M is particularly attractive in turbulent times (43 firms), as it generates recurring revenues.

Conversely, the findings do not lead to the validation of **Hypotheses 3 and 4**. I assumed that the local sensitivity of the downstream activities, mainly linked to the variations of national policies, would limit global diversification. The study shows that almost half of the 70 companies are geographically diversified: 32% of the panel has a physical presence abroad and 17% operate exports, totaling 49%. The figure is neither high nor low to validate Hypothesis 3 or not.

The same parity is observed for customer segmentation. While I assumed that companies facing a period of turbulence are more inclined to target a broad customer segment, only 49% of the panel does actually do so. This also leads to the invalidation of Hypothesis 4. Further research is required on these hypotheses.

Regarding the resources, three types were analyzed: partner network, number of employees, and corporate ownership. The impacts on the panel as a whole vary widely: 54% companies rely heavily on its partner network; 66% of the panel is small and 26% is medium-sized; and 64% of the 70 companies belong to a bigger entity.

These generalities are important. But when it comes to Hypothesis 1 and 5, the analysis has to be done per business model. Indeed, looking at these strategies and resources through the lens of a business model points to three different profiles, enabling me to say that **Hypotheses 1 and 5** are validated. A brief description of these profiles is required.

BM2 and New BM2 groups are similar enough to consider them as a unique set that from here on I call BM2. The BM2 group is largely composed of multi-stage players (78%) involved in the service sector (95%). They are mainly small (70%) and, to a lesser extent, medium-sized (27%). They also largely depend on a bigger entity (at 70%).

Interestingly, BM1 companies have the opposite characteristics of those of BM3: a BM1 company, typically, is vertically integrated (75%), service-based (70%), and targets a broad customer segment (70%), whereas the archetype BM3 company is mono-stage (62%), with a slight trend towards manufacturing activities (54%), and targets a focused customer segment (85%).

Turning to their resources, the demarcation line is also glaring between BM1 and BM3 firms. The BM1 group relies significantly on its partner network (80%) and is small (75%), while the BM3 group is characterized by a low-level partner network (77%) and is medium-sized (23%) or large (39%). As for corporate ownership, while BM3 companies show no preference, there is a significant tendency for BM1 enterprises to depend on a bigger entity.

In consideration of the above, I conclude on the validation of Hypotheses 1, 2, and 5, while the results obtained in this chapter are inconclusive for Hypotheses 3 and 4. Yet it is still unknown whether these strategies are efficient in a context of market turbulence. That is the topic of the final chapter.

Chapter 7: Relations between business model and performance growth, mitigated results

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Résumé

Chapitre 7 : Relations entre business model et évolution de la performance, des résultats mitigés

Le chapitre 7 s'intéresse à l'évolution de la performance des entreprises durant la période de réadaptation, autrement dit entre 2010 et 2015, suite aux turbulences économiques. Nous cherchons à identifier des groupes d'observations relativement homogènes en fonction de l'évolution des actifs, des ventes, du nombre d'employés, et de la rentabilité (rentabilité des actifs, ROA, et rentabilité des ventes, ROS). Pour cela, nous avons adopté un processus en deux phases : l'analyse en classification automatique à K moyenne (*k-means* en anglais) puis la classification agglomérante hiérarchique (*Agglomerative Hierarchical Classification* en anglais).

Ceci nous a mené à identifier quatre trajectoires de performance et donc quatre classes d'entreprises dans un contexte de turbulence : deux classes marquées par la capacité des firmes à investir massivement ; deux classes marquées par des stratégies de réduction de ressources et de recentrage sur leur cœur de métier.

Pour les deux premières classes, l'objectif est d'assurer la viabilité de la firme à moyen terme et son développement à long terme. Leur stratégie est payante puisque leur chiffre d'affaire, leurs actifs et le nombre d'employés ont augmenté de plus de 50% sur la période 2010-2015. Cependant les deux trajectoires diffèrent sur l'évolution de la productivité (Δ ROA et Δ ROS). Dans un cas (**Classe 1**), elle augmente de 50% par rapport à la situation de 2010. Dans l'autre cas (**Classe 2**), elle décroît d'autant. La raison de cette divergence est liée au temps de réponse, c'est à dire, au moment des investissements : la Class 1 a réagi très tôt et très rapidement, alors que Class 2 a réagi plus tardivement. On peut supposer que la Class 2 pourrait voir les bénéfices de ses investissements émerger plus tard.

Les deux autres trajectoires sont le fruit de stratégies plus restrictives (**Classe 3** et **Classe 4**) : une stratégie de repli. Cette stratégie est la plus classique en période de crise, notamment à court terme. L'idée est d'adapter les ressources à la chute de la demande et de se recentrer sur le cœur de métier. L'objectif est donc ici différent puisque les managers se concentrent sur la survie de l'entreprise à court terme.

La différence entre ces deux trajectoires repose essentiellement sur les ressources détenues en 2010. Celles de la Classe 3 représentaient le double de celles de la Class 4. Cette inégalité de départ explique largement les trajectoires de rentabilité des deux classes. La Class 3, par ses importantes ressources, est capable de diminuer ses ressources sans pour autant diminuer sa rentabilité. En revanche, la Class 4, en diminuant ses ressources déjà faibles en comparaison de celle de la Classe 3, s'est privée des ressources lui permettant de redresser la barre et de profiter de la reprise quand elle survient.

Il est important de remarquer que les différentes stratégies ont pour effet une diminution de la performance générale. En effet, ce sont les entreprises les plus rentables qui semblent avoir adopté des stratégies de repli, ce qui explique qu'en fin de période, malgré des évolutions divergentes, on observe une convergence des taux effectifs de retour entre les quatre classes de « survivants ».

De plus, grâce à une approche par business model, il est important de remarquer que les entreprises diversifiées dans deux industries (**BM3**) sont principalement représentées dans les trajectoires de performance décroissante. Quant aux entreprises non-diversifiées (**BM1**) et aux entreprises diversifiées au sein d'une même industrie (**BM2**), malgré une tendance à être plus présentes dans les deux premières classes, il n'est pas possible de faire de lien non-équivoque. Il n'est donc pas possible de valider l'**Hypothèse 6**.

Pour autant, en analysant systématiquement des entreprises qui étaient déjà ou sont devenu producteur d'électricité, on voit poindre une différence marquante en terme de dynamique : les producteurs d'énergie voient leur performance s'améliorer, contrairement aux non-producteurs d'énergie. Ce qui ouvre de nouvelles perspectives d'analyse. En effet, il est important de souligner que cette activité n'a pas été prise en compte dans notre analyse de la chaîne de valeur du photovoltaïque.

The world breaks everyone and afterward many are stronger at the broken places.

Ernest Hemingway

Introduction

It is not an unknown fact that most of the businesses in the downstream segment of the photovoltaic (PV) value chain were hemorrhaging money in the wake of the moratorium. By 2010 some companies were on the verge of collapse, and those that survived faced an uphill battle to produce profits. This led me to turn my interest in the strategies they implemented to survive, as there are many ways for companies to adapt their strategies to the same crisis.

In Chapter 6, I discussed the various, mainly diversification-like strategies used by 70 businesses to survive and grow: industrial, vertical, and geographical diversification, and broadening customer segmentation. Yet I still do not know how much more efficient one survival strategy can be than another one.

In this chapter, I address Hypothesis 6. Hence, I aim to contribute to the diversification-performance relationship literature. It is worth noting that the link between performance and diversification is one of the most appealing research topics in various disciplines, from strategic management to industrial organization, to finance (Christensen and Montgomery, 1981; Datta et al., 1991). Considering the mixed results obtained from previous empirical studies on the diversification-performance linkage, the subject is far from being exhausted.

One of the most studied hypotheses is that related diversifiers can be expected to outperform unrelated counterparts (Datta et al., 1991, p. 532). The justification lies in the potential transferability of core skills and synergistic benefits such as economies of scale and scope in the case of related diversification (Datta et al., 1991, p. 532; Rumelt, 1982, 1974). But many researchers downplay the prediction. For example, Stern and Henderson (2004, p. 489) assume that “effectively transferring knowledge between two businesses is unlikely, then, unless their external environments are similar”.

Furthermore, Dubofsky and Varadarajan (1987, p. 597) argue that related diversification impacts performance but does not guarantee favorable performance. Among other things, strategy types have been shown to affect the recovery times of businesses. I consider that a corporation has recovered if it returns to its pre-crisis performance level. Therefore, I focus on the performance trend. In particular, I related strategy and performance to market turbulence in my analysis of the performance of the 70 companies composing the final panel through the period 2010-2015.

I noticed moreover that each of the diversification strategies is studied independently to explain the firms' performance. I believe however that one combination of strategies performs better than the others in a context of turbulence. This chapter explores potential strategy interrelationships' impact on performance, measured as performance trend, in particular.

I start by presenting the methodology (Section 1). Departing from the performance indicators of previous studies on industrial diversification performance in general, I select those that best fit my purpose and the panel's characteristics. By choosing some of them, I facilitate comparisons with other studies. For this purpose, I use agglomerative hierarchical clustering (AHC) coupled with k-means. These are iterative classification methods based on the dissimilarity between the actors. I then provide a general description of the four classes (Section 2). While I acknowledge that each firm is different from its counterparts, even among those that opted for the same strategy, for the sake of simplification I define four profiles, based on the performance and resource evolution. Section 3 presents the results linked to the best growth performance classes, while Section 4 focuses on those of the poor growth performance classes. I then discuss the link between business model types and performance (Section 5). The chapter ends with the conclusion.

1. Methodology

1.1. Identification of performance indicators

Diversification researchers use various tools to study performance (Christensen and Montgomery, 1981; Datta et al., 1991, p. 533; Li and Greenwood, 2004; Rumelt, 1982, p. 364; Tanriverdi and Lee, 2008, p. 286; Varadarajan and Ramanujam, 1987). The most widely employed performance measures of diversification strategy found in my review of the literature are set out in Table 7.1. below. Along with Varadarajan and Ramanujam (1987), I grouped them into three different categories (cf. Table 7.1.): (1) financial performance measures; (2) profitability measures; and (3) growth measures. However, as they do not all fit the purpose of this study, I discarded most of the indicators regarding two criteria:

1. Lack of information. The question of information access discussed in Chapter 4 applies essentially to the performance measures. I did not use any market performance indicators as I dealt largely with privately-held companies. In particular, I did not consider the following variables: earnings growth, earnings per share (EPS) growth, relative standard deviation of EPS, price per earnings ratio, and market share.
2. Ownership control. The return on capital (ROC) and return on equity (ROE) were also withdrawn from my analysis due to the impact of the ownership on the equity. As seen in Chapter 6, capital is a tricky measure as a large proportion of the companies (45 out of 70) are dependent on a bigger entity. This means that their equity does not reflect the real importance of their source of investment. Hence, dependent companies are not on an equal footing with their independent counterparts.

	Indicators	Calculation
Financial performance measure	Earnings growth	= (Net Income - Dividends on Preferred Stock) / Average Outstanding Shares
	Price-earnings (P/E) ratio	= Market Value per Share / Earnings per Share
Profitability measure	Market share	= (Particular Company's Sales Revenue in Time Period X) / (Relevant Market's Total Sales Revenue in Time Period X)
	Return on asset (ROA).	= Net Income / Total Assets or = Profit Margin / Total Asset Turnover.
	Return on equity (ROE)	= Net Income / Shareholders Equity.
	Return on sales (ROS)	= Operating profit/ Net Sales
	Return on capital (ROC) or Return on invested capital (ROIC).	= Operating Income / Invested Capital.
Growth measure	Sales growth (SGR)	= (Sales in year N – Sales in year N-1)/ Sales in year N-1
<i>Table 7. 1.: Main performance measures on diversification</i> <i>Source: Author</i>		

In other words, I selected only three indicators from the list as they are among the most widely used for the performance study of privately-held companies and SMEs (Che and Langli, 2014; Covin and Slevin, 1989; Crema et al., 2014; Dess and Robinson, 1984; Hashai, 2015; Zahra et al., 2000):

1. Return on asset (ROA). The ROA ratio indicates how efficiently a company is in its use of total assets to generate a profit.
2. Return on Sales (ROS). The ROS ratio reveals the capacity for conversion of revenues into operating profit.
3. And sales growth (SGR) reflects the change in sales in year N. This measure is of particular interest because it indicates the capacity of a company to expand its business (Dess and Robinson, 1984, p. 268).

