Democratisation of Solar Energy in the Housing Market: Accelerating Diffusion of Rooftop Photovoltaic Systems in Germany

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Abstract

Germany aims to obtain 80% of its electricity from renewable sources by 2030, positioning itself as a leader in sustainable energy transition. This requires extending photovoltaic system adoption with a goal of reaching a capacity of 215 GWp by the end of the decade. Participation from citizens, solution providers, the government and the apartment building sector is needed.

This thesis examines the adoption of rooftop photovoltaic technology in the single-family home and apartment building sector. Based on interviews with industry experts and analysis of survey data, the findings identify several key factors for increased adoption. The single-family housing market, previously experiencing rapid growth, is now reaching maturity and saturation. In contrast, the apartment building sector presents a significant, yet largely unexplored, opportunity.

Numerous obstacles, such as regulatory barriers and tenant accessibility issues, impede growth of the sector. Construction of apartment buildings is crucial for democratization of solar energy, as it enables tenants to participate in the transition to renewable energies as Germany pursues a sustainable future.

The primary factors motivating individuals to adopt photovoltaic systems are lower initial cost, financial incentives, peer referrals, and environmental consciousness regarding CO_2 emissions. Housing companies are already actively engaged in sustainability and making progress towards the shift towards renewable energy.

Keywords: Photovoltaic Systems, Energy Transition in Germany, Renewable Energy, Single-Family Homes, Diffusion, Apartment Building Sector

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Resumo

A Alemanha pretende produzir 80% da sua eletricidade a partir de fontes renováveis até 2030, posicionando-se assim como pioneira da transição energética sustentável. A missão exige uma expansão das instalações fotovoltaicas com o objetivo de atingir uma capacidade de 215 GWp. A participação dos cidadãos, do governo, dos fornecedores de soluções e do sector da habitação é essencial para expandir a adoção de sistemas fotovoltaicos.

A presente tese analisa a adoção da tecnologia fotovoltaica em telhados e o seu impacto no sector de residências unifamiliares e multifamiliares. Com base em entrevistas com especialistas e numa análise aprofundada de dados de inquéritos, foram identificados vários factores-chave para a adoção da tecnologia fotovoltaica. O mercado residencial unifamiliar, que anteriormente registou um rápido crescimento, está agora a mostrar sinais de maturidade e saturação. Em contrapartida, o sector multifamiliar oferece uma oportunidade significativa pouco explorada.

Numerosos obstáculos, tais como barreiras regulamentares e questões de acessibilidade dos inquilinos, estão a impedir o crescimento deste sector que é fundamental para a democratização da energia solar. Este oferece aos inquilinos a oportunidade de participarem na transição para as energias renováveis tendo em vista um futuro sustentável.

Os principais factores que incentivam as pessoas a optarem por sistemas fotovoltaicos são os custos de aquisição mais baixos, os incentivos financeiros, as recomendações de amigos e a consciência ambiental quanto às emissões de CO_2. Muitas empresas imobiliárias já estão a participar ativamente na transição para as energias renováveis.

Palavras-chave: Sistemas Fotovoltaicos, Transição Energética na Alemanha, Energia Sustentável, Residências Unifamiliares, Difusão, Sector Multifamiliar

Título: Democratização da energia solar no mercado da habitação: Acelerar a difusão de sistemas fotovoltaicos de telhados na Alemanha

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

PV	Photovoltaic
PVS	Photovoltaic Systems
EU	European Union
kWp	Kilowatt Peak
kWh	Kilowatt Hour
GWp	Gigawatt Peak
SFH	Single-Family Home
AB	Apartment Building
FiT	Feed-in Tariff
CSR	Corporate Social Responsibility
TE	Tenant Electricity
TPO	Third Party Ownership
EEG	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
B2C	Business to Consumer

1. Introduction

Germany is facing challenges as it addresses climate change, depletion of natural resources, and pursues sustainable living practices (Singh, 2021). To mitigate CO_2 emissions the energy sector is adapting and innovating. The power sector was responsible for 34% of Germany's CO_2 emissions in the year 2022 (BDEW, 2023b). It continues to depend on fossil fuels and heavily relies on energy imports, which promotes moves towards greater autonomy (IEA, 2022).

In 2016, Germany ratified the Paris Agreement, which restricts the rise in global temperatures to 1.5°C, lowers carbon emissions and directs financial resources towards climate protection goals. Countries are investing more in renewable energy and reducing emissions to achieve this objective. The German government is actively promoting expansion of renewable energy and has declared it a matter of public interest (BMWK, 2022).

As of 2023, Germany's CO_2 emissions from electricity generation are steadily decreasing, with more than 50% of electricity coming from renewable sources. Household electricity prices are declining after years of peak prices (BDEW, 2023b).

Visionary entrepreneurs are actively working towards making solar power more accessible (Jones & Loubna, 2012). Solar is emerging as a catalyst within the renewable energy industry and has been recognized as one of the principal technologies for achieving decarbonization (Fuentes et al., 2023). From 2000 to 2020, there was a significant growth in the global cumulative solar power capacity, with an increase from 1.3 GWp to 750 GWp. This represents nearly 550 times the initial capacity (Tao et al., 2020). Growing demand for solar energy has prompted a surge in the number of enterprises seeking to capture market share (Kuada & Mensah, 2020).

There is a growing inclination among individual homeowners towards energy autonomy sustainability through solar energy. The provisioning of financial resources is stimulating the development of rooftop photovoltaic systems (PVS) (Chesser et al., 2018). These policy incentives provide subsidies for individuals to install PVS on their rooftops, while also fostering a novel business models. The emergence of new companies in the market has led to increased affordability of PVS (Sareen & Kale, 2018; Zdonek et al., 2022).

PV leasing options by companies through innovative business models, along with government incentives, address the issue of inequitable adoption of PV technology (O'Shaughnessy et al., 2020). Despite growing popularity of residential PVS, there is still debate regarding the primary factors that drive PV acceptance. Individuals with heightened awareness of their carbon footprints, along with a comprehensive understanding of sustainable energy, exhibit greater propensities to embrace PVS, while the impact of household income on adoption of PVS varies depending on geography (Bashiri & Alizadeh, 2018; O'Shaughnessy et al., 2020; Tanveer et al., 2021).

Multiple business models facilitate the increasing enthusiasm towards PVS and broaden accessibility to solar energy for a larger demographic by also targeting the apartment building (AB) sector. Landlords, commercial housing companies and housing cooperatives are enabling tenants to partake in the shift to renewable energies. Housing cooperatives are a German concept, in which tenants become members of an organisation. They aim for democratic leadership, follow a long-term orientation and are not primarily profit oriented (Teichmann & Rasquin, 2003).

Evidence suggests that social norms play a significant role in influencing individuals' inclinations towards adopting PVS (Tanveer et al., 2021). Employing qualitative and quantitative research methodologies we seek to analyse the status quo and come up with future recommendations.

The primary objective is to study the diffusion of rooftop PVS in the German housing market. Specifically, the analysis focuses on top-down and bottom-up initiatives that drive PV adoption. Reviewing the research on photovoltaic technology and the German energy market, covering topics such as pricing trends, business models, and criticism, provides further insights. The adoption of PV, innovation, autonomy, and sustainable practises can be connected to management frameworks. An explanation of the research design and an examination of the findings follow. The discussion section draws potential implications for the future by contrasting our findings with the literature. Finally, a conclusion is drawn and an outlook is given.

2. Literature Review

2.1 Photovoltaic Systems

The topic of PVS and their impact on the renewable energy industry has been thoroughly discussed in academic literature. This literature review covers a wide range of research to provide an overview of the background, criticisms, and factors influencing prices and acceptance.

2.1.1 Photovoltaic Systems Overview

Modular photovoltaic devices convert sunlight to electricity without any emissions, while also offering versatile capabilities as they can come in small cells, panels or arrays (Bull, 2001).

The first solar cell was made in the 1950s, after which the field began to be extensively studied (Bosio et al., 2020). As technology advances, the efficiency of PV modules keeps increasing both in the residential sector as well as the large-scale PV power generation (Polman et al., 2016). The accessibility of PV technology has seen significant reductions in price resulting from economies of scale and technological advancements. This phenomenon contributes to decreasing consumer reliance on the energy grid with economic advantages while mitigating CO_2 emissions (Tervo et al., 2018).

Solar parks and residential PVS must be distinguished. Typically, utility-scale PVS are connected to the power grid, enabling them to supply generated electricity to the grid (Sharan et al., 2019). Residential PVS, conversely, supply electricity directly to residences and may include batteries for the purpose of storing the generated electricity. Unused surplus energy can be sent to the electricity grid in exchange for a predetermined compensation (Li et al., 2019). A study conducted on PVS in Germany showed that even small-scale PV installations can yield favourable returns and generally reduced the overall cost of power usage (Wirth, 2023). The German government provides incentives for PVS by factoring in investment and operational costs, as well as additional expenses (Campoccia et al., 2014).

2.1.2 Photovoltaic System Leasing and Tenant Electricity

The leasing model of PVS addresses barriers to PV adoption by eliminating upfront costs. Homeowners can install PVS and storage systems at a monthly cost. Certain companies provide maintenance and insurance packages in addition to the PVS, significantly reducing the level of expertise required (Liu et al., 2014). The decision to buy or lease is influenced both by technological uncertainty and cash-flow considerations. Research indicates that customers prioritise payback period over net present value, while considering net monthly savings when deciding to install a PVS (Rai & Sigrin, 2013).

The Tenant Electricity (TE) model involves installing a PVS on an apartment building, with the purpose of selling electricity to the building's tenants (see Figure 1). Many landlords, corporations and housing cooperatives choose to seek external assistance due to obstacles such as the need to maintain a balancing model, propose a measuring concept, follow data protection laws, and navigate intricate tax systems. There exist multiple examples of third-party ownership (TPO) in solar energy, with a prevalent approach being leasing of rooftops and subsequent financing of PVS by the TPO entity. Tenants derive advantages from favourable electricity pricing, while the building owner raises the value of the property while lowering emissions. Additionally, the TE firm generates profits from electricity generated and earns a margin on electricity supplied to tenants (Moser et al., 2021).

