Photovoltaics from a business perspective past, present, and future in Germany

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Abstract

Solar energy plays a vital role in the transition to a greener global energy supply. As a decentralized energy source, the expansion of solar energy is not driven by energy suppliers and government as in traditional energy sources but is proliferating through the market through a variety of business propositions. Germany has, for a long time, been a pioneer in the field of solar. The country was the world leader in photovoltaics 10 years ago and continues to maintain a prominent position in this field. This master thesis seeks to investigate the most prominent business models operating in the German photovoltaics market. German photovoltaics companies are utilized as case study objects.

The research methodology adopts an exploratory approach, investigating a less known, less researched, and very dynamic market. Based on German legislation for renewable energy (EEG) as well as the photovoltaics technology itself, six business categories are proposed, consisting of three size segments and two ownership segments. Online research is conducted to map the German market, thus investigating the companies actively participating there. 122 relevant photovoltaic companies have been identified. Of those, 47 companies are deemed to be usable for further investigation. Based on carefully considered selection criteria, two case study objects per proposed business category were selected, resulting in 12 selected case study objects. The case study objects serve as representatives for their respective category and their business models are mapped on the Business Model Canvas (BMC), developed by Alexander Osterwalder. By this mapping, their business models are captured and the underlaying value propositions are made visible. Some notable companies mapped and analyzed in this report were Enpal B.V., 1komma5 Grad GmbH, and Enerparc AG, each with distinct strategies for how to conduct their business, targeting different segments in the German photovoltaics market.

The analysis includes a Master-BMC, which represents a collection of the 12 individual BMC mappings. The Mater-BMC gives an indication of more and less common occurrences within the business structure of photovoltaic companies. The attributes are discussed, with the companies serving as examples. Current trends in the photovoltaics market are highlighted, a prognosis for the future based on theory on technology adaptation is included, and where the technology is today is explained.

Finally, the research questions are answered, the prominent business models in the German PV market are identified, and the pros and cons are discussed.

This thesis serves as an introduction to the photovoltaics business world, accessible to both those with and without prior industry knowledge.

Keywords: *Business Model Canvas, Alexander Osterwalder, Business Model, Photovoltaics, Germany, Erneuerbare-Energien-Gesetz, Solar, Case Study, Enpal B.V, 1komma5 Grad GmbH, Energiekonzepte Deutschland GmbH, Enerparc AG, Belectric GmbH, renewable energy, EEG, Greenovative GmbH, 1komma5° GmbH, Wegatech Greenergy GmbH, DZ-4 GmbH, Sunlife-Montage GmbH, Vario green energy Concept GmbH, Vispiron EPC GmbH & Co. KG, Pfalzsolar GmbH*

Preface

This master thesis was my final project of my Master of Science in Mechanical Engineering, at the division of production management. The thesis covers one semester of 30 ECTS and is the final part of an engineering program of 300 ECTS.

I started this program back in 2012 and should have graduated in 2017. I had a break from 2016-2022, wherein I worked, as an entrepreneur in Berlin. I originally came to Berlin through Erasmus, in the first semester of my master's degree, in 2015. Following this semester, I founded an e-commerce business, a fun and interesting, but also challenging experience, which made me stay in the country. A few years later, COVID-19 happened, and working remotely became easier, including for my university coursework. The idea of finishing my master's started to grow on me since it seemed more likely to be able to do this at a distance as I did not want to move back to Sweden, giving up my entrepreneurial ventures in Germany.

I ended up starting my studies again at the beginning of 2022, having still 60 ECTS of courses to finish, as well as the thesis. On the professional side, I started venturing into the German PV industry, working with sales of PV systems and project rights acquisition for solar companies. In addition to this, I was still operating my online e-commerce business, as well as starting up an NFT collection in the crypto-hype of that year. Adding my studies to all of this ended up being quite challenging workwise. I was working 70-hour weeks, Monday through Sunday. As this chapter of my life is slowly coming to an end, I am happy to get back to a more conventional life and work schedule. During these 1,5 years, I have managed to sell my online business, sell out two editions of our NFT collection, and vastly expanded my own PV knowledge thanks to this thesis. And as of now, , I can write "M.Sc." on my business cards.

The information provided in this report can help anyone to get a better understanding of the German PV industry. Since most of the information is retrieved from German sources, the research may be of particular interest for English speakers, since the perspective from within German is rarely offered to that demographic.

My supervisor on this thesis was Ola Alexanderson. Ola has given solid guidance and support throughout this work. Ola, your guidance has been very helpful in always providing me with a clear structure on how to

undertake this research. Our brainstorming sessions were always rewarding and interesting. You have great knowledge of business and innovation, thus always providing me with new angles and perspectives for my research. You have also had a lot of patience with my working style, which can be sporadic and unconventional. For that, I am very happy with you as my supervisor.

I would also like to pass appreciation to my father, who motivated me to close this chapter of my life. It ended up being a very interesting journey.

Berlin, September 2023

Love Per Sven Ossler

Executive summary

Title: Photovoltaics from a business perspective – past, present and future in Germany

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Background: In the transitioning of the world to renewable energies, solar energy, and photovoltaics technology is an important aspect. Compared to the old fashioned and centralized way of producing energy, photovoltaic is a decentralized initiative, being driven mainly through the market. Germany has a long standing, strong position in the global PV industry. Because of this, they have one of the most highly developed photovoltaic markets as of today. Given its relative maturity, the German PV market is an interesting as geographical focus. The innovative businesses active here may have knowledge to share with the global community, which is why this thesis sets out to investigate those types of businesses.

Purpose: The primary objective of this report is to provide comprehensive insights into the current PV market in Germany. This study involves mapping market actors, classifying their business models, and evaluating the prominent business models that are active in the PV industry today. By doing so, this work seeks to enhance the understanding of the PV industry in Germany as a prominent market in the industry and share this knowledge with the global, English-speaking, community.

Research questions: RQ1. What major business models are available in the German PV market today?

RQ2. How have these business models developed historically?

RQ3. What are the pros and cons of these business models and what target groups do they serve?

RQ4. What business models can we expect to see more of in the future?

Method: The research method utilized in this paper was an exploratory, mixed methods approach. The mixed methods approach consisted of a mostly qualitative approach, combined with some quantitative elements.

Delimitations: This project was limited to the German photovoltaics market.

Storage solutions (batteries) are largely excluded from the analysis.

This report focuses on companies at the end of the value chain, excluding for example component manufacturers.

Niche business models are excluded in this report.

The research of this report is done online, excluding any company without an online presence.

Conclusions: Twelve case study objects, German companies, were identified, two for each proposed business category. Their business models were mapped by the Business Model Canvas by Alexander Osterwalder, to capture their value proposition. Based on these results, some conclusions were made per business category, and this served as a foundation for the analysis, as well as answering the research questions. Four prominent business models were found, and two were considered less prominent. Furthermore, the market is very dynamic and changing fast, as such, there are major changes expected in the business categories within the coming years.

Keywords: *Business Model Canvas, Alexander Osterwalder, Business Model, Photovoltaics, Germany, Erneuerbare-Energien-Gesetz, Solar, Case Study,*

Enpal B.V, 1komma5 Grad GmbH, Energiekonzepte Deutschland GmbH, Enerparc AG, Belectric GmbH, renewable energy, EEG, Greenovative GmbH, 1komma5° GmbH, Wegatech Greenergy GmbH, DZ-4 GmbH, Sunlife-Montage GmbH, Vario green energy Concept GmbH, Vispiron EPC GmbH & Co. KG, Pfalzsolar GmbH

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Abbreviations and definitions

B2B	Business to Business
B2C	Business to Consumer
BMC	Business Model Canvas
	The Business Model Canvas by Alexander Osterwalder, is a visual framework that outlines and describes a business's key components and how they interact.
BM	Business Model
BoS	Balance of System
	The term “Balance of System” is used in photovoltaics, to describe all additional components of a PV system, besides the PV modules. BoS includes components such as wiring and the mounting system.
Bundesnetzagentur	Federal Network Agency of Germany
COP Factor	Coefficient of Performance Factor
	A measure of a heat pump's energy efficiency is calculated as the ratio of the heat output produced by the heat pump to the energy input, typically in the form of electricity. A higher COP indicates a more energy-efficient heat pump, as it delivers more heating or cooling per unit of energy consumed.
CPA	Capacity Purchase Agreement
	A capacity purchase agreement in relationship to solar energy is a way of offering battery storage capacity for rent.
CSS	Category Specificity Score
	The Category Specificity Score was used in the research to measure how narrowly focused

	a business was in a particular category. For example, if a company was active only in Category 1, CSS would equal 1. If a company was active in categories 2, 3, and 5, CSS would be 3.
C&I	Commercial and Industrial
EEG	Erneuerbare-Energie-Gesetz
	EEG stands for "Erneuerbare-Energien-Gesetz," which translates to "Renewable Energy Sources Act" in English. The EEG is a German law that supports the development and expansion of renewable energy sources, such as wind, solar, and biomass. It provides a framework for feed-in tariffs and incentives to promote the generation of renewable energy and reduce greenhouse gas emissions. The EEG has served as a model for renewable energy policy in various countries, aiming to transition to more sustainable energy sources and reduce reliance on fossil fuels.
EEG revenue	The revenue generated by selling electricity to the EEG-feed-in tariffs.
EPC	Engineering, Procurement, and Construction
	This term is widely used in the PV-business in regard to the project development and construction of solar parcs but is also important for larger rooftop systems.
EoS	Economies of Scale
EPBT	Energy Payback Time
	Energy Payback Time refers to the amount of time it takes for a renewable energy system to pay back for the emissions generated in the production process.

Floating PV	Floating Photovoltaics System Floating PV is a water mounted PV system, i.e. with a floating mounting structure.
Ingot	An ingot refers to a large, solid block of crystalline material (typically silicone) that is used in the production of photovoltaic cells, serving as the material base of the wafers later used in the PV modules.
GWp	Gigawattpeak See kWp.
Markstammdatenregister	The Marktstammdatenregister is a public register of the German electricity and gas market, published by the Bundesnetzagentur. Every PV system connected to the electricity grid can be found in this register.
MWp	Megawattpeak See kWp.
OEM	Original Equipment Manufacturer The term OEM refers to a company that produces components or products for another company. The other company often uses the products as its own and rebrands them under its own name.
O&M	Operations & Management Operations and management describes the operation and maintenance of a PV system. O&M can include services such as cleaning repairs, performance monitoring, and guarantee handling.
PLC	Product Life Cycle (Theory)
kWp	Kilowattpeak

	kWp (kilowatt peak) is a unit of measurement representing the peak power output of a PV-module under optimal, laboratory conditions. 1 kWp solar PV-modules would generate 1 kW of electricity under ideal conditions, but this is rarely the case.
PV	Photovoltaics
PV-module	Photovoltaics module
	The solar panel, the most foundational element in a PV system, converts sunlight into electricity.
PV turnkey system	Photovoltaics turnkey system
	A PV turnkey system is a complete and ready-to-use solar energy system. The phrase turnkey comes from the idea of turning the key to start a car – i.e., the system is ready to go, by the turn of the key.
PPA	Power Purchase Agreement
	A power purchase agreement is an electricity contract wherein a party agrees to buy electricity from a solar energy provider at a predetermined rate over a predetermined period.
Project development	Project development in photovoltaics is the necessary qualification needed before a PV system can be built. Project development is necessary for solar parcs and for larger PV-rooftop systems, but less necessary for PV systems pertaining to normal households. Project development usually includes network compatibility tests, structural engineering for buildings (PV rooftop systems), and approvals from local residents (solar parcs).

Representative companies	The business category representative companies studied in this report are used interchangeably with case study objects.
RoI	Return of Investment
W	Watt
Wafer	A wafer refers to a thin, flat, and usually circular slice of material that is cut from an ingot of crystalline material, typically silicon. These wafers serve as the substrate on which solar cells are fabricated

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1. Introduction

This chapter provides an introduction and addresses the current research gap. It begins by presenting the purpose of the study. Subsequently, it outlines the study's scope and delimitations. Finally, it introduces the four research questions that form the foundation of this report.

1.1 Background

In 2022, Europe experienced a period of shortage in energy, resulting in stark price increases in energy. This was reflected in the high inflation, with an EU average of 10,4% in December 2022, up from 5,3% just a year earlier (Eurostat, 18.1.23). Many households in Germany and other EU countries were struggling to pay their electricity bills. In February 2023 the average electricity price for a 3500 kWh household was 48,12 ct. / kWh, a 50% increase from the 2021 average price of average 32,16 ct. / kWh (BDEW, 02.23). This energy crisis began due to sanctions on Russian gas following the Russian invasion of Ukraine. Germany was particularly dependent on Russian gas. 52% of their gas needs were covered by Russia in 2021, and decreased to 22% in 2022 (Reuters, 2023), thus having dramatic effects on the energy supply. Surging prices and unreliability in the political sphere led people to search for reliable energy supply alternatives. A reliable, accessible, and economical alternative for most people was photovoltaic systems, and an explosion in demand followed.

The solar energy industry is currently experiencing a significant boom, but this expansion has been underway for many years. In 2021, the global-installed solar capacity reached an impressive 940 GW, a remarkable increase from 70 GW in 2011 (SolarPower Europe, 2022), marking a 1200% growth over the past decade. This expansion is driven by declining prices and a global commitment to reducing reliance on fossil fuels.

Solar energy has emerged as one of the most cost-effective energy sources today. A 2021 analysis estimated the electricity generation cost for PV systems in Germany to be in the range of 3.12-11.01 cents per kWh (Fraunhofer ISE, 2021). Compared to the average electricity price of 32.16 cents per kWh in the same year (BDEW, February 2023), it's evident that PV is financially appealing, accounting for only 10% to 34% of the average electricity price. As technology becomes more affordable, the industry is shifting from being subsidy-dependent to market-driven.

In addition to its financial advantages, it is well known that solar energy offers significant environmental benefits. This is evident in the Energy Payback Time (EPBT) of a PV system, which is approximately 1.3 years in Germany (Fraunhofer ISE, 2022). In other words, a PV system needs just 1.3 years of operation to offset the carbon emissions produced during its manufacture. Considering that a PV system typically lasts over 20 years, the EPBT is paid back many times over, which is why PV is considered a clean energy source. The European Union has set an ambitious goal to become a climate-neutral continent by 2050 (European Commission, 2022), and solar energy plays a pivotal role in achieving this sustainable future.

Solar energy is a decentralized energy source and comes in varying types. In Germany (2021) around 40 % of the installed power relates to PV systems under 30 kWp (Fraunhofer ISE, 2022), which corresponds to household buildings, whereas 30% of the installed capacity comes from land mounted systems over 1 GWp. The PV market is diverse. Therefore, a variety of companies have developed, operating in different segments with different needs. As the industry progresses towards being more market driven, businesses play a crucial role in the furthering of PV and the transition towards a sustainable world. This thesis aims to investigate the prominent company types active in today's PV market.

There will be a geographical focus on Germany. Germany was, in 2010, the largest producer of solar energy electricity in the world, and continues to hold a strong position with the second highest installed PV capacity per capita in the EU as of 2023 (EurObserv'ER 2023). Germany's PV market is one of the most developed in the world. The businesses active here are of particular interest, due to the long history and high level of competition.

Regarding the research gap, there is limited access for an international audience to the German market due to the language barrier. This thesis aims to spread the knowledge from the German market to an international audience. Although research has been made on the topic of business models in the solar energy industry, no work has done a detailed classification of real-world business models. In recent years, when the market underwent several changes, a lot of new actors have come into existence. This thesis will give a recent, updated view of PV from a business perspective.

1.2 Purpose

The primary objective of this report is to provide comprehensive insights into the current PV market in Germany. This study involves explaining the context of today's PV, mapping market actors in the German market, classifying their business models, and identifying prominent business models. By doing so, this work seeks to enhance the understanding of the PV industry from a business perspective. This thesis should lay the foundation for further research of businesses within the PV industry

1.3 Delimitations

- **Geographical focus.** The German photovoltaics market will be in focus. Only German companies will be used as case study objects. The geographical focus was chosen because such PV companies are mostly acting on a national level, thus one country's market had to be chosen. The German market was deemed a good representative, as it is fairly mature.
- **Technology focus.** The PV modules will be in focus when considering the technology, not other components. PV modules have been the dominant factor when considering the progress of PV, thus, this focus was deemed reasonable.
- **Storage solutions are largely excluded from the analysis.** Batteries and storage are a very important part of the expansion of PV. However, this technology will not be the focal point of attention for this work. Excluding batteries makes different sized PV systems more comparable, e.g., batteries are standard small PV systems for households, whereas, for larger PV systems, storage solutions are rarer. Storage solutions were mainly excluded to keep the complexity of this thesis reasonable.
- **Value chain focus.** This thesis focuses on business models at the end of the value chain, being in direct contact with the end customers. These companies are usually service-oriented, providing some type of general contractor service for the installation of PV systems. Going back to the value chain of a photovoltaics business there are distribution centers, manufacturers of components, software service providers, and more. The business types further back in the value chain will not be considered here. This focus was chosen since these companies are spreading PV technology on a

practical basis. Furthermore, they tend to be also acting locally, suiting the geographical focus.

- **Online research.** The market research is conducted online, thus companies without online presence were excluded. Offline research would not be realistic for the scope of this work.
- **Prominent BMs only.** Only larger BMs will be included in this report. Thus, small and niche business models were excluded. Only prominent BMs are considered since only these indicate successful BMs.
- **Core business of PV.** This thesis is mainly focusing on "PV-at-the-core". Companies offering PV as an add-on e.g., general energy suppliers, or online brokers, are not considered here, since it is not possible to evaluate their business success from a PV focus.

1.4 Research questions

- *RQ1. What major business models are available in the German PV market today?*
- *RQ2. How have these business models developed historically?*
- *RQ3. What are the pros and cons of these business models and what target groups do they serve?*
- *RQ4. What business models can we expect to see more of in the future?*

2. Method

This chapter presents the utilized research approach in this thesis. Furthermore, the data collection and data analysis methods are presented. Finally, a section regarding the reliability of the data is presented.

2.1 Research approach

This thesis employs an exploratory, mixed methods approach to comprehensively investigate and analyze the business active in the German PV market. This approach was chosen for its ability to offer a nuanced understanding of the subject and provide insight for future research.

2.1.1 Exploratory research

Exploratory research is conducted to get a general understanding of a topic. Based on the chosen subject matter, there were many unknown factors. In such a case, a conventional research method can be insufficient to answer the research questions (Höst et al. 2006). For the research questions in this thesis, there was no reliable framework for classifying PV BMs available. Furthermore, the German PV market was not mapped, and there was no broad understanding of those BMs available. Thus, exploratory research was used to investigate these factors, draw conclusions, and then, based on those conclusions, progress to answer the RQs.

2.1.2 Mixed methods approach

Besides exploratory research, a mixed methods approach was utilized based on the data found. This approach is a combination of a quantitative and qualitative approach (Denscombe, M 2010, p.138). The mixed methods research approach is suitable for issues addressing complex problems that require a more complete understanding of a problem, and where the data produced by the different methods can be complementary (Denscombe, M 2010, p. 141). To answer the research questions, both micro- and macro-economic factors had to be considered, thus both types of data were helpful. The method can be used for improved accuracy, getting a more complete picture, compensating strengths, and weaknesses, developing the analysis and as being an aid to sampling. (Denscombe, M 2010, p. 139).

Quantitative data takes the form of numbers and can be associated with research methods such as questionnaires or observations (Denscombe, M 2010, p. 242). A quantitative research approach was used for collecting and analyzing numerical data to understand patterns and behaviors on a wider level, for example, adoption rates and pricing of PV technology, which can imply the success of PV companies. The quantitative research approach was used to get a grasp of the wider German photovoltaics market, which helped to answer RQ1 by offering an understanding of the demand for different types of PV systems.

The qualitative study typically employs verbal or visual data and is often associated with research approaches like case studies or grounded theory, as well as research methods such as observations or interviews (Denscombe, 2010, p. 273). In the context of photovoltaics, qualitative data played a pivotal role in addressing all research questions, particularly in examining factors like legislation. For the investigation of BMs, real German companies were chosen as case study subjects to derive insights into how they operate.

Case study

Case studies are part of qualitative research, focusing on one or a few instances of a particular phenomenon to provide an in-depth account of events, relationships, experiences, or processes occurring in that particular instance (Denscombe, M 2010, p. 52). A case study works best "[…] when the researcher wants to investigate an issue in-depth and provide an explanation that can cope with the complexity and subtlety of real-life situations" (Denscombe, M 2010, p. 55). Since only scarce academic data is available on the topic of BMs in the PV industry, a case study of real companies was deemed reasonable for investigating the prominent BMs of RQ1 and RQ3.

The selection of the case study objects is very important since it will affect the research results. To this matter, Denscombe provides a method of selection. The selection should be done based on specific, significant attributes found in the case – attributes that are particularly significant in terms of the part practical problem (Denscombe, M 2010, p. 57). The selection process is described in 5.3.3 and is based on a financial metric, indicating a strong BM, as well as a metric based on how narrowly focused

the companies were, indicating a clearly targeted BM. Those attributes were deemed significant as selection metrics for the case study objects.

2.1.3 Alternative research methods

Besides the aforementioned research approaches, some alternative research approaches were considered, e.g., the inductive, deductive, or abductive research approach. A deductive approach is a more formal testing of a hypothesis, in reference to an existing theory. The inductive approach seeks to develop and explore data during the research and generate hypothesis as the research goes on. An abductive approach is a combination of an inductive and abductive approach (Hammond et al. 2020). However, the chosen research approach was deemed sufficient for the research questions.

2.2 Data collection

Denscombe (Denscombe, M 2010) mentions four types of data collection methods: interviews, documents, observations, and questionnaires. Documents were the main data type collected in this thesis. Denscombe mentioned that one of the primary attractions of using documents is their accessibility. Up-to-date, recent and a broad range of data was needed for this thesis, and thus, accessibility played a vital role. Some relevant sources of document data for this thesis are (Denscombe, M 2010):

1. **Government publications and official statistics.** These were mainly collected for capturing market statistics, as well as for triangulation of data that were possible to cross check (e.g., financial numbers or registration dates).
2. **Newspapers and magazines.** This data type was used for qualitative data collection about the case study objects when such information was available.
3. **Website pages and the Internet.** Company webpages were the main sources of company specific information regarding the case study objects. Oftentimes, this was the only data source available.

Another relevant data source of interest is interviews. Although several attempts of contact with the case study objects were made, those attempts remained fruitless and no interview was hosted.

Denscombe (Denscombe, M 2010 p.222) mentioned that documentary data shall be evaluated on the four criteria of authenticity, representativeness, meaning, and credibility.

- **Government publications and official statistics** were checked for authenticity by verifying the publisher. Credibility of the German state data was assumed to be high when the publisher was an institution of the German state.
- **Newspapers and magazines** were controlled for authenticity by verifying the publisher. The type and history of the publisher would increase or decrease credibility. Newspapers such as the widely renowned Handelsblatt, a German newspaper that has existed since 1946, were assumed to have high credibility. Newer and less known publishers were deemed to have lower credibility.
- **Website pages and the Internet** have a generally low credibility. The type of publisher would increase or decrease credibility, with larger, more well-known publishers being deemed as having higher credibility. To the extent possible, data was triangulated with other sources. e.g., official company data in the imprint were cross-checked with official government data. Public company data are made available by Bundesanzeiger, the Federal Gazette, which is an official publication and publication organ of Germany, including registration dates and total asset balance information. It should be noted that for some lesser known companies, only scarce information was available.

2.2.1 Literature

According to Denscombe (Denscombe, M 2010 p. 200), a literature should be conducted, so that the researcher finds out what is worthy of inclusion and gives those things priority. The item for inclusions must be limited to the most significant and most relevant results. Previous research can indicate what is worth the focus of attention. According to Höst (Höst et al. 2006), the literature review shall be an iterative process, where the researcher keeps on going back to the literature as the research continues.

Regarding literature on the topics of this report, databases such as LUBsearch and Google Scholar were used to find public- and peer-reviewed information on the topics of business models, the photovoltaics industry,

and photovoltaics technology. Keywords like “photovoltaics”, “business model theory”, “business model canvas”, “photovoltaics business models”, “solar energy”, and “German photovoltaics market” were utilized. These terms were used in both English and German.

Due to the contemporary nature of the research questions, more recent literature on these topics, especially literature published within the last five years, was given predominance. Geographically relevant literature was preferred since the market context was then assumed to be more similar to the context in this report.

2.2.2 Online research

Online research was the main data collection method utilized for information about the case study objects. Some information was publicly available, including companies’ founding dates, PV systems connected to the electricity grid (including system size, location, commissioning date, type of system) and asset balances. Besides that, there was little to no aggregated market data available in regards to the German market. Google was used to map the market, since most companies active were assumed to also be searchable there. Find out more about the conducted online search method in 5.3.1.

2.3 Analysis

According to Denscombe (Denscombe, M 2010, p. 235), the purpose of the analysis is either to describe, explain, or interpret something. A description can serve as an analysis for further research or serve as research in its own right. In this thesis, the work has primarily been descriptive, by describing prominent business models active in the German PV market. This should serve as a descriptive starting point for further research in the matter of PV BMs.

Denscombe mentions (Denscombe, M 2010, p. 237) two approaches to analysis: quantitative analysis by using numbers and qualitative analysis by using words. This thesis utilized quantitative elements for the market overview, for the selection of case study objects and for comparison between companies. The analysis, as well as the answers to the research questions, were qualitative.

2.3.1 Qualitative analysis

Denscombe (Denscombe, M 2010, p. 273) mentions one of the hallmarks of qualitative analysis is that the analysis is iterative, an evolving process over time. It is seen as inductive, working from particular to the general. In this thesis, the analysis progressed over time, building on the findings. The BM analyses, based on individual companies and extrapolated out to general BMs, is an inductive procedure. Some of the advantages of qualitative analysis are the richness and details of the data (Denscombe, M 2010, p. 304). The richness of data is beneficial for serving as a foundation for further research, as in this report.

Some disadvantages noted by Denscombe are that the data may be less representative, which may be the case if the case study objects are not selected well. There is a risk that the interpretation is bound up with the researcher himself, called self-bias, (Denscombe, M 2010), thus generating wrongful results. The selection process of the case study objects is carefully documented in this report, thus the reader can make his own assessment of whether the data is reliable enough for its purpose. As for the self-bias, this could be viewed as positive since the researcher has some personal experience with the PV industry in Germany, thus being able to filter data more selectively.

2.4 Work process

The work process of qualitative data analysis means moving from theory to hypothesizing and concepts. Out of hypothesis and concepts, categories are created, which can then be controlled by the qualitative data (Denscombe, M 2010, p. 287). In this thesis, the business categories, later used for selecting the case study objects, were created by a mixture of concepts available in literature and hypotheses around the German market, based on legislation and technology. These categories were then researched to generate case study objects that could support or disapprove of this categorization.

2.5 Reliability of data

The reliability of the results in this thesis depends on the quality of the online research performed, the selection of case study subjects, and the credibility of company data that was used as the foundation for further

analysis. The online research involved using various keywords selected based on their popularity and relevance. Multiple searches were conducted to achieve data saturation.