One thing is certain: they are all accounting measurements, based on data from income statements and balance sheets. It is nevertheless possible to characterize them in many ways. Apart from profitability-growth indicators, sales-based and asset-based measures are of interest. The first reveals firms' short-term performance (ROS and SGR), which the latter do not, especially in case of large investments (ROA; Geringer et al., 1989, p. 113; Hashai, 2015);

Either way, as a reminder, I am interested in the recovery times of businesses and therefore in the evolution of their performance resulting from their survival

strategies. I, therefore, chose to use the variability of the selected indicators ROA (Δ ROA) and ROS (Δ ROS) instead of the average ROA and ROS, as some researchers did (e.g., Christensen and Montgomery, 1981; Stimpert and Duhaime, 1997).

I also considered two other growth measures, related to the 'resources' dimension of the business model (cf. Chapter 5 and Chapter 6): total assets (Δ Asset) and the number of employees (Δ Employees) (Ball and Shivakumar, 2006; Che and Langli, 2014; Chong, 2008). In accordance with the European Commission's definition, I consider a company to be small if it has fewer than 50 employees and a turnover and total assets inferior to €10 million. A firm is considered to be medium-sized if it has under 250 persons on its payroll, a turnover of less than €50 million and, total assets inferior to €43 million.

For each company, each of these five variables was calculated over the six-year period of this study. I determined three different levels of growth: (1) 'A', superior if the growth is superior to 50%; (2) 'B', medium if it is between 50% and -50%; and (3) 'C', negative in the case the evolution is -50% and below. I reckon that despite the efforts to reduce any resulting bias from my judgmental input, the determination of the performance indicator level is a potential source of judgmental bias. Moreover, acknowledging the potential importance of the starting point in the performance evolution and strategic choice, I took into consideration the data for the five variables for the years 2010 and 2015 per se.

1.2. Clustering Methodology

I assigned the 70 companies of the panel to classes. I sought to define homogeneous groups of companies according to the five performance growth measures chosen in the previous section. For this purpose, I used a method of two-stage clustering with Analysis of Dynamic Clusters (k-means) and Agglomerative Hierarchical Classification (AHC) (Tamura and Miyamoto, 2014). The classification was performed on the five growth indicators, using XLSTAT software.

k-means clustering is an iterative aggregation method. I used it at a preliminary stage, prior to AHC, to optimize class composition. It is useful to divide the observation into homogeneous clusters, based on quantitative variables. I opted for 30 classes. Further details are in Footnote 1⁹³.

The second stage was AHC. This is one of the most popular clustering techniques. It has to be distinguished from the divisive hierarchical clustering, which is performed top-down (i.e. starting from a single cluster and ending with the maximum number of clusters). AHC is performed bottom-up (i.e. starting from the maximum number of clusters to end with a single cluster). The method works on the dissimilarities

⁹³ The clustering criterion is Determinant(W). The stop conditions were 500 iterations and the convergence of 1e-05. The initial partition is random with a repetition of 100. The random numbers were 6227. Considering that the data collected are qualitative, I used multiple component analysis (MCA) to transform them into quantitative. I chose 200 iterations.

between the companies' growth performance. Specifically, I ran it on the 30 classes resulting from the preliminary stages⁹⁴. Results of the AHC test appear in Figure 7.1., Table 7.2, and Table 7.3. AHC is a hierarchical structure of the firms.

There is one k-means characteristic that is both an advantage and a drawback compared to AHC: unlike AHC which generates just one possible outcome, k-means clustering may assign a firm to a class during one iteration and to another class in the following iteration. To overcome this possible flaw, I ran k-means six times. Out of the six times, the same solution appears four times. It was my choice to proceed to AHC.

2. Classes overall description

2.1. Classes' closeness

Using a level of dissimilarity of 69, the method reveals a total of four classes of firms. The subsequent dendrogram was generated (cf. Figure 7.1.). It is a binary clustering tree. The dendrogram is particularly useful as it shows the progressive grouping and the link between companies. At the top is the class containing all the companies; at the bottom, one can visualize the number of clusters that equals the number of objects. Considering that AHC was performed from the 30 classes resulting from k-means, it is normal that the dendrogram represents these 30 classes at the bottom and not the 70 companies. The link between corporations, k-means classes, and AHC classes is done in Annex 7.1.

The dendrogram also displays the truncation (cf. the broken line) representing the dissimilarity line, and the four classes after truncation. The first one encompasses 16 actors (in green, center right), as opposed to 15 for the second cluster (in purple, far right), 19 for the third group (in red, center left), and 20 for the last one (in blue, far left) (Figure 7.1. and Annex 7.1.). Hence, the four classes are well-balanced.

Of interest is the proximity between classes. The pairwise distances comparison of class centroids based on Euclidean distance is given in Table 7.2. It was calculated between all possible pairs of clusters. It shows that Class 1 and Class 4 differ significantly: the highest distances were between these two classes with 2.329. Hence these figures assume that Class 1 and Class 4 have opposite performances due to opposite strategies.

Conversely, the most similar groups are Class 3 and Class 4, with a minimum distance of 1.281. I can, therefore, assume that Class 3 and Class 4 have a similar strategy. Considering a distance of 1.622 between Class 1 and Class 2, it is hard to make the prediction that the same holds true for them. Having said this, Class 2 is relatively close to Class 1 and Class 4 (1.483). Therefore, it is possible to assume that Class 2 has a similar performance for some indicators to Class 1 and for others to Class 4. Table 7.3. confirms this intuition. Specifically, Class 1 and Class 2 have

⁹⁴ I opted for the Euclidean distance, the most common distance measure for AHC, and the agglomeration method of Ward, and the center/reduce options. The last option allowed me to avoid having group creation influenced by scaling effects.

in common a superior SGR, Δ Asset, and Δ Employees; Class 2 and Class 4 both have a greater ROA and ROS.

Class	1	2	3	4
1	0	-	-	-
2	1.622	0	-	-
3	1.848	1.918	0	-
4	2.329	1.483	1.281	0

Table 7. 2.: Pairwise distances comparisons between the class centroids (Euclidean distance)

Source: Author

2.2. Link between classes and the business turnaround literature

The frequencies of the clusters' growth performance are shown in Table 7.3. The firms' distributions according to the performance measures are given in Table 7.4. and Table 7.5.

At first sight, classes have been formed around the evolution of resources (i.e. Δ Asset and Δ Employees). The first two classes experienced a significant growth in most of their resources (superior to 50%). Contrariwise, companies of Class 3 and Class 4 have not significantly improved their resources. Rather, the large majority are classified in medium or negative performance (up to +50%).

Based on this finding, I believe that the 'business turnaround' literature is of particular interest to the description of the four classes. See Schoenberg et al. (2013) for a recent literature review. It sheds light on two specific strategies usually set up in recession conditions: (1) retrenchment (i.e. defensive); and (2) investment (i.e. offensive) strategies (Chastain, 1982; Deans, 2009; Kitching et al., 2009; Robbins and Pearce II, 1992). That is to say that companies faced a dilemma: whether to cut costs to conserve resources and secure activities, or to invest in order to take advantage of the market recovery when it came. For the purpose of this doctoral thesis, I evaluate the former situation with a negative or stagnant Δ Asset and Δ Employees. Conversely, the latter situation is reflected by a superior Δ Asset and Δ Employees (i.e. superior to +50%). Hence, there are two different perspectives to adapt to the new environment, and to secure survival. However, both strategies are assumed to potentially lead to a better performance.

This literature has the advantage of establishing the connection with the discussion in Chapter 5 and Chapter 6 on portfolio restructuring in times of crisis (in short, portfolio restructuring involved either a diversification toward stronger business lines or divestment of the weaker ones). In this research, a superior Δ ROA and Δ ROS (i.e. more than +50%) are considered as a better performance.

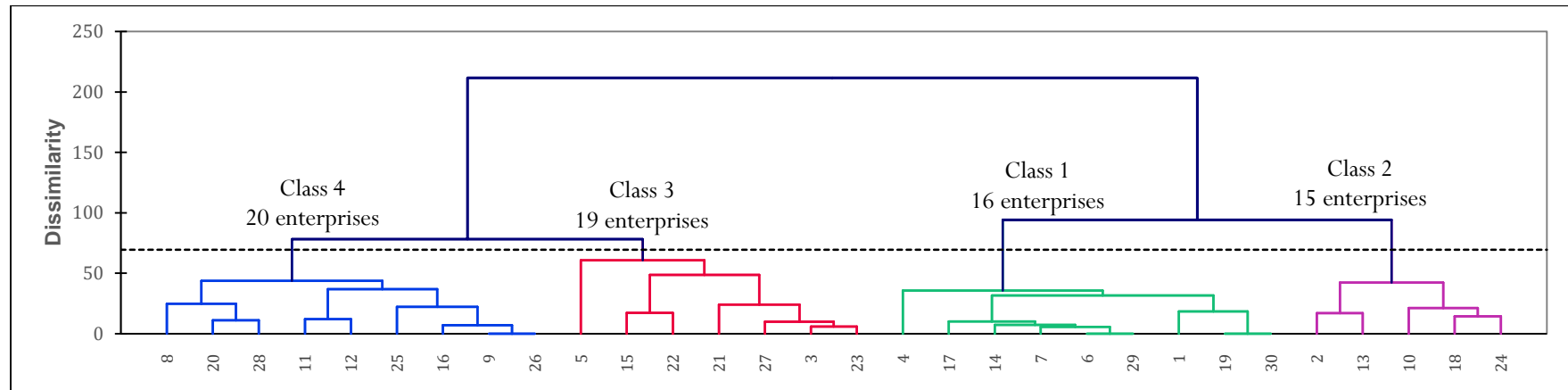


Figure 7. 1.: Dendrogram

Source: Author

Class	Δ ROA			Δ ROS			SGR			Δ Asset			Δ Employees		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1	0.81	0.19	0.00	0.69	0.25	0.06	0.94	0.00	0.06	0.88	0.00	0.13	0.69	0.31	0.00
2	0.27	0.00	0.73	0.00	0.00	1.00	0.53	0.33	0.13	0.73	0.20	0.07	0.73	0.27	0.00
3	0.42	0.47	0.11	0.42	0.42	0.16	0.26	0.58	0.16	0.05	0.89	0.05	0.00	0.84	0.16
4	0.05	0.00	0.95	0.05	0.30	0.65	0.00	0.65	0.35	0.15	0.70	0.15	0.00	0.80	0.20

Table 7. 3.: Class centroids per class

Source: Author

Having said this, it is time to carefully examine the firms constituting the four classes, regarding both their performance and their strategy. It is important to bear in mind that belonging to the same class is not synonymous with sharing the same characteristics. In fact, the method is based on growth performance dissimilarity between actors.

The results are set out in the following sections. I start with the overall performance description of the four classes. I will describe the ways firms addressed the PV market crisis. The description starts with the group with the best growth performance (Section 3) and end with the worst (Section 4).

3. Best growth performance classes

3.1. Investment strategies

Some managers view market crises as opportunities for long-term value creation. These crises afford opportunities to achieve competitive advantage by investing, innovating, and diversifying into new markets (Civi, 2013; Hayter, 1985; Kitching et al., 2009; Pearce and Michael, 2006, 1997; Roberts, 2003; Sands and Ferraro, 2010). The investments include increasing R&D spending, developing new products, targeting new market niches, and increasing marketing expenditures. In other words, they prepare the field to exploit opportunities when the upswing comes. Hence, the objective of investment strategies is the strategic investment or revenue growth (Deans, 2009). This is a point of view encouraged by Rumelt (2009).