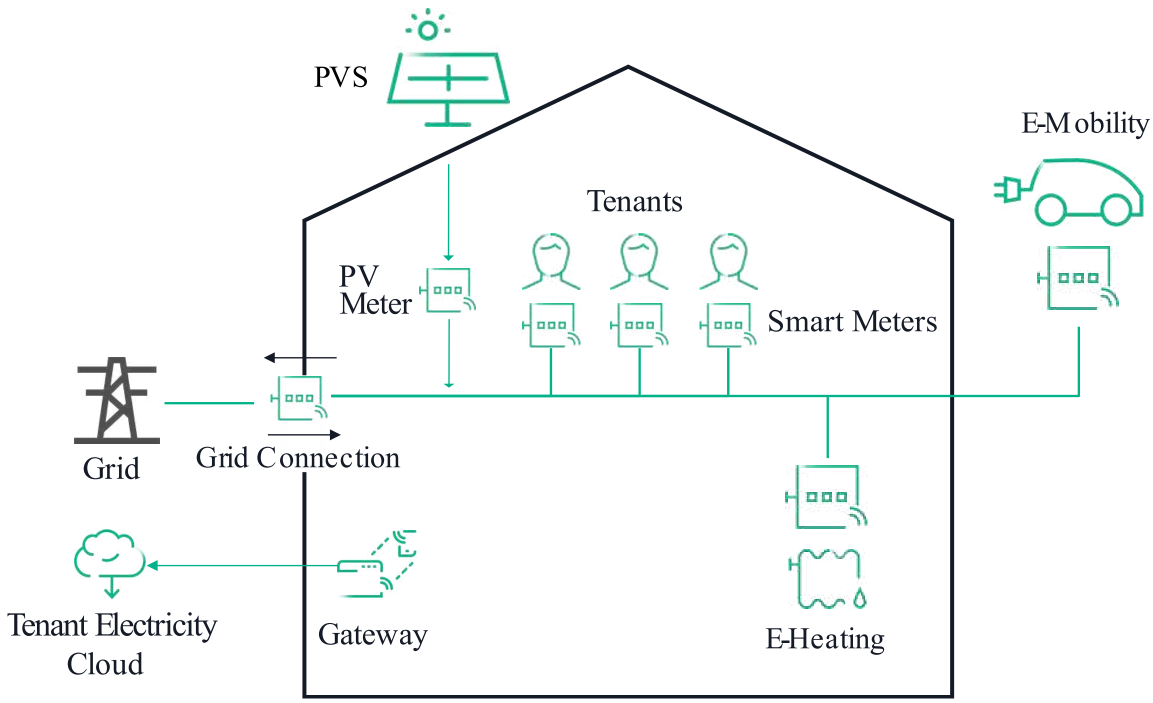

***Figure 1**: Tenant Electricity Model*

Source: Adapted from EINHUNDERT Energie GmbH (2023)

2.1.3 The German Power Grid

Up until 2023, the German electricity mix was made up of nuclear energy, fossil fuels and renewable energies. Figure 2 illustrates how the use of nuclear, hard coal, and lignite electricity has continued to decline between 2012 and 2022. Conversely, the output of renewable energy increased drastically, from 143 terawatt hours to 256 terawatt hours. PVS produced 60.8 terawatt hours in 2022, a 127% increase from 2012 and by far the highest amount ever recorded (Pawlik, 2023). Private households account for 27.4% of all electricity used (BDEW, 2023a).

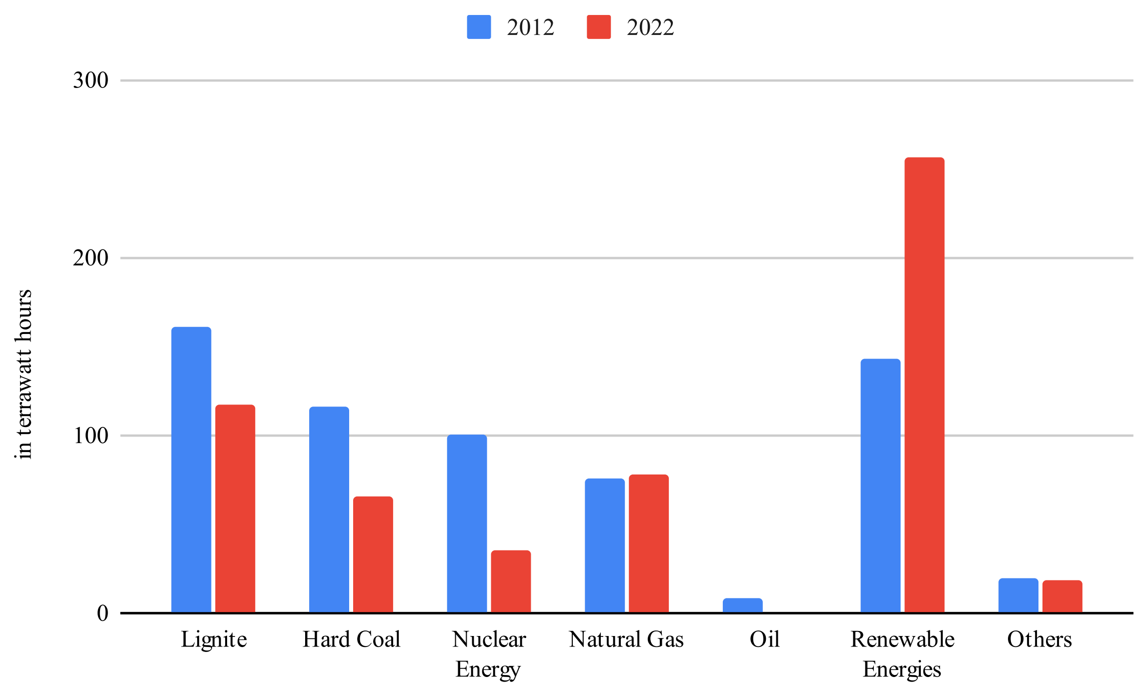

Figure 2: *Comparison of Gross Electricity Generation in Germany by Energy Source between 2012 and 2022*

Source: Own illustration based on BDEW (2022)

As of 2022, 67.4 GWp PV capacity has been installed in Germany (BMWK, 2023b). With 32.1% of the total capacity, private households controlled the majority of PVS in 2019. It is evident that private engagement plays a major role in the shift towards renewable energies (Agentur für Erneuerbare Energien, 2019).

On average, German families paid 37.14 cent/kWh in 2022. Germany implemented an electricity price brake at 40 cents per kWh until April 2024 to address rising electricity prices. Taxes and grid fees have a significant impact on home electricity pricing. The government is providing 5.5 billion euros in subsidies to grid operators in 2022 to lower electricity costs. 2023 had the highest electricity generation costs in recent years, which promoted tax and levy reductions to help consumers. On average, the price of power for business and industrial clients in Germany was less than the European average, with a cost of 19.9 cent/kWh (Strom-Report, 2022). Figure 3 and Figure 4 display the cost evolution for electricity prices and the corresponding price composition respectively.

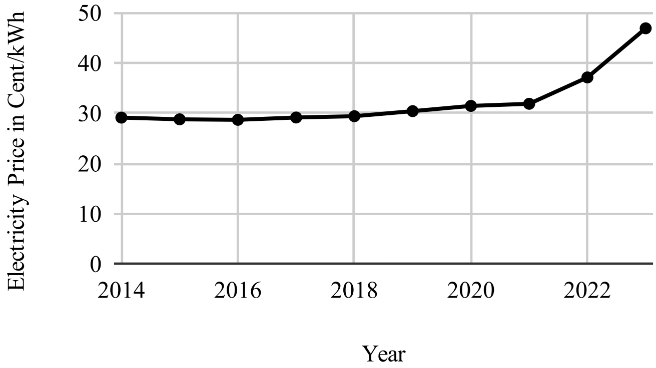

Figure 3: *Electricity Price for households in Germany from 2014 to 2023*

Source: Own illustration based on Strom-Report (2023)

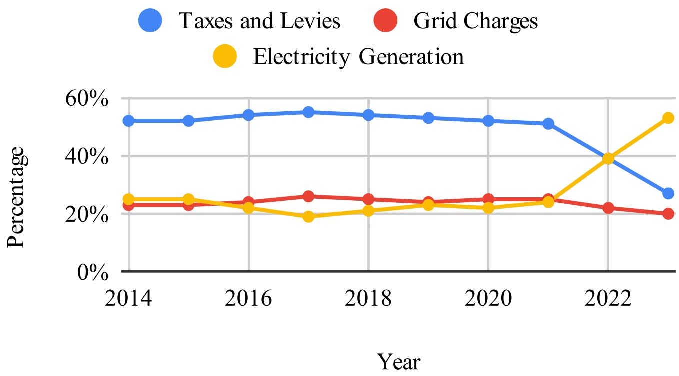

Figure 4: *Cost Structure of Electricity in Germany from 2014 to 2023*

Source: Own illustration based on Strom-Report (2023)

Electricity is traded at energy exchanges, with power producers setting their own prices in accordance with rules set by regulatory agencies. The most economical source of electricity is renewable energy, which is why it is given priority, and the highest-cost electricity is reserved for sale later. The purpose is to prioritise more economically effective methods for generating electricity and to determine pricing based on the lowest marginal cost. Higher marginal cost power plants are added to the system piecemeal until energy demand is met. Because the most expensive power plant sets the price of electricity, the public may not always gain from the integration of renewable energy. To tackle this problem, member states of the European Union have allotted a total of 657 billion euros to protect consumers from rising energy prices since 2021 (General Secretariat of the Council of the EU, 2023).

The power grid is divided into three distinct components, namely power generation, transmission, and distribution. The initial stage involves conversion of various energy sources into electricity. It is subsequently conveyed from power generation facilities to substations close to residential regions via high-voltage long-distance transmission lines. The voltage within substations is reduced by local energy distributors to render it suitable for household consumption. Power transmitted through the distribution system is characterised by a voltage level that ensures safety for both residential and commercial utilisation (Fang et al., 2012).