The selection of case study subjects relied on officially available data, ensuring a reliable selection process.

To verify the credibility of company information, a triangulation approach was employed. This involved cross-referencing information from company websites with official records, newspaper articles, and other deemed reliable sources. In cases of significant discrepancies, the data was omitted from the analysis.

Some assumptions were necessary due to limited available information about the case study subjects. Consequently, certain company details may be inaccurately represented. These results are therefore descriptive and serve as a starting point for further research, where additional information can be obtained.

3. Theory

The theory chapter will present the research topic's relevant theories. The three main domains of theories are business model theory, market development theory, and technology development theory.

3.1 Business models

To answer the research questions regarding prominent business models, a definition and classification framework of business models was needed. One definition of a business model is "[…] business model refers to a company's plan for making a profit" (Kopp, C.M. 25.3.23). In the same article, the value proposition is mentioned as a central pillar in every business model. A business model classification framework can be used to capture this value proposition. Alexander Osterwalder and co-authors (Osterwalder et. al, 2010) define a business model in the following way: "A business model describes the rationale of how an organization creates, delivers, and captures value." Alexander Osterwalder offers one such framework of classification, the visual tool "Business Model Canvas" (BMC). The BMC was created by Alexander Osterwalder in this work "What is a business model?" from 2005. (Jovana Sibalija et al., 2021) The tool was originally thought of as a way for businesses to understand their own BM, meanwhile it is a widely known framework used also in academia (Osterwalder, Pigneur and Tucci, 2005).

3.1.1 Business Model Canvas

The BMC is made up of nine different segments, together capturing the way a business is creating its value. Here is a brief description of these segments (Osterwalder et al. 2010):

1. **Revenue streams.** Revenue streams result from the value proposition being delivered to the customer.
2. **Customer segments.** Focuses on what groups of customers the company is tending to. It may be one or several segments of customers.
3. **Channels**. The company delivers it's value proposition over different channels.

4. **Customer relationships.** This segment describes the relationships that are formed between the company and each specific customer.
5. **Value propositions.** This block describes what customer needs are satisfied by what the company is offering.
6. **Key activities.** The key activities are the most important activities, that are essential for a company for their business model to work.
7. **Key partnerships.** Key partnerships are partnerships that are essential for the business model to function. These can be partnerships taking care of essential tasks that have been outsourced.
8. **Key resources.** Key resources are the assets required to deliver the value proposition.
9. **Cost structure.** The segment will result in a cost structure for the company. It can be distinguished between two broad classes of cost structures. A "cost-driven" cost structure is used by a business focusing on minimizing cost wherever possible. On the other hand, a value-driven cost structure is focused more on value creation and tailoring to customers' needs.

The Business Model Canvas name derives from the fact that the BMC is a visual tool. See Figure 1 for a visual representation of the BMC, with some example entries (Osterwalder et al. 2010) in each segment.

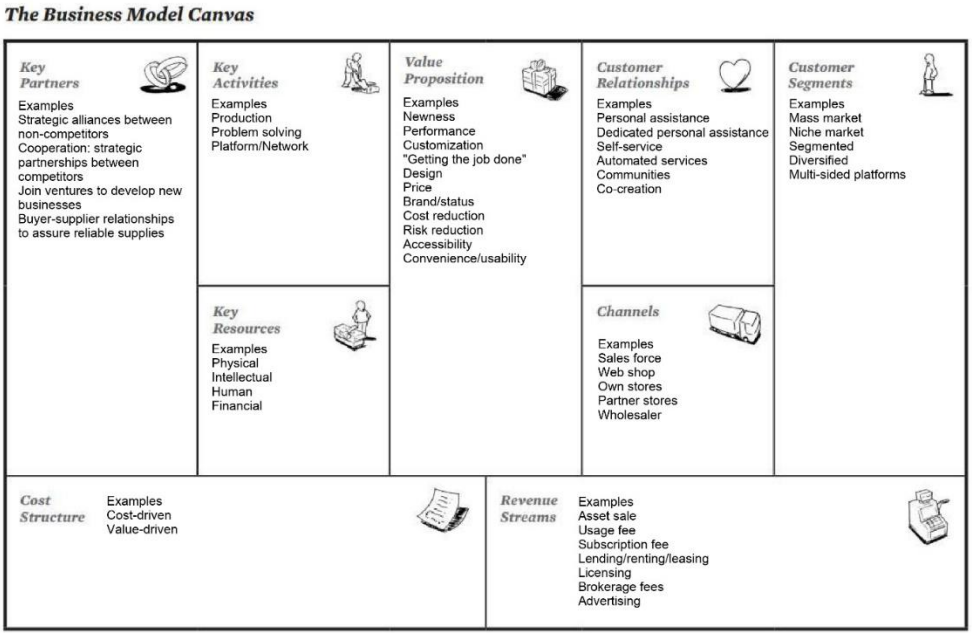

Figure 1: Business Model Canvas by Alexander Osterwalder (Image credit: Adapted with specific examples from Osterwalder et al. 2010, p. 44)

The BMC was used in this thesis to map the BMs of the case objects to give insight into the structure and value proposition of the analyzed companies, with the end goal of answering RQ1 and RQ2. This also made it possible to compare BMs of different categories.

In total 12 BMC mappings were done. Regarding this mapping, standard entries were used, such as in Figure 1. This was to make the findings more comparable and usable for further research (as opposed to customized entries, which would have been more clearly defined but would give less comparable and more complex mapping results).

3.2 Market development

Theories regarding the development of markets can help to understand the current situation, as well as make predictions for the future. This was of particular interest for RQ4.

3.2.1 Product Life Cycle

A market develops through different stages, from immaturity to maturity. During this cycle, there are stages where different growth is projected, and different market actors are present. The "Product Life Cycle" (PLC) theory, originating in the article from Raymond Vernon in his article "*International investment and international trade in the product cycle*" (Vernon 1966), is a widely known theory describing four stages of market development.

1. **Market development.** The product is new on the market and sales are slow.
2. **Growth.** Demand begins to accelerate, and the market is rapidly expanding. Some of the features of the growth stage are:
    a. The duration varies with the industry and can be shorter or longer depending on the product.
    b. Profit margins increase as fixed costs spread over larger volumes (Economies of Scale-advantages – see down below for more information regarding this).
    c. Customer awareness and demand have risen significantly.
    d. Competition is intensifying, with more actors entering the market.
3. **Maturity.** Demand is starting to level off.
4. **Market decline.** The product is starting to lose customer appeal.

Although different segments in the PV industry are operating on different points in the PLC, the PV industry as a whole is clearly somewhere in the growth stage. What is interesting about this amongst others is, 2a), the duration of the stage, wherein the product or industry may determine how long the growth stage exists. Energy/electricity concerns everybody, thus the duration can be expected to be longer here than for other products. This was used later in the thesis to make predictions of PV.

3.2.2 Economies of Scale

Economies of Scale (EoS) is a concept originating from Adam Smith's Wealth of Nations. EoS is a phenomenon that occurs when the cost of producing a unit of a good or service decreases as the quantity produced

increases. This reduction in average costs results from factors like spreading fixed costs over larger production volumes, increased specialization of labor, and improved resource utilization. In simple terms, producing more allows for more efficient use of resources, leading to cost savings. As the production prices go down, the price for the end customers tend to go along with it, therefore opening the product for more customers to afford it.

EoS is a widely known concept, and is especially applicable in the PV industry during the last decade, where mass production of PV modules in Asia has generated massive EoS advantages. These are discussed in more detail in 4.5.3.

3.3 Technology development

Several theories and observations are trying to explain how and why new technologies get adapted in the market, and how they spread. Some of these thesis relevant theories are discussed here.

3.3.1 Innovation adoption theory

Regarding the adaption of new technologies in the market, Everett M. Rogers stated that there were five types of adoption stages of new technologies in the market (Rogers, E.M. 1962), relying on social capital, and the social dynamics between people when new technology gets adapted. The stages, with the corresponding adaptor group, are.

1. **Innovators.** Risk takers, low risk aversion and the first ones to try out a new technology.
2. **Early adopters.** Often well-respected people with large social networks and low risk tolerance, who promotes the spread of the technology.
3. **Early majority.** At some point, the technology has found the “critical mass”. This will increase the adoption rate, and the technology will spread to the majority.
4. **Late majority.** This group is rather conservative and has low risk tolerance. They come into play after the early majority has adopted the technology.
5. **Laggards.** The last ones who reluctantly adapt the technology, only when it becomes necessary. (Shane, 2015)

For visualization, the stages can be seen in Figure 2.

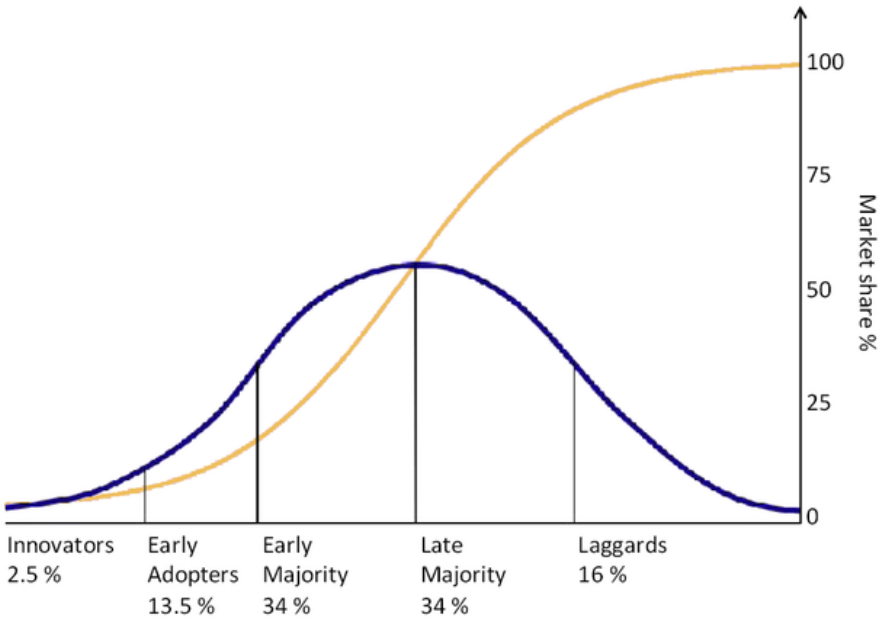

Figure 2: Illustration of the stages of technology adaptation in the Innovation-Adoption theory. (Image credit: Shane, 2015)

Rogers' perspective was that the adoption process was a social transformation process and relied heavily on social capital. In other words, it is not the technology and its benefits that need to be considered, but rather how it is proliferating amongst people.

One interesting point on this curve is the "Critical mass". Once a technology hits the critical mass, the adoption changes to be self-proliferating, and the momentum is so large that the expansion is further continued even without any further efforts on the technology side. The technology expansion is self-sustaining (Sirk, 2020). It has been theorized that this point is between the early adopters and the early majority.

Innovation adoption theory can help one understand the expansion rates of a technology and what to anticipate from the future:

3.3.2 Swanson's law

Existing technologies tend to get further developed and incrementally better over time, and such improvements often lead to cost- and price reductions. One such widely-known theory is the so-called "Moore's Law." This is in fact not a law, but an observation of over time increased computing power per circuit, (Arcuri, G. and Shivakumar, S. 18.10.22) which resulted in prices of computing power going down over time.

It is widely known that the prices of photovoltaics have been dramatically lowered during the last decade. There has been a similar observation to that of Moore's Law, done in the photovoltaics field – the so called "*Swanson's Law*".

Swanson's Law is also not a law but a correlation. The correlation has been upheld since the 1970s. This historical observation says that the price of PV modules tends to drop by 20% for every doubling of the global cumulative shipped volume (The Economist 2012). Over time, this can predict further price decreases in the photovoltaics industry.

3.3.3 Leapfrogging and technology jumps

Leapfrogging is a widely renowned term in the area of technology adoption. The leapfrogging phenomenon refers to the practice of bypassing older, established stages of technological development and directly adopting more advanced innovations or solutions.

This allows countries to make significant progress by embracing the latest technologies, often avoiding the constraints and limitations associated with traditional, incremental development paths (Lee, 2021).

The term leapfrogging has sometimes been used in the context of solar energy e.g. where developing countries can leapfrog directly to a decentralized, solar energy electricity network, not depending on a centralized stable electricity grid, also avoiding getting dependent on fossil fuel sources, as in the case in many western countries. G. Günel (Günel 2021) researched how this leapfrogging took place in sub-Saharan Africa, where stable central electricity grids are often not available.

4. Photovoltaics technology

This chapter aims to give the reader a basic understanding of photovoltaics technology and history for an understanding of the contemporary context of photovoltaics.

Photovoltaics technology represents a way of harnessing the sunshine to generate electricity. A PV system is an electricity producing system composed of the following components:

- PV modules: The modules are the components absorbing sunlight and converting it into electrical energy.
- Mounting system: The modules are securely held in place by a mounting system, designed to hold the modules in place, and optimize their sun exposure.
- Inverter: The inverter is responsible for converting the direct current (DC) generated by the PV modules into the alternating current (AC), which is the standard electricity used in most household devices.
- Energy manager: The energy manager is a component with software monitoring the PV system, electricity consumption, etc.

Moreover, the addition of a battery has become increasingly prevalent to store excess electricity generated during the day for later use, such as during nighttime hours or when sunlight is not readily available.

4.1 PV Basics

The fundamental idea of PV is to harness sunlight to produce electricity. The average solar irradiance per m2 is 1367W on Earth (Shirley, 2006) and around 1000W per m_2 reaches the Earth's surface under clear sky conditions. For reference, a stove, which is a consumption heavy household device requires between 1000-3000W of power (Lawrance Berkeley National Laboratory, n.d.) – would equal a mere 1-3 m_2 of sunlight energy if 100% of this energy could be absorbed. There is a lot of energy to be harnessed from the sun.

Photovoltaics is the technology of producing electric current from solar irradiation. This is different from other solar energy technologies, e.g., solar thermal technologies, where irradiation is used to collect thermal energy. Photovoltaics is the most universal energy generating method since it directly produces useable electricity.

On a molecular level, this current is generated from an atom absorbing energy in the form of light, to release that energy in the form of an electron. The released electrons are being harnessed for electricity (Al-Ezzi and Ansari, 2022). Sunlight is not as powerful as other types of irradiation, therefore the choice of absorption material is essential. The class of materials commonly used for this purpose is called semiconductors. (Esaki, 1981)(A Al-Ezzi and Ansari, 2022). Some examples of these materials are diamond, germanium, and silicone. Semi-(half)-conductors are materials with a conductive ability in-between an isolator (e.g. glass) and a conductor (e.g. any metal).

4.2 Key resources

1. **Renewable.** Photovoltaics is known as a green- or renewable energy source, since it produces almost no waste during the operation. The EPBT for an average PV system was 1,28 years in Germany and 0,44 years in India in 2020 (Fraunhofer ISE, 2023). Considering a life span of 25 years or more, the EPBT is paid back many times over.
2. **Decentralization.** Photovoltaics is a decentralized energy source, and can be produced everywhere without the need for an external grid, like in desolated locations (e.g., space).
3. **Availability**. A photovoltaics system can harness energy pretty much everywhere in the world since the sun is available everywhere.
4. **Cost effective.** Photovoltaics used to be an expensive, niche, technology. Today, it has become very cost effective. The estimated world average installation cost per kWp decreased to $857 in 2022 (IRENA, 2022a). Assuming that a PV system lasts 25 years, and a local solar irradiation of 1 kWh / m2 and year, this would result in an electricity cost of 3,4 ct. / kWh. This price is making solar energy one of the cheapest types of electricity out there.

4.3 Cost structure of a PV system

The most common way to gauge the cost of solar electricity is by measuring consumption cost per watts, allowing for comparisons with other energy sources. This is how electricity price is normally gauged.

The installation price of a PV system is often measured in price per kWp, where kWp stands for “kilowatt peak”, which is the nominal, laboratory, output of a PV system. This price includes everything included in the installation of the PV system and includes amongst other positions, modules, inverters, and installation costs. The data in Figure 3 displays an average cost distribution per kWp, gauged over 36 different countries in 2021 (Fraunhofer ISE, 2023 p.47):

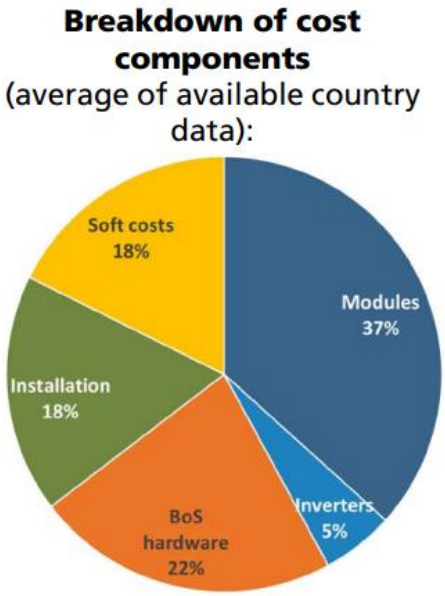

Figure 3: Breakdown of cost components in a normal household PV system, averaged from 36 countries. (Image credit: Fraunhofer ISE, 2023 p.47).

The PV modules are still the most dominant cost factor, although at 37%, they do not constitute a majority of the costs for household PV systems anymore.

Besides the aforementioned costs, common additions to PV systems of today are batteries, wall boxes, and heat pumps.

4.4 PV Modules

The most common PV-module on the market today is the c-si (crystalline silicone) module. Silicone modules account for 95% of the total global production, from which the share of mono-crystalline was ca. 84% and poly-crystalline 16% in 2021 (Fraunhofer ISE, 2023 p.5). Besides silicone

modules, thin-film modules are a fairly common alternative in other application areas. In Figure 4, the production distribution of these types has changed in the years pf 2000-2020.

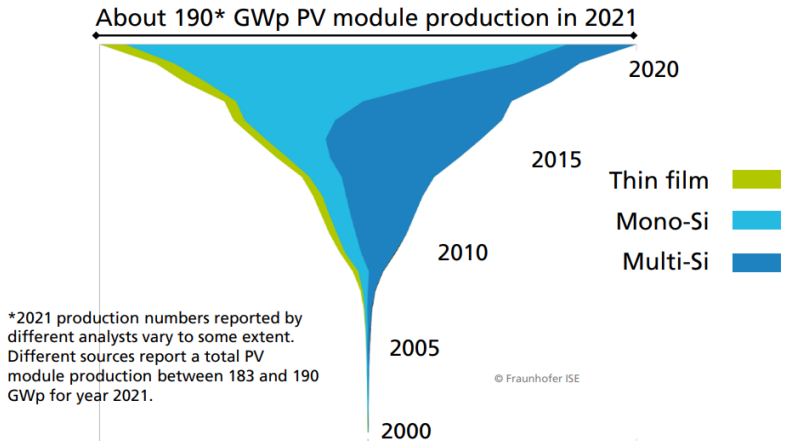

Figure 4: The production distribution of mono crystalline, poly crystalline and thin film modules in the years 2000-2020 (Image credit: Fraunhofer ISE, 2023 p.23).

4.4.1 Mono- and polycrystalline modules

The naming of mono-and poly-crystalline modules goes back to the production, in which the ingots of mono-crystalline production constitute single large crystals, whereas the ingots of poly-crystalline modules are made of multiple crystals. The ingots serve as base materials of the wafers, which are thin cut layers of crystalline silicone, later used in the PV-modules as the electricity material.

The mono- and poly-crystalline structure creates a visual difference in the two types of modules, which helps to tell them apart. The mono-crystalline modules are completely black, whereas the poly-crystalline modules have a dark blue color.

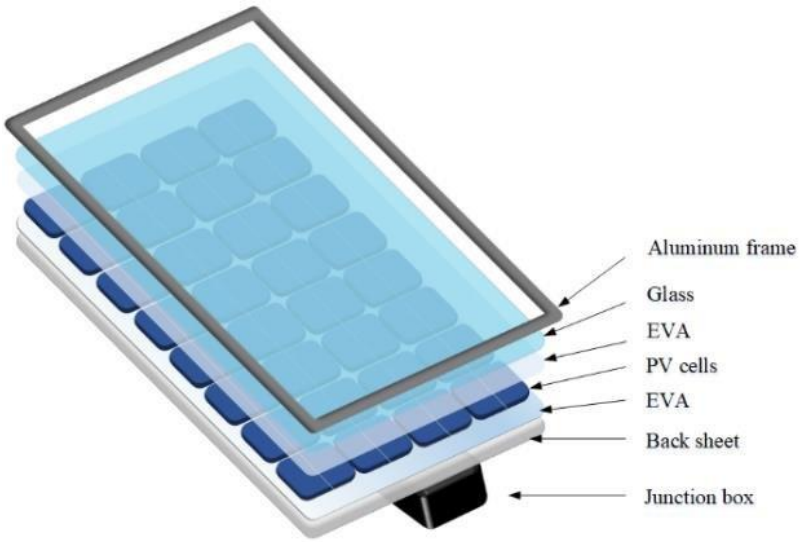

Figure 5: Basic structure of a silicone crystalline PV module (Image credit: Wu et al. (2020), p.2).

In Figure 5 the basic structure of a crystalline module can be seen. The structure includes the frame, which is often made of aluminum (Farzaneh et al., 2012) because the metal is corrosion resistant, lightweight and malleable, (Sukiman et al., 2012) (Farzaneh et al., 2012). This makes the material well-suited for outdoor conditions, transport, and being able to form an exact shape. The front surface is made from glass, a resistant and transparent material. The encapsulant, or EVA (ethyl vinyl acetate), is a thin front- and rear-end sheet, encapsulating and protecting the wafers and wiring. The EVA should be stable under high temperatures, high exposure to UV radiation, have a high transmission rate of light, and have a low thermal resistance. The back sheet can be made from glass or a thin polymer sheet, depending on the price and the output requirements. In the case of bifacial modules, with PV-cells on the back of the module allowing for irradiation uptake here as well, glass is commonly used on the backside too. These modules are called “glass-glass modules” in Germany for this reason. If the glass is replaced by foil, these are called glass-foil models, and are cheaper. The PV-junction box is the output interface of solar electricity from the panel.

In a PV module, the electricity of the semiconductor materials is directed with a metal grid, as seen in Figure 6, so that it can be used in the household.

Figure 6: PV-module and grid lines. (Image credit: (atimedia)).

Thanks to a stable PV-module structure, the typical module is very resistant to harsh outdoor conditions. This is reflected in the long manufacturer warranties – it is not uncommon to see product warranties of 30 years, e.g., a solar panel from Bauer Solar GmbH, BAUER PREMIUM PROTECT 420 – 430 W (Bauer-Solar GmbH, 2023).

The efficiency of a photovoltaics module is measured based on what percentage of the solar irradiation is absorbed and converted into energy. Mono-crystalline modules, sometimes called high efficiency modules, have higher efficiency than poly-crystalline modules. The average efficiency of mono-crystalline modules, based on shipped modules in 2021, was 20,4% in 2021 (Fraunhofer ISE, 2022). Longi Solar, a Chinese-based company, and the biggest producer of PV-modules in the world, recently announced that their modules had reached an efficiency of as high as 26,81% (LONGi Group, n.d.). In comparison, poly-crystalline modules have an efficiency of around 13-16% (Wallender, L. (2023)).

Mono-crystalline modules perform a bit better than poly-crystalline modules in terms of efficiency and lifespan. In return, the poly-crystalline modules are a bit cheaper, and are therefore sometimes used in solar parcs, or PV systems requiring a large number of modules.

The base material of silicone is advantageous for both types of modules. Silicone is the most prevalent material in the crust of the earth after oxygen, thus making it suitable as a raw material for mass production (Earnshaw and Greenwood, 1997, pp.328–366).

4.4.2 Thin film modules

Thin film PV-modules, or TFM, are called thin film because these PV layers are much thinner than the wafers used in mono- and crystalline PV-modules. Thin film layers are 1-2 µm thick, whereas the silicon wafers are 150-200 µm thick (Powalla et al., 2017). The thin layers can be applied on different types of surfaces. Glass is used as a commonly utilized surface material (Powalla et al., 2017). Because of the thin layers, there is a smaller amount of material needed for production, positively lowering the EPBT for these types of modules.

The most common materials used in TFM are the semiconductor cadmium telluride (CdTe), amorphous silicone, which is a combination of amorphous and microcrystalline silicon, and a compound semiconductor made of copper, indium, gallium, and selenium. (Taraba et al., 2019) (R. Corkish, 2013). The materials used in TFM, e.g. Cadmium, Telluride, Gallium and Indium, are often quite rare. The lower availability of the materials introduces a natural limit in the expansion rate of these technologies.

The efficiency of TFMs depends on the material used. Amorphous silicon panels have an efficiency of about 7% (Roy et al., 2021). Cadmium Telluride has an efficiency of about 9%-15%. They lose efficiency rather quickly and have a lifespan of about 10-20 years. (Rajput et al., 2018).

Thin film modules may perform worse on lifespan and efficiency, but in return they are cheaper than mono- and poly-crystalline modules (Roy et al., 2021). These modules have a wide variety of use cases, e.g., they can be integrated with glass façades or windows, thus utilizing surfaces not available for silicone crystalline modules.

4.5 PV applications over time

The expansion of solar energy has been seeing a dramatic increase over the last few years. The worldwide installed capacity of PV was 70 GW at the end of 2011. At the end of 2021, the worldwide installed capacity was 940 GW (SolarPower Europe. (2022)). This equals an increase of 1242% over 10 years. Regarding the total energy production, solar was contributing to 3,6% of the gross electricity production in 2021 (Fraunhofer ISE, 2023 p.4).

Although photovoltaics, of 2023, has become widely known, the technology has been around for a long time. The usage of the technology has shifted as

the technology has developed. In this section, a brief summary of PV is presented to foster an understanding of the developmental phases of PV until now.

4.5.1 Discovery phase (1839-1955)

The photoelectric effect was discovered in 1839 by the French scientist Edmund Bequerel (van Sark, 2012). He discovered that light was affecting the electric current in matter, the fundamental principle in a PV system (Fraunhofer ISE, 2019),

About 100 years later, in 1940, a researcher at the American company Bell Laboratories, Russel Ohl, discovered the photoelectric effect in a silicone material sample (Marques Lameirinhas, Torres and de Melo Cunha, 2022). From this observation, he created a basic solar cell discovery, which was patented(Marques Lameirinhas, Torres and de Melo Cunha, 2022). This patent was used in 1954 by the same company to create the first modern style silicone-based solar panel. It was demonstrated in April 1954 as the first silicon solar cell. The panel was used to power a small toy Ferris wheel and a radio transmitter to prove the functionality (American Physical Society, 2009). This solar panel had an efficiency of about 4%, which was a huge improvement compared to former prototypes.

4.5.2 Development era (1956-2010)

In 1956, solar panels were made commercially available at a cost ca. $300 per Watt (Livingston, 2021). A solar panel of today, at 400W, would cost $120,000, not adjusted for inflation.