Investment strategies inevitably require significant resources, implying higher costs in the short-term. In other words, implementing investment strategies leads to a superior Δ Asset and Δ Employees, but they are supposed to lead to high-performance levels in the longer term (Covin and Slevin, 1989). Hence, investment strategies do not lead to the same profitability performance, as the latter notably depends on the time framing. That is the difference observable between Class 1 and Class 2.

3.2. Class 1, top-performance class

The first group contains 16 companies, equal to 23% of the 70 companies of the panel. There are two main characteristics. First, there is an over-representation of BM2 corporations: three-quarters of Class 1 are of BM2 types (i.e. 12 out 16), followed by three BM1 firms and only one BM3 enterprise. Secondly, their growth performance is out of the line (cf. Table 7.3.). Figures suggest stronger growth than the bare-bones headlines number might indicate. These firms experienced a much stronger growth for all five indicators than did their counterparts. Specifically, between 69% and 94% of the 16 companies had a growth rate superior to 50%, depending on the indicators (cf. Table 7.3.). The percentage rises to a minimum of 88% if I consider both superior (i.e. superior to +50%) and medium (i.e. between +50% and -50%) performance growth. In particular, five companies reached a superior growth for all five indicators, and seven firms for four measurements.

The starting point for explaining their high-performance evolution is major new investments between 2010 and 2014 for almost all of them. This resulted in superior Δ Asset. Interestingly, the mean and median of the total assets in 2015 remained small, with respectively €25 and 46 million (Table 7.4.), while they roughly tripled after 2010.

	Asset			Employees		
	2010	2015	Δ	2010	2015	Δ
Minimum (K€)	107	538	431	1	10	9
Maximum (K€)	85,487	192,124	106,637	88	248	160
Range (K€)	85,380	191,586	106,206	87	238	151
1st Quartile (K€)	3,045	11,912	8867	13	20	7
Median (K€)	7,049	25,420	18,371	23	37	15
3rd Quartile (K€)	22,972	54,169	31,196	43	76	32
Mean (K€)	18,189	45,616	27,427	28	60	32

Table 7. 4.: Growth performance levels and changes for Class 1
Source: Author

One specific investment drives this class: investing in power plants. The main characteristic is the high proportion of energy producers: 11 out of 16 corporations operate and own power plants. This means that almost three-quarters of Class 1 became an energy producer.

Investing in their own power plants has the particularity of generating revenues not only quickly but also recurrently. SGR could be achieved only after at least one year, although this period could be shorter if a company buys a second-hand plant. It is moreover an investment that secures their business in the long-run.

Either way, firm size in terms of employees becomes larger. This growth could simply be explained due to a large proportion of the service-based companies in Class 1, for only two of the 16 companies are manufacturers. Hence, if the activity increases, the companies need more staff.

It is important to understand how these growing resource impacted the performance in details. Definitely, sales exploded. However, despite a minimum SGR rate of 50% over the period 2010-2015, for 94% of the group, Class 1 still exhibits a high proportion of small-and-medium-sized firms in terms of turnover. Indeed, all but two companies have a turnover of less than €50 million: half of them are small (inferior to €10 million) and half are medium-sized (between €10 and €50 million). The two exceptions are Urbasolar (BM1; Box 6.10.) with €66 million and Eole RES (BM2) with €165 million.

Interestingly, in Class 1, the investment strategy effect was significant not only for SGR but also for profitability (i.e. Δ ROA and Δ ROS). Class 1 companies had growing profitability at the end of the year 2015 compared to 2010. Thus, profitability growth was positive and significant in the middle-term. Nevertheless, the profitability median remained low: 0.04 for ROA and 0.03 for ROS (Table 7.5.).

Only four companies had an ROA and a ROS superior to 0.10 (cf. the third quartile). The maximum ROA was high compared to the other classes: 0.33. Turning to ROS, the maximum was high, with 0.26, but not as remarkable as Class 3 and Class 4.

Furthermore, it is noteworthy that a positive growth of profitability does not imply that the profitability by itself is positive. Indeed, the ROA and ROS are negative for respectively two and six enterprises in 2015.

	ROA			ROS			Sales		
	2010	2015	Δ	2010	2015	Δ	2010	2015	Δ
Minimum	-0.65	-0.09	0.56	-12.19	-2.76	9.44	27	406	379
Maximum	0.14	0.33	0.19	0.11	0.26	0.15	109,492	165,562	56,071
Range	0.80	0.42	-0.37	12.30	3.02	-9.28	109,464	165,156	55,692
1st Quartile	-0.22	0.02	0.24	-0.66	-0.03	0.63	1,552	3,275	1,723
Median	-0.02	0.04	0.06	0.01	0.03	0.02	5,477	19,588	14,111
3rd Quartile	0.04	0.10	0.07	0.06	0.11	0.05	10,398	33,704	23,306
Mean	-0.08	0.08	0.16	-1.67	-0.16	1.51	13,842	28,532	14,690
Nb>0	7	14	7	9	10	1			
Nb<0	9	2	-7	7	6	-1			

Table 7. 5.: Profitability levels and changes for Class 1
Source: Author

Arkolia Energies (BM2; Box 6.7.) is a telling example of a BM2, middle-sized energy producer with a positive growth in profitability over the period 2010-2015. Specifically, its assets exploded from €7 to €30 million following its repositioning as an energy producer in 2012. Its staff was increased threefold, from 14 to 31 persons. The turnover more than doubled to reach €44 million. Yet, when considering the year 2010 instead of 2012, the most significant evolution deals with the turnover. Indeed, it increased seven-fold. Profitability remained stable at 0.03 for both ROA and ROS.

3.3. Class 2, investing firms but not yet profitable

This second group, that is, Class 2, is composed of 15 companies, i.e. 21% of the 70 companies. The profile of Class 2 is quite close to that of Class 1. There are predominantly BM2 companies, despite a higher proportion of BM1 and BM3. In details, eight of the 15 Class 2 companies are of the BM2 type; five are BM1 and two are BM3.

They also have the same investment strategy as Class 1 corporations, as their superior Δ Asset and Δ Employees attest. Specifically, their total assets median and mean roughly doubled between 2010 and 2015: respectively €3.6 and €38 million in 2015, up from €1.5 and €20.8 million six years earlier (Table 7.6.). The number of employees median and mean doubled too from 12 and 15 to 19 and 31.

The seed phenomenon of such performance is also significant investments. Energy producers account for a substantial share of Class 2 businesses. This was the case with five companies, equivalent to one-third of the cluster. As regards the ten remaining companies, it is an entirely different matter. The increase of Δ Asset is mainly linked to the evolution of receivables. It may be due to marketing expenditures, development of new offers or offices (to reach new geographical markets), and to a lesser extent the acquisition of competitors or suppliers. An example is provided in Box 6.9. (cf. the maintenance park of Gensun has been increased ten-fold thanks to the acquisition of juwi ENR by the parent company of Gensun).

	Asset			Employees		
	2010	2015	Δ	2010	2015	Δ
Minimum (K€)	71	542	471	2	9	7
Maximum (K€)	113,082	219,290	106,208	31	67	36
Range (K€)	113,011	218,748	105,737	29	58	29
1st Quartile (K€)	654	1,564	910	10	14	4
Median (K€)	1,450	3,619	2,169	12	19	7
3rd Quartile (K€)	12,563	43,967	31,405	21	48	28
Mean (K€)	20,771	38,013	17,241	15	31	16

Table 7. 6.: Growth performance levels and changes for Class 2
Source: Author

Whatever the nature of the investments, it resulted in an increase in the number of Δ Employees. That is predictable, considering that all but two are service suppliers. The same rationale witnessed for Class 1 applies here: recruiting is required for a service-based company to grow.

Sales increased more than 50%, resulting in a superior growth, yet they still remain small. In 2015, 12 companies, equivalent to three-quarters of Class 2, had a turnover inferior to €10 million (Table 7.7.). Interestingly, regarding this criterion, the only large company in Class 2 is Uniper France, with a turnover of €693 million. What is certain, is that their investment strategy is effective for a company's SGR in the short term.

The same does not, however, apply to their profitability. Conversely to Class 1 firms, they faced a negative Δ ROA and Δ ROS performance (i.e. inferior to -50%). That is to say, the most widespread combination is a negative Δ ROA and Δ ROS, combined with superior Δ Asset, SGR and, Δ Employees. In short, despite large investments, profitability decreased.

It is not unheard or unknown that a positive impact of an investment on ROA and ROS requires time. Whatever these investments are, huge depreciation resulting from them impacts on operating profits and net profits (Geringer et al., 1989, p. 113). Geringer et al. (1989, p. 113) also explain that major new investments may not yet generate sales to their full potential at the end of the study period. As such,

they are a source of distortion. This, in turn, led to lower ROA and ROS in 2015 than in 2010, when it was not negative.

	ROA			ROS			Sales		
	2010	2015	Δ	2010	2015	Δ	2010	2015	Δ
Minimum	-0.03	-0.16	-0.13	-0.41	-4.50	-4.09	145	581	436
Maximum	0.23	0.11	-0.12	0.17	0.03	-0.15	349,799	693,245	343,447
Range	0.26	0.27	0.01	0.59	4.53	3.94	349,653	692,664	343,011
1st Quartile	0.01	-0.03	-0.04	0.01	-0.06	-0.07	901	1,966	1,065
Median	0.04	0.00	-0.04	0.02	-0.02	-0.04	3,904	4,699	795
3rd Quartile	0.08	0.01	-0.07	0.08	0.01	-0.07	13,135	9,559	-3,575
Mean	0.06	-0.01	-0.07	0.01	-0.42	-0.43	29,013	52,303	23,290
Nb>0	14	10	-4	8	7	-1			
Nb<0	1	5	4	7	8	1			

Table 7. 7.: Profitability levels and changes for Class 2
Source: Author

It is not unheard or unknown that a positive impact of an investment on ROA and ROS requires time. Whatever these investments are, huge depreciation resulting from them impacts on operating profits and net profits (Geringer et al., 1989, p. 113). Geringer et al. (1989, p. 113) also explain that major new investments may not yet generate sales to their full potential at the end of the study period. As such, they are a source of distortion. This, in turn, led to lower ROA and ROS in 2015 than in 2010, when it was not negative.

Indeed, one may note that the ROA and ROS's median were respectively 0 and -0.02 in 2015 (Table 7.7.). That means that a negative performance of ROA and ROS in 2015 concerned half of the Class 2 companies. It is either due to a negative operating profit or a negative net profit. Only two companies had an ROA superior to 0.05; the maximum was 0.11. This is, even more, striking with the ROS, as none had more than 0.05. Thus, there was a more significant proportion of low and negative ROA and ROS compared to Class 1. Hence, Class 2 corporations performed less well than those in Class 1 in 2015, although they may have provided the same performance if the study period had been longer.

Enercoop is a convincing example in this respect. The company made major investments. Its total assets jumped from €2.6 to €14.6 million and increased more than four-fold. However, its profitability slightly decreased from zero or so to a barely negative level.

3.4. Comparison

Class 1 and Class 2 were both characterized by major new investments during the period 2010-2015. However, there is more than one difference between them. The subtlety lies in four points.

Firstly, the investments in Class 2 are much more diverse. While three-quarters of Class 1 are energy producers, only one-third of the second cluster are also energy producers.

Secondly, Class 2's resources (total assets and number of employees) are much smaller than those of Class 1, even though they grow faster. However, the gap between total assets has been deepening over time. In 2015, the median was at €3.6 million (from €1.5 million), as opposed to €25.4 million for Class 1 corporations (from 7 million) (Tables 7.4 and 7.6.). The same applies to the staff median: from 23 to 47 employees for Class 1; from 12 to 19 for Class 2.