In contrast to conventional fossil fuels, solar energy exhibits a significant degree of dependence on several atmospheric conditions, including, but not limited to, cloud cover variability and temperature. Accurate forecasting is essential for effectively managing energy consumption. Smart grids are designed to effectively monitor and regulate transmission of power to meet the demands of end users and mitigate occurrences of blackouts (Wan et al., 2015). The advantages of smart grids include their ability to accommodate fluctuating power demands, enhance customer options, facilitate the introduction of novel products, services, and markets, and bolster resilience against potential disruptions (Fang et al., 2012)

2.1.4 Drivers of Photovoltaic Price Decrease

From 1990 to 2020 cost per installed kilowatt peak (kWp) for rooftop PVS in Germany decreased 92%. The prices of PV-modules have been decreasing due to rising demand and the relocation of production to Asia (Philipps & Warmuth, 2023). During the Covid-19 pandemic, prices rose for a brief time but now continue to decline as of 2023 (Goldman Sachs, 2023). Currently, PV modules can be categorised into two main types: crystalline silicon PV modules and thin-film PV modules. Monocrystalline silicon modules are the most widely manufactured type of solar panels, and it is anticipated that this will persist into the foreseeable future. Despite lower production costs associated with thin-film modules, their larger size due to reduced efficiency, renders them less optimal for residential applications (Kumar et al., 2020).

Drivers of lower module prices, categorised as low-level mechanisms, are the declining prices of polysilicon, relocation of production to China, reduced use of polysilicon, expansion of wafer area, and enhanced efficiency. Scaling in plant size during the period from 1980 to 2012 was found to be associated with a decrease of 40% in price. This can be attributed to economies of scale, which arise from using common infrastructure and enhancing quality-control measures, seen as high-level mechanisms. The positive correlation between research and development and cost reduction underscores the significance of public and private investment to facilitate PVS affordability (Kavlak et al., 2018; Pillai, 2015). Considering the learning curve, the PV module price has decreased by 25% with each doubling of global module production over the past 40 years (Fraunhofer Institute, 2023). Chinese manufacturers can drastically lower their production costs through government subsidies, economies of scale, lower operational cost, and their domestic polysilicon industry (International Energy Agency, 2022).

Policy changes, shown in Table 1, can have a significant impact on innovation, cost structure, and investment behaviour within the PV industry (Baur & Uriona M., 2018). The provision of a 20-year guaranteed feed-in tariff (FiT) incentive by the government increases the likelihood of investors allocating funds towards research and development programmes. Consequently, this results in higher import and export activities. Moreover, with increasing stabilisation of prices, there is a corresponding rise in the number of enterprises venturing into the PV space (Kim & Kim, 2015). The rapid growth of PV installations in Germany can be attributed to two key factors: subsidies and appealing FiTs. During the period from 1990 to 1999, the photovoltaic market in Germany experienced a state of stagnation. The Renewable Energy Sources Act (EEG), which introduced the FiT in 2000, resulted in a significant surge in solar power systems in Germany, a 196-fold rise by the year 2011 (Chowdhury et al., 2014). The "Energiewende" (energy transition), started by the EEG, promoted decentralized generation, and intensified price competition, enabling new players to enter the market (Brunekreeft et al., 2016).

Laws and amendments	Main implication for small size (private household) PV plants
Renewable Energy Act (EEG) 2000	FiTs are defined specifically for PV and guaranteed over 20 years with a nominal digression
Photovoltaic Interim Act 2003	Increase of FiTs for small size PV plants
Renewable Energy Act (EEG) 2009	Digression for PV FiTs was lifted from 5% to 8-10%, depending on the newly installed capacity (so called 'corridor system', target 2.5-3.5 GW)
Photovoltaic Act 2010	Automatic digression adjusted to 8-13%, followed by an additional cut down of 3% for all; self consumption incentives were enhanced
Photovoltaic Interim Act 2011	Further adjustment reducing FiTs
Photovoltaic Amendment 2012	Reduction of FiTs of 15% earlier than originally planned, special digressions agreed on
Renewable Energy Act (EEG) 2014	Yearly installed capacity target of PV is reduced to 2.4-2.6GW ('corridor adjustment'), market approach for lager PV plants as test, further adjustment of tariffs to reduce costs
Renewable Energy Act (EEG) 2017	Market approach for larger PV plants incorporated, FiT system remains in power for small size plants, Tenant Electricity Model is introduced
Renewable Energy Act (EEG) 2021	Self-produced and consumed electricity is not affected by the EEG-apportionment
Renewable Energy Act (EEG) 2023	New PVS benefit from higher FiT Grid operator does not need to be present for PVS with <30 kWp at time of connection

Table 1*: Overview of German legislation affecting PV panel attractiveness for individual households*

Source: Adapted from Baur & Uriona M. (2018)

2.1.5 Criticism around Photovoltaic Systems

PVS often evokes concern among both the general public and the scientific community. The perception of PVS is influenced by various factors, such as aesthetic considerations, apprehension regarding the possibility of missing out on more advanced technological developments and being an early adopter. Furthermore, environmental concerns pertaining to production and recycling processes, issues regarding the security of supply, regulatory complexities, and technical obstacles such as the lack of cost-effective electricity storage solutions are often raised (Karakaya & Sriwannawit, 2015; Lee & Song, 2021; Sinke, 2019).

Supply security is important given the potential catastrophic effects associated with power outages. PV technology currently constitutes a small portion of the overall electricity generation capacity. However, research suggests that Germany has the potential to transition to a fully renewable energy system, exclusively relying on renewable sources by the year 2050. In addition, household PVS do not provide all of the required electricity, with the remaining portion supplied by the grid. Nonetheless, the level of self-sufficiency can be significantly enhanced by implementing battery storage systems, specifically lithium-ion technology. Seasonal storage, which entails the storing excess electricity during the summer months for use the winter, will be significant for enhancing self-sufficiency (Zhang et al., 2016).

Use of various materials in PV modules raises concerns regarding recyclability. Since February 2014, European Union (EU) regulations have mandated that all manufacturers of modules are obligated to participate in the free-of-charge take-back and return of product recycling system. Moreover, in Germany these devices are categorised as electrical appliances, hence imposing a requirement to repurpose and recycle a minimum of 80% of constituent components (Wirth, 2023). Presently, there are efforts to significantly diminish or entirely substitute the lead content with non-toxic substances (Deutsche Umwelthilfe e.V. and partners, 2021). Additionally, the profitability of PV module recycling remains a challenge. Effectively isolating dangerous compounds and obtaining high-purity fractions of valuable minerals remains an enormous challenge (International Energy Agency, 2022).

2.2 Management Theories

To examine the connection between the PVS landscape and management frameworks, below is an outline of management principles relevant to the central study topic. Furthermore, frameworks for PV adoption are examined.

2.2.1 Corporate Social Responsibility

Corporate social responsibility is a framework that posits firms as having an obligation not only to maximise profits for their shareholders, but also to consider the interests of a wider range of stakeholders (Tiep et al., 2021; Wang et al., 2016). According to Carroll's pyramid, it is necessary for businesses to prioritise their economic and legal responsibilities as they define the core of the organisation. Once the necessary foundation has been established, organisations should uphold ethical and philanthropic obligations. To effectively manage stakeholder involvement, it is essential to identify and evaluate stakeholders based on their respective stakes, as well as the opportunities and problems they present (Carroll, 1991). Furthermore, it is argued that businesses can effectively generate economic value while also addressing social and environmental concerns. Hence, it is possible to incorporate social and environmental factors into the business practices. The consideration of unmet needs and the prioritisation of long-term stakeholder value creation are key factors that contribute to innovation, which in turn facilitates economic growth (Porter & Kramer, 2011).

Numerous companies and cooperatives have implemented climate pathways to facilitate the transition towards a sustainable future. Key factors include energy renovations of buildings, adoption of heat pumps, and widespread installation of PVS. The need to comply with energy standards is modernising existing buildings. Barriers, such as rising operating and construction costs, hinder businesses from investing in PV due to financial constraints (Hartwig et al., 2022).

2.2.2 Black Swan Events and the Growing Need for Autonomy

Black swans refer to phenomena that are commonly perceived as having a low probability of occurrence but possess substantial and far-reaching implications. Decision makers frequently lack preparedness for these occurrences and fail to implement suitable responses. The COVID-19 pandemic is an instance of an unforeseen occurrence that evolved from a public health crisis into an economic catastrophe (Phan & Wood, 2020).

The Russia-Ukraine war serves as another black swan event. Countries were not prepared for the scale of the war, with energy prices increasing on average from 9 cent per kw/h in 2021 to 14.85 cent per kw/h in 2022 for non-household consumers, observed on average across 28 European countries (Kozicki et al., 2023). To decrease dependence on Russian oil and gas, countries have increased investments into domestic renewable energy (Saktiawan et al., 2022). There is a discernible change of perspectives on energy reliance at the governmental level, and individuals have also identified energy autonomy as a motivating factor for adoption of PVS (Alipour et al., 2020). Gas prices controlled by cartels results in the financial support of authoritarian regimes, while heavy dependence on fossil fuels in nations abundant in natural resources necessitates a shift towards more energy self-sufficiency. Germany can locally produce PV modules, thereby reducing economic and political dependence (Wirth, 2023).

Energy autonomy offers different benefits such as supply security, potentially reduced energy cost, and can significantly reduce CO_2 emissions (Rae & Bradley, 2012).

2.2.3 Resource Based View and Stakeholder Theory

Resources are tangible and intangible assets permanently tied to a firm which affect the firm's strength. These include, but are not limited to, in-house knowledge of technology, efficient procedures, and machinery (Wernerfelt, 1984). To make a resource heterogenic and immobile, it needs to be valuable, rare, imperfectly imitable and there cannot be substitutes that are neither rare nor imperfectly imitable. Understanding one's own resources is crucial for attaining long-term competitive advantage, given that the interaction among these resources may not always be apparent. The replication of strategies employed by other organisations may not necessarily lead to the anticipated outcomes, as the intricate dynamics of resource allocation remain uncertain. The fundamental premise of this argument is that there exists heterogeneity in resources across different firms (Barney, 1991). The mix of products, economies of scale, and reputation are valuable resources that possess characteristics that make them difficult to imitate, ultimately exerting a significant influence on the performance of a corporation (Peteraf, 1993).