Between 1957 and 1960, Hoffman Electronics was improving the efficiency of the solar cells from 8% to 14%, making rapid progress on the efficiency side (Richardson, 2018).

In 1964 solar cells, also from Bell Labs, were used to fully power a satellite from NASA with an energy output of 470 Watt (Richardson, 2018). At the end of the 1960s, solar energy was a standard option to power satellites, and since then, every telecommunications satellite has used solar energy for power (Clark, 2022). This displays one of solar energy’s first key resources, its availability. No other type of energy can be easily harnessed in space.

In the 1970s, technological developments made by the American doctor Elliot Berman significantly reduced the price per Watt from $100 to $20 (U.S. Department of Energy, 2004). Later in 1974, as the world experienced a world crisis, the US government enacted its first push for solar energy, committed to make solar energy affordable and available in the public (Chu and Tarazano, 2019).

In 1981 Paul Macready built the first solar powered aircraft, that flew from France to England, powered by 1600 solar cells (U.S. Deopartment of Energy, 2004. In 1985 an efficiency of 20% was obtained from University of South Wales, an efficiency similar to commercially viable mono-crystalline modules of today (Blakers and Green, 1986). The same year, the price per Watt was estimated to around $7 for solar energy (Lamont, 2012).

In the year 1990 Germany launched a large-scale political initiative called the 100,000 Roofs Solar program, committing to spread solar energy amongst normal households (Lamont, 2012).

In 1999, the cumulative installed PV capacity reached 1000 MW, or 1 GW (U.S. Department of Energy, 2004).

It was in the 2000s when solar energy started to find its way into normal households, alongside many state initiatives from Western governments. Solar energy started to expand heavily in Europe, prominent countries were Spain and Germany, which granted generous subsidies to solar energy (Lamont, 2012). The US government initiated solar energy investment tax credits in 2006 to increase the investments into solar, thus increasing the cost-effectiveness of solar energy (Chu and Tarazano, 2019).

4.5.3 Mass adoption (2010-present)

Since 2010, the cost-effectiveness of solar energy has gotten even better. Solar energy has been shifting from being a subsidy-driven, to a market-driven industry. In Figure 7, the significant increase of the cumulative installed PV capacity over the years of 2010-2021 can be seen.

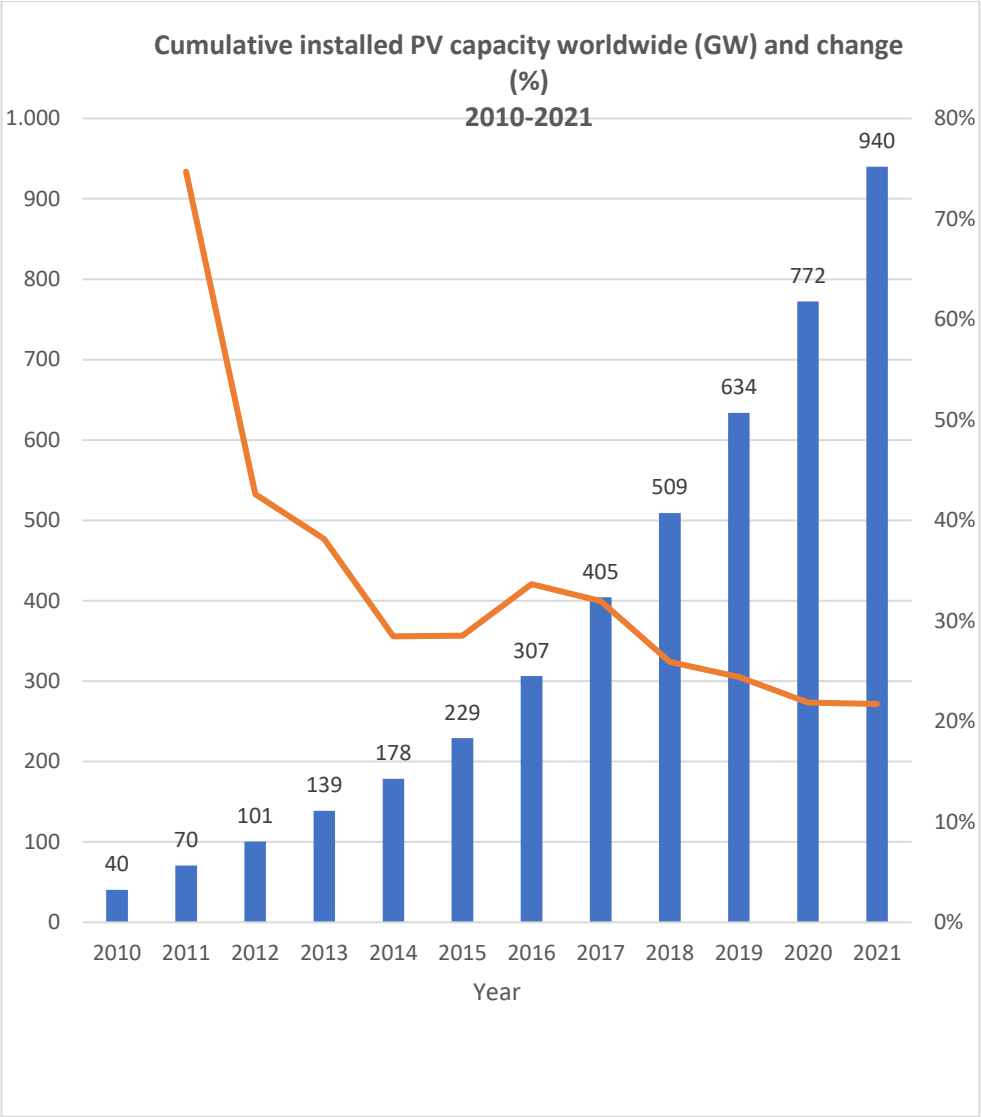

Figure 7: Worldwide cumulative installed PV capacity (Gigawatt) over the years 2010-2021. Additionally, the yearly change of the cumulative capacity in percent (Data source SolarPower Europe, 05.22, Global Market Outlook for Solar Power 2022-2026, p. 17).

Mass production has taken shape, and global production has shifted geographically towards Asia, predominantly in China. China accounted for 75% of the production in 2021, whereas 94% of the production was situated in Asia (Fraunhofer ISE, 2023). The production shift towards Asia over time

can be observed in Figure 8.

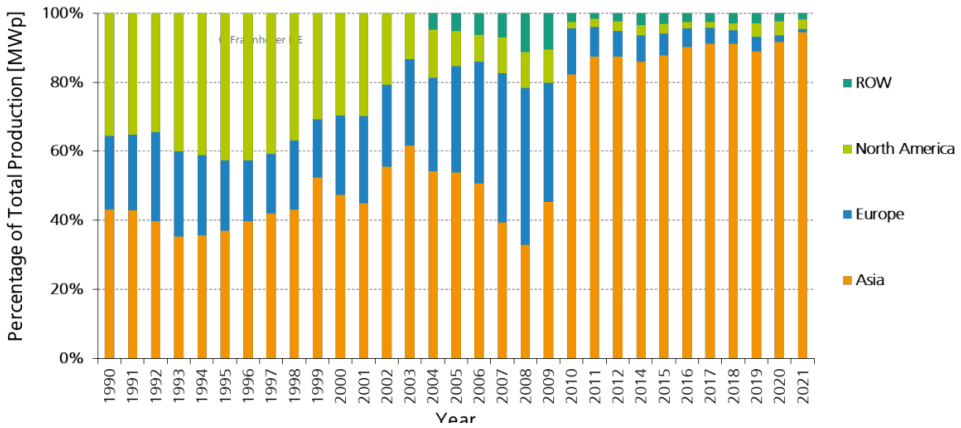

Figure 8: Geographical location of PV module production in the world (Image credit: (Fraunhofer ISE, 2023 p.12).

It is worth noting that the total quantities of modules produced have been increasing dramatically during the same period, as can be seen in Figure 9.

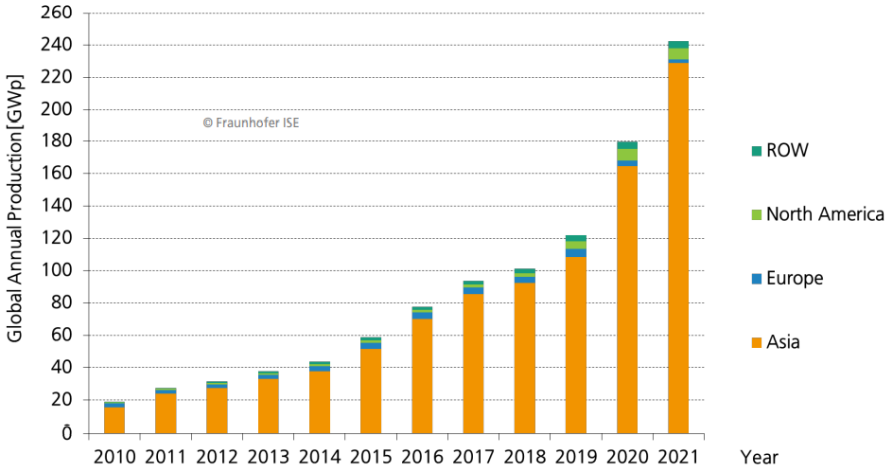

Figure 9: Annual, global production of PV modules GWp (Image credit: (Fraunhofer ISE, 2023 p.13).

The mass production and EoS advantages have resulted in a sharp decline in prices during the same period. In Figure 10, the global average price decrease per installed kWp in the years 2010-2021 can be seen.

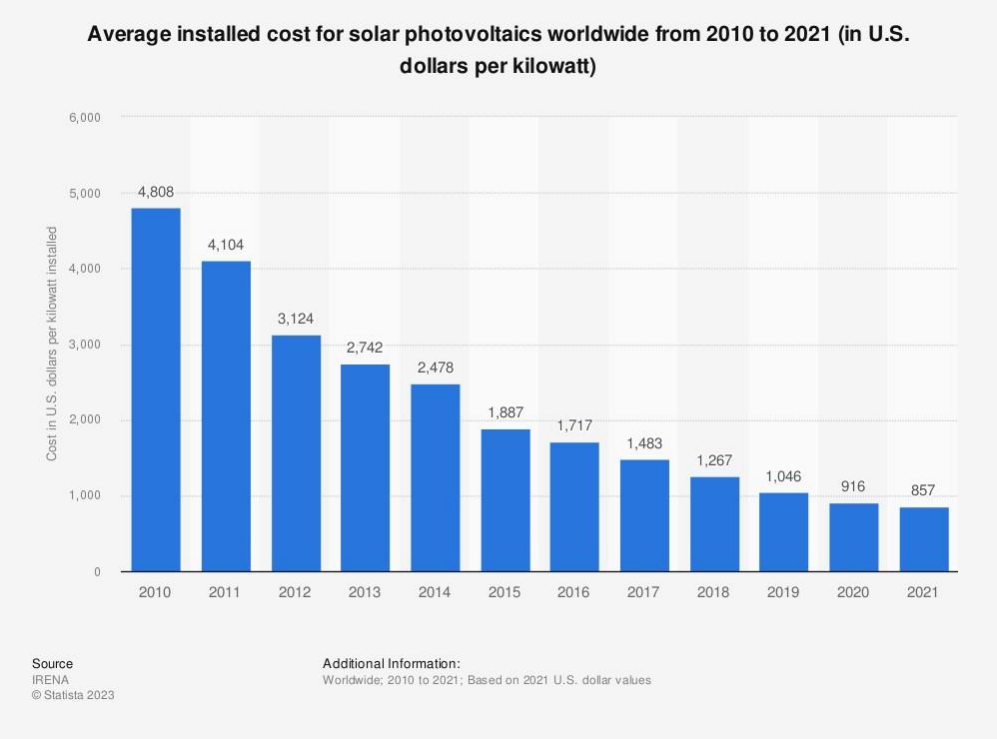

Figure 10: Cost of installed capacity per kWp globally in the years, 2010-2021 (Image credit: IRENA. (2022)).

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The average price per kWp declined from $4808 in 2010 to $857 in 2021, a reduction of 82%. At a system with a lifespan of 25 years, this equals to 3.4 ct. / W, at a solar irradiance of 1000 kWh / kWp, not adjusted for inflation. Compared to the average electricity prices of 17 ct. / kWh in the US ("Average Energy Prices for the United States, Regions, Census Divisions, and Selected Metropolitan Areas : Midwest Information Office : U.S. Bureau of Labor Statistics") as of June 2023, a new key resource for solar becomes very apparent: the cost effectiveness. The solar energy of today has transitioned from being a niche technology used for its key resources of availability and decentralization to being one of the cheapest energy sources

available, which may be the reason for the significant expansion of PV during the same period.

Worthy of note here is that cost per kWp includes the PV modules, as well as other cost posts (see chapter 4.3). This cost structure has also changed over time. While the PV-modules are getting cheaper because of mass production, the same trend may not apply to inverters, BoS, or soft costs. The percentual cost of the modules from the full PV system has changed in the period, accounting for 54% of the total cost in 2011 to only 39% of the total cost in 2021 (Fraunhofer ISE, 2021).

5. German photovoltaic business models

Germany has a special relationship with PV, once being a world leader and still being a prominent player in this field. The reasons behind this are discussed in the first part of the chapter.

This chapter will map the current German PV market. Furthermore, 12 suitable case study objects will be carefully selected based on this mapping. The BMs of the case study objects will be mapped on the BMC, and every company will be introduced to the reader.

5.1 PV in Germany

Germany was an early pioneer in photovoltaics, at one point being the country in the world with the most installed capacity globally (Bosch et al., 2023). The cumulative installed PV capacity in Germany was 34 GW in 2012 (BWK, 2022), compared to a worldwide capacity of 101 GW (see Figure 7 in chapter 4.5.3 Photovoltaics history). Derived from this, Germany accounted in 2012 for an astonishing 34% of the worldwide capacity this year, with less than 1% of the world population.

In 2021 more countries have adopted PV. In Europe, Germany is still the leading actor with 60 GW of installed capacity (BMWK. 2023). The worldwide capacity the same year was 940 GW, reducing Germany’s share of the worldwide capacity to around 6%.

Observing the newly installed capacity in Germany throughout 2001-2022, the trend is quite surprising.

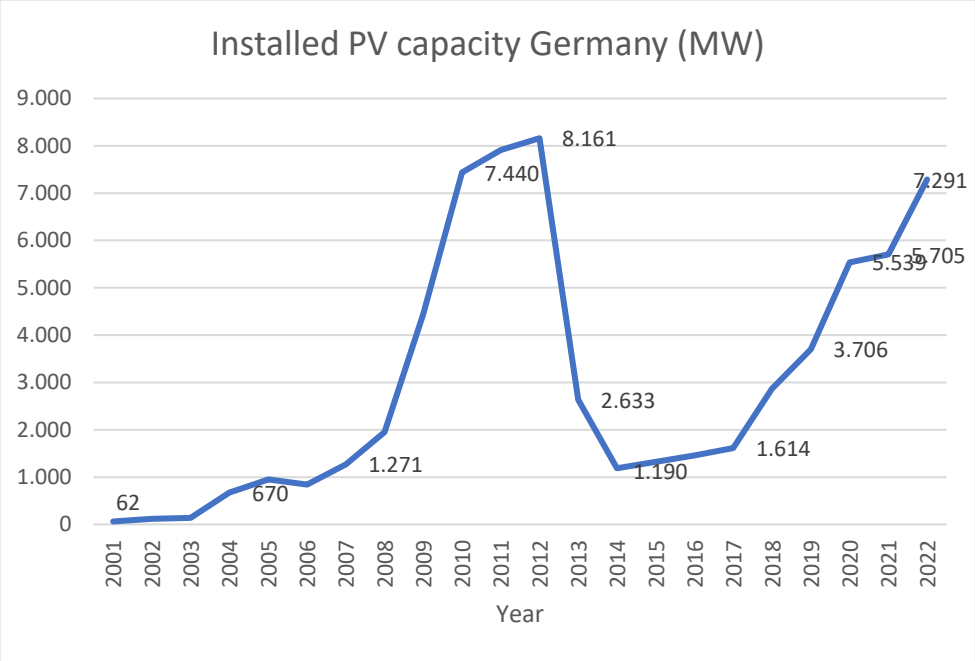

Figure 11: Installed PV capacity per year (Megawatt), Germany, in the years of 2001-2022 (Data source: BMWK. 2023).

Compared to installed capacity on a global scale, where the installed capacity has been increasing every year during the same period, Germany had its biggest year in terms of installed capacity in 2012. Due to the global price changes in PV during this period, this development was clearly not market driven since the global prices of PV were much higher in 2012. As a matter of fact, Germany have had a law in place since the year 2000 supporting the expansion renewable energies called EEG – Erneuerbare-Energie-Gesetzt. The EEG has been the driving factor for PV in the country for many years.

5.1.1 EEG

The EEG regulates feed-in tariffs for electricity produced from renewable energy sources. A feed-in-tariff is the electricity price obtained when feeding renewable, in this case solar, electricity into the net.

A PV system operator will generate revenue for all the solar electricity that he is feeding into the net based on the feed-in-tariffs. In Germany, the EEG

feed-in-tariff is fixed for 20 years, thus giving anyone investing in PV a high degree of plannability (Informationsportal Erneuerbare Energien, n.d.). The tariff depends on the PV system size and commissioning date. In Figure 12 below, the EEG tariffs for 2023 can be seen.

Leistung der PV-Anlage	Feste Vergütung	Direkte Vermarktung
bis 10 kWp	8,20 Cent / kWh	8,60 Cent / kWh
bis 40 kWp	7,10 Cent / kWh	7,50 Cent / kWh
bis 100 kWp	5,80 Cent / kWh	6,20 Cent / kWh
bis 300 kWp	-	6,20 Cent / kWh
bis 750 kWp	-	6,20 Cent / kWh

Figure 12: EEG feed-in tariffs year 2023 (Image credit: Yannick Van Noy, 2021).

Figure 12 displays feed-in tariffs up to 750 kWp. For larger PV systemPV systems there is also a possibility to receive EEG support. This is done in tender processes hosted by the Bundesnetzagentur, the German federal network agency (www.bundesnetzagentur.de, n.d.). The Bundesnetzagentur has a quota to fill for each tender process and grants EEG support to the cheapest tenders, thus regulating the EEG tariff for the larger systems after market conditions (www.bundesnetzagentur.de, n.d.).

The EEG and the feed-in-tariffs have changed many times over the years. For example, in 2022, after the energy crisis and the following accelerating electricity prices, there was a premium added for “Volleinspeisung”. Volleinspeisung is a concept where a PV system feeds 100% of the generated electricity in the net, instead of internal consumption (Verbraucherzentrale, 2023a).

The EEG tariffs exhibit an inherent degression rate that corresponds to the number of installed PV systems. When more systems than anticipated are installed, the tariffs decrease at an accelerated rate (Bundesministerium für Wirtschaft und Klimaschutz, n.d.). Conversely, if fewer PV systems are installed than expected, the rate of tariff reduction slows down or halts altogether. This mechanism allows the German government to effectively

harness the EEG as a tool to promote renewable energy sources and ensure Germany achieves its objectives in this industry.

5.1.2 Present and historical context

Germany, as most countries of today, are in the favor of the transition to renewable energies. However, there is another reason why Germany was early pioneering in the PV-field – this goes back to 2002, and the so called "Atomausstieg" (eng. "atom exit").

The "Atomausstieg" was a decision of Germany, taken in 2002, to stop the commercial use of nuclear reactor (BASE, 2023). Following this decision, several reactors were closed in the following years. As of 15th of April 2023, the last nuclear reactors in the country were taken out of service, making Germany a nuclear free country (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV, 2023). Considering that the contribution of nuclear energy was 30,5% to energy production in 2001 (Pawlik, 2023), this drastic reduction in production had to be compensated for by other energy sources. This paved the way for the EEG regulation and the expansion of solar- and windpower.

In the period of 2010-2020 Germany saw a steady increase in electricity prices, see figure 13.

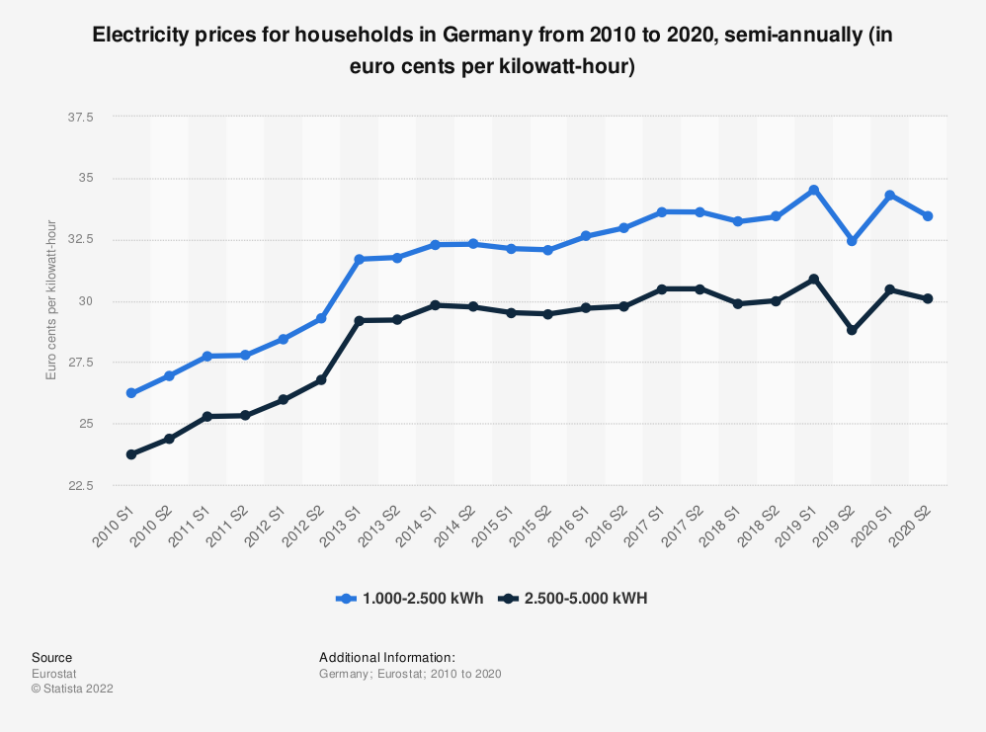

Figure 13: Average electricity prices in Germany for different types of households, in the period 2010-2020 (Image credit: Eurostat. 2021).

On price side, prices for PV systems has been decreasing in Germany, just as in the rest of the world. In 2010, the prices for PV systems in Germany was around 2950 € / kWp (Solarthemen Media GmbH, 2010), In 2022 the price have been decreasing to1050-1650 € / kWp (Fraunhofer ISE, 2022).

The combination of more affordable PV systems and rising electricity prices has shifted the German PV market from being subsidy-driven to market-driven. Therefore, the number of installations during the recent years has almost gotten back to the numbers from the early solar boom in 2010-2012. There were 6.1 GWp PV capacity installed in 2021, which means it is over 2010's level again for the first time since the crash in 2013 (BSW Solar, 03.23).

At the end of 2022 there were 2,65 million PV systems active in Germany, at a population slightly above 80 million. Solar energy was producing 12% of the gross energy production in the country (Fraunhofer ISE, 2023). There

were 51.000 people working full-time in solar (IRENA, 2022b) and then total turnover of the market (including production, installation, and maintenance), was 12 billion euro (Spinnler).

5.2 Mapping of the PV market

This section explains how the PV market in Germany was first segmented, to get an understanding of the German PV market.

5.2.1 Market segmentation

There were no official records found regarding what specific companies are active on the market, except for collections sold by private companies, which were not complete mappings. Nevertheless, records of installed PV systems, their size, type of system, and commissioning date can be found in the Marktstammdatenregister. This is a register of the German electricity and gas market, published by the Bundesnetzagentur (Bundesnetzagentur, n.d.). Data from this register, together with EEG-legislation, was used to oversee what types of PV systems are installed on the German market. The market was segmented into size and ownership, as these were considered natural segmentations pertaining to different business categories.

Market segmentation - size

The German PV market was divided into size segments. The size of a PV system affects the price per kWp, service needed, and type of customers (e.g., private households and solar parcs), thus it will influence what type of businesses are active within the segment.

To derive an appropriate size segmentation of the market, a combination of EEG legislation and type of PV system was used.

Regarding PV systems in the range of 0-30 kWp, where 30 kWp corresponds to approximately 210 m2 (calculated on approximately 7 m_2 per kWp) of roof surface, these PV systems usually regard private households. Everything between PV balcony systems and larger private household roofs is found in this segment. Furthermore, the 30 kWp limit plays a role in tax incentives. For PV systems under 30 kWp, no VAT (19% in Germany) must be paid for the system. Also, no income tax must be paid on the revenue

generated from the system, thus lowering the bureaucratic effort (Ministerium für Finanzen Baden-Württemberg, n.d.). For PV systems in this range, no grid capacity check must be done by the grid operator, easing the technical aspect of implementing such a system (Stadtwerke Norderstedt, n.d.). 30 kWp is a limit also corresponding to a lower EEG-tariff limit, see figure 12.

In the range of 30-750 kWp, larger buildings are found, usually commercial and industrial facilities, C&I. A 750 kWp system corresponds to approximately 5250 m_2 of roof surface. These PV systems have higher technical requirements, including project development. Project development of such systems includes grid capacity checks and static calculations if the system is mounted on a roof, which is usually the case for this size range. The 750 kWp limit also represents the limit of the fixed EEG-feed in tariff.

For PV systemPV systems larger than 750 kWp there is no fixed EEG support available, only tender awarded. In this segment, much larger systems are found, with the average PV system in this segment being 4.7 MW (see further down in this chapter), which usually corresponds to ground mounted solar parcs. A building hosting such a PV system would need a roof surface of approximately 32,900 m2 with the same calculation used previously, a size that is rarely seen. Solar parcs have higher requirements relating to project development. In contrast to PV rooftop systems where no building permission is needed (Maier, 2022), solar parcs need building permission and approval from local residents and governments (Klimaschutz- und Energieagentur Niedersachsen, 2023). On the positive side, since PV installation costs are decreasing with increasing kWp-size, solar parcs profit the most.

Based on this information, the German PV-market was divided into three size segments.

1. “**Small”:** 0 - 30 kWp
2. **“Medium”:** 30 kWp – 750 kWp
3. “**Large”:** >750 kWp

PV system size distribution in the German market

Through the lens of the size segments, data from Markstrammdatenregister 2022 was analyzed. This data is found in a conclusion file called EEG-Zubauwerte (Bundesnetzagentur, 2022), and all analyses made in this

chapter are based on this data. This conclusion includes data entries of every installed PV system in Germany (connected to the grid), including an identification number, mounting type of the PV system, installed kWp, commissioning date, and more. In 2022, there were a total of 356,319 PV systemPV systems installed, amounting to a total of ca. 6.1 GWp.

In figure 14, the distribution between the different sized PV systems can be seen. There is a clear dominance in the number of systems for category Small, which contributes 97.47% of the total number of systems built. It should be said that even very small PV systems, like PV-balcony-systems, are included in this segment. Category Medium contributed to 2.35% of the total number of systems built, and category Large contributed to 0.18%.