Thirdly, while I note a significant increase in sales, the firm size of Class 2 in terms of turnover remains smaller than Class 1. In 2015, 12 companies, equivalent to three-quarters of Class 2, were small, as they had a turnover inferior to €10 million (Tables 7.5. and 7.7.). That is much higher than the 43% of Class 1, and the gap widened. The median of Class 1 evolved from €5.5 to 19.6 millions, while that of Class 2 rose from €3.9 to 4.7 millions.

	Class 1	Class 2
Company Name	Arkolia Energies	Enercoop
Business model	BM2	BM2
Total Assets in 2010	7,665,933	2,624,900
Vertical integration	Multi-stage	Mono-stage
Customer segmentation	Broad	Specialized
Geographical diversification	International	National
ΔAsset	3.14	4.55
ΔEmployees	1.82	3.42
SGR	4.76	5.09
ΔROA	0.72	-23.24
ΔROS	-0.01	-3.44

Table 7. 8.: Comparison of two companies
Source: Author

The last but the least relates to profitability. Both classes made major new investments during the study period, generating an increase in sales. However, their profitability evolved in opposite directions. Class 1 companies experienced an increase in their profitability, while the best businesses of Class 2 barely recovered from the crisis, or were on the verge of doing so, in terms of the two profitability growth measures. The reason for this difference lies in the timing of investments. Precisely, investments impact profitability negatively in the short-term but positively in the longer term. In short, long-term investments pay off. See Table 7.8. for an illustration of the two outcomes.

4. Poor growth performance classes

4.1. Retrenchment strategies

Here, managers aim at maintaining the companies' survival in the short-term. That is to say, retrenchment strategies aim at protecting revenues and profit margins (Deans, 2009). Put simply, they are intended to make the most efficient use possible of resources. For this purpose, they control costs, divest from non-core assets, close businesses, reduce staff, etc. (e.g., Geroski and Gregg, 1997; Kitching et al., 2009). Concretely, companies did not increase their total assets or staff during the study period 2010-2015. Some even reduced their resources.

This strategy is the most popular solution, especially in the short-run (Kitching et al., 2009). Admittedly, retrenchment strategies may also be chosen because a firm lacks the resources needed to engage in investment strategies (Kitching et al., 2009).

It is worth noting that a possible side effect is the reduction of the firm's capacity to adapt adequately when market conditions improve (Geroski and Gregg, 1997; Kitching et al., 2009), as managers' shortsighted view causes them to put aside innovation and growth. This is the difference observed between Class 3 and Class 4. Both groups witnessed slight fluctuations (between -50% and +50%) of total assets, the number of employees, and sales between 2010 and 2015. But their profitability differentiates them: Class 3's profitability remained mainly stable, while that of Class 4 decreased sharply.

4.2. Class 3, stable performance class

Class 3 groups together 19 companies, i.e. 27% of the panel. Its composition is starkly different from that of Class 1 and Class 2. It is a mixed group in that there are seven BM1, eight BM2, and four BM3 firms. It is equivalent to 35%, 30%, and 31% of their respective sub-group in terms of business model type. There is also a higher proportion of manufacturers (five out of the 19 companies), while manufacturers were virtually non-existent in the two other classes.

Another sharp difference is that the strategy does not consist of investing in the future but rather in waiting and seeing, and in firmly establishing their activities. That is to say, the companies increased neither their total assets nor the number of their employees. Instead, spending dried up and they underinvested in business opportunities (Table 7.9.).

	Asset			Employees		
	2010	2015	Δ	2010	2015	Δ
Minimum (K€)	523	295	-228	8	7	-1
Maximum (K€)	998,130	713,541	-284,589	1,704	1,557	-147
Range (K€)	997,607	713,247	-284,360	1,696	1,550	-146
1st Quartile (K€)	3,011	4,036	1,024	22	18	-4
Median (K€)	25,961	19,648	-6,312	64	31	-33
3rd Quartile (K€)	51,442	55,972	4,530	95	114	19
Mean (K€)	124,088	101,606	-22,481	256	222	-34

Table 7. 9.: Growth performance levels and changes for Class 3
Source: Author

Significantly, they failed to make new major strategic investments in the development of power plants that would have increased revenues and profitability. It is worth noting that seven companies in Class 3 are energy producers, but this does not exclude the possibility of large investments. In this case, the depreciation of previous investments is greater than the potential new ones. To be precise, their tactic allowed these firms to make better use of their resources, resulting in at least a stable ROA and ROS compared to 2010.

Either way, it resulted in stable sales in the best cases. If I look in detail, I see that Class 3 companies' size in terms of turnover is as small as that of Class 1 companies: 16 out of 19 firms had a turnover in 2015 inferior to €50 million (10 of which companies had a turnover lower than 10 million). All but one of these small and medium-sized companies are either BM1 or BM2 types. The three large companies are all BM3.

As for profitability trends (i.e. Δ ROA and Δ ROS), 42% of Class 3 firms have a medium performance (between -50% and +50%) (cf. Table 7.3.). The same percentage has a growth superior to 50%. The maximum is reached at 0.29 (cf. Table 7.10.). Interestingly, the ROA has been improved compared to 2010 and is now positive for all. Moreover, the median is at 0.09. As such, it is the best class in terms of ROA in 2015.

It is also true for the ROS in 2015. It is the best performing class regarding the median (0.06), the maximum (0.52), and the number of companies with a negative ROS due to a negative operating profit (only three). In other words, most of them make money.

Hence, the retrenchment strategy kept these businesses afloat, in the case of Class 3. Some companies fully recovered from a plodding start at the beginning of the decade, but they recovered only on the back of a strong PV market recovery or of their stronger business lines.

The bottom line is that Class 3 companies underperform compared to their Class 1 and Class 2 counterparts in terms of Δ ROA and Δ ROS. But the opposite is true if

one considers the profitability indicators per se and not their evolution. These figures are unquestionably better than those of Class 1 and Class 2.

	ROA			ROS			Sales		
	2010	2015	Δ	2010	2015	Δ	2010	2015	Δ
Minimum	-0,54	0,00	0,53	-8,36	-1,08	7,29	17	71	54
Maximum	0,30	0,29	-0,01	0,44	0,52	0,08	395 204	373 355	-21 849
Range	0,83	0,29	-0,54	8,81	1,60	-7,20	395 187	373 284	-21 903
1st Quartile	0,00	0,02	0,02	0,01	0,03	0,01	2 022	2 898	877
Median	0,06	0,09	0,02	0,04	0,06	0,02	10 120	7 593	-2 527
3rd Quartile	0,11	0,13	0,02	0,13	0,10	-0,03	49 896	31 529	-18 367
Mean	0,04	0,09	0,05	-0,41	0,04	0,45	69 789	59 277	-10 512
Nb>0	15	19	4	15	16	1			
Nb<0	4	0	-4	4	3	-1			

Table 7. 10.: Profitability levels and changes for Class 3
Source: Author

It is worth depicting two cases to illustrate the profile diversity and retrenchment strategy in Class 3. kiloWattsol (BM1; Box 6.6.) and UNITE (BM2; cf. Box 6.3.) are both Class 3 firms, but their situations could hardly be more different.

KiloWattsol is a service-based, mono-stage company specialized in PV, as described in Chapter 6. Its ROS has plummeted from 0.44 to 0.06 (negative Δ ROS), due to the evolution of its operating profit, which started at €250k and ended at €53k. The same holds true for its ROA, which declined from 0.14 to 0.10, and its staff, which was reduced from 11 to eight persons (medium Δ ROA and staff). Contrariwise, the total assets and the turnover have increased approximately by 40% (though not enough to be considered as superior growth).

Consider UNITE (BM2), an intra-industry diversifier, developing project and manufacturing notably PV systems. Its ROA and ROS slightly increased, respectively from 0.00 and -8.36 in 2010 to 0.01 and -1.08 in 2015. This was possible thanks to a better use of its assets and employees. Total assets increased but in a way that increased the company's profitability. The company raised its total assets from €19 to €24 million.

4.3. Class 4, the lowest-performing class

Class 4, with 20 companies or 29% of the panel, is the largest group. Similar to Class 3, there is a significant representation of each business model, with five BM1, nine BM2, and six BM3 firms, equivalent to 20%, 24%, and 46% of their respective business model group. Hence, it is hard not to conclude that BM3 firms are mainly positioned in Class 4.

Class 4 is moreover another group whose strategy to deal with the PV market crisis was retrenchment. But the outcome was different. Actually, Class 4 firms suffered

the most. Not only did this class present worse scores than the other groups for all variables, but also, it did not show a high performance for any of my five growth indicators.

Specifically, for resources (Δ Employees and Δ Asset) and SGR, the large majority of Class 4 companies experienced a medium growth, and to a lesser extent a negative one. When considering the median, the trend is more striking. In particular, the total assets' median was halved, starting the study period at €13.7 and ending at €7.3 millions (Table 7.11). The same holds true for the number of employees', where the median dropped from 27 to 20 persons.

Turning to sales, the median was reduced threefold, from €19 to €5.3 millions. However, I also note that there is a higher proportion of companies with a turnover superior to €50 million. Actually, the companies are evenly distributed among the three size categories.

	Asset			Employees		
	2010	2015	Δ	2010	2015	Δ
Minimum (K€)	1,491	901	-590	12	2	-10
Maximum (K€)	4,035,579	4,391,335	355,756	5,426	5,429	3
Range (K€)	4,034,088	4,390,434	356,346	5,414	5,427	13
1st Quartile (K€)	2,804	2,258	-546	15	10	-5
Median (K€)	13,700	7,267	-6,433	27	20	-7
3rd Quartile (K€)	51,120	60,064	8,944	126	89	-37
Mean (K€)	279,624	309,226	29,603	492	503	11

Table 7. 11.: Growth performance levels and changes for Class 4
Source: Author

Having said this, the most striking observation is that all companies of this class experienced a decline of their ROA and their ROS, which turned significantly negative for some of them, with few exceptions. Specifically, the ROA and ROS of eight companies became negative, although not significantly so (Table 7.12.). In other words, overall they are still struggling to return to their respective initial level of 2010.

A case in point of Class 4 is Clipsol. This is a manufacturer, owned by Engie. It was specialized in systems manufacturing and installed and maintained its own systems. The company went down so badly that it closed in 2017. Its profitability sharply decreased to be negative in 2015. The ROA dropped from 0.13 to -1.13; the ROS from 0.11 to -0.79. It resulted from a plunge in turnover from €39 to €6 million, of assets from €24 to €6 million, of employees from 115 to 78.

	ROA			ROS			Sales		
	2010	2015	Δ	2010	2015	Δ	2010	2015	Δ
Minimum	-0,21	-1,13	-0,92	-0,39	-0,79	-0,40	1,427	560	-867
Maximum	0,49	0,03	-0,47	0,45	0,49	0,04	1,186 k	1,097 k	-89 k
Range	0,71	1,16	0,45	0,84	1,29	0,45	1,185 k	1,097 k	-88 k
1st Quartile	0,03	-0,06	-0,08	0,02	-0,11	-0,13	4,323	1,707	-2,616
Median	0,07	-0,01	-0,08	0,06	0,00	-0,06	18,940	5,304	-13,636
3rd Quartile	0,25	0,02	-0,24	0,16	0,01	-0,15	56,757	25,660	-31,097
Mean	0,12	-0,11	-0,23	0,07	-0,06	-0,13	137,301	123,410	-13,890
Nb>0	18	10	-8	17	10	-7			
Nb<0	2	10	8	3	10	7			

Table 7. 12.: Profitability levels and changes for Class 4
Source: Author

4.4. Comparison

Admittedly, both Class 3 and Class 4 adopted retrenchment strategies in the wake of the moratorium. However, they differ on three points.