Stakeholder theory and the resource-based view have differing perspectives on sustainability. The former emphasises the importance of considering all stakeholders impacted by a decision, while the resource-based view connects sustainability to long-term competitive advantage. Sustained stakeholder relationships are associated with long-term competitive advantage. The resource-based view regards individuals as instrumental means to achieve ends, while stakeholder theory advocates for individuals to be treated as ends in themselves. To enhance the comprehensiveness of the resource-based view, it is suggested to integrate normativity, redefine sustainability, expand the perspective on individuals, and promote cooperative behaviours (Freeman et al., 2021).

2.2.4 Innovation Theory

To achieve successful innovation, it is imperative to understand market demands, optimise manufacturing procedures and product specifications, and cultivate an environment that sustains the innovative process. Certain technologies can create financial vulnerabilities or even lead to insolvency during their early stages due to high development expenses, which further highlights the significance of market timing (Kline & Rosenberg, 2009)

Within an innovation economy, innovation is distinctively separated from invention (Schumpeter, 1942). Innovation includes the construction of novel plants and equipment, the emergence of new enterprises, and the ascendance of new people assuming leading roles, whereas invention is the creation of a new idea or method. The concept of diffusion of innovation, as elucidated by E. M. Rogers in 1962, has garnered significant attention and popularity in subsequent years (Robertson, 1967).

According to Rogers, innovation does not necessarily need to be a completely new product, but rather it must be subjectively recognised as such by the individual. The perceived newness of a product might be linked to an individual's level of awareness and their subsequent choice to embrace it. The concept of diffusion pertains to the way an innovation is disseminated to individuals within a social system over a period via designated communication routes. The adopted model categorises individuals into five distinct groups: innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%), and laggards (16%) as shown in Figure 5. The group of early adopters holds significant influence on the diffusion of a product due to their ability to deliver positive testimonials. Laggards, as indicated by the curve, pose the greatest challenge in terms of client acquisition, and exhibit the highest level of resistance towards change. The early majority typically exhibits a higher level of formal education and social position, hence enabling them to effectively navigate uncertainty with less risk (Rogers, 1983). Diffusion of Innovation is characterised by a pattern represented by S-curve. The process of reaching the stage of early majority acceptance entails significant time, after which there is a notable acceleration until the laggards are convinced. Likewise, the process of generating a sequence of progressively larger segments with diminishing utilities follows a comparable pattern. A product that initially caters to a specific and specialised market can transition into a more widely accessible product, although with reduced utility (Brown, 1992).

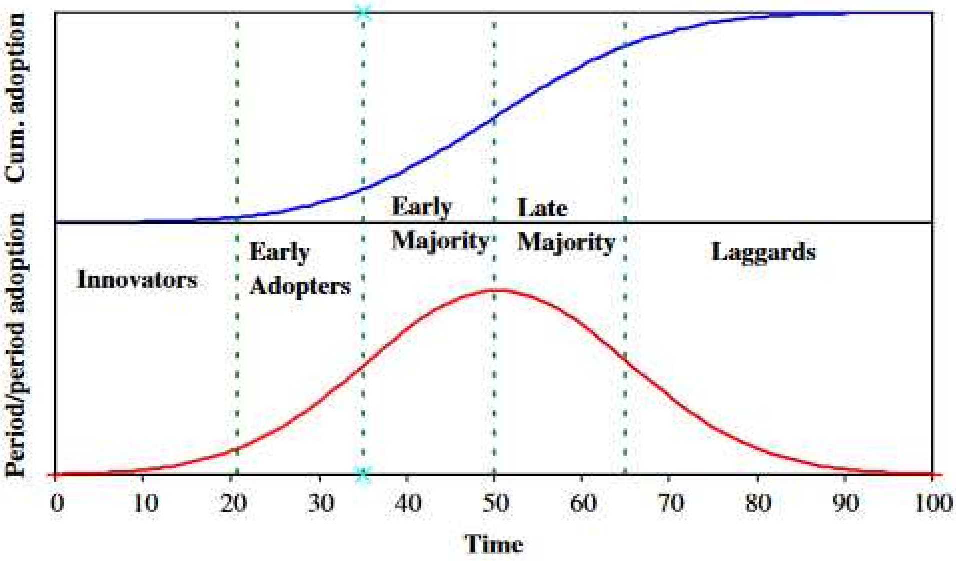

***Figure 5**: Stylised diffusion curves*

Source: Meade & Islam (2006)

Policies can also be examined from the perspective of the diffusion of innovation. The factors of relative benefit, complexity, trialability, and observability exert a significant impact on diffusion. Learning effects are of crucial importance in the implementation of new policies as states actively engage in the "race to the top" (Jordan & Huitema, 2014). While bottom-up initiatives are very prominent, research has shown that top-down governmental initiatives are still of utmost importance to incentivize PV adoption from a financial standpoint (Reinsberger et al., 2015).

Davis's technology acceptance model investigates acceptance by analysing perceived ease of use and perceived usefulness in the context of system characteristics and system usage (Marangunić & Granić, 2015). It is advisable for suppliers and manufacturers to prioritise the simplification of PV technology, as households tend to exhibit lower propensity for adopting PVS when they have uncertainties over the system's user-friendliness. Likewise, observing favourable effects of PV technology will increase the probability of individuals embracing PV for their own use (Alam et al., 2021). Environmental protection, social acceptance and economic benefits are part of the perceived usefulness of technology and positively linked to the likelihood of PV adoption (Ali et al., 2020).

Disruptive innovation refers to inventions that achieve market dominance by creating novel products or services that target previously overlooked or emerging client categories. To achieve successful disruptive innovation, firms must consider factors such as price sensitivity, convenience, and addressing the marketing strategies (Schmidt & Druehl, 2008). Accurately identifying disruptive innovation involves doing a comparative analysis between the innovation in question and a preexisting product or service, thereby comprehending its effects inside the present value chain (Nagy et al., 2016). On the other hand, sustaining innovation entails modifying or enhancing products or services in a manner that enables the acquisition of new customers, reduction of costs, and improvement of quality. Innovative enterprises encounter the dual difficulty of either developing entirely novel methodologies or endeavouring to incrementally expand their existing portfolio (Christensen, 1997).

2.2.5 Theory of Planned Behaviour

The Theory of Planned Behaviour analyses intentions and subsequent behaviour. Human behaviour is influenced by attitudes, subjective norms, and perceived behavioural control. *Attitude* towards behaviour refers to the assessment of the behaviour and whether it is considered favourable or unfavourable. Perceived positive outcomes lead to positive attitudes. *Subjective norms* consider external social pressure and influence. The behaviour of individuals can be significantly influenced by the expectations they perceive from others. Social disapproval reduces the likelihood of individuals engaging in certain actions. *Perceived behavioural control* pertains to an individual's confidence in executing an action. If individuals lack confidence in their ability to perform a behaviour successfully, they are likely to have a negative perceived behavioural control, resulting in a reduced intention to engage in that behaviour. If these factors are positive, the individual's intention is likely to be positive as well, increasing likelihood of engaging in a specified behaviour (Ajzen, 1991). Theory of Planned Behaviour is the expansion of Theory of Reasoned Action, which does not account for external constraints, such as financial situation. Thus, perceived behavioural control was added to account for limitations (Paul et al., 2016).

3. Methodology

3.1 Research Questions

The main question this dissertation investigates is, *how can bottom-up and top-down initiatives drive the diffusion of photovoltaic systems in the German housing sector*. Within this, a focus on companies' participation in democratising solar energy, the impact of governmental regulations and funding programs, and the main determinants of PV adoption in the single-family home (SFH) market were investigated.

3.2 Research Design

The literature review provided an overview of the current understanding of PVS. This was achieved by an analysis of available secondary data, with a specific emphasis on the preceding decade. Management theory literature was synthesised to provide an overview of how management practises can influence the PV landscape. Next expert interviews and a survey were conducted, and outcomes will be examined based upon the previously established framework. By performing interviews, valuable insights were obtained. The survey and interviews yielded more understanding barriers preventing individual houses from adopting PVS. Furthermore, the potential customer market and the key factors driving the adoption of PVS were identified. Triangulation was employed, because a single research approach is insufficient for addressing all aspects of a research question (Patton, 1999).

3.3 Data Collection

Data was collected through primary and secondary research. The purpose of the individual data collections will be clarified.

3.3.1 Primary Data Collection

Given the scarcity of management literature on PVS, a series of expert interviews were conducted. Industry professionals, listed in Table 2, provided comments and evaluations regarding obstacles, ongoing initiatives, and future requirements. To engage with each expert on an individual basis, a series of semi-structured interviews were held. The existing set of predetermined questions is supplemented by additional inquiries that arise spontaneously during the conversation (DiCicco-Bloom & Crabtree, 2006). This allowed for unbiased assessments to be voiced and later analysed. To further verify the interview insights, 122 participants were surveyed focusing on their current consumption patterns, motivation for PV adoption and attitudes. The survey was created based on the gathered interview data and executed using Qualtrics. Implementing a 5-point Likert scale provides valuable data regarding the participants opinions (Dawes, 2008).

Interviewee ID	Role	Company Type	Expert Justification
I01	Company CEO	Multi-Tenant Solar	Founder of PV Startup
I02	Ex Company CEO / PV Advisor	Solar Startup / Federal Ministry for Economic Affairs and Climate Protection	Founder of PV Startup & works for the government as a guide for PV expansion
I03	Product Owner	Multi-Tenant Solar	Regulation expert
I04	Product Owner	PV Startup	Energy product expert
I05	Energy Consultant	Consumer Protection	15+ Years experience
I06	Energy Consultant	Energy Consultancy	10+ Years experience
I07	Strategy & Business Development	PV Startup	Contact to many investors
I08	Strategy Manager	Housing Cooperative	Housing cooperative with >3000 flats in Germany
I09	Key Account Manager	PV Startup	7+ Years experience
I10	Solar Installer	PV Installation	Leading role in solar installation firm for 5+ years

***Table 2**: List of Interview Partners*

3.3.2 Secondary Data Collection

To gather relevant data and scholarly research for the literature component of this study, comprehensive research on reputable databases like JSTOR, ScienceDirect, and Scopus was conducted. The management frameworks were summarised, placing significant emphasis on scholarly research published in well ranked journals. Certain persistent questions found in the literature influenced the content of the interviews. This secondary data helped for developing guidelines to facilitate discussions (Snyder, 2019). Reports on PVS from both governmental entities and corporations provided a comprehensive and reliable overview. All statistical information was sourced from reputable data collection enterprises or authoritative government agencies.