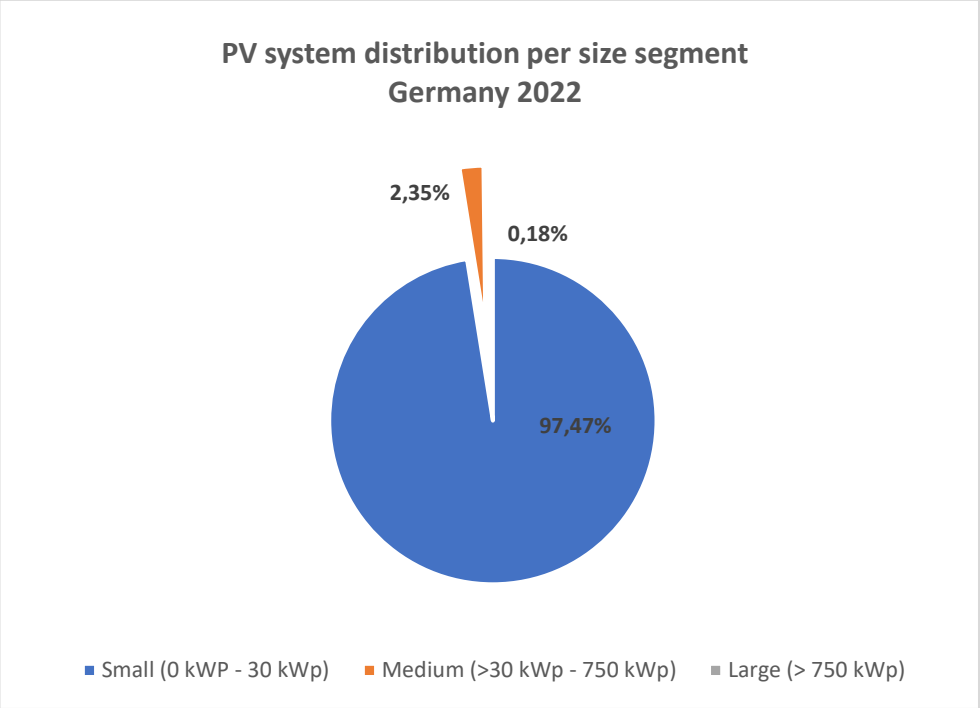

Figure 14: Distribution of PV systems installed per size segment, Germany 2022, according to the Markstammdatenregister (Data source Bundesnetzagentur).

In terms of installed power, the distribution can be seen in Figure 15. Category Large accounts for the highest amount of installed power, contributing 44%. Segment Small accounts for 40% of the installed power,

whereas segment Medium accounts for only 16% of the installed power.

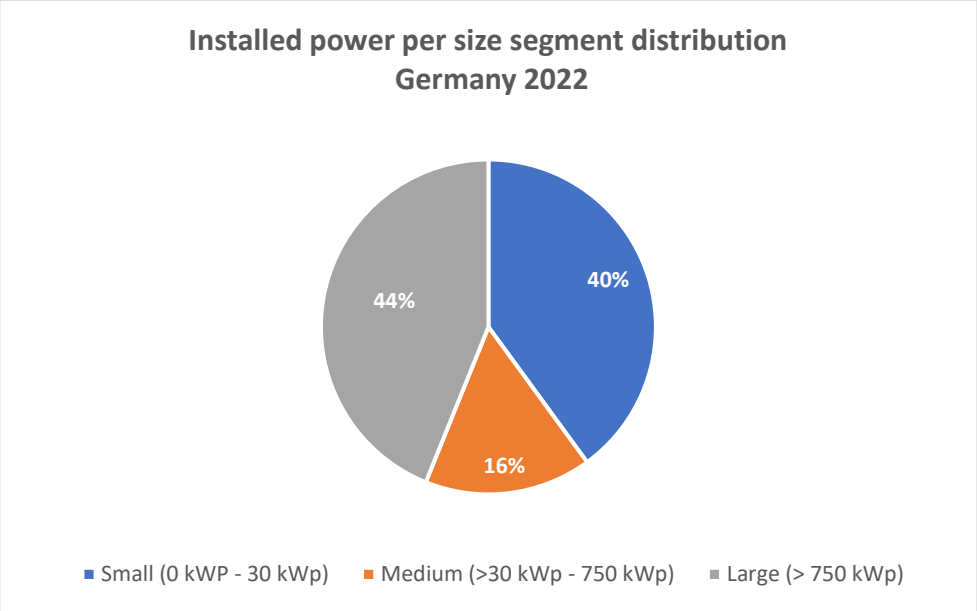

Figure 15: Distribution of the power installed per size segment, according to the Markstammdatenregister (Data source Bundesnetzagentur).

Furthermore, the average PV system size per segment was:

- 8 kWp for category Small.
- 135 kWp for category Medium.
- 4,714 kWp for category Large.

Also relevant for businesses is the type of mounting, which indicates the type of PV system. In Figure 16, the kWp distribution of different mounting types can be seen.

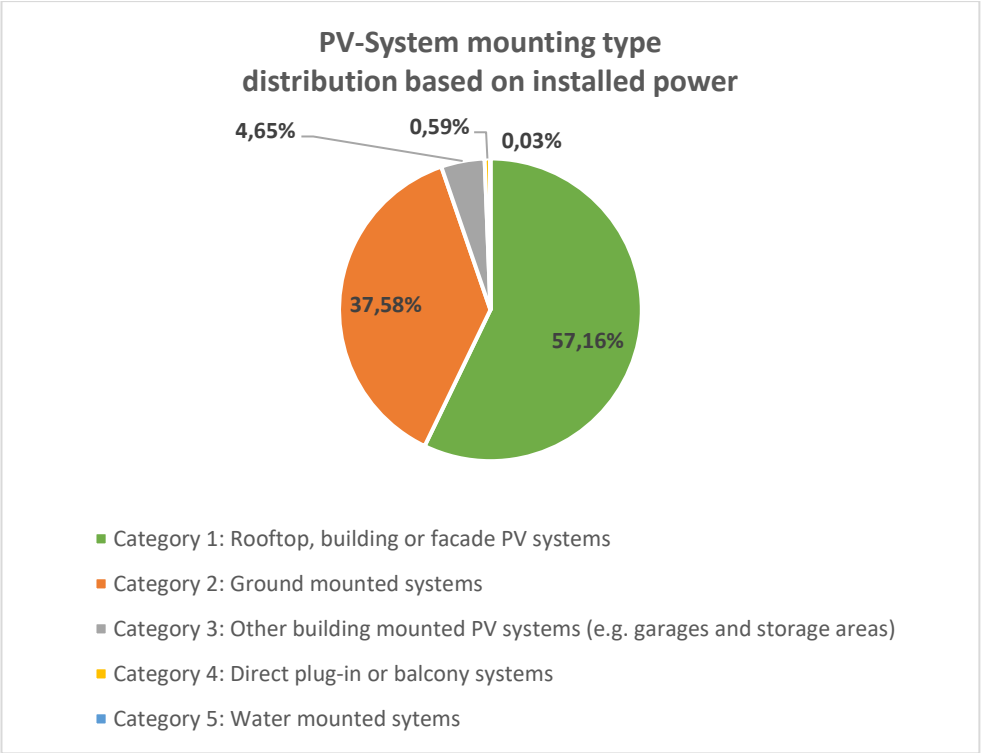

Figure 16: Distribution of PV-mounting types, according to the Markstammdatenregister (Data source Bundesnetzagentur).

Furthermore, the average size within each category of figure 16 was derived. The categories are organized in descending order in terms of market dominance:

- Category 1 (57.16%): 13.37 kWp.
- Category 2 (37.58%): 1,739.33 kWp.
- Category 3 (4.65%): 68.71 kWp
- Category 4 (0.59%): 0.82 kWp
- Category 5 (0.03%): 305.50 kWp

Categories 1 and 4, rooftops and balcony systems, are clearly associated with segment Small. Category 2, ground mounted systems, is clearly associated with segment Large. Categories 3 and 5 are associated with segment Medium. It should be said that Category 5 is very niche – there were only six such systems installed in the whole year.

Market segmentation - ownership

Traditionally, PV systems have been owned and operated by the same entity. This is called Direct Ownership or DO. However, because PV systems are capital intense, leasing models have been growing in popularity during recent years. The leasing model comes in different forms, two common examples are contracting and the Power Purchasing Agreement (PPA).

The contracting model is a leasing agreement, usually directed towards private households as customers. The leaser takes care of everything from installation to maintenance and financing of the system. The leasee thus saves the initial investment and the maintenance. In return he pays a long-term lease, usually over 20-25 years.

In PPA, the customer pays for the electricity consumed, as he would in the context of a normal electricity contact. The PV operator is thus acting as an energy supplier. PPAs are usually regulated over longer time spans than normal electricity contracts and give both provider and consumer a plannable electricity tariff. This model is usually directed towards larger consumers of electricity.

Since the property owner and PV system owner are separated in leasing models, this is called Third Party Ownership, or TPO. TPO models have a different business approach from DO models. Therefore, the market is also segmented into two ownership segments:

- **Directly Ownership (DO):** The property owner and the PV system owner are the same entity.
- **Third-Party-Ownership (TPO):** The property owner and the PV system owner are separate entities.

5.2.2 Business categories

As a basis of the mapping of the German PV market, out of the three size segments, and two ownership segments, six business categories were created:

- Category 1: DO Systems, Small.
- Category 2: DO Systems, Medium.
- Category 3: DO Systems, Large.

- Category 4: TPO Systems, Small.
- Category 5: TPO Systems, Medium.
- Category 6: TPO Systems, Large.

These categories were used as the framework of the mapping.

Because of the lack of consolidated market information, online research was deemed a reasonable alternative for the mapping, since most companies active in the PV market were assumed to be findable in search queries. The categories served as a framework for different business models.

Based on these six categories, the objective was to find two prominent companies within each category (case study objects), equaling a total of 12 companies. These case study objects were selected as representatives for their respective business categories.

5.3 Finding case study objects

To find the case study objects, the representative companies, a mapping was conducted through online research. Based on the results of the mapping, the most appropriate results were selected as representatives for their categories. The mapping and selection procedure is described in this chapter.

5.3.1 Online research

The market mapping was conducted through online research on Google. Only German was used in the search queries. The method included the following steps:

1. **Finding suitable keywords**. Suitable keywords were identified for each category. A keyword was deemed suitable based on popularity, with more responses being evaluated higher. A keyword was tried for a few search results to check if the results fit the profile. Two example keywords:
    - „ dach verpachten“ (Eng. Rent out roof): This search query generated a lot of results for Category 5. The search query generated 1.1 million hits.
    - “solarpark entwickler” (Eng. Solar parc developer): This search query generated many results for categories 3 and 6. The search query generated 72,000 hits.

2. **Searching**. Based on the keywords, a search query was done for each keyword. Results were being sequentially processed, from top to bottom, starting at the first page of the search query. The results appearing first in the search query were prioritized, as those search results generally have more traffic. Promoted results were excluded, as their position is not solely generated by organic traffic.
3. **Including or excluding data**. As the search results were being processed, it was first determined if a company, should be included or excluded. Results were included based on the following criteria:
    - German-based companies. The company registration information was controlled on www.unternehmensregister.de, which is an online publication from the Bundesanzeiger, operated by the Bundesministerium der Justiz or in English, the "Federal Ministry of Justice and Consumer Protection", a ministry of the German state.
    - Companies that had business models aligning with at least one of the business categories from 5.2.2.

    Results were excluded based on the following criteria:

    - Online brokers. These were often disguised as PV-companies, but when checking the company registration data, they turned out to be online marketers, thus not being PV at core businesses.
    - Municipal utility companies (Stadtwerke). These are general energy suppliers, many of them being state owned. Their core BM was not considered to be mainly PV, but energy supply.
    - Newspapers, magazines and other publications.
    - Component manufacturers. As seen in early chapters, the production is mostly done in China, thus not being German companies.
    - Online-shops. Their BM was deemed to be e-commerce, thus not considered to be mainly a PV-business.
4. **Assigning categories to the company**. Based on the available information on the company website, one or several categories were assigned to the company. Categories were assigned by:
    - Checking references. The reference objects displayed usually indicated what types of PV systems were in focus.

    - Website interface. Companies that had a “Gewerbe”-section, usually worked in the C&I, Medium, segment. Companies that explained PV in simple terms, providing the user with basic data, were assumed to target private customers in the Small segment.
    - Services offered. This could range from contracting, to selling turnkey PV systems and EPC, to name a few.
5. **Registering important data.** Data important for further research was registered. This data included:
    - Founding date.
    - Type of firm (e.g., solar technician, developer, roofing company).
    - Website.
    - Total asset balance of the company and year of last report, to guarantee current data.
    - Company legal form.
    - Location of company headquarters.
    - PV only – stating if the company was active only in the PV-field, or within other business ventures.

The search query resulted in a list of a total of 123 different companies. Following is the number of results per category. Note that a company could be active in one or several categories:

- Category 1: 60 results.
- Category 2: 32 results.
- Category 3: 28 results.
- Category 4: 13 results.
- Category 5: 18 results.
- Category 6: 27 results.

5.3.2 Useable results

Based on the research results found in 5.3.1, there was one further filtration done, before the selection of the representative companies. This filtration mechanism was based on two criteria.

- **The core business should revolve around photovoltaics.** The company should be mainly focused on PV. Therefore, companies

like online brokers, energy producers, municipal utility companies, or webstores, were all deemed as not useable results.

- **Publicly available total asset balance of the company.** Economic data can be used as a success indicator of any business. Total assets balance, as the only financial metric widely available, is publicized on www.unternehmensregister.de for limited companies (e.g. GmbH or AG). This financial metric was later used for the selection, thus needed to be considered a usable result.

With both criteria fulfilled, a result was deemed usable. Of the 123 companies found in 5.3.1, there were 47 usable results extracted for further investigation.

5.3.3 Representative company selection

Out of the usable results, 12 case study objects were selected.

Three selection criteria were being used as significant attributes, as described in chapter 2, under section “Case Studies”, of this report:

- **Total asset balance of the company.** Higher asset balance was deemed better, as the BM was assumed to be more successful.
- **Category Specificity Score (CSS).** Companies found in the research were often active in several categories. The CSS gauged this by an index, e.g.:
  - CSS = 1 meant a company was active in one category.
  - CSS = 5 meant a company was active in five categories.

  Lower CSS was considered positive, with more focused and distinguished companies. Companies with CSS>1 could potentially be a representative for any of the categories in which the company was involved. At the time of the selection, it was not known if the company focused more on one category than another.
- **PV only**. PV only companies were prioritized over companies working with other sources of revenue, reason being that the business success of PV only companies could be directly attributed to PV.

A conclusion of these criteria per category can be found in Table 1 below:

Business Category	Usable results	CSS (average)	Total assets balance average (Millions)
1	30	2,2	19 €
2	16	3,3	16 €
3	19	2,9	397 €
4	7	2,4	33 €
5	8	3,5	36 €
6	19	3,0	396 €

Table 1: A summary of selection criteria per business category.

In Table 2 and 3, one can find the chosen representative companies together with how they performed on the selection criteria.

Company	1komma5° GmbH	Energiekonzepte Deutschland GmbH	Greenovative GmbH	Wegatech Greenergy GmbH	Enerparc AG	Belectric GmbH
Category	1	1	2	2	3	3
Founded	2021	2018	2013	2010	2008	2001
CSS	1	1	4	2	1	2
PV Only	No	No	Yes	No	Yes	Yes
Other service	Heating solutions	Heating solutions	x	Heating solutions	x	x
Total assets (€ M)	x	31	9	8	1650	61
Installed capacity	80.000 PV systems	25.000 PV systems	700 PV systems	3.000 PV systems	4.100 MWp	4.000 MWp

Table 2: Selected representative companies, categories 1-3.

Company	Enpal B.V.	DZ-4 GmbH	Sunlife-Montage GmbH	Vario green energy Concept GmbH	Vispiron EPC GmbH & Co. KG	PFALZSOLAR GmbH
Category	4	4	5	5	6	6
Founded	2017	2012	2012	2000	2014	2003
CSS	2	1	3	1	2	2
PV Only	Yes	Yes	No	Yes	Yes	Yes
Other service	x	x	Roofing	x	x	x
Total assets (€ M)	x	x	10	3	91	62
Installed capacity	48,000 PV systems installed.	x	x	x	225 MWp	x

Table 3: Selected representative companies, categories 4-6.

It should be noted that total assets were missing for two representative companies, 1komma5° GmbH and Enpal. Both companies were, through

other sources found to be in the top five of the largest companies in the B2C market ranked by turnover. Therefore, the decision was made to include them anyway.

5.4 Information and BMC mapping of representative companies

This chapter presents a brief description of each category, an introduction to every case study object, as well as one BMC mapping for every case study object. A more detailed discussion regarding the BMC entries is found in Chapter 6.

5.4.1 Category 1 – Direct Ownership, Small

Category 1 was found to be a category that mainly offered PV-turnkey systems to private customers.

1komma5° GmbH

1komma5 Grad, or 1komma5, was selected as a representative company for Category 1. They have a CSS score of 1, and a turnover of over €200 Million in 2022, ranking 3rd in turnover in the B2C segment in all of Germany (Steinschaden, 2023). They are not a PV only company, offering heat pumps as a popular addition to PV, although PV is still considered to be the core business.

The company was founded in Hamburg in 2021 and since then has seen remarkable growth. In 2023, they were ranked as a unicorn, a privately held company ranked over $1 billion, as the second company in the PV industry after Enpal (Schütze, 2023). The founder, Philip Schröder, made it possible by convincing investors of his vision to consolidate the fragmented manual labor market within PV under one roof. This vision secured him over €200 million in financing in the first couple of months of the company's history (Handelsblatt, 2022). The goal, according to Philip Schröder, is to be market lead in a very fragmented market by acquiring solar technicians.

1komma5 is an international company, operating in Germany, Sweden, Finland, and Australia. They are planning to expand into more countries. The company has an international focus with ambitions outside of Germany – in 2022 they went into the Australian market by acquiring one of the

biggest installers of PV systems (Business Insider, 2022). They are "building Europe's largest one stop shop for photovoltaics" (1komma5° GmbH, n.d.).

On their website, 1komma5 markets themselves as a company group of experienced specialist companies, as well as a regional specialist company, something often sought after, with over 60 offices across Germany (1komma5° GmbH, n.d.). They offer an "everything from one place" service, with fast implementation and long guarantees (1komma5° GmbH, n.d.).

The company offers a good number of value propositions, amongst others performance, through the energy manager "Heartbeat". Heartbeat is an energy management module developed by the company and acts as a traditional PV energy manager by managing the usage of electricity in the household, but also as a trading manager, through which electricity can be traded on the spot market (buying and selling). Furthermore, they are advancing also on the component front, developing their own PV modules, 1komma5° module, that is meant to be sustainable also in the production (1komma5° GmbH Modules, n.d.).

<table>
<tr>
<td rowspan="2">Key Partnerships

Investors</td>
<td>Key Activities

Company acquisition

Platform/Network

Funding</td>
<td rowspan="2">Value Propositions

Risk reduction

Performance

Accessibility

Convenience</td>
<td>Customer Relationships
Personal assistance

Pay-per-Use:</td>
<td rowspan="2">Customer segments

B2C Electricity customers

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<tr>
<td>Key Resources

Human Capital

Financial Resources</td>
<td>Channels

Sales force</td>
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Value-driven</td>
<td colspan="2">Revenue Streams
Turnkey PV systems

Heating solutions
In-house components

Electricity trade</td>
</tr>
</table>

Table 4: The BMC mapping of 1komma5's BM.

Energiekonzepte Deutschland GmbH

Energiekonzepte Deutschland GmbH, or EKD, was selected as the second representative company of Category 1. They have a CSS of 1, and a total asset balance of approximately €31 Million. Furthermore, they had a turnover of €260 Million in 2022, (inFranken, 2023) ranking 2nd, based on turnover in the German B2C segment. EKD also offers heat pumps as an addition to its PV solutions but is a PV business at its core.

EKD was founded in Leipzig in 2018 by Mathias Hammer, who is also the founder of Senec, a well-known battery manufacturer in Germany (Solarserver, 7.1.2020) (EKD Solar, n.d.) - *Über uns*. The company targets nationwide private households in the Small segment, offering PV-turnkey system for sale in a package called "Rundumsorglospaket" (Eng. care-free-package). This includes mounting, installation, registration, and maintenance.

The components included in their PV systems, include batteries, modules, wallboxes and energy managers and come from the brand "Ampere German Electric Innovation GmbH" (EKD Solar, n.d.) a company with the same managing director as EKD. Ampere may be part of the same company group, although this is not entirely clear.

According to EKD (Energiekonzepte Deutschland GmbH, n.d.), they have a network of over 100 manual labor firms hired for electricity work, mounting work, etc. Furthermore, they cooperate with 2,400 energy consultants, the sales force, and a force of external contractors. EKD's internal staff amounts to around 300 people (ENERGIEKONZEPTE DEUTSCHLAND GMBH, n.d.), indicating that they are outsourcing most of the labor-intensive work like manual work, installations, and sales, whereby EKD acts as an orchestrator. Since most of the work is outsourced, the model is quite scalable, and this is reflected in the impressive growth journey of EKD since being founded in 2018.

<table>
<tr>
<td rowspan="2">Key Partnerships
Manual labor firms

Sales force</td>
<td>Key Activities

Platform/Network

Sales</td>
<td rowspan="2">Value Propositions

Risk reduction

Performance

Accessibility

Convenience</td>
<td>Customer Relationships
Personal assistance</td>
<td rowspan="2">Customer Segments

B2C</td>
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Strategic Alliances and Partnerships

Intangible Assets

Human Capital</td>
<td>Channels

Sales force

Website</td>
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<tr>
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Value-driven</td>
<td colspan="2">Revenue Streams
Turnkey PV systems

Heating solutions

Components</td>
</tr>
</table>

Table 5: The BMC mapping of EKD's BM.

5.4.2 Category 2 – Direct Ownership, Medium

Category 2 has the smallest median total asset value of all categories, €2.6 million, and a rather high CSS score of 3.33. This indicates that companies in this segment were smaller and less narrowly focused than in other categories.

Category 2 mainly concerned PV-turnkey-system sales in the C&I segment.

Greenovative GmbH

Greenovative GmbH, or Greenovative, has a CSS of 4. Their total asset balance amounted to €9 million, making them the third largest company by this metric in this category. They are a PV-only company. Based on these metrics, they were deemed as suitable representatives of Category 2.

Greenovative is a company that was founded in Nuremberg in 2013 (Northdata, n.d. - Greenovative GmbH). They are a company of 60 people, active in categories 2-3 and 5-6, based on their website, which claims having built over 700 large scale PV systems. Their reference objects displayed a mixture of large PV rooftop systems and solar parcs. The PV systems were in the size interface of Mediumand Large segments. The solar parcs were not huge, many of them are in the range of 2-3 MWp.

The C&I segment was targeted on their website by marketing solar as a way for companies to go green and lower their electricity costs. Payback times of 6-11 years for such systems were mentioned (Greenovative GmbH, n.d.) - *Photovoltaik Dachanlagen für Unternehmen*. They offer care-free-package for businesses, with promised customized solutions. There was also an option for real estate owners to lease out their rooftops (Category 5) in the same section.

On the solar parc section, there is also a leasing option for landowners (Category 6). Regarding those, they were more focused, especially solar parcs, on a model called “Bürgerbeteiligung” (eng. “citizen participation”). This is an exclusive option for residents to invest in local solar parcs. Greenovative offered participation investments of as low as €1,000. This model was found to be quite common in the German PV market. The reason may be that solar parcs need approval from local residents in the project development phase. Thus, this model can be a great way to increase the

support of the solar parcs in the local communities, besides finding investors with idealistic incentives to invest.

Greenovative is an engineering business at its core, thus focusing on the technical implementation for larger PV systems, being active Medium/Large-size segment.

Outwardly, they claim to be the leading provider of larger PV systems in the region of Nuremberg, thus offering familiarity to customers, in terms of being a safe and local partner with a lot of experience. The familiarity and locality of Greenovative may play a big role for their customers and, indirectly a value proposition in the form of risk reduction.

<table>
<tr><td rowspan="2">7. Key Partnerships
Communes

Real estate owners
Electricity grid operators</td><td>6. Key Activities
EPC
Project rights acquisition</td><td rowspan="2">5. Value Propositions
Risk reduction

Customization</td><td>4. Customer Relationships
Communities
Dedicated personal assistance</td><td rowspan="2">2. Customer Segments
B2B

Local residents</td></tr>
<tr><td>8. Key Resources
Intangible Assets</td><td>3. Channels
Website
Referral program</td></tr>
<tr><td colspan="2">9. Cost Structure
Not enough information</td><td colspan="3">1. Revenue Streams
Turnkey PV systems
Solar parc shares
Electricity trade</td></tr>
</table>

Table 6: The BMC mapping of Greenovative's BM.

Wegatech Greenergy GmbH

Wegatech Geenergy GmbH, or Wegatech, has a CSS of 2, being active in categories 1 and 2. Their total assets accumulated to €8 million in 2021, making them the fifth largest company in Category 2 on this metric, with the highest largest asset balance of companies with a CSS of 2 or lower. They are not a PV-only company, offering heating solutions as an additional revenue stream, but PV is at the core of their business.

Wegatech is a solar company founded in 2010 in Munich (Wegatech Greenergy GmbH, 2022). On their website, they have a private section for B2C customers, as well as a commercial section for B2B customers. Their Category 2 systems are in the range of 50 kWp – 100 kWp, which is on the lower end of the spectrum of size segment Medium. These systems are below the average of the Medium size segment of 135 kWp, indicating that Category 2 is more of an add-on service to Category 1. They have installed over 3,000 PV systems since 2010, most of them assumingly in Category 1, since they had a very scarce number of references from Category 2. For Category 1, the number is rather low compared to the giants of Category 1, EKD or 1komma (see tables 2 and 3).

Wegatech offers a carefree package until the commissioning of their PV systems but does not offer maintenance afterward. For their heating solutions, they offer long service packages, which is a rather unusual service.

As regards a unique value proposition, it was difficult to say. They are marketing themselves as a full package provider, providing all services needed around PV turnkey systems and heating solutions, however, many providers were offering the same.

Wegatech's income statement was publicly available, showing displeasing numbers. They have been making losses every year since 2014 (Northdata, n.d.) - *Wegatech*. In the year 2021, the loss was particularly dramatic at €4.1 million, whereas the turnover of the year was at €10.8 million, thus giving a profit margin of approximately -40%. Wegatech's business model thus seems rather dysfunctional and unclear. As for the classification, it may have been more appropriate to assign Wegatech to Category 1, since this category was more in focus.