First, Class 3's resources (total asset and number of employees) are twice than those of Class 4 in 2010. The difference widens in 2015 regarding total assets. The median of total assets of Class 3 was 2.7 times bigger than that of Class 4, while it was only 1,9 times bigger in 2010. Turning to the number of employee's median, Class 3 employs more than Class 4 but the reduction of their staff was more intense. That results in the reduction of the gap between these classes.

Second, both classes experienced a sharp drop of their sales. The one of Class 4 is the most spectacular: the first quartile, the median and the third quartile indicate that only one third of their sales of 2010 remained six years later.

Third, the most striking difference is about the profitability. Overall, Class 3 profitability is stagnant or increased but remains positive, while that of Class 4 sharply dropped to become negative.

5. Industrial diversification and class performance

Having discussed the performance growth for each classes, I am now poised to expose the one between classes and business model types. Overall, based on Table 7.13., BM2 enterprises are evenly distributed across the four classes, with an inclination towards the best growth performing classes (i.e. Class 1 and Class 2). BM1 firms are also evenly distributed but with an inclination towards the retrenchment strategies classes (i.e. Class 3 and Class 4). Conversely, BM3 firms are far more present in Class 3 and Class 4.

	BM1			BM2		BM3	
	Total	Number	%	Number	%	Number	%
Class 1	16	3	15	12	32	1	8
Class 2	15	5	25	8	22	2	15
Class 3	19	7	35	8	22	4	31
Class 4	20	5	25	9	24	6	46
Total	70	20	100	37	100	13	100

Table 7. 13.: Distribution of business model across classes
Source: Author

There is no perfect match between a business model and a class, especially for BM1 and BM2 types. The relation between them is much more complex. It is therefore worth studying the varieties. I propose to consider two sub-profiles for the most widespread business model across all classes: BM1 and BM2 groups. The dividing line deals with the activity of energy production. Thus, I consider five different profiles, analyzing them each in turn. The study starts with the BM3 group, for which I consider only one profile. The proposal still constitutes a follow-up of the discourse, which is that there are only a few business models in an industry (cf. Hypothesis 1 and Teece, 2010).

5.1. BM3 group, the most homogeneous one in terms of performance

As noted earlier, BM3 companies are present essentially in the classes characterized by retrenchment strategies, i.e. ten out of 13 (Table 7.13.). That is to say, they only marginally engage in investments. As such, they differ from the others. The foremost reason is that the PV market only represents an additional revenue stream for them.

It is worth noting moreover that their size was already significant. This holds true for the total assets, the number of employees, and the turnover. The details are given below in Table 7.14.

Firstly, despite the stagnation or decline of the total assets for most of the BM3 companies in 2015, the median total assets was €32 million (Table 7.14.), that is, twice as much as those of BM2 companies (€14.5 million), and seven times more than that of the BM1 group (€4.5 million).

	Total assets (in millions)	Employees	Sales (in millions)
BM1	4.5	28	6
BM2	14.5	18	8.7
BM3	32	45	29.6

Table 7. 14.: Variables' median per business model in 2015
Source: Author

Secondly, a similar gap is found regarding the size of the staff. BM3 companies had a median of 45 employees in 2015. That is far more than their counterparts: 28 for BM1 and 18 for BM2 companies.

Thirdly, consistently with the two previous criteria of firm size, the turnover confirms that the BM3 group contains the larger firms. It has a median turnover of €29.6 million, at least three times more than BM1 and BM2 groups. Their respective medians were €6 and €8.7. million.

Another characteristic of the BM3 group is their relatively high profitability. While there is no significant difference when considering the median ROA and ROS for both 2010 and 2015, the study of the average provides interesting results. Even though there are many BM3 companies in Class 3 and Class 4, that is, those that I described as poor growth performance classes, they still had the best average ROA and ROS in 2015, at respectively 0.03 and 0.02. Actually, this is the only business model for which the average ROA and ROS in 2010 were both positive. Their counterparts' average ROA and ROS were null or negative. That is to say, the BM3 profitability was still better than those of BM1 and BM2 groups despite its decrease in 2015. The bottom line is that the overall performance of BM3 corporations decreased but not enough to be life-threatening.

5.2. BM1 and BM2 groups, highly heterogeneous regarding performance

5.2.1. *To be an energy producer or not to be*

Studying the overall BM1 and BM2 performance and characteristics led us to generalities. It is very hard to make sweeping generalizations because each business model is relatively heterogeneous. Considering that the evolution of the total assets is usually the starting point to explain a company's performance, it is worth exploring the subject. I analyzed BM1 and BM2 groups for a specific activity: energy production. Energy producers are distinct from operators in that they operate their own power plants to generate power for sale to utilities and end-users.

Until now, I have put the activity of generating energy for sale in the O&M value chain segment. After considering the performance of classes, I am however of the opinion that energy producers might be put in a different stage. Perhaps this activity is a distinguishing feature that I should study separately when characterizing business models? This will be the subject of further research.

All in all, there are 28 energy producers, 22 of whom are of the BM2 type (cf. Table 7.15.). They are represented in Class 1, with 11 out of 15 companies (i.e. 73%). In the other classes, they are far less numerous: five energy producers in Class 2, seven in Class 3, and five in Class 4. The proportion varies: respectively, 38%, 47% and, 36%.

	BM1				BM2				Total	
	EP	%	Non- EP	%	EP	%	Non- EP	%	Nb	%
Class 1	3	50	0	0	8	36	4	27	15	26
Class 2	0	0	5	36	5	23	3	20	13	23
Class 3	2	33	5	36	5	23	3	20	15	26
Class 4	1	17	4	28	4	18	5	33	14	25
Total	6	100	14	100	22	100	15	100	57	100

Table 7. 15.: Distribution of energy producers (EP) across business model and classes
Source: Author

5.2.2. *BM1 companies, largely non-energy producer with a decreasing profitability*

Before analyzing the differences and commonalities between BM1 energy producers and non-energy producers, it is worth specifying that all six of them became BMI energy producers during the period 2010-2015 or slightly before.

Concerning the business model characteristics, there are no significant differences between BM1 energy producers and non-energy producers, and they are well-balanced regarding geographical diversification (cf. Table 7.18.). There is moreover a similar pattern across classes, with a preference for being multi-stage service providers, and targeting a generic customer segmentation, with a ratio approximatively at two-thirds. Hence, no conclusion can be drawn from these criteria. Therefore, characteristics of companies that became energy producers are to be found elsewhere.

Actually, the first and foremost criterion for a company to transform itself into an energy producer is to have enough resources and time to engage in major investments. BM1 energy producers had median total assets of 33 million in 2010 (cf. Table 7.16.), as opposed to less than €3 million for non-energy producers (cf. Table 7.17.). The gap still holds true in 2015. The median staff size of energy producers was less than double that of non-energy producers, with respectively 47 and 25 in 2010, and 49 and 28 in 2015. Turning to corporate ownership, there is a difference between the two sub-groups: the non-energy producers are two-thirds dependent, while there is an equal number of dependent and independent BM1 energy producers.

Regarding the importance of the partner network, I, however, found the same inclination towards a significant partner network for both BM1 sub-groups. Therefore it is not a distinguishing resource-related feature. To conclude, larger companies in terms of total assets and staff, are more inclined to become energy producers. But is there a link between BM1 energy producers and the growth of profitability?

	2015				2010			
	ROA	ROS	Total Assets (in K€)	Empl.	ROA	ROS	Total Assets (K€)	Empl.
Min.	-0,02	-2,76	17 826	10	-0,65	-12,19	1 942	1
Max.	0,13	0,35	272 257	176	0,14	0,09	102 016	219
Range	0,16	3,11	254 431	166	0,79	12,28	100 074	218
1st Q.	0,03	-0,01	19 314	14	-0,45	-0,49	10 669	18
Median	0,04	0,02	29 934	49	-0,12	-0,08	33 804	47
3rd Q.	0,05	0,07	68 313	81	-0,01	0,05	36 110	67
Mean	0,04	-0,38	74 472	63	-0,22	-2,13	35 234	66
Nb >0	5	4	-	-	1	3	-	-
Nb <0	1	2	-	-	5	3	-	-

Table 7. 16.: Summary statistics of the six BM1 energy producers
Source: Author

The performance of BM1 energy producers evolves inversely to that of BM1 non-energy producers. In 2010, five out of the six BM1 energy producers had a negative ROA (the third quartile was -0.01), and three out of these six companies had a negative ROS (Table 7.16). Six years later, it is a different story. The ROA and ROS were still negative for respectively only one and two BM1 energy producers. The first and third quartile as well as the median increase over time. Overall, their profitability improved.

	2015				2010			
	ROA	ROS	Total Assets (K€)	Empl.	ROA	ROS	Total Assets (K€)	Empl.
Min.	-0,43	-0,26	907	5	-0,21	-0,22	70	2
Max.	0,29	0,21	19 648	122	0,42	0,44	25 960	159
Range	0,72	0,47	18 741	117	0,63	0,67	25 890	157
1st Q.	-0,09	-0,02	1 488	16	0,02	0,01	837	13
Median	0,00	0,01	3 517	28	0,06	0,06	2 784	25
3rd Q.	0,08	0,06	4 622	40	0,13	0,10	9 205	51
Mean	-0,03	0,00	4 744	37	0,09	0,08	6 679	42
Nb>0	8	9	-	-	12	12	-	-
Nb<0	6	5	-	-	14	14	-	-

Table 7. 17.: Summary statistics of the 14 BM1 non-energy producers
Source: Author

Contrariwise, BM1 non-energy producers started the study period with a positive ROA and ROS for the overwhelming majority (12 out of 14; cf. Table 7.17.). The medians were 0.06 for both ROA and ROS. In 2015, they ended up with respectively 0.00 and 0.01. The same trend is observable for the first and third quartile. Specifically, while there were only two companies with a negative ROA and ROS in 2010, the number grew to respectively six and five companies. In other words, the profitability decreased over time for BM1 non-energy producers.

		PV value scope		Value Proposition			Customer segmentation		Area		Partner network		Corporate ownership	
Total		Mono-stage	Multi-stage	Serv.	Prod.	Services & Prod.	Broad	Focused	Internat.	National	High	Low	No	Yes
Non-energy producer	14	4	10	9	3	2	10	4	6	8	11	3	5	9
Energy producer	6	1	5	5	0	1	4	2	4	2	5	1	3	3
Total	20	5	15	14	3	3	14	6	10	10	16	4	8	12

Table 7. 18.: BM1 characteristics
Source: Author

		PV value scope		Value Proposition			Customer segmentation		Area		Partner network		Corporate ownership	
Total		Mono-stage	Multi-stage	Serv.	Prod.	Services & Prod.	Broad	Focused	Internat.	National	High	Low	No	Yes
Non-energy producer	15	3	12	13	0	2	8	7	8	7	8	7	7	8
Energy producer	22	5	17	22	0	0	10	12	12	10	11	11	4	18
Total	37	8	29	35	0	2	18	19	20	17	19	18	11	26

Table 7. 19.: BM2 characteristics
Source: Author

5.2.3. *BM2 Companies, largely energy producers with a stable profitability*

The situation in BM2 groups is different from that in BM1 ones. Firstly, there is a higher number of BM2 companies that started producing energy well before 2010 or before entering the PV market. That impacts total assets and profitability. It is, therefore, a limit in my comparison study. However, intriguingly, I found that BM2 energy producers and non-energy producers differ on the same criteria as the BM1 actors. This confirms the results relating to the BM1 group.

Let me start with the non-determining criteria. Similar to the BM1 group, BM2 energy producers and non-energy producers have the same business model characteristics. All BM2 companies consist overwhelmingly of multi-stage service-providers (77%) (cf. Table 7.19.). A parity is also found for geographical diversification. Regarding the importance of the partner network and customer segmentation, they do not influence any particular side. There is parity for both BM2 energy producers and non-energy producers.