3.4 Research approach

Qualitative content analysis according to Mayring is used to systematically analyse and interpret qualitative data. Inductive category development was employed to minimise biases by organically deriving categories from the data. The material was revised after 50% of the category creation process to assess the meaningfulness of the selected categories. Extracted information was condensed by utilising constant feedback loops to prioritise the most discussed topics. The reliability of responses was driven by careful selection of interview partners and cross-comparisons. Inclusion of individuals with different backgrounds and expertise resulted in a diverse range of data, providing a more comprehensive overview of the market. The chosen approach was selected for its ability to offer flexibility and enhance understanding of patterns in the data, related to the participants' experiences, opinions, and perspectives (Mayring, 2004). Considering the diverse expert backgrounds (see Table 2), a survey based on the data gathered , focused on understanding customer behaviour. This was done to apply quantitively supported interview data in the management context.

3.5 Research Limitations

Only a portion of the existing literature was examined in the literature review. Even though the analysis was limited to the highest-quality, most referenced sources, other works may differ from the selected research. Moreover, the results of a survey conducted with 122 participants and a geographic concentration on western Germany may skew results. Time constraints also made it difficult to assess how the survey respondents' perceptions of PV may have changed. To exclude personal perspectives from this body of work, biases, judgements, and assumptions were questioned through interviews, the survey, and thorough examination of literature.

4. Analyses & Findings

4.1 Qualitative Findings from the Interviews

The interview data was analysed by coding the responses and identifying relevant categories in MAXQDA 24, an analysis tool for qualitative research, widely used by academic institutions. In the following, the expert interviews are summarised in abstracts chosen according to assigned codes and thematic context. A focus was set on the most discussed statements (see Appendix 1). To attribute each statement to its respective expert, they are denoted by the references I01 to I10.

4.1.1 The Past and Status Quo

In recent years, various factors such as the Covid-19 Crisis, labour shortage, hardware scarcity and the war in Ukraine had significantly constrained the supply of PV technology. Due to increasing demand, customers experienced significant wait times for PVS products. Additionally, companies faced bankruptcy as they were unable to meet orders, while new competitors entered the market. Despite this, the rising energy prices led to a drastic increase in energy consulting requests (I01, I04).

Currently, the production of PV technology is operating at maximum capacity, and modules are no longer limited in supply. Battery technology is increasingly installed and gaining popularity. PVS are primarily targeted at SFH and commercial buildings, but ABs are also experiencing an increasing adoption of PV technology. This is significant due to the sector's vast potential (I01, I02, I03). Germany has a total of 3.3 million AB houses, which contain a combined total of 22 million flats (Statistisches Bundesamt, 2022).

The reduced cost of consuming self-generated electricity has surpassed the financial benefits of the FiT, resulting in a diminished influence on the adoption of PVS. This implies that companies should aim to maximise customer cost savings through software and tariff solutions to gain market share (I01, I03).

4.1.2 Solution Providers and their Role in the Market

Solution providers have a significant impact on the adoption of PV technology in the SFH market. This typically requires a comprehensive package that includes planning, installation, and service. Energy management systems and smartphone apps provide cost savings and informative user interfaces (I01, I04, I05). The leasing model often focuses on lower-income households unable to afford purchasing a PVS outright. According to the consumer protection consultant, leasing models are generally not advantageous for customers. This notion suggests that high power consumption, such as charging an electric vehicle or installing a heat pump, is more common among high-income households. This group has the financial means to purchase the PVS directly, which allows them to achieve greater cost savings compared to the leasing model. Furthermore, those who choose the leasing model are less inclined to seek assistance due to their perception that companies already offer sufficient information (I05). This poses a potential issue as certain customers may lack the ability to determine if the product is suitable for their needs (I04, I05).

During crises, nation-wide operating solution providers and installers were more prepared than local businesses due to their optimised supply chains and larger stock (I01, I04). Furthermore, the sales and installation process is optimised to ensure full installer utilisation. This decreases costs and leads to a competitive advantage (I03). Moreover, venture capital-backed companies implemented impactful marketing campaigns on a large scale to enhance public awareness. It is anticipated that many solar companies will go bankrupt due to heightened competition and fulfilled demand (I01, I03, I04). Local installers often derive greater advantages from word-of-mouth referrals and recognition. Customers highly value geographic proximity due to the feelings of connection and security it provides (I10).

The commercial and AB sectors require substantial innovation and specialised knowledge to be considered viable customer segments (I02, I08). Contracting options generally lack substantial financial incentives for the building's owner. Nonetheless, housing cooperatives utilise a contracting model to lower electricity expenses for residents and adhere to a climate strategy (I01, I03). The current CO_2 tax incentive for building owners does not consider the emission savings associated with photovoltaic systems, except for the electricity they provide to power electric heating systems. However, this is expected to change in the future (I01, I08). If PVS were included in the classification of buildings' energy efficiency class, leading to a reduction in CO_2 tax for the landlords, significant increase in demand is anticipated (I01, I02, I03, I04, I08).

Certain municipal utilities, which prioritise their operations within specific regions, also provide TE solutions (I06, I09). They greatly benefit from their broad acceptance and strong regional representation. In addition, housing cooperatives, which frequently have established business relationships with municipal utilities, sometimes choose to collaborate on projects

(I08). Due to limited scalability and expertise, these projects frequently encounter numerous challenges and unforeseen issues. Moreover, municipal utilities typically do not transfer the corresponding CO_2 savings to the building owner, reducing the attractiveness of the project (I04, I06, I09).

4.1.3 The Customers

The growth of the SFH market is believed to have reached its peak. Assuming no significant catastrophic events that impact electricity prices, demand is expected to remain constant (I01, I05, I06). The market phase of innovators and early adopters has been concluded, and the market is currently in the early majority stage. In addition to disposable income, technical affinity remains a significant factor influencing the adoption of PVS (I01, I05). The average adopter in Germany is a male above the age of 50. Although the reasons for adoption vary regionally, cost savings are still considered the primary motivator for PV adoption, while CO_2 savings have a lesser influence on this customer segment. This attitude has been significantly reinforced in Germany, particularly because of the Ukraine-Russia war and the resulting drastic price increases for electricity and gas (I05, I06, I09, I10).

Most B2C customers still feel overwhelmed when evaluating offers for their PVS and upselling oversized technology is common. To combat this, the government is funding free and independent consultancy services to help customers select a suitable PVS for their rooftop. This is in response to customers facing difficulties in determining their specific requirements (I05). However, certain customers may overestimate their capabilities and purchase technology that is not suitable for their requirements (I02, I04, I05).

Word-of-mouth and social pressure are influential factors in the adoption of PV technology (I10). The sense of belonging and avoiding being left behind during a crisis enhances this acceleration. Overall, it can be said that there is a rush to become more energy autonomous if the financial situation allows for it. Periods of economic uncertainty, such as the freezing of the government spending on 20^{th} November 2023, led to a significant increase in demand for consulting appointments (I05, I06). This applies to both residential and commercial sectors (I05, I06, I07).

The main obstacles to PV adoption are still recognised as insufficient technical knowledge, limited financial resources, time constraints, insurance considerations, and choice overload (I05, I06). Additionally, accurately predicting the profitability of projects is challenging due to numerous unknown factors. Given the long-term nature of PVS, it is crucial to possess financial literacy to make informed decisions (I05, I06, I07).

In the B2B sector, housing cooperatives often show interest in PV contracting models. Housing cooperatives are a German concept and focus on member participation and cooperative ownership, which leads to affordable housing with a non-profit orientation and a community focus. The objective is to prioritise the long-term stability and fulfilment of members' needs over the sole pursuit of maximising profits (I08, I09). Tenant electricity (TE) models are an appealing choice for housing cooperatives due to their elimination of upfront costs, long-term focus, and ability to reduce electricity expenses for tenants (I01, I02, I08, I09). A TE company's survey showed that drivers of switching to their service were lower cost per kW/h, a cloud-based information portal, monthly billing and emission free electricity (I09).

4.1.4 Driving Forces of the Industry

Solar installation firms in Germany have shifted from fragmentation to consolidation, facilitated by companies such as Enpal and 1KOMMA5°, which acquired various installation companies (I01, I05, I07). Through this they were able to operate on a national level, and leverage industry expertise. Numerous small companies in the regional market faced bankruptcy due to personnel shortages, supply chain disruptions, and insufficient demand, leading to a situation where not every installer has sufficient work (I01, I10).

German manufacturers of PV components are challenged due to elevated energy expenses and intense competition from China. Currently, most modules are manufactured in China and significantly more affordable while maintaining comparable quality (I06, I09). These companies benefit from factors such as low energy prices, sufficient resources, and personnel, and reduced operating expenses (I01). Overproduction of modules is highly probable and will result in significant price reductions, already reaching new lows (I03, I04).

The German government influences the trajectory of the PV industry. FiTs demonstrated how government incentives promoted adoption of PV technology (I01, I02). Germany's pioneering of the concept, which is now broadly applied, can be regarded as a success. Moreover, providing subsidies to individuals for PVS has been found to effectively stimulate demand for PV and is generally met with positive reception (I01, I02, I04).

Investment firms play a crucial role in the German photovoltaic market (I07). Despite not typically being considered a risk-tolerant country, Germany exhibited early enthusiasm for PV.

Unicorns such as Enpal and 1KOMMA5° demonstrate growing investor interest and willingness to invest in the PV sector (I01, I07). Investment capital enables firms to expand across the country and concentrate on business growth strategies, including optimising customer satisfaction. Digitalization presents a market barrier for smaller installers because they lack the financial resources to develop in-house software (I05, I10). Investors are increasingly focusing on industry knowledge and intangible assets that present a unique selling point. Despite the significant increase in interest rates and the difficulty in acquiring investments, the overall investment sum appears to be growing (I01, I02, I7).