<table>
<tr><td rowspan="2">7. Key Partnerships
Manual labor firms</td><td>6. Key Activities
Sales</td><td rowspan="2">5. Value Propositions</td><td>4. Customer Relationships
Dedicated personal assistance
Long-term-contracts</td><td rowspan="2">2. Customer Segments
Regional households
B2C</td></tr>
<tr><td>8. Key Resources
Intangible Assets</td><td>3. Channels
Sales force
Website
Referral program</td></tr>
<tr><td colspan="3">9. Cost Structure
Cost-driven</td><td colspan="2">1. Revenue Streams
Turnkey PV systems
Heating solutions</td></tr>
</table>

Table 7: The BMC mapping of Wegatech's BM.

5.4.3 Category 3 – Direct Ownership, Large

Category 3 was, together with Category 6, far larger than the other categories. The category had a median total assets value of €14.4 million. Eleven of the companies active in Category 3 had a clear focus on Large systems. Referring back to Figure 12, this makes sense, because the Large segment is the largest one on the German market, and thus a lucrative one. Many large international energy concerns dealing with renewable energies, for example wind power, were found here.

ENERPARC AG

Enerparc AG, or Enerparc, had a CSS of 2, being active in Category 3 and 6, a common feature of companies active in Category 3. Enerparc had a total assets balance of €1.7 billion, making them the largest company in Category 3 in terms of financials. They are a PV-only company, thus being an excellent representative of Category 3.

Enerparc was founded year 2008 in Hamburg. Today they are an international company active in 25 countries (Enerpac AG, n.d.)).

Enerparc has, over their company history, installed an impressive amount of 4,100 MWp , 3,500 MWp of which have been installed in Germany ((Enerparc, n.d.) *Projekte*). The installed power is distributed over 600

projects, which gives an impressive average of 6.8 MWp per project. These are large solar parcs, with huge investment volumes per project. On their website, reference parcs in the range of 6 – 90 MWp were found.

From the installed 4,100 MWp capacity, over 3,000 MWp remains in the portfolio of Enerparc (Enerparc, n.d.) *Eigenbestand*. This is an indication of their role as an asset manager rather than a developer. This is further supported by their stated company vision of investing in long term projects, with safe yields (Enerparc, n.d.) *Expertise*. These are EEG-supported solar parcs with fixed feed-in tariffs, or solar parcs supported by large PPA-agreements. One example of the latter is the 90 MWp solar parc in Gaarz, Germany. A yearly purchase amount of 80 GWh by Deutsche Bahn corresponds to pretty much the whole yearly output of the solar parc (Enerparc, n.d.) *Projects*. Long-term and safe yields are seen positively by investors, which are needed to build such massive solar parcs, enabling the financing part of the business. Different types of investors are targeted on Enerparc's website, amongst them private investors, financial institutes, and local residents (Enerparc, n.d.) *Investors*.

For the development of solar parcs, an important key partnership, real estate owners, as well as a key activity and project rights acquisition, should be highlighted. Companies active in this segment need land space as an elementary part of every project. Land space, as being limited, can thus represent the main bottleneck. Acquiring project rights with land space included is one of the essential components of their BM. Another important key activity is winning tender, since they are only building either EEG- or PPA-supported solar parcs.

Since Enerparc is mainly focusing on asset management, their BM is going more in the Category 6 direction of TPO ownership of the solar parcs, whereas the EPC, the development (Category 3), is more of an add-on-service, expertise that they have acquired in the process of developing their own solar parcs.

As their unique value proposition, they are especially big on risk reduction, with their secure long-term yield model and their vast experience in implementing such projects.

<table>
<tr>
<td>7. Key Partnerships
Manual labor firms
Communes
Real estate owners
Electricity grid operators</td>
<td>6. Key Activities
EPC
Tender awards
Project rights acqusition

8. Key Resources
Intangible Assets
Financial Resources</td>
<td colspan="2">5. Value Propositions
Risk reduction
Performance</td>
<td>4. Customer Relationships
Dedicated personal assistance
Co-creation
Long-term contract
Pay-per-Use:
Communities

3. Channels
Website
Tenders</td>
<td>2. Customer Segments
Investors
B2B Electricity consumers
Local residents</td>
</tr>
<tr>
<td colspan="3">9. Cost Structure
Cost-driven</td>
<td colspan="3">1. Revenue Streams
Consulting
EPC
O&M
Electricity trade</td>
</tr>
</table>

Table 8: The BMC mapping of Enerparc's BM.

Belectric GmbH

Belectric GmbH, or Belectric, has a CSS of 1, being very focused on Category 3. They are financially the 6th largest company in this category, with an asset balance of ca. €61 million. They are a PV only company.

Belectric was founded in 2001 in Volkach (North Data GmbH Belectric, n.d.), and has since then been a prominent player in the German PV market. In 2012, they were the first company in the world to reach 1,000 MWp of installed capacity (Belectric GmbH, n.d.) *Solar parcs*. As of today, they have installed ca. 4,500 MWp capacity worldwide. This is more than Enerparc's 4100 MWp, which is interesting when comparing financials. Beletric has a total asset value of €61 million compared to Enerparc's €1.7 billion. The reason can be found in Enerparc's activity in Category 6, keeping capital-intense solar parcs in their own inventory, thus increasing the asset balance. Belectric on the other hand, is only active in Category 3, and is not keeping any solar parcs in their inventory.

Belectric has offices in five countries, and references from all around the world. Amongst the references are large PV floating parks in Israel (Belectric GmbH, 2022). They clearly focus on the development of solar parcs of all kinds, thus being a technically oriented company.

Their unique value proposition is a combination of risk reduction, due to their vast experience, brand/status, from their globally well-known name, and customization. To the latter point, they are offering "hybrid parcs", which are solar parcs with added storage, as well as PV-floating. Both PV-floating and large storage solutions are fairly new in the PV market which indicates that Belectric is at the forefront of the development.

Besides being active on the EPC side, Belectric also has a strong position as an asset manager in the O&M field. In their O&M portfolio, they are administrating 2.1 GWp of external capacity worldwide (Belectric, n.d.) *O&M.*

<table>
<tr>
<td rowspan="2">7. Key Partnerships
Manual labor firms
Electricity grid operators</td>
<td>6. Key Activities
EPC
Asset management
Tender awards</td>
<td rowspan="2">5. Value Propositions
Brand/Status
Risk reduction
Customization</td>
<td>4. Customer Relationships
Dedicated personal assistance
Long-term-contracts</td>
<td rowspan="2">2. Customer Segments
B2B</td>
</tr>
<tr>
<td>8. Key Resources
Intangible Assets
Brand Reputation</td>
<td>3. Channels
Website
Tenders</td>
</tr>
<tr>
<td colspan="2">9. Cost Structure
Cost driven</td>
<td colspan="3">1. Revenue Streams
EPC
O&M
Storage solutions
Floating PV</td>
</tr>
</table>

Table 9: The BMC mapping of Belectric's BM.

5.4.4 Category 4 – Third Party Ownership, Small

Category 4 businesses are mainly focused on contracting in the Small segment. This category had the fewest usable results, as not as many providers could be found. A low CSS of 2,4 indicate a rather narrow focus within the category.

Enpal B.V.

Enpal B.V., or Enpal, has a CSS of 2, although they are heavily concentrated in Category 4. Category 1 was an add-on service introduced at the beginning of 2023. The total asset balance of the company is not available, although they were ranked as a unicorn in 2021 (Handelsblatt, 18.10.21)., having received over €2.2 billion of funding over the years (Crunchbase Enpal, n.d) and had a turnover of €413 Million in 2022 S(Statista Q & Enpal, 2023). They can be assumed to be, by far, the largest company in Category 4. They are a PV only company. Therefore, they are *the* candidates for representing Category 4.

Enpal was founded in Berlin in 2017. They are active all-around Germany but have no international activities. According to a survey, they are the biggest company in the B2C-segment for PV systems in Germany, with a turnover of €413 million. In 2022 Enpal was ranked as the fastest growing company overall in Germany (Stern, 8.4.22).

Enpals focuses on contracting, targeting private households. In Germany, the name Enpal is almost synonymous with leasing a PV system. The basic contract involves a 20-year-long lease agreement, with fixed monthly payment. At the end of the agreement, the customer receives the PV system for free. Enpal has, in its history, built over 48,000 systems (Enpal GmbH, n.d.).

Since contracting is initially a capital intense model with slow returning cashflow over 20 years, there is a need for large capital investments for any company expansion. This is the reason why they have collected such massive amounts of funding, making funding a main activity of the company.

It should be noted that although the cashflow is slow, a good RoI makes the contracting model interesting anyway. In an example from Enpal, a 10 kWp PV system cost is €231 monthly for leasing, adding up to €55,440 over 20

years. Buying the same PV system costs €26,930. The added profit of the contracting system thus is €28,510, or ca. 106% extra. It is easy to see why investors like this idea.

Enpal's main value proposition is first and foremost an appropriate monthly lease. Since the customer does not own the system, nor is he responsible for the maintenance, he has less incentive to care about the quality of the components, thus being more focused on the lease. Since leasing is more expensive than buying in the long term, the contracting model may mainly attract less financially stable customers. The company offering the best lease will win those customers over. Due to the massive size of Enpal, they will get significant EoS-advantages on the installation side. Due to their financial strength, they will get better financing conditions. Those factors combined make it possible for Enpal to offer a great lease, perhaps the lowest in the market. This may have been the reason why they have such a dominant position in Category 4, creating a semi-monopoly situation. Other companies in Category 4 do not come close to the size of Enpal.

<table>
<tr><td rowspan="2">7. Key Partnerships
Manual labor firms

Investors</td><td>6. Key Activities

Sales
Asset management

Funding</td><td rowspan="2">5. Value Propositions

Risk reduction

Convenience

Accessibility

Performance</td><td>4. Customer Relationships
Personal assistance
Long-term-contracts

Pay-per-Use</td><td rowspan="2">2. Customer Segments

B2C

Affiliates
Electricity customers</td></tr>
<tr><td>8. Key Resources
Financial Resources
Brand Reputation</td><td>3. Channels

Sales force

Website

Referral program</td></tr>
<tr><td colspan="2">9. Cost Structure
Value-driven</td><td colspan="3">1. Revenue Streams

Contracting

Turnkey PV systems

Electricity trade

Components</td></tr>
</table>

Table 10: The BMC mapping of Enpal's BM.

DZ-4 GmbH

DZ-4 GmbH, DZ-4, has a CSS of 1 and is entirely focused on Category 4. They have an asset balance of ca. €9 million and they are a PV only company. In terms of financials, they are tiny compared to Enpal. Nevertheless, they are the only company in Category 4 with a CSS of 1, and at the same time are a PV only company, which indicates a narrow focus within Category 4. Therefore, DZ-4 is an interesting candidate as a representative company in Category 4.

DZ-4 was founded in 2012 in Hamburg. They brought the contracting model to Germany from the US (DZ-4 GmbH, n.d.). By being the first provider to offer the model, the company had a first movers' advantage in this niche although it did not get a strong foothold until years later. In 2012, PV systems were more expensive, while electricity prices were lower, thus making contracting less interesting than today.

Financially, the company has been making losses for the last 5 years where numbers are available, ranging from €-2.6 Million (2018) to €-4.6 Million

(2017) (Northdata, n.d.) *DZ-4 GmbH*. These losses are quite hefty in comparison to the asset balance of the company. That the company would fail is however quite unlikely, as they were acquired by EnBW in 2021 (EnBW Energie Baden-Württemberg AG, 2022). EnBW is one of the largest energy suppliers in Europe.

It is not entirely clear if DZ-4 offers its services nationwide or locally. Their partners are available in Berlin, Mecklenburg-Vorpommern, and a few more German regions (DZ-4 GmbH, n.d.).

The offerings of DZ-4 are almost identical to those of Enpal's, although no pricing examples were displayed. The leasing time is a bit longer at 25 years. They have no leasing option with Wallbox like Enpal has (DZ-4 GmbH, n.d.).

DZ-4 seems to do all their consultations on-site, whereas Enpal does most of their consultations online.

DZ-4's main value proposition is that they are now a subsidiary of EnBW, and can then be considered a safe provider with strong financial backing. In the first years, they also had a first movers' advantage, which may have helped them to secure funding of over €62 Million (Crunchbase, n.d.) *DZ-4*. and sustain for over 10 years in the contracting market.

<table>
<tr><td rowspan="2">7. Key Partnerships
Manual labor firms</td><td>6. Key Activities

Sales</td><td rowspan="2">5. Value Propositions
Brand/Status</td><td>4. Customer Relationships
Dedicated personal assistance
Long-term-contracts</td><td rowspan="2">2. Customer Segments

B2C</td></tr>
<tr><td>8. Key Resources
Financial Resources</td><td>3. Channels

Sales force
Website</td></tr>
<tr><td colspan="2">9. Cost Structure
Value-driven</td><td colspan="3">1. Revenue Streams

Contracting</td></tr>
</table>

Table 11: The BMC mapping of DZ-4's BM.

5.4.5 Category 5 - Third Party Ownership, Medium

In Category 5, two business propositions were commonly found: the rooftop lease model (ger: “Dachpacht”) and PPA. The rooftop lease model was by far the most common one found.

In the rooftop lease model, a real estate owner leases his roof for 20-30 years to a solar firm or investor. In return, he is profiting by receiving lease payments. In this model, the roles are reversed from contracting. Here, the property owner is the leaser, and the company is the leasee. The company profits by feeding electricity into the grid as per EEG tariffs.

Category 5 had an average CSS of 3.38, the highest of all categories. However, some of the top results from the search queries had lower CSS scores and were more specific, but because their companies were often recently founded, there was no financial information about these companies available online, deeming them as unusable results.

The median total assets value of the category was €9.3 million, quite a lot higher than the €2.6 million on the DO side (Category 2). This is assumingly because Category 5 companies are holding capital intense PV systems in their financial books.

Sunlife-Montage GmbH

Sunlife-Montage GmbH, or Sunlife, has a CSS score of 3 and is active in categories 2, 5, and 6. The company had a total assets balance of €9.5 million, making it the 3rd largest company in Category 5. They are not a PV-only company and are a roofing company as well. However, PV is at the core of their business model.

Sunlife was founded in 2012 in Poppenricht. Being a roofer firm, they have an unusually high total asset balance compared to other manual labor firms found in the research. Sunlife has managed to grow bigger, indicating they found a well-functioning BM.

The target groups of Sunlife are clearly displayed on their website, where terms like “Dach verpachten” (Eng. “lease out your roof”) or “freifläche anbieten” (Eng. “offer land space”) are found everywhere. Sunlife is acquiring roof and land space for building PV systems and solar parcs to keep in their own portfolio and feeding electricity in the grid on EEG basis.

Regarding Category 5 companies, they could either sell the assets to investors or keep the assets in their own portfolio to produce electricity. Outward, both models look the same. They are told apart by two factors. The first factor is the asset balance of the company. Total assets are generally much larger when the PV systems are kept in the portfolio. The second factor is the targeting of the website. In the case of Sunlife, they are not actively targeting any investors or customers, only real estate owners.

Their website was not up to date or of high quality, indicating that this is not important to their customer base.

Real estate owners can be assigned both a customer and a partnership role, although they were classified as partners since they are the leaser in this model. In this type of BM, real estate portrays the major bottleneck.

The main value proposition of Sunlife is their reliability, based on the fact that they are a roofing company and doing most of the manual work in-house, with hands-on experience. Thus, customers and partners deal with the same entity. This value proposition is mainly important for their key partners, the real estate owners, who also represent the bottleneck in the business. With these clients, they enter long-term partnerships. Leasing out a rooftop for 20 years or more will require a big portion of trust.

<table>
<tr>
<td rowspan="2">7. Key Partnerships

Manual labor firms
Real estate owners
Electricity grid operators</td>
<td>6. Key Activities
Project rights acquisition</td>
<td rowspan="2">5. Value Propositions

Reliability</td>
<td>4. Customer Relationships
Dedicated personal assistance
Pay-per-Use</td>
<td rowspan="2">2. Customer Segments
Electricity consumers
B2B</td>
</tr>
<tr>
<td>8. Key Resources
Human Capital</td>
<td>3. Channels
Website</td>
</tr>
<tr>
<td colspan="2">9. Cost Structure
Cost-driven</td>
<td colspan="3">1. Revenue Streams
Turnkey PV systems
Electricity trade</td>
</tr>
</table>

Table 12: The BMC mapping of Sunlife's BM.

Vario green energy Concept GmbH

Vario green energy Concept GmbH, or Vario, is the only company with a CSS of 1 in Category 5. With a total assets value of €2.7 million. Being a PV only company, Vario was deemed a suitable candidate for Category 5.

Vario was founded in Holzgerlingen in 2000, which makes it a relatively old company in the solar energy industry (Northdata, n.d.) - *Vario.* They have been, and are still, a family-run business. The company is active nationwide, which is the case for most providers in the Medium and Large segments, where logistics is less of an issue. They are supposedly also internationally active, according to their website, although the references are only from Germany (Vario, n.d.) *Über Vario*.

Their reference objects on the websites display a multitude of PV rooftop systems of sizes between 100-1,000 kWp with a few exceptions beyond this range. From the references, there are also several smaller solar parcs found (<1 MWp), which are rather uncommon.

Vario, just like Sunlife, acquires rooftops over their website by establishing contact directly with real estate owners. Just as in the case of Sunlife, the website seemed outdated, and the last activity on their Facebook page was 2021, indicating that Vario was not using their website as their main channel, although it was not possible to tell what other channel was utilized.

Vario targets investors on their website, which is different from Sunlife, which only targets real estate owners. This, together with their rather low total asset balance, indicates that the PV systems are not held in their portfolio but sold to investors.

Vario's main value proposition is its reliability, coming from a long history in the industry and being a family-run company. This reliability can play an important factor in establishing relationships with the real estate owners, who grant access to project rights, thus targeting the bottleneck in this type of business.

<table>
<tr><td rowspan="2">7. Key Partnerships
Electricity grid operators
Real estate owners</td><td>6. Key Activities
Project rights acquisition

EPC</td><td rowspan="2">5. Value Propositions

Reliability</td><td>4. Customer Relationships

Co-creation</td><td rowspan="2">2. Customer Segments

Investors</td></tr>
<tr><td>8. Key Resources
Intangible Assets</td><td>3. Channels

Website</td></tr>
<tr><td colspan="3">9. Cost Structure
Not enough information</td><td colspan="2">1. Revenue Streams

EPC
Turnkey PV systems</td></tr>
</table>

Table 13: The BMC mapping of Vario's BM.

5.4.6 Category 6 - Third Party Ownership, Large

Category 6 mainly concerned renewable energy companies who invest and operate solar parcs. The boundary between Category 3 and 6 is a bit vague because the landowner and PV system owner in the Large segment is normally not the same entity. Category 3 companies were oriented towards EPC, whereas Category 6 companies were investment-oriented.

The CSS of Category 6 was 3.0, with most companies being active across the Large segment. The total asset balance was identical to that of Category 3, thus sharing the top position in terms of financial size with Category 3. These companies were mainly concerned with acquiring land space, as well as targeting investors for the implementation of solar parcs.

Vispiron EPC GmbH & Co. KG

Vispiron EPC GmbH & Co. KG, or Vispiron EPC, has a CSS of 2, being active in categories 3 and 6. They are the 4th largest company in Category 6 with a total assets value of €91 Million. They are a PV only company and were deemed a good representative for Category 6.

Vispiron EPC was founded in 2007 in Munich (Vispiron EPC, n.d.) *About us*. The company is part of a company group named Vispiron GmbH (founded in 2002), working with R&D and all aspects of renewable energy such as financing, charging stations, IT systems, and more. The company is, according to its website, internationally active, however, the reference objects are all Germany-based (Vispiron EPC, n.d.) *References*. Germany is assumed to be the main market.

Vispiron EPC has installed a total of 225 MWp capacity, from which 50 MWp remains in their own portfolio (Vispiron EPC) *Jobs*. By these numbers, they are much smaller than the formerly mentioned Enerparc or Belectric. However, their focus seems to be wider, encompassing different business ventures apart from EPC and solar parc investing. As a company group, they offer everything from IT systems, R&D, eco investments, their own high power charging stations, and much more.

Vispiron EPC business areas include solar parcs, with and without battery storage, independent storage systems, high power charging stations, and solar carports.

Solar parcs combined with storage capacity is a concept they have offered since 2020 (Vispiron EPC, n.d.) *About us*. Solar parcs with storage capacity seemed to be on the rise in the Large segment, with advantages such as stabilizing the local electricity grid by more even grid feeding. This in turn can be seen favorably by the electricity grid operator, since they are at times overwhelmed by the current expansion of solar and overloading of the electricity net. Storage solutions of this magnitude are expensive, but can increase profitability by enabling a more efficient electricity trade. On this note, Vispiron EPC is collaborating with another company called SE Trade (founded by Amir Roughani, the same founder as for Vispiron Group) that offers long-term fixed PPA tariffs, CPA (Capacity Purchase Agreement) for their battery storage solutions, as well as the flexible tariffs. These partnerships with subsidiaries within the Vispiron Group give them an edge in their offers and contribute to their value proposition of flexibility.

One innovative concept is their solar carports. Real estate owners are given the possibility to lease their parking area, whereas Vipiron EPC sells electricity directly to e-mobility customers, giving the real estate owner a percentage of the revenue. This concept displays one facet of their customer relationships: co-creation.

Vispirion's services include EPC and O&M. In their EPC service, they include everything from the acquisition of project rights to the commissioning of the PV system.

7. Key Partnerships	6. Key Activities	5. Value Propositions	4. Customer Relationships	2. Customer Segments
Electricity grid operators Subsidiaries Real estate owners	R&D Asset management EPC	Flexibility Risk reduction Customization	Co-creation Dedicated personal assistance Long-term-contracts Pay-per-Use	B2B Investors Electricity customers
	8. Key Resources Data and Information		**3. Channels** Website	
9. Cost Structure Not enough information		**1. Revenue Streams** Electricity trade Storage solutions O&M Solar carports EPC		

Table 14: The BMC mapping of Vispiron's BM.

Pfalzsolar GmbH

Pfalzsolar GmbH, or Pfalzsolar, has a CSS score of 2, being active in Category 1 and 6, a rather odd combination. They were the 6th largest company in Category 6 with a total asset value of approximately €62 Million, and a PV-only company, making Pfalzsolar an interesting candidate for Category 6.

Pfalzsolar was founded in Neustadt an der Weinstraße in 2003. The company was founded as a joint venture between Pfalzwerke AG, or Pfalzwerke (a municipal utilities company), and Schott Solar. The same year, they built their first solar parc in their founding region, a solar parc of 2 MWp, which is still active (Pfalzsolar, n.d.) - *Über uns und unsere Vision*. In 2008, Pfalzwerke took over Pfalzsolar completely and has since been a 100% subsidiary of Pfalzwerke (Pfalzsolar, n.d.) *Unsere Geschichte*. As of today, Pfalzsolar is an international company, that is active in the UK, Netherlands, Spain, and more countries. The services differ a bit between

the countries. In the Netherlands, they offer EPC and O&M for Large systems. In Spain, they offer PV systems to private households. More specifically, to Germans living in Mallorca.

Pfalzsolar works with investors, real estate owners, and private households. These customer segments are all targeted on the website. The Large segment is in focus, as the company has been active in constructing solar parcs since the early 2000s. Furthermore, EPC is at the forefront when entering new markets (e.g. Greece, US, UK and Neatherlands). Pfalzsolar has a B2C segment abroad in only one place, Mallorca, which is a popular tourist destination for Germans. To this point, Pfalzsolar was one of the few companies found that were offering B2C systems abroad, 1komma5 Grad was another one. Regarding their B2C activity in Germany, they are building about 600 private PV systems yearly according to their website (Pfalzsolar, n.d.) *References*.

Pfalzsolar has a private and a commercial section on its website. The private section included PV systems sale, as well as an O&M section. The O&M section included services such as cleaning, repair, taking care of guarantees, and checking the BoS. In the private section, Pfalzsolar also links to their Mallorca page, for PV systems there.

In the commercial section, the company targets investors, businesses, and real estate owners. Investors and businesses are being approached in terms of PV systems as a great way of making yield. Landowners are given the possibility to offer their land space for long-term rental payments. Services offered include EPC and O&M. Pfalzsolar is handling 150 MW in their O&M portfolio, although it is not clear how much of this is external assets and how much is their own assets (Pfalzsolar, n.d.) - *Unsere Geschichte*.

Pfalzsolar’s main value proposition is their brand/status as a subsidiary of Pfalzwerke, thus having a financially strong mother company. Their long history in the German PV field also gives them a certain credibility that is valuable for large scale PV deals.

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Table 15: The BMC mapping of Pfalzsolar's BM.

6. Analysis

The analysis chapter analyzes the results from the BMC mappings in chapter 5. The mappings are concluded into a Master BMC, and the segments and contents are discussed. Thereafter, there is a category level analysis performed, to discuss relevant category level results.

A comparison between the different categories is made, including some pros and cons of each category. Thereafter current trends in the PV market are presented, as well as a prognosis of the future, based on the current situation and relevant theory.

6.1 Master BMC analysis

The information of every individual company BMC from the last chapter, was collected into one master BMC. This master BMC was broken down into the nine BMC segments and presented/analyzed in this chapter. In the analyses, the segments are discussed, and examples from the case study objects are given. Note that not every entry will be discussed, but more general tendencies and appropriate examples.

6.1.1 Revenue streams

1. Revenue Streams	Companies
Turnkey PV systems	**1,2,3,4,7,9,10,12**
EPC	**5,6,10,11,12**
Electricity trade	**1,3,5,7,9,11**
O&M	**5,6,11,12**
Heating solutions	**1,2,4**
In-house components	**1,2,4**
Storage solutions	**6,11**
Floating PV	**6,12**
Contracting	**7,8**
Solar parc shares	**3,5**
Components	**7**
Consulting	**5**
Solar carports	**11**

Number	Category	Company
1	1	1komma5° GmbH
2	1	Energiekonzepte Deutschland GmbH
3	2	Greenovative GmbH
4	2	Wegatech Greenergy GmbH
5	3	Enerparc AG
6	3	Belectric GmbH
7	4	Enpal B.V.
8	4	DZ-4 GmbH
9	5	Sunlife-Montage GmbH
10	5	Vario green energy Concept GmbH
11	6	Vispiron EPC GmbH & Co. KG
12	6	Pfalzsolar GmbH

Table 16: The "Revenue stream" segment of the Master BMC, including revenue streams of all representative companies.

Turnkey PV systems

PV-turnkey systems were the revenue stream of offering fully installed PV systems, ready to produce electricity. The systems always include PV modules and BoS components. Optionally, they can also include a battery and a wall box. The battery was standard for all providers in the Small size segment. Companies like EKD and 1komma5 have profited significantly from this revenue stream over the last couple of years, as PV systems have become more profitable.

EPC

EPC, or Engineering, Procurement and Construction, pertains to project development and installation of larger PV systems (Medium and Large segments). In many cases, it included land and/or project rights acquisition, although this was not always the case.

EPC was offered by companies across the board in the size segment Large, and by companies in Category 5. Project development is necessary to some

degree for all projects over 30 kWp, however especially in the Large segment it is more complex and expensive.

EPC was the main activity of companies in Category 3, e.g., Belectric.