Contrariwise, they clearly differ when it comes to corporate ownership, as in the case of BM1 companies, but not in the same way. Unlike BM1 cases, there is parity for BM2 non-energy producers and a strong predominance of dependent BM2 energy producers (18 out of 22). There is also a clear gap between the two sub-groups, concerning the total assets and the number of employees and their respective evolution (cf. Table 7.20. and Table 7.21.). Specifically, in 2010 the medians of the total assets were €19.5 million for energy producers and €2.8 million for non-energy producers. The gap was spreading as the median for the first sub-group had more than doubled to reach 48 million, while the one of the second sub-group remained relatively unchanged.

	2015				2010			
	ROA	ROS	Total Assets (in K€)	Empl	ROA	ROS	Total Assets (in K€)	Empl.
Min.	-0,09	-4,50	773	2	-0,25	-9,70	1 449	4
Max.	0,33	0,52	4 391 335	1 484	0,49	0,45	4 035 579	1 415
Range	0,42	5,03	4 390 561	1 482	0,74	10,15	4 034 129	1 411
1st Q.	0,00	-0,27	15 197	19	-0,03	-0,49	8 112	14
Median	0,01	0,00	47 984	49	0,01	0,01	19 518	24
3rd Q.	0,04	0,09	152 724	85	0,07	0,13	65 745	53
Mean	0,04	-0,31	274 986	123	0,03	-1,05	230 078	95

Table 7. 20.: Summary statistics for the 22 BM2 energy producers
Source: Author

The same applies to the number of employees. In 2010, the staff median lines were 24 for energy producers and 14 for their counterparts. There was no change for the latter while the staff of energy producers doubled in six years. It is worth noting that

the first and third quartiles of non-energy producers decreased over time, while that of energy producers increased.

	2015				2010			
	ROA	ROS	Total Assets (in K€)	Employ.	ROA	ROS	Total Assets (in K€)	Employ.
Minimum	-1,13	-0,79	294	7	-0,08	-0,02	107	3
Maximum	0,30	0,18	30 558	78	0,27	0,16	41 409	115
Range	1,43	0,97	30 263	71	0,34	0,18	41 301	112
1st Q.	-0,04	-0,06	1 334	10	0,03	0,03	1 439	13
Median	0,03	0,01	3 218	15	0,06	0,04	2 783	14
3rd Q.	0,09	0,10	5 547	25	0,14	0,10	7 018	29
Mean	-0,04	-0,04	5 695	21	0,08	0,06	7 697	24

Table 7. 21.: Summary statistics for the 15 BM2 non-energy producers
Source: Author

The last but not least criterion is profitability. As for BM1 non-energy producers, both the ROA and ROS medians for BM2 non-energy producers decreased over time, dropping respectively from 0.06 and 0.04 in 2010 to 0.03 and 0.01 in 2015. The same applies to the first and third quartiles.

The trends for BM2 energy producers were not the same as those of their BM1 counterparts, as the medians remained stable. The first quartile rose from an ROA of -0.03 and a ROS of -0.49 to correspondingly 0.00 and -0.27. But the third quartile decreased from an ROA of 0.07 and a ROS of 0.13, to 0.04 and 0.09 respectively. In other words, the range reduced over time.

The explanation may be twofold. Firstly, as noted earlier, many BM2 energy producers were already energy producers in 2010. Secondly, as I study the overall profitability of BM2 companies and not per business lines, the profitability of the other energy business lines impacts their overall profitability.

Conclusion

Differing priorities and strategies have emerged within firms in the wake of the PV moratorium, leading to different performances. Analyzing the link between performance and survival strategies leads us to classify companies operating in the PV market into four classes according to their performance trends. Overall, these classes can be put into pairs, according to the manager's business horizon focus. These managers focus either on immediate survival (Class 3 and Class 4) or on long-term objectives (Class 1 and Class 2). The result provides strong support for the conclusion of previous studies on turnaround literature. As would be expected, investing enterprises are more likely to have a better overall performance growth.

In respect of the three accounting-performance growth measures (i.e. SGR, Δ Asset, and Δ Employees), the largest number of Class 1 and Class 2 firms outperformed Class 3 and Class 4 ones. The first and foremost reason is that they bounced back by investing in the future. In other words, they found a way to go forward by investing heavily, especially in PV plants as an energy producer. Hence, Class 1 and Class 2 companies are associated with large investments that reflect their confidence in a brighter future of the PV market.

The major new investments, notably in power plants, have however produced different outcomes according to time-serial perspectives in terms of profitability growth (Δ ROA and Δ ROS). Even though the short-term effect of large investments is mainly negative on firm profitability variation (cf. Class 2), the profitability trend eventually changes significantly to a positive outcome, due to a longer-term positive effect of these investments (cf. Class 1). See Table 7.6. for an illustration of the two different outcomes. In short, long-term investments pay off.

Conversely, Class 3 and Class 4 companies displayed the opposite tendency, with the largest number falling in the null or negative growth performance bracket. Thus, their strategy of adapting their resources (through cost efficiencies, asset retrenchment, and focus on the firm's core activities) to the falling demand led them to limit their potential gains from the PV market recovery. As such, Class 3 and Class 4 enterprises' stances negatively impacted performance growth. Intriguingly, most of them had a positive ROA and ROS in 2015, albeit a lower one than those in 2010. As for the majority of these enterprises, their survival is not uncertain even in Class 4.

It is worth noting that total assets decreased over time due to depreciation. This does not imply that there were no new investments at all. Some of these firms did invest during the study period. These potential investments were simply smaller than depreciation resulting from previous investments.

When looking at the matching between business model type and class performance, a division between BM1 and BM2 enterprises on the one hand, and BM3 ones on the other, is evident in their position in classes and the activity of energy production. In particular, BM3 firms are concentrated in classes characterized by retrenchment strategies, while BM1 and BM2 are more evenly distributed across classes. Furthermore, energy producers are only in BM1 and BM2 groups. Therefore, it is hard to conclude on any correlation between a company's positioning, its diversification strategy, and a performance growth class for BM1 and BM2 groups. That is why I have broken down BM1 and BM2 groups into two sub-groups: energy producers and non-energy producers.

Geographical diversification and broadening of customer segmentation are considered as non-related to energy production if we look at their distribution across energy producers and non-energy producers. It is noteworthy moreover that the difference between energy producers and their counterparts are in the same areas for

BM1 and BM2 groups. These differences involve total assets, number of employees, corporate ownership, and profitability.

Without any doubt, total assets and the number of employees are much higher for energy producers than for non-energy producers. Over time, the gap may widen. Turning to corporate ownership, there is not the same tendency, whether one considers the BM1 or the BM2 group.

Finally, it is possible to conclude with a positive correlation between energy producers and performance: non-energy producers are associated with lower return profiles and energy producers increase their performance over time. In other words, the energy producers have proven to be less affected by market turbulence than their counterparts. The impact is particularly glaring for the BM1 group.

To sum up, being diversified, be it intra or inter-industry, does not lead to better performance or prevent a business from being hit by the PV crisis. On the contrary, being active in investing early and widely, notably in being an energy producer, may favor more a better performance in case of market recovery. In other terms, Hypothesis 6 is invalidated.

Having said this, it is worth pointing out that energy production has been excluded from the scope of our analysis, as it is not an activity defining the PV value chain. Hence, taking into account energy production in the analysis of the business model may lead to different results.

General conclusion

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Résumé

Conclusion générale

La conclusion générale résume notre processus cognitif nous amenant à notre question de recherche. En partant de la littérature sur les chaînes de valeur mondiales, nous avons souligné l'attention portée sur les firmes motrices et leur pouvoir de gouvernance sur les chaînes étudiées. Or toutes les chaînes de valeur ne sont pas gouvernées par ces acteurs, comme l'illustre celle du photovoltaïque. Plus précisément, cette chaîne est modulaire permettant des types de gouvernance variées et des « gouvernants » différents, tout au long de la chaîne, - en particulier dans la partie aval. Nous avons montré dans cette partie que le « gouvernant » est institutionnel. Il s'ensuit que les gouvernements ont eu un rôle prépondérant dans le déploiement de la technologie et des entreprises en aval de la chaîne. Il est par ailleurs important de souligner que ces entreprises sont essentiellement dans les services et de petite taille.

Après avoir démontré l'impact des aides étatiques déterminant les trois phases d'évolution du marché, nous avons mis l'accent sur la dernière phase, caractérisée par des turbulences suite à une réduction drastique des aides publiques. Ces turbulences se sont traduites par une chute des installations photovoltaïques et donc du nombre d'entreprises. Ce qui nous amène au cœur de la thèse : la question des stratégies de survie des firmes dans un contexte de turbulence. Les entretiens réalisés soulignent l'importance des stratégies de diversification. C'est la raison pour laquelle nos hypothèses tournent autour de ces stratégies.

Nos contributions sont au nombre de trois.

La première concerne une nouvelle taxonomie des stratégies de diversification industrielle. Les taxonomies proposées par la littérature sont basées sur le concept de proximité. Or ce concept implique (1) l'accessibilité des informations, ce qui n'est pas possible pour le cas des entreprises privées, et (2) une forte subjectivité dans le positionnement des entreprises, limitant la transposabilité des résultats. Pour ces raisons, nous proposons de fonder notre taxonomie sur les frontières d'un marché et d'une industrie. Cette taxonomie ne requiert ainsi ni une forte connaissance des différents marchés dans lesquels une firme est impliquée, ni l'appréciation subjective de l'analyste. Il découle de notre taxonomie quatre familles de stratégie : (1) entreprises non-diversifiées ; (2) entreprises diversifiées au sein d'une même industrie ; (3) entreprises diversifiées dans deux industries ; et (4) entreprises diversifiées dans plus de deux industries.

Deuxièmement, nous contribuons en démontrant que les business models individuels des firmes ne sont que des variations de business models génériques dans une industrie. En effet, quatre business models correspondent à ces quatre possibilités.

Plus précisément, les entreprises diversifiées au sein d'une même industrie (BM2) sont verticalement intégrées (78%), sont prestataires de services (95%), et sont de petite (70%) ou moyenne taille (27%).

Les caractéristiques des entreprises non-diversifiées (BM1) et celles des entreprises qui se sont diversifiées dans deux industries (BM3) sont diamétralement opposées. Les firmes BM1 sont verticalement intégrées (75%), orientées services (70%), et vise une segmentation large de la clientèle. Elles reposent beaucoup sur leurs partenaires (80%) et sont de petite taille (75%). A l'inverse, les entreprises BM3 n'occupent qu'un maillon de la chaîne (62%), sont plutôt manufacturières (54%), et visent un type de clients en particulier (85%). Elles n'ont pas un réseau de partenaires fort (77%) et sont de moyenne (23%) ou grande (39%) taille.

Finalement, nous avons identifié quatre trajectoires différentes des firmes dans leur performance à moyen terme. Deux facteurs expliquent ces différences : l'horizon stratégique des managers et le temps de réponse. Il est également montré que les entreprises ayant les meilleures performances avant la crise optent pour une stratégie de réduction qui a pour effet de réduire leur performance générale. Inversement, celles qui ont de moins bonnes performances au début s'engagent dans de gros investissements, sous condition de ressources, résultant en une meilleure performance. Ainsi, la différence de performance entre les firmes se réduit. En d'autres termes, on observe une homogénéisation des performances à moyen terme.

Pour terminer, nous discutons des limites de ce travail de recherche. La taille de l'échantillon et la durée de l'étude (de six ans) sont notamment discutées. Une attention particulière est également portée sur le fait que seules les entreprises survivantes sont étudiées. Autrement dit, elles ont eu les moyens et le temps pour se repositionner pour survivre ou croître. Un travail portant sur les entreprises sortantes permettrait de nuancer nos conclusions. Une autre limite d'importance est le rôle des producteurs d'électricité dans notre travail. A l'instar de nombreuses définitions de la chaîne de valeur du photovoltaïque, nous n'avons pas pris en compte la production d'électricité dans notre définition et donc dans notre analyse. Or, cette activité joue un rôle significatif dans l'évolution de la performance des entreprises et donc dans leur survie. Ainsi se posent les questions de la définition de la chaîne de valeur et de la place de cette activité dans la caractérisation des business models.