4.1.5 Future of the Industry

The industry's immediate future appears promising, although experts expressed less optimism regarding its trajectory over the next two decades (I01-10). Despite the unprecedented relevance of uncertainty, companies are making market predictions based on existing regulations. A distinguishing factor of the PV industry is the long-term planning that is required to achieve profitability in a market environment that is rapidly changing (I01. I09, I10). Therefore, companies must advocate for supportive policies that facilitate the transition to renewable energy through collaboration with the government (I03). These days, it seems like venture capital-funded businesses are getting more desperate with their marketing efforts, even going so far as to highlight the drawbacks of rival companies rather than their own advantages (I01, I05, I07, I10).

Solar energy is one of the most cost-effective methods for generating electricity. The increase in PVS demand may lead to a decrease or removal of FiTs. Additionally, the prevalence of solar energy will exacerbate the disparity in production between summer and winter. Therefore, cost-effective solutions are needed to store surplus energy for winter (I03, I04).

To remain competitive, companies must adapt to the needs of ABs in the future (I01, I03). The SFH market, as well as the AB market, will be controlled by a small number of market players who focus on optimising their supply chains, efficiency, and marketing (I01). Companies that quickly acquire industry knowledge and expertise will be difficult to surpass. Additionally, the transition of a business model from SFH to ABs poses significant challenges due to the substantial differences in concept (I01, I06, I09).

It is crucial to generate public interest in cost and CO_2 savings associated with PVS to promote further expansion (I06, I07). By implementing strategies such as lowering prices and introducing innovative business models, the perception of PVS is expected to become more favourable.

The use of gamification to promote CO_2 emission reduction is considered a strategy to increase awareness and engagement among the general population (I05). Accurately tracking electricity consumption and CO_2 emissions is already a popular feature in PV startup applications (I04, I08).

Certain states and cities, such as Berlin and Hamburg, have implemented a PV mandate, which requires building owners to install a PVS when constructing new buildings or undertaking substantial renovations (I10). These obligations are increasingly becoming nationwide and expanding across residential, public, and commercial sectors (I01, I02).

Despite recycling and reuse solutions in the industry, it is expected that additional companies will emerge with a specific focus on end-of-life solutions for modules and batteries (I04). Currently, PVS have an anticipated lifespan of 20 to 30 years, with minimal operational concerns during their operational period. Module resources are typically expected to be recyclable and reusable for new modules, despite ongoing concerns regarding the profitability of recycling (I10).

4.1.6 Problems with PVS diffusion

Among the key issues are grid fees, overreaction to perceived market demand, the fact that batteries do not present a business case, and issues that arise when ABs are equipped with PVS (I1-I10).

To expand and maintain the electrical grid, local grid operators charge grid fees. Since rooftop PVS electricity is consumed in the residence that generates it, it is not impacted by these grid fees. This thereby reduces the amount of grid fees that households must pay significantly because the electricity provided by the grid only accounts for a small portion of the overall amount needed (I01, I02). As a result, homes without PVS installed must pay grid fees to maintain the energy infrastructure, which is also crucial for PVS owners because they profit from feeding excess electricity into the system (I09). It is already evident that areas with larger renewable energy percentages pay higher grid fees (I01). Grid operators are already having difficulty without assistance from the government, thus a rapid increase in grid fees is anticipated soon (I02). This is a serious problem because the demand for energy will rise significantly because of heat pumps, e-Mobility, population growth, and technological advances (I08). It becomes clear that a significant increase in PVS adoption among Germans will require a modification of the grid fee exemption, as well as a revision of the FiT (I01, I02, I04).

Furthermore, issues persist regarding insufficient electricity generated by PV technology in winter as seen in Figure 6 (I04). Despite advancements and cost reductions in battery storage, the economic feasibility of implementing large-scale battery systems remains limited. It is not feasible to store sufficient PV generated electricity to meet energy needs of households lacking PVS. Due to the low price of electricity and high expenses of battery production, there is a lack of financial motivations for companies to focus on developing extensive battery storage systems. Seasonal electricity storage remains impractical, even for individual households (I04). Due to the substantial electricity generation by PVS during summer, grid operators encounter challenges related to excess supply. Consequently, it is imperative to be able to curtail PVS output (I03, I04).

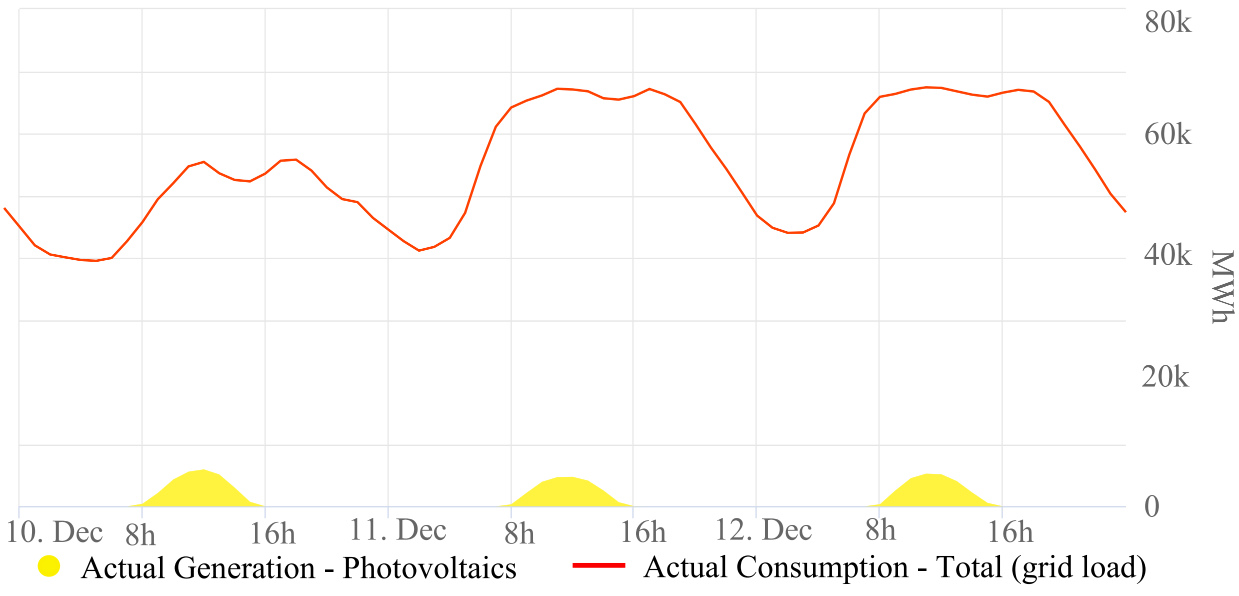

Figure 6: *Hourly PV Generation and Electricity Consumption between 10th of December and 12th of December 2023 in Germany According to the Federal Network Agency*

Source: SMARD (2023)

Additionally, incorporating ABs into the transition to renewable energies using PVS presents a considerable obstacle. The "Solarpaket I", a legislative package, facilitates the sale of photovoltaic-generated electricity to tenants in ABs for the respective real estate owners, with fewer obstacles than previously (I01, I02, I09). This enhances the utilisation of PV generated electricity and, in theory, amplifies the financial incentive. The installation of such a system remains burdensome for both residential building companies and private owners. This is why many choose TE models (I01, I06, I08, I09).

Government incentives are frequently criticised for subsidizing affluent individuals. Households planning to install PVS often benefit from incentives, irrespective of their financial circumstances. A PVS funding programme has provided up to €10,200 to households who own an electric car and intend to construct a PVS. The 500 million Euros allocated were depleted in a span of 24 hours. Some argue that this did not result in an increase in planned PVS, but rather only provided financial relief for the wealthy (I03, I06).

PVS expansion assumes that Germany's infrastructure is prepared for the transition to renewable energies. In practise, numerous SFH are unsuitable for PVS. Possible factors contributing to this phenomenon include shadows, orientation, and roof structures (I05, I10). This is particularly important for ABs given their limited roof size. Buildings with a high number of tenants have smaller benefits from the PVS due to insufficient electricity generated to meet overall demand. However, fewer tenants decreases a project's financial viability (I01, I04, I10).

4.2 Quantitative Findings from the Survey

To validate the answers of the respondents, an attention check was implemented, that all 122 respondents answered correctly.

4.2.1 Demographics

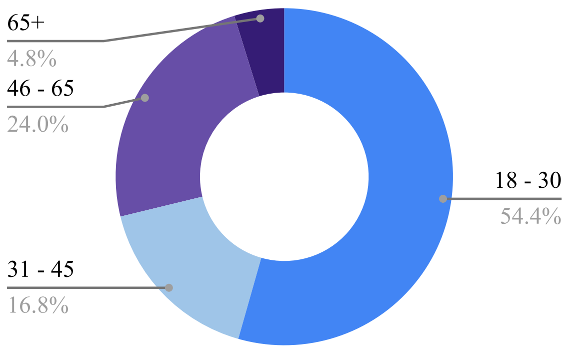

***Figure** 7: Age distribution of survey respondents*

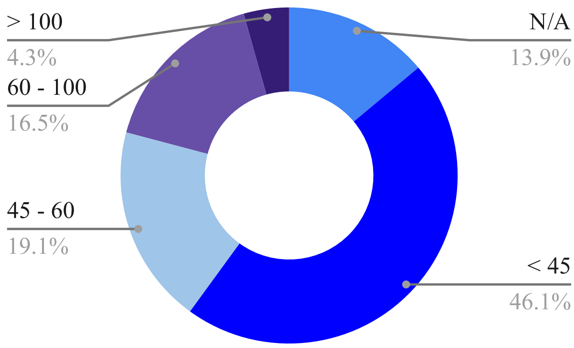

***Figure 8**: Yearly gross income distribution of survey respondents in thousand Euros*

Of the survey participants, 69 were male and 53 were female. Most respondents were between the ages of 18 and 30 and had higher education. A diverse range of individuals was addressed, which allowed for a comprehensive overview: 73 tenants, 4 apartment owners and 45 SFH owners participated in the survey.

4.2.2 General Questions

57 % of participants stated that they did not have a green electricity tariff or did not know whether they had one. Additionally, 59% are unaware of their current price per kWh, while only

15% regularly switch their electricity supplier. A moderate correlation of 0.402, indicates that an individual that knows if they have a green electricity tariff, or has one, has a higher tendency of knowing their price per kW/h. Only 18 respondents said, that they regularly switch electricity providers, which strengthens the argument that electricity is not a high engagement product.

To enable a wider range of responses, a Likert scale (1-5) was utilised.