Electricity trade

Electricity trade could either relate to the selling of electricity (e.g. on the spot market or by EEG), or electricity brokerage, i.e. selling a third party's electricity.

Enerparc was clearly focused on this income stream – 73% of their installed capacity, or 3.0 of 4.1 GW remained in their own portfolio, selling electricity through PPA or EEG-supported models.

1komma5 Grad and Enpal utilize electricity brokerage by selling the electricity of their customers on the spot market. This was enabled through smart energy managers developed by the companies. Although their customers have PV systems in the Small category, the large number of such systems still add up to an impressive amount of capacity. For example, Enpal's 48,000 installed systems would amount to 480 MWp, if the average system is 10 kWp.

O&M

Operations and maintenance is a service pertaining to repairing, cleaning, maintenance, and performance monitoring of a PV system. This is normally done on a yearly basis.

O&M was typically offered by providers in the size segment Large. Belectric had over two GWp in their O&M portfolio of external solar parcs. In Category 1, O&M was usually not found, with the companies offering service only until commissioning, perhaps because of the large logistical challenges such service would encompass. One exception here was Pfalzsolar, who did offer O&M for Small systems as a standalone service. The Category 4 providers did not offer it as a service but did perform maintenance of their own systems.

Heating solutions

Heating solutions mainly consider the sale and installation of heat pumps. Heat pumps generate heat from electricity to a COP factor of around 4, which makes them a great complement to PV systems. The installation of heat pumps is subsidized in Germany by Bafa (BAFA, n.d.).

This revenue stream was utilized from 1komma5, EKD and Wegatech, as a complement to their PV-turnkey systems in the Small segment. Wegatech included long-term maintenance contracts in their offering.

In-house components

In-house components regard the sale of components that are in some capacity developed by the company itself. OEM products, as well as self-developed technical solutions, were included here. This revenue stream is on the rise amongst providers in the Small segment. A reason for this may be that it is a way to add an extra value proposition in an otherwise commoditized market.

1komma5 and Wegatech offered in-house developed energy managers. The one of 1komma5, “Heartbeat”, was particularly impressive and was highlighted as one of their main value propositions. Besides managing household energy, it enabled the trade of electricity on the spot market – selling electricity when prices were high and buying electricity when prices were low, thus increasing revenue and decreasing electricity costs of the user (1komma5, n.d.). 1komma5 also offered its own PV module, which long guarantees additional sustainability in the production as well.

Storage solutions

Storage solutions pertain to batteries and were considered a separate revenue stream when this offer was separated from the PV system. This was usually the case in the Large segment, where storage solutions were not standard. Storage solutions in this category were however on the rise.

Storage solutions are standard as part of a PV turnkey system in the Small segment, thus not treated separately, although they did all include storage solutions.

Every representative company, apart from Enerparc, had included battery storage in some capacity. Two of those offered storage solutions as separate services from PV: Belectric and Vispiron, in the Large segment. Vispiron has offered storage solutions since 2020 (Vispiron EPC, n.d.) - *Solar Battery Storage*. Belectric had several references for solar parc battery storage solutions on their website.

Floating PV

Floating PV is a fairly new technology on the rise (Kumar, Humaid Mohammed Niyaz and Gupta, 2021). The technology pertains to PV modules mounted on water. This mounting structure is more expensive than land-mounted systems, however it offers some great advantages. Primarily, there is no competition for land space in such models, and there is no shadowing on the sea. Furthermore, the modules are cooled down by the water, increasing their efficiency (Raniero Cazzaniga and Rosa-Clot, 2021) (Torunn Kjeldstad et al., 2021).

As was seen in **chapter 5.2**, Floating PV is very rare in Germany, with only five such systems built in 2022. As such, the providers offering this technology were international players in the Large segment: Belectric and Pfalzsolar. Belectric's references regarding floating PV, a total of 7 objects, were all based in Israel.

Components

Component sales regard the sales of components from brands that do not belong to the company. This revenue stream was mostly found in online shops, and those BMs were not included here, making this revenue stream quite rare.

Enpal offered components as a service directed towards their affiliated manual labor firms. This service may be essential to keep their nationwide service congruent when working with different partner firms. Other companies also working with affiliates may also sell components, although this information was not available on their websites, as in the case of Enpal.

Contracting

Contracting is, as previously explained, a long-term lease of a PV system. The contracting models found included a lease time of 20-25 years, with the possibility of battery storage and a wall box in addition to the offering.

Enpal and DZ-4 were (almost) exclusively focused on this model. This revenue stream is quite particular and was not found as an add-on revenue stream amongst any provider working in a separate segment.

Solar carports

Solar carports regard the mounting of PV modules over parking spaces and the sale of electricity to e-mobility customers, essentially operating a gas station for e-mobility.

This service was offered by Vispiron, who leased parking spaces over a long-time for this purpose.

6.1.2 Customer segments

2. Customer Segments			**Number**	**Category**	**Company**
B2B	**3,4,5,6,9,11,12**		**1**	1	1komma5° GmbH
B2C	**1,2,4,7,8,12**		**2**	1	Energiekonzepte Deutschland GmbH
Investors	**5,10,11,12**		**3**	2	Greenovative GmbH
Electricity consumers	**1,5,7,9,11**		**4**	2	Wegatech Greenergy GmbH
Local residents	**3,5**		**5**	3	Enerparc AG
			6	3	Belectric GmbH
			7	4	Enpal B.V.
			8	4	DZ-4 GmbH
			9	5	Sunlife-Montage GmbH
			10	5	Vario green energy Concept GmbH
			11	6	Vispiron EPC GmbH & Co. KG
			12	6	Pfalzsolar GmbH

Table 17: The "Customer segment" part of the Master BMC, including customer segments of all representative companies.

B2B

Business to business was the most frequently appearing customer segment. Except for companies clearly focusing on B2C/private households, e.g., 1komma5 Grad or Enpal, the rest of the companies were working with B2B customers. B2B customers could pertain to real estate owners, any type of business using facilities, affiliate firms, renewable asset manager companies, and more.

The business-to-business customer was multi-faceted and could be any business with some land or roof space available, investing either in lowering electricity costs or investing in PV as a revenue generating asset. It could pertain to businesses investing in PV as an investment,or as a mean to lower electricity costs.

Companies in the Large segment focused on big business, e.g. Belectric, which usually won tender awards. Other companies, e.g. Wegatech, targeted smaller businesses, either local or nationwide.

B2C

A typical B2C was a private household, owning their own house, utilizing photovoltaics to cover their own electricity need. By doing so, they increased their self-sufficiency, thus lowering their electricity costs. Furthermore, it contributed to their green energy production.

Companies targeting B2C had modern, good-looking websites, with basic information about PV. These websites usually included a “solar calculator” (de “solarrechner”), where the basic data about electricity consumption and the house was entered to calculate an appropriately sized PV system, and being emailed an offer.

Companies active exclusively in the B2C segment such as 1komma5 Grad or Enpal were most prominent in terms of media exposure since they build a large number of systems across the nation. 1komma5 Grad has a record of 80,000 PV systems, whereas Enpal has installed over 48,000 PV systems. With prolific founders, there was a lot of information found about these companies online.

Two companies target international B2C customers: 1komma5 and Pfalzsolar. 1komma5 Grad was active in several countries outside of Germany, with an aggressive expansion strategy. Pfalzsolar had a more

modest B2C international approach, offering private PV systems to Germans in Mallorca.

Investors

Investors were customers usually found in the larger size segments and could be private investors, banks, or other entities investing in PV.

Investors were considered as a customer segment for investments in individual PV projects, as opposed to when investors were funding a company, and then considered partners.

PV systems are capital intense, with long payback periods but with safe yields, thus making PV interesting for this target group. For larger systems, especially solar parcs, funding is essential.

There were different types of investors targeted. Enerparc for example, was targeting private investors, financial institutions, and energy companies. Furthermore, they acted as an investor, investing in their own project portfolio. At Vispiron, investors had their own login portal for overseeing their investments.

Electricity consumers

Electricity consumers could be any customer group consuming electricity. The most obvious ones are anyone consuming electricity from the grid. These customers must not be targeted in any particular way, instead the electricity is being sold on the spot. PPA customers are another type of electricity customers, bound up on long term energy supply contracts.

For providers in the Large segment, large PPA-customers could represent an interesting customer type for making the realization of solar parcs possible with stable long-term yields. One example is the 90 MWp solar parc in Gaarz, Germany, installed by Enerparc, based on a PPA contract with Deutsche Bahn. For Enerparc, who focused on long-term, stable yields, PPA-customers were the main targeted group when EEG-support was not available.

Local residents

Local residents were a type of investor that deserved some additional attention. This is a great customer base for companies implementing solar parcs. Firstly, local residents serve as a customer base that has financial and ideological (supporting the local community) incentives for the investment. Secondly, this group supports the project development process in terms of getting approvals.

Local residents were targeted by Greenovative and Enerparc. At Greenovative, local residents could invest with as little as €1,000 in a solar parc share (Greenovative, n.d.) *Bürgerinitiative*. For them, local residents were their main customer group. For Enerparc, local residents were one of many customer groups.

6.1.3 Channels

3. Channels			**Number**	**Category**	**Company**
Website	**1,2,3,4,5,6,7,8,9,10,11,12**		**1**	1	1komma5° GmbH
Sales force	**1,2,4,5,7,8,12**		**2**	1	Energiekonzepte Deutschland GmbH
Referral program	**3,4,7,12**		**3**	2	Greenovative GmbH
Tenders	**5,6,12**		**4**	2	Wegatech Greenergy GmbH
			5	3	Enerparc AG
			6	3	Belectric GmbH
			7	4	Enpal B.V.
			8	4	DZ-4 GmbH
			9	5	Sunlife-Montage GmbH
			10	5	Vario green energy Concept GmbH
			11	6	Vispiron EPC GmbH & Co. KG
			12	6	Pfalzsolar GmbH

Table 18: The "Channels" part of the Master BMC, including entries of all representative companies.

Website

Due to the nature of the solar business being geographically spread and most companies in the research having nationwide as well as international customer offerings, the most frequently used sales channel was the company

website. It should be noted however, that PV systems could not be purchased directly on the website. The website was instead used for establishing contact.

Regarding the companies operating in the Small segment, e.g. 1komma5 Grad and Enpal, the websites typically act as lead generators. For the providers in the large segments, the websites were more informative, with references being displayed.

Sales force

A sales force was used by every company in the Small segment. The sales force, usually called energy consultants, often consisted of external, independent contractors. The use of external salespeople can be a necessity for a company offering a nationwide service in the Small segment, unless they have offices all around the country, which is usually not the case.

PV system sales require a technical on-site evaluation. For Small systems, this evaluation is simple and can be done by people with minimal technical expertise. Furthermore, since PV system. PV systems are capital intense, the commissions can be quite high. These two factors combined make it easier to attract salespeople.

The use of an external sales force helped EKD to grow fast. They had a sales force of over 2,400 people, while their internal staff consists of about 300 people, making the sales force 8x larger than the staff of the company. The company itself is available only in its Leipzig office, but it covers all of Germany with its sales network.

Referral program

Four companies use referral programs to reach their customers: Greenovative, Wegatech, Enpal, and Pfalzsolar. These all had in common that the referrals targeted customers in the Small segment. The referral bonus amounted to €100 (Pfalzsolar) - €500 (Wegatech) for referrals that led to successful deals. Since PV service is mainly a service, referrals may be more effective than other channels.

Tenders

Companies working in the Large segment utilized tenders to reach their customers. Tenders processes were a necessity for all companies in the Large segment opting for EEG support, as well as for some companies competing for large international orders.

6.1.4 Customer relationships

4. Customer Relationships			**Number**	**Category**	**Company**
Dedicated personal assistance	**3,4,5,6,8,9,11,12**		**1**	1	1komma5° GmbH
Long-term-contracts	**4,6,7,8,11,12**		**2**	1	Energiekonzepte Deutschland GmbH
Pay-per-Use	**1,5,7,9,11**		**3**	2	Greenovative GmbH
Co-creation	**5,10,11,12**		**4**	2	Wegatech Greenergy GmbH
Personal assistance	**1,2,7,12**		**5**	3	Enerparc AG
Communities	**3,5**		**6**	3	Belectric GmbH
			7	4	Enpal B.V.
			8	4	DZ-4 GmbH
			9	5	Sunlife-Montage GmbH
			10	5	Vario green energy Concept GmbH
			11	6	Vispiron EPC GmbH & Co. KG
			12	6	Pfalzsolar GmbH

Table 19: The "Customer relationships" part of the Master BMC.

Dedicated personal assistance

The most common type of customer relationship was dedicated personal assistance. This is an intimate, one-on-one relationship, where the company offers advisory services and guidance with an assigned personal representative.

This type of customer relationship was often promoted by the companies as being "customized to customer needs" etc. In the case of DZ-4, they were offering on-site consultation and full maintenance of the system after the commissioning of the PV system. In the case of Vispiron, they were promoting that the customer could outsource the full implementation and maintenance of the system.

Long-term contracts

Long-term contracts were a frequently occurring customer relationship. Any PV-provider offering O&M or contracting services utilized this type of customer relationship, with maintenance contracts in place over the operations phase of the PV system.

Long-term contracts were available among all providers in the Large segment. Solar parcs need proper maintenance and monitoring to produce an optimal yield. Even smaller deviations can lead to significant diminishing returns in this segment.

As for providers in Category 1, long-term contracts were not available. The service ended after the commissioning of the system.

Pay-per-use

Pay-per-use was the customer relationship relating to electricity trade and pertained to selling electricity.

Co-creation

Co-creation is a collaborative process where businesses and customers work together to create value.

This customer relationship was available amongst some providers in the Large size segment, regarding landowners and investors. Both parties can be seen as customers as well as partners, and both are usually involved in a project from the start, being a necessity for successful implementation. The real estate owner hosts the PV system on his property, thus being an essential party. The investors are funding the system so that it can be built for a long-term yield. Both parties must be convinced that it is a good idea to collaborate with the solar firm over a long period of time and be convinced of their expertise.

For example, Enerparc and Vispiron used co-creation for the installation of their solar parcs. Thanks to this type of customer relationship, the firm must not offer anything more than expertise. Capital and land are sourced externally, which makes such models very scalable.

Personal assistance

A more automated and less customized customer relationship was personal assistance. The service is still personalized, but there is not necessarily a dedicated customer representative for their customer, and the customer relationship goes more in the direction of automatization, in comparison to dedicated personal assistance. This customer relationship was utilized mostly by providers in the Small segment, especially Category 1, which seemed to be a category of automatization of process flows. Those providers, e.g. EKD, had some form of personal contact with the customer, but judging based on online reviews, they were also notoriously bad at handling this part, which makes sense based on the way the company is built up.

Communities

Greenovative and Enerparc utilized communities in the form of local resident solar parcs as a customer relationship segment.

6.1.5 Value propositions

5. Value Propositions			**Number**	**Category**	**Company**
Risk reduction	**1,2,3,5,6,7,11,12**		**1**	1	1komma5° GmbH
Performance	**1,2,5,7**		**2**	1	Energiekonzepte Deutschland GmbH
Customization	**3,6,11**		**3**	2	Greenovative GmbH
Brand/Status	**6,7,12**		**4**	2	Wegatech Greenergy GmbH
Accessibility	**1,2,7**		**5**	3	Enerparc AG
Convenience	**1,2,7**		**6**	3	Belectric GmbH
Reliability	**9,10**		**7**	4	Enpal B.V.
Flexibility	**11**		**8**	4	DZ-4 GmbH
			9	5	Sunlife-Montage GmbH
			10	5	Vario green energy Concept GmbH
			11	6	Vispiron EPC GmbH & Co. KG
			12	6	Pfalzsolar GmbH

Table 20: The "Value propositions" part of the Master BMC.

Risk reduction

Risk reduction was the most commonly occurring value proposition. Risk reduction could pertain to any type of risk such as the solar firm going bankrupt, installation risk, and more. Some examples of those risks are:

- Financial risk: Pre-payments are common in this industry. Should the solar firm go bankrupt, advance payments can be lost, and work can be left incomplete.
- Installation risk: Technical malfunctions can lead to hazards or damage to expensive components.
- Project success risk: Lacking project development expertise can lead to solar parc projects being rejected.

PV systems are capital intense, therefore risk reduction is important to most customers. Thus, it is not surprising that this is a common value proposition amongst prominent companies.

The risk reduction aspect was promoted and indicated in different ways. For providers in the Small size segment, this was usually implied by stating the number of systems installed – 1komma5 Grad installed over 80,000, Enpal over 48,000, and EKD over 25,000 systems - proving a successful track record, thus offering a risk reduction in the system implementation. Companies in the Large segment, being older and having longer histories, usually made their reference objects visible, and promoted the long experience of the industry.

Performance

Performance as a value proposition pertained to either the performance of the system, i.e., the output and functionality, or the installation service of the system, i.e., the speed and quality of installation.

In the case of 1komma5 Grad and Enpal, they offered improved functionality and performance of the PV system through their self-developed energy managers described previously.

Enerparc promotes both system and installation performance. As for the installation performance, they offered expert implementation procedures for their solar parcs, having a long history of installing such parcs. In terms of functionality, they promised optimal output and yield.

Sunlife was bigger on the installation performance aspect. They promoted a better installation service, as they were a roofing company, with a long experience of roof mounts. Furthermore, not being a GC like many other solar firms, instead handling most manual laborwith company resources, they promised short decision processes, with few third-party companies involved.

Customization

Every PV system can be classified as customized to a varying degree since they are always installed in relation to a unique location. On the other hand, most systems also use components from the same Asian brands, thus being quite the opposite of customized. Nevertheless, some companies were promoting the customization of their installed system as the main advantage.

In the case of Greenovative promoted its B2B solutions as perfectly customized. As for Wegatech, the customization aspect regarded the components of the PV system, the customer could choose the type of PV modules included, which was an optionality not found at other providers in the Small segment.

Accessibility

Accessibility was ascribed only to companies working in the Small segment. Although most representative companies in the Small segment were offering a geographically accessible service with nationwide coverage, this was not the case for most Small companies found in the research, many of them operating locally only. In terms of logistics, it is more difficult for companies acting in this segment to provide a geographically spread service.

1komma5, EKD, and Enpal all offered a fully covered, nationwide service. Enpal and EKD were able to provide this accessibility with the help of external companies. 1komma5 Grad offered this service through their acquired specialist companies, thus providing the service through their own staff. 1komma5 was the strongest company in this value proposition, being a “regional specialist company” (1komma5 Grad, n.d.), available all over Germany.

For most Medium and Large segment companies, logistics were less of an issue, thus most offered nationwide, accessible service, but this was not a unique value proposition.

Convenience

Convenience was a common occurring value proposition amongst the Small companies, acting as a "one-stop shops" for photovoltaics, where customers could get everything from photovoltaics, wall boxes, batteries, and even heat pumps installed through the company. The idea is that the customer can safely outsource the installation project to one GC, who takes care of the whole process.

The vision of 1komma5 Grad was to become the one-stop shop for photovoltaics. This is also similar to what EKD and Enpal were offering, but less explicit for the latter. EKD is said to have been the founder of the "care-free-package", a standard in today's PV industry in Germany.

Enpal had a quite remarkable value proposition in terms of convenience. Since the start of 2023, they have offered PV systems for sale (Category 1), going beyond contracting. This opened up Enpal Flex (Enpal GmbH, n.d.) – a program where the customer can wait up to six months after the commissioning of the PV system to choose between buying and contracting without paying anything during this period. This gives the customer unique insight into the actual output of the system, and the possibility to make an informed decision based on real data. This is a great value-add only seen at Enpal, giving them the strongest value proposition in terms of convenience among all companies.

Brand/status

Brand/status is a value proposition that can affect a customer's buying behavior because of a name. Branding was not found to be particularly significant in the PV industry, perhaps because it is a commodity industry, the market is rather new and fragmented or most companies are not being particularly known to the average person. Branding will probably get more important over time. In this study, two companies were found to have a slightly elevated brand status: Belectric and Pfalzsolar.

Belectric has an impressive track record. They have over 20 years of experience developing solar parcs. In 2011, they were ranked as the largest developer in the whole world, with the most installed capacity (Newswire, 2011). As of today, they have a diverse portfolio of PV floating, hybrid parcs, and solar parcs and are currently one of the leading developers. This history and experience grant them an elevated status amongst developers.

Pfalzsolar is the subsidiary of Pfalzwerke, an old and trusted regional municipal utilities company, been around for over 100 years. By sharing their name and their trust, Pfalzsolar is granted certain credibility regionally in Germany (Pfalzsolar, n.d.).

Reliability

Reliability is an attribute that builds trust and confidence in the product or service.

This was a value proposition from both companies in Category 5. Vario was marketing their reliability as a 20-year-old, family-led company. Sunlife on the other hand, marketed their experience as a roofing company. Both companies were local and “trusted”, because of the owner structure.

Reliability may play an elevated role in Category 5 since the long-term lease contracts with real estate owners and solar firms require a large amount of trust.

Flexibility

Vispiron was a provider that offered great variation and flexibility in their solutions. They offered solar carports and eco-living apartment complexes. A subsidiary of the Vispiron Group, SE Trade, acted as an electricity broker and offered CPA deals to the customers of Vispiron EPC, thus increasing the attractiveness of large storage solutions.

Furthermore, they installed innovative PV floating systems, some references to those were found in the Small segment.

In general, their PV system references were quite diverse and innovative. This flexibility and multitude of services was unique for Vispiron. As a diverse company group active in renewable energies, they could offer an all-encompassing service that is hard to beat.

6.1.6 Key activities

6. Key Activities			Number	Category	Company
Asset management	**5,6,7,8,11,12**		**1**	1	1komma5° GmbH
EPC	**3,5,6,11,12**		**2**	1	Energiekonzepte Deutschland GmbH
Project rights acquisition	**3,5,9,10,12**		**3**	2	Greenovative GmbH
Sales	**2,4,7,8,12**		**4**	2	Wegatech Greenergy GmbH
Tender awards	**5,6,12**		**5**	3	Enerparc AG
Platform/Network	**1,2**		**6**	3	Belectric GmbH
Funding	**1,7**		**7**	4	Enpal B.V.
R&D	**11**		**8**	4	DZ-4 GmbH
Company acquisition	**1**		**9**	5	Sunlife-Montage GmbH
			10	5	Vario green energy Concept GmbH
			11	6	Vispiron EPC GmbH & Co. KG
			12	6	Pfalzsolar GmbH

Table 21: The "Key activities" part of the Master BMC.

Asset management

Asset management could pertain to management of owned assets e.g. leased contracting systems, as well as to O&M of both internal and external assets.

For the contracting providers, Enpal and DZ-4, asset management plays a central role in managing the large number of PV systems that remain as their company assets.

For providers like Enerparc or Vispiron, asset management revolves around managing the assets in their own portfolio.

As for Belectric, they offered O&M as one of their main services, managing an impressive 2 GW of external assets.

EPC

EPC was a key activity, and necessary element, for every provider active in the Large segment.

EPC, especially in the project development phase, is important for project realization. It includes everything from project rights acquisition to the commissioning of the PV system.

As the requirements and complexity of EPC increase, the PV system increases. Thus, it is usually offered as a service in the Large segment, where companies with the right experience are found. EPC is sometimes in the Medium segment too, but less frequently. It is not found in the Small segment at all.

Project rights acquisition

Project rights acquisition means the securing of rights to use land or rooftop space. The project rights pertain to installing and running a PV system or solar parc for a defined period, usually 20 years or more.

The project right acquisition can be done either directly by purchasing such rights from other firms or external contractors or by acquiring the rights directly from the real estate owners. For companies focusing on project rights acquisition, the latter could be seen on the websites, where real estate owners were heavily targeted. This was especially the case in Category 5. In the case of those companies, Sunlife and Vario, their websites were mainly designed for establishing contact with real estate owners.

Sales

Sales was a key activity for most companies working in the Small size segment. These companies often had large sales forces, sometimes external ones.

In the case of Small systems, having less technical requirements, it can be difficult to tell PV systems from different providers apart. Thus, a large sales force can be a way to compete in the market. A great example is the sales force of EKD, with 2,400 salespeople/energy consultants working with along with a 300-person company. This is probably one reason for the stark, organic growth EKD has seen over the last five years. With independent contractors helping them to expand, they could scale their business all over Germany, without the necessity of investing in their own staff.

Tender awards

Participation of tenders is a central role for developer focused companies, opting for EEG support and closing PPA deals. It is sales, but for larger companies, thus being relevant companies in the Large segment.

For Belectric and Pfalzsolar, tenders were explicitly or implicitly referred to on their website. Belectric depends on winning tenders, as they are focusing on the development of huge solar parcs. Pfalzsolar mentions winning a large tender of 60 MW for a solar parc in the south Netherlands in 2021, which is their biggest project in history (Pfalzsolar, n.d.) *Unsere Geschichte*. For Enerparc, participating in tenders is important for getting EEG-support for their own projects.

Platform/Network

Platform and network mainly involve the following attributes:

- Establishing a network of specialist companies of solar technicians, electricians and other manual labor firms that are necessary for the installation of a PV system.
- Establishing an external, commission-based, sales force.

Because of the fast growth in the industry, the companies that can secure such resources will be more successful. For a company active in the Small size segment, building thousands of PV systems per year, and especially doubling this capacity on a year to year ratio, a company can only keep up the expansion rate when those resources are available.

This capacity has to be secured externally if not everything is done in-house. 1komma5 Grad was integrating this capacity into the company through their acquisition strategy of consolidating the market. This will secure these resources for 1komma5 Grad, while at the same time withdrawing those resources for every other solar firm that has previously used them.

Funding

Funding regards the company funding itself for expansion purposes.

Companies working in Category 4 have an essential funding need. Enpal has, with its contracting model, a liquidity problem. They are installing PV systems today that will pay themselves back over 20 years. Thus, securing

capital is essential for further expansion. The cashflow may turn positive first in years. Enpal has raised over €2.2 billion in venture capital in 14 rounds (Crunchbase, n.d.) *Enpal*, and this process may go on for years until Enpal's cashflow can carry itself. DZ-4 was also funded, although to a lesser degree, since the EnBW takeover, this may not be needed anymore.

For 1komma5 to sustain its acquisition strategy, it must also secure capital. Although they could grow organically as EKD, their ambitions are set higher, with rapid expansion and an international focus. They are aiming to be in the top 5 PV providers in every large PV market in the world (Business insider, 2022). To further uphold this expansion strategy, a repeated need for funding is expected over the years (1komma5° GmbH, 2023).

R&D

Although the production of PV components, as well as the research, is mostly situated outside of Germany as of today, some companies are still working in this domain.

Vispiron EPC as a part of the Vispiron group, is utilizing R&D to provide improved new and better solutions to their customers. They work particularly with R&D in the solar industry, and have large research facilities for testing in the company. This key activity enables Vispiron EPC to offer their innovative solutions e.g., solar carports (Vispiron EPC, n.d.).