1. Context

1.1. Global value chain literature and photovoltaic value chain

Studies on value chains within the framework of Global Value Chain (GVC) revolve around two questions: the chain governor and the chain governance. Clearly, they are intertwined.

Prior studies have been attached to a specific chain governor: lead firms. These actors have the particularity of holding a lot of power to define the division of labor and the distribution of margins between their suppliers, clients, and themselves (Gereffi et al., 2001). Basically, they play the role of the orchestrator of value chains. The stage of the value chain occupied by lead firms is thus characterized by a situation of an imperfectly competitive market, i.e. high concentration of actors. It is noteworthy that these firms were confined for a long time largely to manufacturing activities, which are now outsourced, essentially to low-cost labor countries. Lead firm activities have thus moved from manufacturing activities to soft activities, including R&D and marketing (Ponte and Sturgeon, 2014, pp. 201–202; Sturgeon, 2002, 2001).

The photovoltaic (PV) upstream value chain is a case in point of the power of lead firms. It is worth starting with a description of the upstream activities. The four activities composing the upstream segment are polysilicon, wafer, cell, and module making. These technologies are distributed at the global level and are highly technical, thereby raising the barriers to entry and generating high returns. The lead firms occupy the cell manufacturing stage. They establish standards and have seized not only most of the cell market but also most of the wafer and module making stages. In other words, they have engaged in vertical integration. The population of actors is moreover highly concentrated due to high barriers to entry: ten large and multinational manufacturers account for more than 70% of the cell market. The battle for this market raged for years, as manufacturing shifted from OCDE to non-OCDE countries, especially towards Latin America and Asia, forcing European and American cell makers to give up. The winners come largely from China. The reduced cost of Chinese cells was important in the battle, but not as much as the impact of the local demand for driving the cost down.

Going back to the GVC literature, there are many topics that have received very little attention. For instance, only a handful of studies addresses the topic of value chain disaggregation i.e. vertical specialization (Beugelsdijk et al., 2009). That is unfortunate as such disaggregated value chains imply more complicated governance.

The role of politics and states in particular has also been overlooked in the GVC literature as Mayer and Phillips (2017) and Levy (2008), in particular, pointed out. Indeed, the GVC literature highlights the predominant role of lead firms, and sometimes of other less powerful actors but that nonetheless exert control over the chain from the inside of the chain (i.e. suppliers) or from the outside (e.g., institutions and regulators). Consistently, governance studies largely refer to governance by lead firms (Mayer and Phillips, 2017, p. 135).

Similarly, most of the value chains studied in the literature depict a high market concentration as the entire chain is held by a handful of powerful actors, i.e. lead firms. Lead firms have indeed operated in imperfectly competitive markets (Erickson, 1972), and as such their power is equated to that of monopolies or oligopolies (Gibbon et al., 2008, p. 14; Phillips, 2017, p. 432;435; Selwyn, 2016). As a result, governance in situations similar to perfect competition is neglected.

In short, when it comes to discussing non-concentrated and disaggregated value chains and linkages between two stages without lead firms, the studies are scarce, if not inexistent. Yet, the governance of such linkages in such value chains is of interest.

The PV downstream segment addresses these gaps. That is possible because the PV value chain is highly modular as there are many combinations possible between the upstream and downstream segments. The difference between the upstream and downstream segments is striking with regard to the chain governor and governance. The variations are also particularly glaring between the different stages in the downstream segment.

In this part of the value chain, the characteristics and governance are diametrically opposite to the situation observed upstream. In the downstream, actors are low-tech or service-based firms. Precisely, the downstream segment encompasses the following activities: systems manufacturing, balance of supply (BOS) manufacturing, project development (including PV system installation), and operation and maintenance (O&M). Considering that there is no communicating vessel between these activities, it is highly probable that the downstream part of the value chain is disaggregated. Moreover, the downstream segment is characterized by a proliferation of actors with no lead firm to govern. As such, the chain governance is market-like. It is worth noting that 75% of the gross employment in the EU-28 in 2016 was in project development, installation, and O&M (EY Global Cleantech Centre and SolarPower Europe, 2017, p. 25). Europe had more than 50,000 direct and indirect jobs in 2016 for these activities (EY Global Cleantech Centre and SolarPower Europe, 2017, p. 24). Admittedly, this figure represents only a small fraction of the situation in 2008, with its 250,000 jobs. The reason for this scramble of enterprises, and therefore of jobs, is government policies, because the governor in the downstream segment is governmental, through procurement practices and policies. Considering that regulations vary from one country to another, every Government is the governor of the downstream segment in its own country.

1.2. Government

With respect to emission reduction strategies and the willingness of countries to be less hydrocarbon-dependent, substantial sums have been invested in PV technology. Significant technological improvements can therefore be noticed. The various energy-provision processes proposed are all technically feasible. But, until recently, the limiting factor was the economics: the technology was not sufficiently cost-effective compared to the dominant electricity system (e.g., nuclear in France).

A massive policy drive was required to develop cheaper solutions to favor larger-scale industrial deployment of PV systems through public procurements by local

initiatives (e.g. the French agglomeration Perpignan Méditerranée and the Bavarian village Wildopoldried). Government policies have also contributed to the maturity of PV technologies and markets. Yet one form of government involvement that I have considered in this thesis, and that is particularly useful is government demand-focused policies. The most widespread and essential measure is the feed-in-tariff (FiT). Admittedly, there are wide institutional and policy discrepancies between countries, even between two relatively similar ones like Germany and France, but these policies have had a similar impact in terms of PV demand and number of actors over the last 15 years. Three periods were identified.

The first one started in the early 1990s with Germany. Other countries, including France, followed in the early 2000s. But at that time, efforts were unsatisfactory to offset the huge amount of investment to install a PV system and therefore to stimulate PV demand and attract new players.

From the mid-2000s to 2010, two changes occurred. First, installation costs dropped sharply. Second, several Governments including France and Germany offered more generous subsidies and other demand-driven policies (mainly feed-in-tariff, the obligation of power utilities to buy excess power from customers at relatively high prices, and tax credit). For example, in France the FiT rose from 14 cents €/kWh in 2005 to 58 cents €/kWh in 2010, whereas the PV system price dropped from 11.6 to 5.9€ cents/kW.

Such measures were consequently financially appealing, resulting in the proliferation of PV projects and actors until the end of this period. Specifically, the number of direct jobs in France rose exponentially, from 1,238 in 2006 to 24,300 in 2010 (ADEME, 2011, p. 33), as did the number of companies in the downstream segment, from 735 in 2007 to 6,074 in 2010. Most of this growth was due to the installation companies: from 630 to 6,000 (ADEME, 2011, p. 21, 2008, p. 17). They accounted for a growing share of all companies in the segment: from 86% to 97% over the period (ADEME, 2011, p. 21, 2008, p. 17). Significantly, 80-85% of installation companies had fewer than 10 employees (ADEME, 2011, p. 28), which is why this proliferation of jobs, and thereby of companies, is synonymous with a low concentration of actors. This dual proliferation, in turn, explains why there are no lead firms.

The last period started in 2010-2011. It is marked by an abrupt and unforeseen policy change. As the favorable policies during the second period turned out to be a financial burden for Governments, they decided to suspend or reduce their policies. This resulted in a turbulent period for the PV market. Such turbulence is reflected in a sizeable decrease in the number of PV installations and jobs in the industry, leading to setbacks for the PV market.

These stop-and-go policies, also called policy inconsistency (Charlier and N'Cho-Oguie, 2009, p. xviii), clearly impacted companies' business choices and survival. Downstream companies struggled financially to make up for the lost revenues due to government policies. This doctoral thesis thus focuses on firms' survival, and more

particularly on the performance evolution of survival strategies in turbulent times, which is what drove my research on strategy.

1.3. Strategy

One strategy that emerged most often from interviews with CEOs and managers at the end of the year 2014 was diversification and to a lesser extent the widening of their customer segment. Three diversifications are identified in the literature: industrial diversification, across business lines; global diversification, across multiple national markets; and vertical diversification, across stages inside a value chain (Ansoff, 1957; Boons and Lüdeke-Freund, 2013; Denis et al., 2002; Rumelt, 1974). Irrespective of the form it takes, diversification is seen as a risk-spreading strategy but does not guarantee survival nor market success (Dubofsky and Varadarajan, 1987, p. 597). Companies must draw on complementary strategies. Generalizing these preliminary results is of particular importance to be sure that they are not the exception, along with studying the performance of these strategies.

This doctoral research therefore focuses on the performance of diversification strategies. This is an age-old question, but to date no consensus has been reached on it. The reason lies in the variety of the companies' characteristics and sectors. I therefore established a common set for a better comparison of performance between the selected companies. This industry-specific manuscript contributes to the knowledge in the field of diversification performance, by analyzing the impact of turbulence on the performance of no- or low-tech, small and medium-sized companies. The empirical application uses firm-level data from the PV downstream industry in France, covering the period 2010–2015. Localization is important in the downstream segment due to the variety of national regulations.

2. Contributions

By empirically testing the hypotheses, this doctoral research offers several contributions that improve managerial and theoretical understanding of diversification performance and firms' survival capacities.

2.1. Classification of industrial diversification based on the boundaries of the PV market and energy industry

It is impractical to study in detail all the diversification strategies implemented by 70 companies to survive in turbulent times. A classification is a more advanced way of analyzing them. Considering that some activities are not unique to the PV value chain and rather transcend it, the crossings of activities across value chains have to be taken into consideration in the strategic choice of these firms. That is why I consider industrial diversification in particular.

Admittedly, there are plenty of industrial diversification classifications proposed in prior research. The most popular ones are those of Wrigley (1970) and of Rumelt (1974), both based on relatedness between business lines. Yet the relatedness notion is grounded on subjectivity and requires detailed information, especially regarding the distribution of the turnover between the various business lines. These

characteristics lead to two issues (Christensen and Montgomery, 1981; Datta et al., 1991; Park and Jang, 2013; Varadarajan and Ramanujam, 1987; Venkatraman and Grant, 1986). The first one relates to access to information. It is not a problem if a researcher studies public firms, but in the case of private-held ones these taxonomies are not viable. The second problem lies in the subjectivity of the research, which entails the difficulty of replicating the results.

Because of the difficulties associated with previous related versus unrelated diversification classifications, I proposed another taxonomy of industrial diversification that overcomes the shortcomings of prior ones. Specifically, my classification is based rather on the boundaries of the PV market and energy industry, differentiating intra-industry from inter-industry diversification. In using it, my research not only generates replicable results, but also requires limited information for this purpose. Four possibilities stem from the intersection of intra- and inter-industry diversification: (1) single-business enterprises; (2) intra-industry diversifiers; (3) inter-industry diversifiers in two industries; and (4) inter-industry diversifiers in more than two industries. The taxonomy may be applicable to almost all cross-industry products and services from bank-insurance to food, and from apparel to IT security.

2.2. A handful of business models in an industry

My findings also provide a more nuanced understanding of diversification through business models. Two proposals are of utmost importance in my rationale. The first one is that of Casadesus-Masanell and Ricart (2010), who consider that a business model is the reflection of a corporate strategy.

The second is from Teece (2010) and Baden-Fuller and Morgan (2010). They posit that there is only a handful of business models in an industry. I also drew on some components of the Business Model Canvas of Osterwalder et al. (2010). Specifically, I used the following, admittedly while adapting them: value proposition; key activities; channels; customer segmentation; key resources; and partner network. These components match with the repositioning of firms to face a crisis. The objective is to reconnect the business model concept to diversification strategy through ideal business models, and to prove both assertions (the one of Casadesus-Masanell and Ricart and the one of Teece, Baden-Fuller and Morgan) empirically.