Respondents were asked to indicate to which extent they pay attention to their electricity consumption, enjoy new technologies, inform themselves about electricity tariffs and worries about climate change (see Appendix 3). With a mean of 4.09, climate change worries ranked the highest, closely followed by enjoying using new technologies (3.6) and paying attention to electricity consumption (3.51). A moderate positive correlation of 0.44 between informing about electricity prices and paying attention to electricity consumption may be associated with raised cost-awareness. Standard deviations of 1.06 to 1.20 indicate homogeneity across survey respondents' behaviour.

99 participants answered that they know someone that owns a PVS. Considering a mean of 3.33 for increased adoption possibility with more peer-testimonials, this information shows that word-of-mouth campaigns could affect a broad audience.

Social recognition was ranked the lowest impacting factor, while lower initial cost, as well as more knowledge about funding programs was ranked the highest. Considering the funding programs aim to make PVS installation more cost effective, these two categories can be combined to financial incentives. On the other hand, more awareness for CO_2 reductions were perceived as influential.

Lack of trust in the technology, no interest in PVS and aesthetic concerns were negligible for tenants faced with the scenario that they would own a SFH.

4.2.3 Photovoltaic System Adopters

Among the SFH owners that answered to have a PVS, 11 were female, 13 male and 2 did not disclose their gender. This information does not imply a gender bias, as respondents from the same household can have answered the survey, potentially skewing the data. Nonetheless, the average income was in the 45,000 – 60,000 € range and the average age was 48. Out of the 26 adopters, only 4 chose a leasing option. A regression analysis was performed investigating the effects of age, income, education level, electricity price knowledge and knowing peers with PVS. Limited responses and an adjusted R^2 of 0.17 deemed the data insufficient for further statistical analysis. Nonetheless, as the age increases by one unit, having PV is estimated to change by approximately 0.0107 units, ceteris paribus.

The main reasons for adoption were financial motivations, CO_2 free electricity production and autonomy from conventional suppliers. This is strengthened, as 22 of the adopters opted for a PVS with an integrated battery system. Every respondent was satisfied with the decision of adopting PV and 23 said, that their expected electricity savings were fulfilled.

5. Discussion

5.1 Discussion Approach

In this section, interview results, survey results and literature will be connected to apply management literature theory onto the given context. The SFH sector and AB sector will be discussed separately.

5.2 The Sustainability Aspect

Electricity is not a high-involvement product, while PVS are. The survey reveals that most respondents do not conduct thorough research on electricity tariffs. Moreover, the respondents' lack of awareness or decision not to subscribe to a green electricity plan suggest a lack of comprehension or concern regarding the implications of relying on fossil fuel-generated electricity. This is supported by the fact that despite this, most respondents expressed concerns about climate change. Installing a PVS requires deliberate decision-making and thoughtful consideration of one's preferences for electricity production and consumption. Given most respondents express favourable views towards PVS, but do not decide for green electricity tariffs, it is evident that factors beyond sustainability must also serve as significant motivating factors.

The government is actively promoting CO_2 emission reduction in the housing sector through the implementation of CO_2 emission taxes. In addition to tax considerations, building owners are highly motivated to reduce CO_2 emissions in their portfolio due to the significant impact it can have on the financial valuation of the buildings. An online housing marketplace found that in 2023 property value can decrease by as much as 51% dependent on the building's energy efficiency class (ImmoScout24, 2023). The increasing interest in sustainable living practices suggests that PVS enjoy a positive reputation, attracting tenants and potential buyers to choose real estate with PVS.

5.3 Single Family Home Adopters

The SFH market is largely focused on adopters, that want to actively partake in the change to renewable energy, enjoy new technologies and seek financial investment possibilities. Software solutions that monitor electricity consumption, production and improve the consumption pattern, have a high significance for individuals adopting PVS. In the past, the adoption of PVS was mainly driven by the guaranteed FiTs, which resulted in a secure investment, competitive to other investment opportunities (Strupeit & Palm, 2016). Additional aspects found within the scope of the research will be discussed in the following.

5.3.1 Autonomy

Although survey respondents did not prioritise independence from electricity prices, some still considered it as an important motivator. Increased consultation demand during crises, such as the Ukraine-Russia war and the government budget freezing imply a link between crises and PV interest. Grid costs are set to climb by 100% beginning January 1st, 2024, resulting in higher cost of electricity for end users. The German government's withdrawal of subsidies in the renewable energy sector makes determining the influence of the current financial position on the dissemination of PV technology difficult. Uncertainty appears to be a substantial positive element driving PV technology adoption, whereas subsidies serve mostly as incentives rather than as the fundamental determinant. As a result, reduced government spending on lowering traditional power rates is likely to result in increased demand for PVS.

5.3.2 Technology Acceptance, Diffusion of Innovation and Theory of Planned Behaviour

Technology acceptance is critical for the implementation of PV, as established in the literature (Ali et al., 2020). Individuals who have an affinity for adopting novel technologies are more inclined to adopt PVS. Cloud-based services and applications are also substantial contributors. As a result of the importance of emission reduction to adoption, prosumers are interested to acquire information regarding their reductions. Prosumers are classified as producers and consumers of a good. Graphical user interfaces that exhibit generated electricity, purchased electricity, and cost savings are considered crucial. Even though the survey suggests that respondents feel a sense of understanding of PV technology, experts still say that installers often try to upsell oversized technology. Literature and expert interviews indicate that greater PV adoption is associated with product simplification and uncertainty reduction (Alam et al., 2021; Ali et al., 2020).

Middle-aged men with technical occupations were the primary early adopters of electric vehicles in Germany (Plötz et al., 2014). According to the gathered data from interviews and the survey, a comparable set of people often choose to install PVS. The SFH market is now thought to be at the early majority stage, with growth expected to slow down in the following years. Price dumping, innovation, and strong marketing campaigns are all the result of a highly competitive market. Despite the possibility for increasing adoption, experts believe that most SFH owners who want a PVS have already purchased one. Furthermore, despite the addition of leasing options, PVS remain primarily available to wealthy customers. This model's popularity is likely to decline as more people realise that taking out a loan to finance the initial investment is typically a more profitable option. Additionally, leasing contracts typically span 20 years, which presents another barrier for adoption, as it is a long-term commitment (Cai et al., 2013). Nationally running enterprises, which often have a larger workforce, can have availability advantages over local installers. In terms of innovation diffusion, the expansion of PVS confronts a particular difficulty. Some people who want to install a PVS may be limited if their roof is unsuitable for such an installation, even if they have the necessary funds. This severely limits the possible market and begs the question of whether new alternatives are required. Balcony power plants, which may be built on balconies or rooftops, can have a big impact on the democratisation of solar energy. These PVS are small, require little regulation, and can be self-installed.

Marketing campaigns and government subsidies have significant impact on the attitude towards PV (Cai et al., 2013). While social recognition was not identified as a significant reason for adopting PVS in the survey, expert interviews indicate that individuals may feel left out if many people in their social circle install PV systems. Word-of-mouth recommendations is recognised as a powerful strategy for influencing people's opinions, which can be categorised as subjective norms. Additionally, free independent PV consultancy services provided by the government are critical for adopters experiencing uncertainties, enhancing perceived behavioural control. Filling information gaps, increasing environmental awareness and knowledge sharing can positively affect adopter confidence and aid in the decision for PV technology in accordance with the theory of planned behaviour. The willingness to purchase and adoption of PVS are not directly affected by subjective norms. Instead, they are influenced by perceived behavioural control and attitude. Subjective norms were found to effectively promote the technology (Khuong et al., 2020). These findings are consistent with the survey and expert evaluation. The study revealed a positive correlation between higher income and both attitude and perceived behavioural control (Khuong et al., 2020). Adopters are often classified as high-income individuals based on the collected data. Financial constraints hinder the adoption of PV among lower-income individuals, indicating that our adoption data does not allow for a direct comparison of attitudes.

5.3.3 Accelerate Diffusion in the Single-Family Home Sector

Positive referrals, from peers that already adopted PVS, appear to be a strong driver of potential PV adoption. Most survey respondents knew someone within their social circle, that already has a PVS, implying that most of the market could be reached through referrals. This point is backed up by the expert interviews, which underlined the necessity of peer endorsement and incentive plans for hiring peers to expedite the diffusion of PV. In the USA, visibility on neighbours' rooftops has increased willingness to invest in PVS and is associated with reduced uncertainty. Additionally, government incentives that lower initial cost have a strong impact on PV adoption (Crago & Chernyakhovskiy, 2014). According to research, the perceived trustworthiness of peers has a considerable influence on the likelihood of influencing purchasing decisions. It is suggested that influential individuals in a community can promote PV technology adoption by arguing for its benefits (Scheller et al., 2022). Trust and relationships are recognised as drivers of potential PV adoption. While well-connected individuals would make excellent ambassadors, government bodies such as consumer protection agencies can fill that position and provide helpful assistance. Raising awareness and enhancing accessibility are critical in encouraging potential adopters to use the services that are provided. Trust in the governments ambitions is particularly vital when assessing the government's influence on PV adoption, as open policymaking is required for long-term PV strategy (Baur & Uriona M., 2018).

Studies have demonstrated that the presence of solar installers in a city has a significant impact on the rate of PV adoption. The selection of an installer is primarily influenced by peer feedback and trust (Scheller et al., 2020). These findings are consistent with the evaluation of the experts. Peers have a significant impact on potential adopters during the awareness and early interest stages, but their influence decreases as the adoption process progresses(Rode & Müller, 2020). Energy consultants play a significant role in the later stages by providing support in finalising investment decisions, as indicated by expert interviews.

Removing the 19% value added tax on PVS is a cost-cutting approach that, in theory, should significantly reduce the final price. Nonetheless, the expert interviews reveal that cost savings typically benefit the installer and have little impact on the eventual customer. Long-term rewards are more effective than upfront incentives, according to research in the United States (LEE et al., 2017).

5.4 Apartment Building Market

Improving accessibility of PVS in the AB sector is vital due to the significant impact on a larger population compared to the SFH market, as most Germans live in apartments. Moreover, AB roofs offer great potential due to their size.