Company acquisition

1komma5 Grad's expansion strategy is based on acquiring larger manual worker firms, to cover nationwide markets. The founder, Philip Schröder, aims to pick the top 1% of local manual workers firms that already have established customer networks and working businesses, acquire them, and thus expand the business of 1komma5 Grad (Newsfile Corp., 2022). The sourcing and selection process of this, to find the right companies in the right places at the right time, is a key activity.

Although currently not commonplace, more frequent company acquisitions are anticipated as the PV industry matures. In the growth stage, as we are in right now, the market is fragmented and hosts a large diversity of new entrants, competing for market shares. As the market progresses, according

to PLC theory, the market will consolidate, and a few dominant players will remain. They will get there partially by acquisitions.

6.1.7 Key partnerships

7. Key Partnerships			Number	Category	Company
Manual labor firms	2,4,5,6,7,8,9,12		1	1	1komma5° GmbH
Electricity grid operators	3,5,6,9,10,11,12		2	1	Energiekonzepte Deutschland GmbH
Real estate owners	3,5,9,10,11,12		3	2	Greenovative GmbH
Communes	3,5,12		4	2	Wegatech Greenergy GmbH
Subsidiaries	11		5	3	Enerparc AG
Financing banks	12		6	3	Belectric GmbH
Sales force	2		7	4	Enpal B.V.
Investors	1		8	4	DZ-4 GmbH
			9	5	Sunlife-Montage GmbH
			10	5	Vario green energy Concept GmbH
			11	6	Vispiron EPC GmbH & Co. KG
			12	6	Pfalzsolar GmbH

Table 22: The "Key partnerships" part of the Master BMC.

Manual labor firms

Manual labor firms are companies working with construction, roofing, electricity and/or other manual labor involved in installing a PV system. Subcontracting this type of work makes the BMs scalable, and the solar firms can focus on the sales, and offering towards the end customer. However, because of the stark growth in the PV market, there is a large demand for such companies, but not always the supply, making it important for companies to secure these resources. Furthermore, for a GC to keep its quality of services consistent, they must have a certain quality control, which is only possible in long-term partnerships.

Electricity grid operators

Electricity grid operators present a key partnership for every company installing PV system above 30 kWp. Above this, limit capacity control and approval from the electricity grid operator is necessary. Thus, those key partners for companies in the Medium and Large size segments.

Real estate owners

Real estate is a pre-requisite of most PV systems, whenever it is ground- or roof-mounted. For DO providers, this is not a concern, but TPO providers must secure such real estate as a foundation for their projects. Thus, they must cooperate with real estate owners. This does not apply in the Small TPO segment though (Category 4), since the customer in this case is normally the property owner. In the Medium and Large segments, the property owner is normally different from the customer (investors), thus making this key partnership important.

Communes

Communes include both local government and residents. Approval of these groups is necessary for the construction of a solar parc, hence this could be listed as a partnership for all companies active in the Medium and Large size segment, for any company working with “local resident solar parcs”, where the local community gets involved in the development of such parc. Enerparc, Pfalzsolar, and Greenovative all offered this model, making communes a key partnership for them.

Subsidiaries

Subsidiary companies represented a key partnership for Vispiron EPC. As a part of Vispiron Group, synergies and value adds within here contributed to Vispiron EPC.

SE Trade, a subsidiary of Vispiron, offered the customers of Vispiron EPC PPAs and CPAs, as well as AI-based trading models for their electricity generation, thus providing additional value for Vipsiron EPC customers, who can increase their profit on solar parcs and storage solutions.

Another subsidiary of Vispiron was Klimahelden GmbH, which focuses on making eco-auditing for companies, making them mission neutral. This is another complementary service for Vispiron EPCs customers, as green initiative when investing in solar.

Vispiron EPC can provide great value propositions in the areas of flexibility and customization thanks to its subsidiary key partnerships.

Financing banks

Financing banks as funding parties/lenders, compared to private investors, have other investing perspectives, usually lower risk tolerance, usually longer time horizons, and usually lower interest rates. Financing banks can be a great help when developing capital intense PV systems, especially when the capital costs are of essential importance. This can be the case when investing in self-owned PV assets, and the profit is calculated on a few percentages on the margin, as in the case of large solar parcs.

Banks were mentioned as a long-term key partner of Pfalzsolar, specifically the bank Umweltbank AG, which is a German bank promoting environmental investments (Pfalzsolar, n.d.) *Testimonial.* Although Pfalzsolar was the only company to explicitly mention this, other companies in the Large segment may also work with financing banks as lenders.

Sales force

Maintaining and growing an external sales force is essential for companies in Category 1 unless this capacity exists in-house. A strong benefit of an external sales force is that it can be quickly expanded in a growth phase. An in-house sales force may be more knowledgeable and efficient. However, it carries a bigger financial risk in terms of salary costs and takes a longer time to ramp up.

A disadvantage of an external sales force is that they may be less informed and pass on more wrongful information than an in-house one. Since Category 1 companies oftentimes do not have long-term contracts with their customers, this may be less of an issue. Therefore, the sales force is a key partnership. Category 4 companies, also active in the Small segment, seemed to have their sales forces in-house, which may pertain exactly to this reason: they have very long relationships with their customers, where a

good start and the right information may be more important. In the case of EKD, a Category 1 company that utilizes a huge external sales force, this is assumed to have contributed to their rapid expansion and enables EKD to have a nationwide presence. 1komma5 was left out because they are undertaking an acquisition strategy, taking over sales forces of local companies.

Category 4 appeared to primarily utilize in-house sales forces. In the Medium and Large segments, however, sales forces were scarcely identifiable, if not entirely absent.

Investors

Investors were a key partnership for 1komma5, which was able to implement their expansion strategy based on funding from investors.

6.1.8 Key resources

8. Key Resources			**Number**	**Category**	**Company**
Intangible Assets	**2,3,4,5,6,10,12**		**1**	1	1komma5° GmbH
Financial Resources	**1,5,7,8,12**		**2**	1	Energiekonzepte Deutschland GmbH
Human Capital	**1,2,9**		**3**	2	Greenovative GmbH
Brand Reputation	**6,7**		**4**	2	Wegatech Greenergy GmbH
Data and Information	**11**		**5**	3	Enerparc AG
Strategic Alliances and Partnerships	**2**		**6**	3	Belectric GmbH
			7	4	Enpal B.V.
			8	4	DZ-4 GmbH
			9	5	Sunlife-Montage GmbH
			10	5	Vario green energy Concept GmbH
			11	6	Vispiron EPC GmbH & Co. KG
			12	6	Pfalzsolar GmbH

Table 23: The "Key resources" part of the Master BMC.

Intangible assets

Intangible assets included company experience and know-how in the implementation of PV systems.

Experience was often used as a marketing attribute. PV companies investigated in this report are mainly service companies, and nothing proves a good service is better than a long, successful company history Experience builds trust in customers, i.e., reliability and risk reduction, two common value propositions.

Regarding the know-how, this is the knowledge of how to organize a successful PV system, including aspects of mounting, electricity, cabling, output prognosis, tax knowledge, and legal requirements. Solar companies are usually outsourcing this type of work, but as GCs, they must have the right know-how to put a well-coordinated package of services together in a neat way that results in a successful PV system, holds up what it promises, and lastly, generates a profit.

Financial resources

Financial resources can pertain to company or project funding.

In the case of 1komma 5 Grad, DZ-4, and Enpal, those were financed through venture capital in multiple rounds of funding. Thus, financial resources were a key resource for their BMs.

Regarding 1komma5 Grad, the company managed to secure an impressive €300 million in the first months of the company's history (Handelsblatt, 11.04.22). The capital was used for their acquisitions of regional solar technicians, including local staff and customer bases. About one year after they were founded, they were one of the biggest B2C PV providers in Germany. While continuously raising capital, they have successively managed to enter new markets abroad, most recently entering the Australian market by acquiring one of the largest solar technicians in the country in 2022 (Newsfile Corp., 2022).

While 1komma5 Grad currently has raised over €630 million (Crunchbase, n.d.) *1komma5* in their short history, the king of raising funding in this industry is Enpal ("King of Funding"), who raised over €2.2 billion since 2017 (Crunchbase, n.d.) *Enpal*. These financial resources have elevated them into the largest B2C provider in Germany. For companies working with contracting, such as Enpal and DZ-4, strong financial resources are key for the expansion of these businesses, and a necessity.

In the case of Pfalzsolar, their financial resources were secured as a subsidiary of the energy supplier Pfalzwerke. As such, they have had financial backing from the start of their business ventures, which has enabled them to be active from an early stage in the German PV market.

The financial resources are also a key resource for Enerparc, whose financial resources pertain to private investors, banks, and local residents instead of venture capital firms like in the examples of Enpal and 1komma5 Grad. The financial resources of Enerparc pertain to the individual solar projects of the company. These investors are also different, looking for stable and safe yields. The financial resources are key for the possibility of the projects of Enerparc.

Human Capital

Human capital was a key resource in the case of three companies: 1komma5 Grad, EKD, and Sunlife. It could be argued that more companies had human capital as their key resource. However, since the PV technology and business processes are relatively standardized today, the expertise itself does not seem to be a bottleneck, except for slightly regarding project development.

In the case of 1komma5 Grad and EKD, the human capital is related to their founders, Philip Schröder and Mathias Hammer.

Philip Schröder had long experience in the PV market and was country manager for Tesla in Germany (Businessinsider, 24,.5.22) a few years before he founded 1komma5, based on the vision that the bottleneck in the PV market currently was not in the technology, but the practical implementation from the solar technicians. The solar technicians were operating in a fragmented way, on a local basis, with varying business practices. Based on the idea of consolidating this fragmented market, Schröder managed to fund his business heavily from the very beginning, thus opening up the success story of 1komma5.

In the case Mathias Hammer from EKD, he had a long entrepreneurial experience in the German PV market before EKD. He founded Senec, one of the largest battery producers in Germany, many years back (Solarserver, 7.1.2020). He founded EKD in 2018 based on the idea of the carefree package - *“The idea was to offer an all-round carefree package by*

combining coordinated components and an installation service" (Diebewertung, 25.2.23). At this time, this concept was new. EKD managed to grow fast based on the idea of bringing the convenience of a package PV deal to the customer. Today, the carefree package is the industry standard in Category 1.

Regarding Sunlife, their main value proposition of quality is derived from their experience as a roofing company. This is a human capital key resource in the form of company staff.

Brand/Reputation

Two companies, Belectric and Enpal, had a reputation as a key resource.

In the case of Belectric and having a reputation of being a renowned and worldwide provider, they have a good chance of winning tenders on a bigger international scale.

Enpal in Germany almost become synonymous with the contracting model, or "Mietanlagen" (leasing systems), and has become the go-to provider for such systems, being able to reach out to more customers through this strong reputation.

Data and Information

Data and information were a key resource of Vispiron EPC and the company group Vispiron, which is active on many fronts in the solar industry and is conducting its own R&D. The data information between the subsidiaries as previously explained boosts Vispiron EPC's value proposition and gives them an innovation edge in the industry.

Strategic Alliances and Partnerships

EKD was, as previously mentioned, outsourcing most of its sales and installation service. This makes their partnerships with external salespeople, as well as their large network of local solar technicians, an important key resource.

6.1.9 Cost structure

9. Cost Structure			Number	Category	Company
Cost-driven	**4,5,6,9,12**		**1**	1	1komma5° GmbH
Not enough information	**3,10,11**		**2**	1	Energiekonzepte Deutschland GmbH
Value-driven	**1,2,7,8**		**3**	2	Greenovative GmbH
			4	2	Wegatech Greenergy GmbH
			5	3	Enerparc AG
			6	3	Belectric GmbH
			7	4	Enpal B.V.
			8	4	DZ-4 GmbH
			9	5	Sunlife-Montage GmbH
			10	5	Vario green energy Concept GmbH
			11	6	Vispiron EPC GmbH & Co. KG
			12	6	Pfalzsolar GmbH

Table 24: The "Cost structure" part of the Master BMC.

For certain companies, it was challenging to determine whether they were primarily cost-driven or value-driven. These companies have been categorized as 'Not enough information' in terms of their cost structure to avoid making inaccurate assumptions.

Cost-driven

Cost-driven was the most frequently occurring cost-structure in the research.

The companies operating in the Medium and Large sized segments tended to be cost-driven. Tenders are by nature cost-driven, where the lowest bids usually win. This applies to EEG-tenders, where the official policy is that the lowest bid wins. Regarding companies investing in their own asset portfolio, e.g., Enerparc, their income is fixed on the revenue side (fix EEG-support or PPA-rate). Thus, the way to increase yield will be possible only by cutting costs. Such businesses are naturally cost driven.

For companies in the Medium size segment targeting C&I, low pay-off times and high yield rates are their main value propositions. These attributes will perform well under low-cost conditions, making businesses here cost-driven too.

Value-driven

Every company in the Small size segment was value driven. Value drive here meant that the pricing was not correlated to the cost, but rather to what the customer perceived to be an appropriate value for the product.

Regarding 1komma 5, the company frames its service as top-performing and sustainable. Furthermore, their service was offered nationwide, with congruent pricing. However, on the installation side, many different subsidiaries were operating, assumingly with different cost structures as well. To keep a congruent pricing, it needs to be set on a value-driven basis, and not on a cost-driven variable basis since this would be too complex.

For EKD, the cost-structure is clearly value-driven (EKD, 23.09.22). Their revenue was €33.6 million and EBITA €15.5 million, thus being a very profitable business, displaying great margins. The cost of goods was €8.4 Million was the highest cost post, or ca. 25 % of the revenue, which is less than half of the companies in the cost-driven segment. The salary payments in 2021 accumulated to €1.4 million or 4.2% of the revenue, also less than half of what was available in the cost-driven segment.

For Enpal and DZ-4, the contracting model as a concept is value-driven, since the customer pays a higher price for the PV system, for the possibility of paying back the system in rates over the years. The pricing is set on whatever the customer finds an appropriate monthly fee for the system, or at the price level where competitors are at. The system cost is much lower than the accumulated lease payments, as was displayed previously.

6.2 Category analyses

In this chapter, the business categories are discussed on a category level. Some conclusions based on the results of the case studies are presented.

Category 1 – Direct Ownership, Small

This category is mainly focused on the sale of PV turnkey systems to private customers. The category is market driven and is currently growing significantly in Germany because of the increase in electricity prices and decrease in PV prices during recent years. The companies found in this category were young and fast-growing companies with impressive financial

numbers. EKD and 1komma were very profitable businesses indicating their mainly value-based cost structure.

Category 1 had the lowest CSS score, 2.2, of all categories studied, indicating that these companies were the most narrowly focused. This was reflected in the case-study companies as well as those who had a clear category focus.

The basic concept behind these companies is to coordinate sub-services to create wholesome, convenient PV offers for the end customer. The system usually includes a “care-free” package, promising maintenance and support. The value proposition of the care-free package was the founding idea behind EKD. Meanwhile, this concept is standard for Category 1 companies. The validity of the care-free package may be questioned after reviewing, for example, EKD reviews online with many customers complaining about non-existent customer service. The companies seemed mostly active until the commissioning, with few providers offering O&M as a standalone service thereafter.

The pricing was value driven. The pricing structure is congruent nationwide, whereas the cost structure is incongruent due to cooperation with many different subcompanies. The pricing is set on whatever the customer perceives as an appropriate price. Customers with little to no experience with PV have no way of determining the actual costs, thereby opening up for value-driven pricing in a competitive and fragmented market.

It is a standard practice for Category 1 companies to charge advance payment for their services. Therefore, the companies do not need funding themselves since the projects are funded by the customers. Since no funding is needed, entry barriers are low in this category. Since manual work can be outsourced, the BM is very scalable. Furthermore, with implementation times of 6-12 weeks, cash flow returns to the company at a high pace. This mixture in combination with a growing market, makes for an interesting business prospect, which may contribute to the high competition in this segment.

Because of the practice of commissioning labor-intense work, the companies act as central nodes in a larger network structure. This structure brings logistical challenges. These challenges are assumed to be essential in Category 1, but also in Category 4, across the Small size segment. These

take predominance over technical challenges, which are not a major concern in this category.

The online presence of these companies displayed modern, well-designed websites, including some type of solar calculator ("Solarrechner"). This calculator estimated the PV system size, whereupon an offer was emailed, thus collecting contact information from the customer and generating leads over the website. The websites targeted people with little or no experience with PV, a conclusion drawn from the material presented.

Category 1, named B2C PV turnkey provider, had some of the most prominent companies in the whole PV industry which is a major business model.

Category 2 – Direct Ownership, Medium

Companies in Category 2 provided PV turnkey systems in the Medium size segment. This mainly pertains to C&I facilities. This category is market driven with companies targeting the electricity costs of the customers.

The CSS of the category was 3.3, the second highest of all categories researched. With an average assets balance of €16 Million, they ranked at the bottom of all categories of this metric. These numbers indicate less focused, smaller companies. Reverting back to the general statistics about the Medium size segment, representing only 16% of the installed capacity in Germany in 2022, this may be a less interesting business prospect.

The wider focus also applied to the case studies. In the case of both case studies from this category, Wegatech and Greenovative, it turned out that their main focus areas were not Category 2. Wegatech would fit better as a representative of Category 1, and Greenovative Category 6, thus making the results for this category less reliable. A reason for this may be the less activity within the Medium size segment, representing only 16% of the installed capacity in Germany in 2022.

The cost structure of the Category 2 companies was cost-driven. Their value proposition of lowering electricity costs for their customers will improve as they reduce their prices. Thus, there is a natural incentive to be cost-driven. Furthermore, customers in the C&I segment are more numbers-driven than private consumers, which also promotes a cost-driven structure.

The average size of a Medium-size segment of 135 kWp was presented in chapter 5.2. The average volume per order is not really high, considering that the Medium segment extends to 750 kWp. A combination of being cost-driven, with low volumes, makes the category as a prospect less interesting.

Category 2 companies were active nationwide and did not have the logistic challenges of Category 1. The technical challenges are more complex than for Small companies but lesser than for Large companies. Thus, there is no significantly targeted expertise needed in either the domain of logistics or EPC. As such, it may be suitable as an add-on category for other business prospects.

One final consideration within this category is the complex issue of targeting customers. In the C&I segment, properties are often leased. Property owners may not always have incentives to invest in PV systems since they are not affected by electricity costs. Likewise, C&I customers leasing the property may have less motivation to invest, as the return on investment for PV systems can span 10-20 years, potentially extending beyond the leasing period. Unfortunately, this research did not find any compelling solutions to address this dilemma

Category 2, named B2B PV turnkey provider, seemed mainly to have developed as an add-on category to other business models. Based on the results, it is not a major business model.

Category 3 – Direct Ownership, Large

Companies in Category 3 are mainly focused on the development of ground-mounted PV systems (solar parcs). Although there are some rooftops found in this segment, as the PV system size increases, only solar parcs are found. More recently, storage solutions are increasing in popularity, as well as the mounting technology of PV floating.

Customers in this segment can be everything from different types of investors to large international asset managers investing in renewable energies.

The CSS of this category was 2.9, with most companies being active across the Large segments. The average assets balance of the category was €397 million, being many times larger than the balance from the Small and Medium segments.

The companies in this category began in the period 2000-2010, thus being around for longer than companies in other categories. The reason for this is that this segment was, and still is, incentive driven. As stated by Enerparc, for example, they only invest in solar parcs based on EEG support and PPA. Although market-based PV has boomed in recent years, state support through EEG has been around since the early 2000s, thus such companies have been around since back then. Companies in this category have developed into large, international entities.

The core activity of companies in this category is the EPC. EPC can include everything from securing project rights to system commissioning. It is mainly focused on the technical and political challenges. Proper project development will determine the success chances of a solar parc project. The process of political approvals from local governments and residents is not an easy task and requires certain experience. A more consolidated market and a larger need for know-how set up higher entry barriers in this category.

The risk-reduction-through-experience value proposition was highlighted by the representative companies in this category. Because of the huge investments in such PV systems, risk reduction is very important. The market is concentrated around fewer providers. Belectric was a clear-cut example of a Category 3 company, as a well-known, international provider. On a global scale, there are not many companies with this type of experience available.

The cost structure of Category 3 companies is exclusively cost-driven, with material constituting a larger part of the total costs. Tender processes, whether it is EEG- or PPA- tenders, usually win by lowest bids, thus driving a cost-driven business model. This is compensated by large volumes. The Large segment is the largest one in the German market, accounting for 44% of the installed power in 2022. Furthermore, with the average PV size of 4.7 MWp in the same year, these are interesting business prospects.

Category 3, named solar parc developer, is a major business model, focusing on EPC pertaining to ground-mounted PV systems.

Category 4 - Third Party Ownership, Small

Category 4 companies mainly worked with the contracting model. They target private households with the value proposition of lowering their

electricity costs. Because of this, Category 4 is just like Category 1: market-driven. The category has seen a strong upswing during recent years, as the PV industry is doing well.

The CSS of Category 4 was 2.2, the lowest of all categories, indicating a clear category focus. Furthermore, there were only 7 usable results found in the research, indicating that there are fewer providers active in this category.

The customer profile of Category 4 deviates slightly from Category 1. Households in this category outsource the capital investment, as well as the maintenance responsibility to the contracting provider. In return, the customer will carry a higher accumulated investment over time. For a very patient investor, this is a good deal.

The Category 4 market was consolidated around Enpal. When looking at top providers in Germany for PV B2C systems (including Category 1 and 4), Enpal is the largest one. Enpal is the only contracting business in the top 8 (Statista Q & Enpal, 2023), the rest being Category 1 businesses. This can be the consequence of EoS advantages for Enpal, installing the highest number of systems. Due to their size, they will be able to secure the best funding. With EoS advantages and good funding, they can offer the lowest lease, thus having the by far most important value proposition locked down. This has seemingly created a semi-monopoly structure in the contracting marketing, to Enpal's advantage.

Regarding important activities in Category 4, the priority is securing funding. The model depends on funding for expansion. With a payback period of 20-25 years, the cashflow cannot carry an organic expansion. Both representative companies have managed to get properly funded.

As far as expertise is concerned, Category 4 has the most complex logistical challenges of all categories. Zooming in on Enpal, they currently install 40 PV systems per day. Furthermore, they have over 48,000 PV systems in their portfolio, requiring O&M. Installation and maintenance of this number of systems is quite a nightmare.

Category 4, named contracting provider, is a major business model that has seen great advances during the last years and may result in natural monopolies.

Category 5 – Third Party Ownership, Medium

Category 5 companies mainly focused on developing TPO assets. The assets were either kept in-house for electricity trade as a revenue stream or sold to investors. Thus, the customers were either electricity consumers or investors. Real estate owners represented a combination of a partner and a customer, but since they are profiting from lease payments, they were classified as a partner.

The CSS of the category was 3.5, indicating a wide focus. Although the two representative companies were active in several categories, there was a clear Category 5 focus, with other categories being add-ons to their main offering.

Category 5 is an almost exclusively EEG and thus incentives-driven category. In the Medium size segment, PV systems get fixed EEG support, thus making the revenue side secure and attractive for long-term investors.

The online presence of those companies was focused on acquiring rooftop spaces in the range of ca. 1,000 – 10,000 m_2. With fixed EEG-support and lower technical requirements compared to those in the Large segment, the project rights of such rooftops represent the bottleneck in this category. For a company to be successful, it should be successful at managing this bottleneck. This is done by establishing and maintaining good relationships with real estate owners, with something mainly managed offline, outside of the website parameters. The websites of both representative companies were outdated and looked less professional, indicating that this was not their main channel. The company owner structures in Category 5 may be another aspect of establishing relationships with real estate owners. Sunlife being a roofing company doing most manual labor in-house and Vario being a family-led company for 20 years, both conveyed familiarity and reliability.

Category 5 companies were found to be active nationwide in Germany. No companies were found to invest internationally, which is reasonable, considering that they are EEG-based.

Category 5, PV rooftop investor, is an established business model, but not a major one. There is a bottleneck of available rooftop prospects that may set a natural barrier to this category.

Category 6 – Third Party Ownership, Large

Category 6 companies invest in solar parcs as monetary assets. The companies were either focused on electricity trade, when developing their portfolio, or on asset sale, when selling solar parcs, or shares thereof, to investors. Developing these assets for the companies' own portfolios was a common alternative.

The companies in this category were large and international entities, many of them being around for 10 years or more. They were oriented towards safe and long-term yields supported mostly by EEG and sometimes PPA. As such, the category is still mainly incentive driven.

The CSS of this category was 3.0, with most companies from this category also being active in Category 3. The average assets value was €396 million, thus being almost identical to Category 3, and much higher than other categories.

Project-based funding is one of the most essential aspects of this type of business, considering the multimillion-dollar investments required for solar parcs of this scale. However, safe and long-term yields are attractive for large capital and investors as a trusted company can enable the right financing conditions necessary for funding such projects. Such a company needs the right track record, experience, and know-how, which takes time to acquire. Thus, entry barriers are high in this category.

The core business of Category 6 was investing in renewable energy as money-making assets. Wind power was a common addition to the PV, however, companies working with wind power were excluded from the usable results (see chapter 5.3.2). The companies of Category 6 were active in the whole value chain of developing a solar parc – from the project rights acquisition to the sale of the parc or electricity trade and maintenance. As they are investment-oriented, services like EPC were developed to implement their own PV projects and were offered as add-on services. This expertise was developed to be utilized for their own PV projects but was not a core business activity.

Project rights acquisition is very important in this category, and securing those is one of the most essential activities. Appropriate project rights are an important success factor for such companies.

Category 6, named solar parc investor, is a major business model. Category 6 companies mainly invest in PV as a renewable, money-making asset.

6.3 Comparing the business models

In this section, the different categories are compared on a size segment level. Characteristics as well as advantages and disadvantages are presented.

6.3.1 Small-size segment

Following is a list of characteristics, as well as pros and cons within the Small size segment.

Common characteristics

- Market-driven. Because of this, companies active in this segment are currently fast growing.
- Young companies. Most companies found in these categories were formed during the last five years.
- B2C customers. Both categories serve private households.
- Value-driven pricing. Pricing is based on customer perception.
- Narrow focus within the category. Both categories have low CSS.
- Large logistical challenges. Both categories are building a large number of small systems around Germany.
- Diversity of revenue streams. Additional revenue streams were commonly utilized here e.g. heating solutions and in-house components.
-

Different characteristics

- Market fragmentation. Category 1 is a very fragmented market. Category 4 was concentrated around Enpal.
- Customer profile. Category 1 and 4 customers are different in terms of financial standing, here Category 1 customers are better off.
- Cash-flow. Rapid returning cashflow in Category 1, slow returning cashflow in Category 4.

- Funding necessity. Funding is not needed for growth in Category 1 but is needed for expansion in Category 4.
- Entry barriers. Entry barriers were low in Category 1 and high in Category 4.

Advantages

- Both categories are market driven, thus expanding rapidly as the PV market currently grows.
- The B2C segment is the largest in most industries. Thus, the future market shares of Category 1 and 4 may be the largest ones of all categories.
- The possibility of upselling thanks to a larger variety of income streams.
- Market fragmentation is a possibility for new, dominant players to conquer market shares in Category 1.
- Rapid RoI in Category 1, with implementation times of up to three months.
- Low entry barriers benefiting new market entrants in Category 1.
- High entry barriers serve as competition protection for Category 4.
- A value-driven structure opens up higher profit margins to be attained.