The results show that companies undertook a repositioning to face the crisis. The repositioning could be internal to the PV value chain, (1) through different activities (vertical diversification) and (2) through new geographic territories (i.e. global diversification), and/or (3) external to the PV value chain through intra and inter-industry diversification.

Linking diversification strategy to business model also reveals some business model characteristics specific to a particular situation identified in the taxonomy of diversification strategy. I do not study the case of inter-industry diversifiers in more than two industries because the PV market represents only one limited market among a multitude of business lines. As such, the PV turbulence does not impact a company's survival.

Single-business companies deal essentially with vertical integration in services, broad customer segments, and partner networks, and are small. Inter-industry diversifiers, on the other hand, are specialized in one stage of the PV value chain, target a focused customer segment, do not have a strong partner network, and are medium-sized or large. As for intra-industry diversifiers, they are vertically integrated into services and are small. Consistently, three business models are derived from the three diversification strategies identified in the PV value chain.

It is noteworthy that, in response to the PV market turbulence, many inter-industry diversifiers disengaged from the PV market and the others stopped investing in PV for a while. The reason behind these moves was that PV was only an addition to their core activity. That is to say, their survival was not fully linked to the PV business lines.

2.3. Survival strategies and performance

Finally, I also contribute to studying the performance of survival strategies. The turnaround literature is typically interested in strategies aiming not only to stop performance decline (i.e. secure survival), but also to improve performance (Kitching et al., 2009; Robbins and Pearce II, 1992; Schoenberg et al., 2013). Yet the link between performance and survival strategies has been overlooked in the turnaround literature (Kitching et al., 2009, p. 53). This study identifies two factors impacting a firm's survival capabilities and growth performance in the middle term: (1) the business horizon focus of managers largely depending on a firm's capacity to change (cf. resources), and (2) timing of business responses. In other words, firms face two distinct dilemmas.

The first one deals with the strategy implemented during the crisis period. Prior research outlined two effective but contrasting survival strategies: retrenchment and investment strategy (Kitching et al., 2009; Robbins and Pearce II, 1992; Schoenberg et al., 2013).

At one end of the spectrum are those practicing retrenchment strategies. Simply put, managers aim for the company's survival in the short-term. These firms keep a lid on their costs and reduce, or at least adapt, their resources as the demand drops (i.e. close agencies, reduce staff, and sell non-core assets). This is consistent with the literature as retrenchment strategies can involve cost efficiencies and asset retrenchment, and focus on the firm's core activities (Schoenberg et al., 2013). It is noteworthy that retrenchment strategies are the most popular type of strategy, especially in the short run (Geroski and Gregg, 1997 in Pratten, 1998, p. 1595). The downside is that companies engaged in retrenchment strategies limit their potential gains from the PV market upturn.

At the other end of the spectrum are those pursuing investment strategies. Admittedly, investment strategies depend on resources. Here, managers consider crisis as an opportunity to invest, innovate, and diversify (Kitching et al., 2009, p. 54). They therefore bounce back by investing in the future, mainly through diversification. What is certain is that placing bets on more than one horse reduces the risk of high losses. It is worth noting that an investment that stood out in my

panel was in solar plants. Some companies such as Arkolia Energies, Apex Energies, and Urbasolar started owning solar plants or increased their solar parks, from which they sold the energy produced. This energy production activity generates recurring revenues that are valuable in a period of turbulence.

By considering the performance in itself and the growth simultaneously, I was able to observe the trajectories of the performance in relation to the starting point. My findings run counter to those of Geroski and Gregg (1997 in Pratten, 1998, p. 1595). Their book concludes with a sharp increase of performance differences between firms in the recession. The results of my study demonstrate the opposite: higher performers are more inclined to engage in retrenchment strategies that reduce their overall performance; lower performers tend to invest large amounts, resulting in a better performance. Therefore, the performance differences between firms decline over time.

The second criterion impacting the performance of firms in a period of turbulence is the timing of business responses. The literature has identified it as a key issue (Dobbs and Koller, 2009; Kitching et al., 2009, p. 36). Firms face a dilemma in their investment decision-making: the question of whether to invest now or later. The results of my study indicate that companies that invested early in the wake of the crisis increased their profitability by more than 50%, with few exceptions. Those that postponed their investment decision to a later period had a lower profitability in 2015 compared to 2010. Hence, the short-term effect of these late large investments was negative on firm performance variation. In the long term, the effect of these investments may turn positive. In short, investment strategies have produced different outcomes according to time-serial perspectives in terms of profitability growth.

3. Limitations and direction for further research

This doctoral research has several limitations.

First, the short timeframe of the study may draw criticism, as market turbulence has a long-lasting effect on business survival. I stopped my data collection in 2015, so the empirical study extended only five years after the shock occurred. That implies that I may not have enough time to observe a negative growth performance turning positive at the end of the study period. Hence, a longer time period could lead to a different set of results.

Second, it is an exploratory study. As such, it does not provide any statistical robustness. Further studies would therefore be needed to replicate the findings of this doctoral research, with a possibly larger sample in this industry. The smallness of the sample is therefore also a limit to the study.

Third, the study focuses on a specific industry. Further research could involve other industry-specific analyses to ensure the generalizability of the results, which could then indicate the extent to which my findings are applicable to other (turbulent)

sectors. The results merit being replicated, not only to other no-or-low-tech industries, but also to high-tech ones (e.g., bank-insurance, food, apparel, IT security).

Considering that the study consists largely of small and medium-sized enterprises (SMEs), caution should moreover be exercised when drawing conclusions. This population mainly differs from larger counterparts on two points. First, SMEs are more vulnerable to a turbulent environment. Second, they have more limited resources (finance, skills and, network), which undoubtedly influences their strategic behavior. In other words, there is a firm-size effect.

I also draw the reader's attention to the survivor bias of this doctoral research, along with other studies from the literature of strategy and turnaround. As I only studied the strategies of surviving firms, the findings on non-surviving firms may differ from those of this manuscript.

Finally, I admit another limit: I did not take into consideration the energy production in the definition of the PV value chain and in the analysis of the business models. Indeed, I opted for the most well-known definition of the value chain. The PV value chain is usually defined as the sum of the activities leading to the production of electricity and the supporting activities, excluding the production of electricity itself. Yet, Chapter 7 has proved the importance of this activity in the survival capacities of companies in a context of turbulence. This conclusion raises the question of the frontiers of a value chain and their evolution in the context of turbulence.

These issues provide important avenues for future research.

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Abbreviations and acronyms

AC	Alternating-current
a-Si	Amorphous Silicon
BIPV	Building-integrated PV systems
CdTe	Cadmium Telluride
CPV	Concentrating Photovoltaics
CSP	Concentrating Solar Power
CIS	Copper-Indium-Diselenide
CIGS	Copper-Indium-Gallium-Diselenide
c-Si	Crystalline Silicon
EPIA	European Photovoltaic Industry Association
EU	European Union
FiT	Feed-in Tariff
GW	Gigawatt
HV	High Voltage
kW	Kilowatt
kWh	Kilowatt hour
LCOE	Levelised Cost of Electricity
MW	Megawatt
PV	Photovoltaic
RES	Renewable Energy Sources
R&D	Research and Development
ROA	Return on Asset
ROS	Return on Sales
SGR	Sales growth
U.S.	United States of America
W	Watt

Annexes

		Market barriers	Financial barriers	Technical barriers	Quality	Standards
Upstream	Silicon	High due to long-term contracts with existing suppliers; market shares with semi-conductor industry	Highly Capital-intensive	Complex manufacturing line, not as turnkey available;	High level of purity	Medium for quality from 7N to 11N
	Ingots Wafer	Low	High			High
	Cell Manuf.	High due to low PV cell prices	High capital costs of building PV cell manufacturing units and for manufacturing equipment.	High; Complex manufacturing line, Technical skills, Improvements and R&D	Own cell concepts for differentiation and higher efficiencies than turnkey concepts	Medium: efficiency and shape can vary widely.
	Module Assembly	Low as don't involve any technologically complex or capital-intensive processes; competition with further integrated module manufacturers and with global players.	Increasing investment cost for automated processes equipment, Investment into training of the workforce	Low as it has to be synchronized with cell design, Low technical skills required for assembling, Trend to higher automated processes	Long-term stability of assembly, Testing and qualification for stability and long-term output,	Synchronized with cell design,

		Market barriers	Financial barriers	Technical barriers	Quality	Standards
Downstream	BOS components	Large demand required to build a production line	Medium investment cost in manufacturing and equipment and quality inspection site	Highly skilled professionals needed for the development and quality management	Correct functioning to prevent grid instabilities or shutdowns	Standard equipment; Standard quality of electrical works
	System Manuf.		Medium investment cost in manufacturing and equipment	Highly skilled professionals	Highly variable	Low
	Project development	Low	Low: Investment into training of workforce; Low investment cost for the Development; High financial risk during execution	Special training and qualification necessary; Highly skilled professionals with university degrees	Quality and time management of total project has to be done	Low
	O&M	Low	Low	Skilled professionals		Low
Annex 2.1.: Entry barriers in the photovoltaic industry <i>Source: Author</i>						

		Barriers to entry	Geography	Number of actors	Standardization level	Customer specifications level	Market concentration	Governance type
Upstream	Silicon		International	79		Standardization		Price
	Ingots Wafer		International	150		Standardization		
	Cell Manufacturing		International	66		Standardization		Price
	Module Assembly		Can be local			Standardization		Lead firms
Downstream	BOS components		Can be local					
	System Manufacturing		Can be local					
	Project development		Local					
	O&M		Local					
Annex 2.2: Competition overview of the photovoltaic industry <i>Source: Compiled by the author from Weber (2015), Sontakke (2015), and interviews.</i>								

Observation	k-means Class	AHC Class
8.2 France	1	1
Adiwatt	2	2
Albioma	3	3
ALTUS ENERGY	4	1
APEX ENERGIES	5	3
Arkolia Energies	6	1
Axdis	4	1
BELECTRIC France	5	3
Cardonnel Ingénierie	7	1
CLIPSOL	8	4
COBA Energies Renouvelables	8	4
Compagnie Nationale du Rhone	9	4
Cythelia Energy	10	2
Easy Confort	11	4
ECO DELTA	12	4
EDF en services	1	1
Emeraude Solaire	13	2
Eneco France	1	1
Enercoop SCIC SA	2	2
Engie Green France	14	1
éolane Solar	15	3
EOLE RES	1	1
ETERNIT	10	2
EXOSUN SAS	1	1
FONROCHE Solaire	16	4
FRANCE WATTS	8	4
Fronius France	8	4
GAGNEPARK	17	1
GenSun	18	2
GISOLAIRE	2	2
Global ecopower	19	1
Greensolver	13	2
HYSEO Energies Renouvelables	20	4
IMERYS TC	21	3
Innovation energie developpement (IED)	21	3
Jura Energie Solaire	22	3
KILOWATTSOL	23	3
KRANNICH SOLAR France SAS	20	4
Langa	24	2
LARIVIERE	21	3
Mecojit	25	4
Methode carré	2	2
MITJAVILA SAS	21	3
Nass&wind sas	15	3
Neoen	4	1
Omnisolis	20	4
ROSAZ ENERGIES	8	4
SCNASOLAR	26	4
SETA Energies	25	4
SMA FRANCE SAS	27	3
SMAC	8	4
SNEF	9	4
SOLAIREDIRECT SAS	11	4
SOLARDIS	28	4
Solewa	5	3

Solvéo Energie	24	2
SunPower France SAS	22	3
Tecsol	15	3
Terre Solaire	13	2
TERREAL SOLAIRE	22	3
Transénergie	11	4
Uniper France Energy Solutions	2	2
UNIT e (unit energy)	22	3
URBASOLAR	29	1
Valeco	22	3
VALOREM	27	3
Vents d'Oc energies renouvelables	10	2
VOL-V Solar SAS	30	1
VOLTALIA	24	2
VSB Energies nouvelles	4	1
Annex 7.1.: Classification of companies		
<i>Source: Author</i>		