Disadvantages

- High logistical complexity in this segment.
- Low order volumes per system.
- Slow return of capital for Category 4, with payback times of 20-25 years.
- Low entry barriers create a very competitive market in Category 1.
- High entry barriers prevent new market entrants in Category 4.

6.3.2 Medium-size segment

Following is a list of characteristics, as well as pros and cons within the Medium size segment.

Common characteristics

- Less activity. Both categories had less dominant and smaller actors than in other categories.
- Less complex project development than in the Large segment. This pertains to the fact that no building permits are necessary, as well as no approvals from local residents and governments.
- Fragmented market. Both categories had fragmented markets, with no single large dominant player.
- Geographical focus in Germany. Both categories had a nationwide focus, but no international focus.
- Both categories have a cost-driven structure.

Different characteristics

- Customer profile. Category 2 targeted C&I customers, whereas Category 5 targeted electricity consumers, investors, and real estate owners.
- Main business activity. Category 2 is mainly focused on customer acquisition, whereas Category 5 is focused on securing project rights.
- Market/Incentives driven. Category 2 is market-driven, whereas Category 5 is incentive-driven.
- Category focus. Category 2 companies were not mainly focused within the same category, whereas Category 5 was not.

Advantages

- Customer acquisition is less complex for Category 5. Electricity consumers must not be acquired at all, and investors are not difficult to come by as long as the project is profitable.
- Less complex project development for both categories, making this process cheaper and less risky.
- Less logistical complexity than the Small segment.
- Less EPC complexity than in the Large segment.
- Fixed EEG-support and thus revenue for Category 5.
- Category 2 was less competitive than other categories.

Disadvantages

- Lowest market share in Germany. The Medium segment has a total of 16% market share of installed power in Germany, making it by far the smallest.
- Securing project rights is a bottleneck for Category 5.
- Category 5 is dependent on EEG and thus exposed to a political risk. Furthermore, this may inhibit the growth rates in this category.
- Due to relatively small order sizes of 135 kWp, and being cost-driven categories, the mixture of low volumes and profit margins is reducing the attractiveness of this segment.

6.3.3 Large-size segment

Following is a list of characteristics, as well as pros and cons within the Large size segment.

Categories 3 and 6 overlap quite a bit, with most companies being active in both categories simultaneously, thus being more difficult to tell apart. However, it is suspected that Category 6 is much more the main business category with Category 3 having developed as a complement.

Common characteristics

- Both categories offered EPC as a service.
- Both categories included, on average, much larger companies than in the other categories.
- Entry barriers are high in both categories, although they are considered higher in Category 3 since a lot of trust is needed to get hired for such projects.
- Both categories worked with O&M as a service.
- Both categories are cost-driven, with material costs constituting the dominant cost position.

Different characteristics

- EPC is the main business activity for Category 3, for Category 6 this is an add-on service.

- The EPC did include project rights acquisition for some Category 6 companies.
- Investing in solar projects is the main business activity for Category 6.
- Category 3 is focused on winning orders e.g., EPC tenders for solar parcs, whereas Category 6 is focused on securing project rights and winning EEG-tenders.
- Project funding is essential for Category 6, not for Category 3.
- Revenue is sporadic for Category 3, whereas it is long-term and frequent for Category 6 (regulated over PPA and EEG).

Advantages

- Large volumes in each order for Category 3 – average PV system of 4.7 MWp.
- High plannability in the revenue for Category 6.
- Large is the most attractive segment in terms of installed power, at 44% in Germany.
- A consolidated market protects established market actors.
- Fewer projects with high volumes bring lower logistical complexity than in other categories.
- Less customer service.

Disadvantages

- Complex project development and unclear outcomes are a financial risk for Category 6 companies.
- High entry barriers prevent new market actors from entering.
- Higher capital risks bound up in individual projects.

6.4 Current trends

As of 2023, photovoltaics is going mainstream. The market is also transitioning from being mostly incentive driven, to becoming more market driven. The underlying driving factors for this transition are increasing electricity prices and lower installation costs of photovoltaic systems. Additionally, the market expansion is further promoted by social capital, as

it can be considered to have hit the critical mass in the innovation adoption theory, thus paving the way for more people to embrace this technology.

Categories 1 and 4 are doing particularly well because photovoltaics is currently a cheaper alternative than alternative energy sources, and combined with cheaper storage solutions, the energy supply is getting manageable as well. The companies in these categories are growing at a much higher pace than other categories, based on the available numbers. Those categories were also particularly affected by the Ukraine-Russia war in 2022, when the electricity prices skyrocketed in Germany, and people turned to photovoltaics as a way of guarding themselves against the ever-increasing electricity costs, and a safe energy supply.

A trend observed amongst some of the B2C companies was the sale of in-house components as a way to increase their value proposition as PV modules are commoditized, e.g., Enpal and 1komma5 with their own energy managers or 1komma5, with their recently developed sustainable PV modules. Through smart energy managers, PV operators in the Small segment can these days sell their electricity on the spot market as well, thus being able to benefit from a more fluid electricity pricing, both on the buying and selling side.

Companies in the Large segment were found to mainly invest in PV based on EEG support, thus still being incentives driven. Market-based solar parcs can be developed based on PPA models or trading electricity on the market. For the latter, storage solutions are a great addition, since they enable companies to trade electricity optimally. These storage solutions are helping to drive the development of non-subsidy-based solar parcs. Regarding storage solutions for Large systems, this was incorporated in the portfolio of most companies during recent years, and the sinking EEG-rates may drive this development, as well as storage capacity getting cheaper.

The low-interest situation during the last few years in Europe has not been considered in this report. However, as it has changed in 2023, this may affect the market of photovoltaics since PV systems usually are funded through credits.

As for alternative technologies, PV floating is a technology that is on the rise. These systems have a much more expensive mounting structure than traditional land-mounted systems. However, these systems do not compete for land space, and there is no shadowing on the sea. This technology is

rapidly expanding for these reasons. PV floating was incorporated into the portfolios of Belectric, Pfalzsolar, and Vispiron in recent years.

Regarding the PV modules, the mono-crystalline alternative is dominating the market today. The poly-crystalline modules' main advantage is being cheaper. This advantage is losing relevance with the price drop in mono-crystalline modules. The efficiency of crystalline modules keeps improving, although it is beyond the scope of this work to estimate how far this efficiency improvement can go.

6.5 Prognosis of the future

Photovoltaic systems have undergone a remarkable transformation, emerging as one of the most cost-effective energy resources available today. This transformation can be primarily attributed to the continuous improvement and cost reduction of silicon crystalline modules. This is connected to the proliferation of mass production facilities in Asia during the last decade. This has yielded substantial EoS advantages, resulting in significant price reductions. While the trajectory of further development remains a question, it is important to note that solar modules, which used to be the predominant cost driver in PV systems, now constitute approximately 37% of the total system costs. Assuming Swanson's Law continues to hold in the coming years, a 20% reduction in PV module prices can be anticipated the next time the cumulative PV capacity doubles. In 2021, as indicated in Figure 7, the year-on-year cumulative capacity change was approximately 22%, suggesting that it would take approximately 4.5 years for capacity to double, assuming the derivate would not go down. This 20% cost reduction pertains solely to the 37% portion of total costs of a PV system of today (concerning normal households), resulting in an overall price reduction of approximately 7.4% expected over the next 4.5 years - in accordance with Swanson's Law. Given these circumstances, the expectations for further dramatic price reductions in the PV sector over the next decade should not be as high set as for the past 10 years, and the price curve is expected to flatten out. However, there is a silver lining for systems in the Large segment, which tend to be more material-intensive. Material costs constitute a higher percentage of the overall expenses for these systems, thus, categories 3 and 6 may continue to benefit from this development to a higher degree than companies in the Small and Medium size segments.

With solar contributing to 3.6% of the gross energy production, there is a lot more room for expansion of the technology, considering that the energy market concerns 100% of all people on Earth. It is currently one of the cheapest technologies available almost everywhere and is not dependent on a stable centralized grid. This makes it a great option for energy production for most people in the world. Relating to the innovation adoption theory, we are just in the beginning of the early majority-stage, where continuous progress may be seen just from the social adoption, rather than technical progress.

As for relating the developmental stage to PLC theory, the PV industry is currently in the growth stage, and according to PLC, the duration of this stage depends on the type of industry. Through the lens of the PLC, the PV industry is expected to continue expanding for many years to come, thus driving the expansion of every BM discussed here with more niche models to come. Being in this situation in the growth stage anticipates a high level of competition, new entrants, and emerging market leaders.

One of the key resources of solar, decentralization, enables people in developing countries without stable centralized grids to secure their own energy supply, which drives leapfrogging onto this technology, with resulting explosions of demands globally when such countries are entering on the demand side. This will drive the internationalization of PV businesses since the potential upside can be massive.

The expansion of renewable energies is increasing the volatility in energy production, which drives price volatility. In Germany, there have been negative electricity prices observed since September 2008 (Bundesministerium für Wirtschaft und Klimaschutz, n.d.). Negative prices mean that consumers are being paid for using electricity. As this volatility increases, storage solutions will become a natural part of every PV system. In the B2C segment, battery systems are already standard. For a couple of years, storage solutions have started to show up at solar parcs too, as observed at Vispiron EPC and Belectric. In the coming years, storage solutions will be standard for systems in the Medium and Large segments as well, granted that they are market driven. This is further supported by diminishing EEG rates, as was described in chapter 5, where the degression rate of the EEG was connected to the expansion rate of PV.

Regarding the German market development, the fragmented market in Category 1 is expected to consolidate around fewer and more dominant players, which normally happens as a market matures. This trend is already set in motion by the acquisition strategy of 1komma5 Grad. As the market matures and the expansion within Germany reaches a limit, companies in Category 1 are expected to reach outside of the country's borders. 1komma5 is already doing this by entering new international markets. Other dominant players in this category are expected to do the same.

As for companies in Category 2, this category is expected to split up into niche sub-categories, targeting different types of C&I customers. C&I customers come in different shapes and colors and have different needs. Sub-categories targeting specific C&I customers will be able to offer much stronger value propositions to those customers.

As for companies in Category 3, being international companies, their market is expected to keep growing and the established players are expected to grow together with the market.

In the semi-monopolistic market of Category 4, Enpal is expected to continuously get stronger. Their advantage of being by far the largest player in this category will only get bigger, thus solidifying their position. As the German market is captured, Enpal will most likely go international with their concept as well to uphold their expansion, otherwise being capped by the size of the German market.

As for the EEG, the slow disappearance of this support will mainly affect the more incentive driven categories of 5 and 6. Category 5 is almost completely dependent on EEG, being nationally bound and building systems based on this support. This category will either vanish or transition to a market-based model. As for Category 6, although companies here are mostly building EEG-supported systems in Germany, they are also internationally active and thus are less affected by this law.

As for the technology itself, further incremental improvements are expected. There may not be any quantum leaps seen in the technology during the coming years, since there is no urgent need for this. The current PV modules are stable over time, cheap, and relatively efficient. However, different types of PV modules, like ultra-high efficiency modules, or thin film modules, will be further developed to cover niche use cases e.g. where the rooftop surface is too limited or not viable for standard PV modules. Examples of

such use cases are multiple-level apartment complexes with small roof surfaces and high energy consumption, or thin film modules applied on the surface of e-cars.

7. Conclusion

This chapter presents a summary of the results retrieved in this report. The research questions from Chapter 1 will be answered. Furthermore, so that the reader can evaluate the credibility of the findings, the trustworthiness of those is discussed. Lastly, suggestions for further research on this topic, based on the findings in this report, are presented.

7.1 Summary

This work investigated prominent BMs in the German photovoltaics market.

The background and purpose of this topic, as well as the research questions, are presented in chapter 1.

In chapter 2, the research method, an explorative mixed methods approach, is presented and described in detail.

Chapter 3 presents theory relevant to answering the research questions. This includes the business model theory, market theory, and technology adaptation theory. The business model theory was utilized to classify the business models. The market and technology adaption theories were used to understand where the PV market is currently at. They were also used later for the prognosis of the future.

In chapter 4, PV is discussed from a technological perspective, a cost perspective, a key resource perspective, and a historical perspective. Furthermore, PV modules are explained in detail. This chapter sets the context of PV, so that anyone, with or without prior knowledge of PV, can understand the future findings in the report.

In chapter 5, the German market is mapped. EEG was found to play a big role in the German PV market and has been a major contributor to the early development of PV in Germany for over 20 years. EEG regulation, combined with some inherent characteristics of PV technology, resulted in three PV system size segments (Small/Medium/Large). Public data from the Markstammdatenregister from 2022 was used to analyze these size segments to understand what types of systems are being installed today. Besides the size segments, two ownership segments (Direct Ownership/Third-Party-Ownership), were used as another important way of segmentation. The size and ownership segments combined resulted in six

business categories. These categories were a framework for online market research. These categories were also used to identify 12 case study objects, two per category, as category representatives.

The online market research, done through a methodic approach explained in 5.3.1, resulted in finding 123 PV-companies active on the market. Out of those, 47 companies were deemed usable for further investigation, based on significant selection criteria described in 5.3.2 and 5.3.3. From these usable results, the 12 representative companies/case study objects were selected. The purpose of the selection was to find prominent companies with clear and focused business models that would act as representatives for their respective business models.

The business models of the representative companies were mapped on the BMC, resulting in 12 BMCs, one per company. This mapping and an introduction to each company is found in 5.4.

In Chapter 6, these 12 individual BMCs were collected into a Master BMC. The Master BMC was used to identify common entries, e.g. revenue streams and customer segments, for PV companies. The contents of this master BMC were discussed. The business categories were then analyzed on a category level, with the information from the case study objects supporting the analyses. The business categories were also named in this section. The business categories were then compared in terms of advantages and disadvantages, with this comparison being done in 6.3. In 6.4 and 6.5, current trends in the market are identified, as well as a prognosis for the future based on current trends and formerly discussed theory.

Four business models were found to be major:

- Category 1: B2C PV turnkey provider.
- Category 3: Solar parc developer.
- Category 4: Contracting provider.
- Category 6: Solar parc investor.

Two business models were considered minor:

- Category 2: B2B PV turnkey provider
- Category 5: PV rooftop investor.

7.2 Answering the research questions

This chapter will answer the research questions from chapter 1.4. Note that only the major business models identified in RQ1, are discussed in RQ2 and RQ3.

RQ1. What major business models are available in the German PV market today?

The major business models found were:

- Category 1: B2C PV turnkey provider.
- Category 3: Solar parc developer.
- Category 4: Contracting provider.
- Category 6: Solar parc investor.

Category 2, B2B PV-turnkey providers, and Category 5, B2B roof leasing, were not major business models.

These were found to be major business models based on the case study objects investigated and analyzed in the respective category.

RQ2. How have these business models developed historically?

Category 1 is closely tied to the B2C market in Germany and has thus been around since B2C systems have been around in the country. The B2C market expansion started picking up speed as the German market started to see market-driven growth, around 2017-2018. EKD was formed in 2018 and claims to have created the “care-free-package” model, which is today’s standard and main value proposition of this category. Because this market has seen increasing growth year to year, there are a lot of new players coming into this category, and the category is fragmented and dynamic.

Category 3 has been around since the introduction of the EEG in the early 2000s. Solar parcs were, and still are, mainly incentives driven in Germany. Therefore, the development of this category is closely tied to the EEG. Several companies active in this segment were formed back then, e.g. Pfalzsolar and Belectric. Many of these companies have entered international markets during the last decade and have formed large international companies.

Category 4, based on the contracting model, was introduced in Germany in 2012 by DZ-4. Although the category has been around for more than a decade now, it did not see significant growth until the last five years, along with the rest of the B2C market. As the electricity prices have risen and PV costs have sunken, the leasing systems have become more viable, promoting this category. Enpal was founded in 2017, and together with this company, the model has become widely known. The Category 4 market is currently consolidated around Enpal, with few competitors.

Category 6 has followed the development of Category 3 and has been around since the original formation of EEG. This category has formed large, international companies, investing in solar parcs on a global scale.

RQ3. What are the pros and cons of these business models and what target groups do they serve?

Category 1 - B2C PV turnkey provider

Pros

- Profiting from a stark growth in the B2C market.
- The B2C market is anticipated to grow into the largest one, thus creating a lot of room for expansion.
- Value-based pricing, opening up for high profit margins.
- Fast capital returns of 2-3 months, which corresponds to the installation time of a PV system in this category.
- Welcoming for new companies due to low entry barriers.
- The fragmented market leaves room for dominant players to conquer market shares.
- Scalability, being able to contract all the manual labor externally.
- Possibility of upselling through a diverse set of revenue streams e.g., heating solutions or in-house components.

Cons

- High level of competition due to low entry barriers.
- High logistical complexity from installing many smaller PV systems.
- Low order volume per PV system.

- Low entry barriers create a competitive market.

Target groups

- B2C house owners with stable finances.

Category 3 - Solar parc developer

Pros

- Largest market share in Germany
- Large order volumes, with an average PV system size of 4.7 MWp.
- International scalability. EPC knowledge can be transferred to other countries.
- High entry barriers in a consolidated market serve as protection from competition.
- High order volume per PV system reduced the logistical complexity.
- Less demand for customer service and customer assistance.

Cons

- Potentially declining market on a national level, since the category is indirectly incentives driven. Many of the solar parc investors are investing based on EEG, and with diminishing EEG rates, the order volumes can shrink over time.
- Cost-driven customer acquisition process of tenders naturally pushes margins down.
- High entry barriers make it difficult for new companies to enter the market.
- Higher capital risks pertaining to each project due to the large order sizes.

Target groups

- Investors.
- Solar firms in need either of EPC or O&M services.
- Renewable asset managers in need either of EPC or O&M services.

Category 4 - Contracting provider

Pros

- Profiting from a stark growth in the B2C market.
- The B2C market is anticipated to grow into the largest one, thus creating a lot of room for expansion.
- Value-based pricing, opening up for high profit margins.
- Excellent RoI. The contracting model allows for charging a higher price for the PV system than what would be possible at a normal sale.
- High entry barriers serve as protection for the established, dominant companies.
- Possibility of upselling through a diverse set of revenue streams e.g., heating solutions or in-house components.

Cons

- Required funding for expansion making it impossible to grow organically, and a constant need for new funding.
- Slow capital returns. The investments are returned to the company over 20-25 years.
- Complex logistics and asset management. A large number of PV systems are installed and maintained by the companies (e.g. Enpal installed over 48,000 such systems).
- Low order volume per PV system.
- High entry barriers prevent new market entrants in Category 4.

Target groups

- B2C house owners with less stable finances. These households are unable to carry the initial investment, thus preferring a leasing model.

Category 6 - Solar parc investor

Pros

- Largest market share in Germany in the Large segment at 44%.
- Safe and plannable revenues, supported by EEG or PPA.

- Good possibilities for project-based funding. EEG- or PPA-backed yields are considered safe investments, which are positively viewed by investors, thus paving the way for the funding of the company's projects.
- Scalability. Financing, component suppliers, etc., are all freely available to successful companies in this segment, with project rights being the only bottleneck.
- Fewer projects with high volumes bring lower logistical complexity than in other categories.
- High entry barriers protect established companies.
- Less customer service.

Cons

- Bottleneck of land spaces available, which can be difficult to acquire.
- Financial risk in the EPC phase. The EPC of solar parcs are rather capital intense, and have an unclear outcome, being dependent on uncontrollable factors e.g. local residents.
- Potentially shrinking profitability as the EEG support is decreasing over time.
- More capital risk is bound up in individual projects.
- High entry barriers prevent new entrants from entering the market.

Target groups

- Electricity consumers. Either market or PPA consumers.
- Investors, when selling solar parcs or shares thereof.
- Real estate owners, for land acquisition. Real estate owners represent both customers and partners for these companies.

RQ4. What business models can we expect to see more of in the future?

Generally, there will be more seen of all market-driven, and less of the incentive-driven BMs. As the market conditions continue to improve, incentives tend to be reduced. This effect is built into the EEG legislation, through the degression rate. The PV industry is expected to keep on

growing, as is already one of the cheapest energy sources available. This is driven by a political will to phase out fossil fuels.

Category 1 is expected to keep growing significantly in the next few years, being a market-driven category. Since the B2C market is the largest segment in most industries, it is expected to be the largest one in the solar industry too. Category 1, being the most dominant category in the B2C segment, is thus expected to grow into the largest one. PLC is predicting that market leaders will be formed in the growth phase, which predicts a consolidation during the coming years.

Category 2 is expected to grow together with the PV market and break up into niche businesses, targeting different types of C&I customers, with different electricity needs. This category may also service multi-level apartment buildings, and other facilities, where the owner structures are complicated and may require additional expertise.

Category 3 is expected to grow globally as countries embrace PV as an energy source and develop large solar parcs. For these companies, material costs, especially PV modules, constitute a majority of the costs. Therefore, they will profit more than other categories by a cost reduction, if Swanson’s law holds up over the coming years. Additionally, they may experience sharp demand increases as developing countries are leapfrogging to PV since Category 3 companies are usually internationally active.

Category 4 is expected to grow alongside Category 1, also riding the wave of growth in the B2C market. One may think that Category 4 will diminish as PV systems are getting cheaper. However, PV is not expected to get much cheaper in the B2C segment. Swanson's law predicts further price decreases for PV modules. However, this cost component represents currently only 37% of the cost structure of a B2C system, with cost components like BoS and service slowly taking over. These cost components are not decreasing, they may even be increasing, thus the PV prices may remain relatively stable over the coming years. Therefore, since PV systems are expected to continue being capital intense in the future, there will be a future need for Category 4 too, serving financially fewer stable households, or households that wish to outsource responsibility of the PV system. This category has already formed a strong market lead in Enpal. Competition to Enpal may come from large international players, rather than from local competition in Germany.

Category 5 is active in Germany only, and almost fully dependent on EEG support. As EEG is gradually diminishing, the companies active in this segment will stop being profitable. Thus, Category 5, in its current form, is expected to disappear. Some companies are expected to transition to PPA-based models, as the PV market gets more market driven. PPA-based models may be more interesting as a concept, as battery prices continuously go down, possibly serving as a great alternative.

Category 6 has an international focus and is not dependent on the EEG as a category. Therefore, this model is expected to continue to grow on an international scale, investing wherever it is profitable based on incentives or PPAs. The PPA is expected to play an increasingly important role in the future for companies like these. Trading electricity through the on the spot market may also play an important role, in combination with cheaper storage solutions. As a company active in the Large segment, they will profit more from the expected decrease in the material prices, just as Category 3.

Besides the categories researched in this thesis, we expect to see the more niche categories, e.g., Category 1 companies offer solutions for more complex roof types, Category 2 breaking up into serving different C&I customers, or Category 6 breaking up into incentives and PPA-backed BMs.

We are expecting to see more PV floating, as this technology does not compete for land spaces, which are already scarce, and 71% of the world's surface is covered by water (Visbeck, 2018).

Specialized BMs for facilities with especially high energy needs, e.g. multi-level apartment complexes or industries where a conventional PV-system does not generate sufficient amounts of energy, are expected too.

As the previously described energy production volatility is increasing alongside the expansion of renewable energies, many BMs are expected to form around storage solutions and electricity trade.

7.3 Trustworthiness of findings

To ensure that the findings in this report were trustworthy, the research approach and method have been clearly documented. By offering the reader insight into how information has been gathered, used, and analyzed, as well as the thought process behind it, thus being transparent to the reader about

the undertaken research, the degree of credibility can be evaluated by the reader.

To guarantee the validity of the general market data, only information from German state institutions the federal network agency was used.

Regarding the case study objects, information was mainly gathered from the companies' own websites. Therefore, the information was treated very carefully. The researcher has personal work experience in the field of PV in Germany, which helped determine what could be seen as reliable information and what should be classified as unreliable information. The PV industry includes a lot of new actors and heavy marketing and a certain filtration of what can be seen as reliable and unreliable information must be done to gather reasonable information. Company statements were, to the extent possible, triangulated with other information sources, such as official company data (including founding date, financial numbers, asset balances, etc.) or sources such as credible newspapers and magazines. This triangulation was easier regarding the prominent B2C companies, where more information was available online, and more difficult for the rest of the companies with scarce information available. Companies that seemed dubious, or that were giving out provenly wrong information were treated very carefully, although no such companies were amongst the case study objects.

As for the choice of representative companies, the selection of these may have affected the conclusions drawn in this report. Different selection criteria could have resulted in different results. Thus it should be considered by the reader if the selection criteria and the resulting case study objects seem reasonable for the research purpose.

Furthermore, since most case study objects were active in several business categories simultaneously, their BMCs would include entries from all categories in which they were active. It was also not possible from the outside to determine the main business category to 100%, although there were usually some clear indications, as in the case of Enpal, who launched their Category 1 activity in 2023, formerly only being active in Category 2. Nevertheless, the BMC mappings will, in such cases, include entries from all business activities, e.g., revenue streams of Category 1 in Enpal's BMC, although they are clearly focused on Category 4. Thus, the mappings should

be treated as very general, and if more detailed information is needed, an in-depth study should be conducted for that particular company.

During the BM mapping of Enerparcs, Wegatech, and Greenovative, it was suspected, based on the found information, that their core BM is more closely related to another category than the one assigned. This should be taken into consideration when interpreting the results of Categories 2 and 3.

As for the results of this report, two case study objects per business category were researched. This number may not be enough to draw general conclusions about the market. Therefore, the findings should not be regarded as general truths, but rather an indication of the market situation for further research.

7.4 Suggestions for further research

This research has utilized an exploratory approach to give a brief introduction to the global and German PV market, and in this context, give insight into active and prominent BMs in the German market. Due to the scope of this work, only a subsegment of the market was mapped and investigated. Thus, this report shares some insight into the inner workings of the German PV market, but it is not an all-encompassing picture. Doing a more complete mapping of the market, especially in the research phase where potentially thousands of companies could have been found, would give a more complete picture. Such mapping would also encompass smaller, more regional, and more niche PV providers. Such providers can give a good indication of the future development of the market. Therefore, a more complete mapping of the German PV market would be an interesting research topic.

Regarding business categories processed in this work, it should be noted that these are rather wide. Therefore, companies within the same category differ on aspects that could be significant, e.g., the expansion strategies of 1komma5 and EKD from Category 1, with 1komma5 growth based on acquiring manual labor firms, and EKD grew organically by organizing an external network of such firms. These companies could be treated as different business categories with different frameworks. For further research, the categories in this report could be broken up into subcategories, segmented based on other attributes e.g., type of funding or network structure.

Regarding the BMC analyses, these were not analyzed on a category basis. For further research, it would be interesting to create standardized BMCs for each category, to get an insight into how such a company functions with a standardized BMC as a template. For this, it would be advisable to include more than two companies per category.

The mapping done in this report could be done in other countries, and similarities/differences between countries can generate interesting observations to get a better understanding of the global market. Thus a similar research project conducted in a different market could generate an interesting comparison to these results.

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