5.4.1 Stakeholder Theory Applied to the Apartment Building Sector and Disruptive Innovation

The AB sector encompasses housing cooperatives, commercially motivated housing companies or individuals, and homeowner communities. To examine the implementation of PVS on ABs from a stakeholder theory perspective, it is necessary to identify the relevant stakeholders. TE solutions impact various stakeholders, including residents, real estate owners, grid operators, and governmental entities. Understanding stakeholder needs is essential for developing a product that meets their requirements.

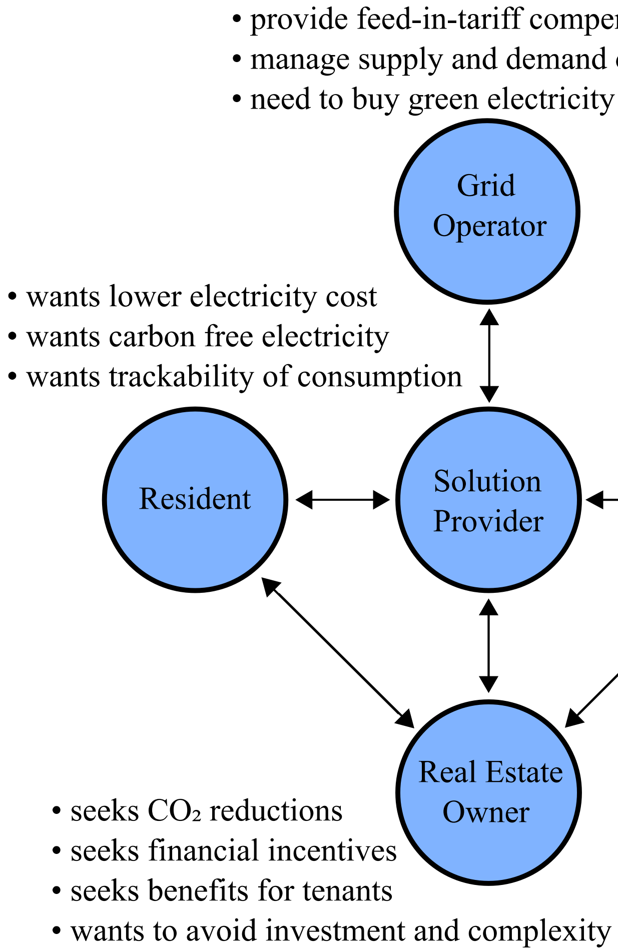

Figure 9*: Own visualisation of stakeholder analysis in the apartment building sector in a TE model*

As seen in Figure 9 the solution provider is connected to all stakeholders. Industry businesses frequently exert influence over regulations and incentives. In this scenario, customers are divided into two groups within the project. The real estate owner is an essential business partner for TE providers as they provide the roof for the PVS. To ensure profitability of a project, the TE provider must convince residents that their product is superior to their current electricity provider. According to the experts, roughly 40% participation rate are sufficient to make a project profitable. Real estate owners are significantly affected by government policies, through requirements and regulations. Lastly, the grid operators are affected by excess produced electricity, as they provide compensation in the form of the feed-in-tariff and are obligated to purchase electricity from renewable sources.

Housing cooperatives, commercial housing companies and individual AB owners present suitable business partners for TE providers, as the decision to adopt PV lies within one entity. Contrary, in homeowners' communities, a 50% consensus of installing a PVS among all the individual owners is often unattainable. In this case, the building's ownership rests with the collective residents, making installation of a PVS a personal decision. Nonetheless, government regulations are expected to significantly increase demand for PVS over the coming years. Due to the reluctance of these communities to invest their own money in PVS, alternative solutions, such as TE, may be effective.

TE can be seen as a modification of the business model of equipping ABs with PVS. Before 2017, the year the EEG enabled TE, equipping ABs with PVS necessitated considerable investment from the real estate owner and tenants would typically not benefit from the decision of adopting PVS. It can be classified as incremental innovation rather than disruptive innovation since it relies on regulations and does not completely transform the market situation. Nonetheless, it introduces novel methodologies, allowing the acquisition of new customers, reducing cost, and quality improvement. These criteria facilitate a connection to innovation literature (Christensen, 1997).

5.4.2 Resource Based View and Investment

Solution providers are of utmost importance for the extensive rollout of PVS in Germany. TE firms enable tenants to partake in the transition to renewable energies. Thus, examining investment behaviour, which enables the solution providers to scale is relevant to the democratisation of solar energy.

The investment decision is largely based on intangible assets, which make a firm stand out from the competition. Established business relations, a skilled workforce, deep understanding of the market and optimised technology are the main drivers for raising capital. As it is assumed that existing companies in the SFH sector cannot easily switch over to the AB sector, establishing an early lead is important. With the depletion of the SFH market, firms with greater capital will look to diversify and branch out. Therefore, firms participating in the apartment sector market must establish a strong brand presence, form strategic alliances, continuously improve their product, and foster their innovation. This can create imperfectly imitable solutions that may enable long-term competitive advantage.

5.4.3 Accelerate Diffusion in the Apartment Building Sector

The government's regulatory framework significantly affects the rapid diffusion of PVS in ABs. Legislative packages such as the "Solarpaket I" aim to reduce obstacles to the implementation of financially viable solutions. These changes include “flexibilization” of larger scale PVS, implementation of communal building supply, improvements for multi-tenant solar concepts, accelerating grid connection and simplifying direct marketing (BMWK, 2023a).

Direct marketing pertains to a scenario where excess electricity is sold on an electricity exchange rather than being compensated through the FiT. Previously, all PVS that desired to participate in direct marketing were required to be remotely controllable. For PVS below 25 kWp, this regulation has been eliminated because smart meters are deemed to be sufficient. As an alternative to multi-tenant solar, communal building supply permits building owners to supply electricity to their tenants. This measure was introduced to lower the barrier for AB PV adoption. In this context, the real estate owners do not need to provide supplementary electricity for their tenants. In addition to the lease with their landlord, tenants are also required to have a contract with an established electricity company. There are persistent obstacles, and setting up the system requires considerable effort. Furthermore, the substantial upfront expense presents an impediment to the extensive implementation of the idea, deeming it ineffective for an extensive rollout.

Grid connection is a persistent issue with inadequate staffing of grid operators, and lengthy completion times. The new regulations for TE systems primarily affect the virtual totalizer. This pertains to the procedure through which electricity meter readings from smart meters are transmitted from individual tenants to a virtual totaliser. This data is subsequently transmitted by the virtual totalizer to the TE company to facilitate invoicing. Physical totalizers frequently necessitated significant investments, resulting in diminished profitability and elevated prices for tenants. Additionally, the potential market is expanded by allowing the installation of PVS on historically protected buildings.

5.5 Key Strategies and Recommendations

Reducing bureaucratic obstacles, providing financial incentives for PV adoption, and collaborating with industry stakeholders to facilitate innovative business models have demonstrated their efficacy. However, to guarantee the future expansion of the market, this thesis offers suggestions to expedite the spread and influence of PV acceptance across three areas shown in Figure 10. In this context, top-down initiatives refer to government-led measures, such as incentives, requirements, and funding programs. Bottom-up initiatives encompass actions and efforts from the public and companies aimed at improving public perception and fostering adoption.

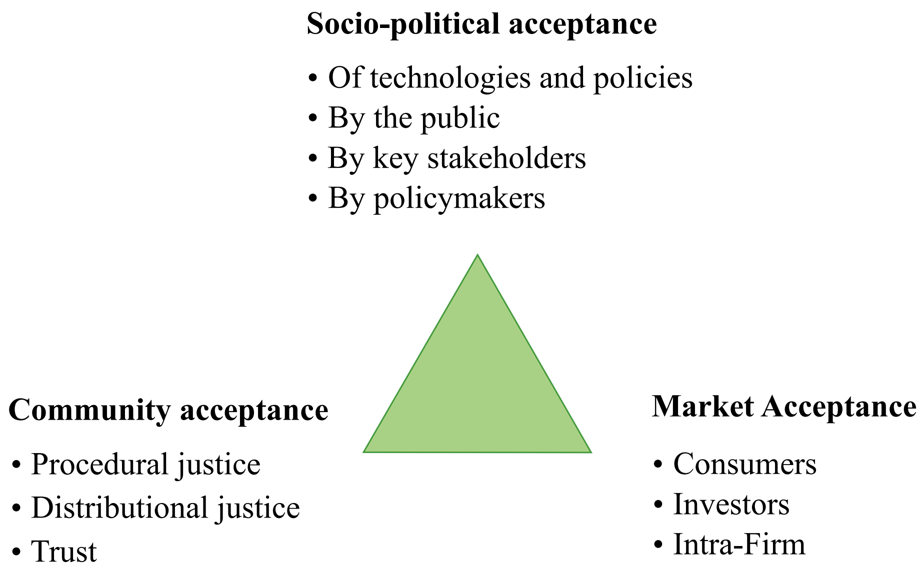

***Figure 10**: The triangle of social acceptance of renewable energy innovation*

Source: Own adaptation of Wüstenhagen et al. (2007)

5.5.1 Top-Down Initiatives

Government-led consulting services are crucial for accelerating the adoption of PVS in the German housing industry. State-funded initiatives decrease knowledge barriers, offer objective assessments, and significantly reduce the risk of purchasing an oversized system. During periods of economic uncertainty, there is a heightened demand for PV consultation appointments. This suggests that reducing funding for these programmes during times of crises should be avoided.

The importance of the FiT has decreased since grid parity was achieved. This implies that the compensation is below the average retail electricity price. Hence, self-consumption of generated electricity is more cost-effective than selling it and purchasing electricity from an external provider. Nonetheless, the profitability of PVS relies on the income generated from excess electricity production (Karakaya & Sriwannawit, 2015). The expert assessment suggests that the FiT may be subject to future changes due to its lack of financial sustainability. Therefore, it is advisable to promote the widespread adoption of direct marketing among PVS owners, while also reducing barriers to entry. In this scenario, the owner of the PVS sells their surplus electricity on the electricity exchange with the assistance of a business partner. If the electricity price is lower than the feed-in-tariff, the government provides additional compensation to the owner of the PVS until the same monetary value is reached (Figure 11). This is funded by the EEG surcharge, applied to all consumers of conventionally sold electricity. When the electricity exchange price exceeds the FiT, the seller benefits from increased revenue.

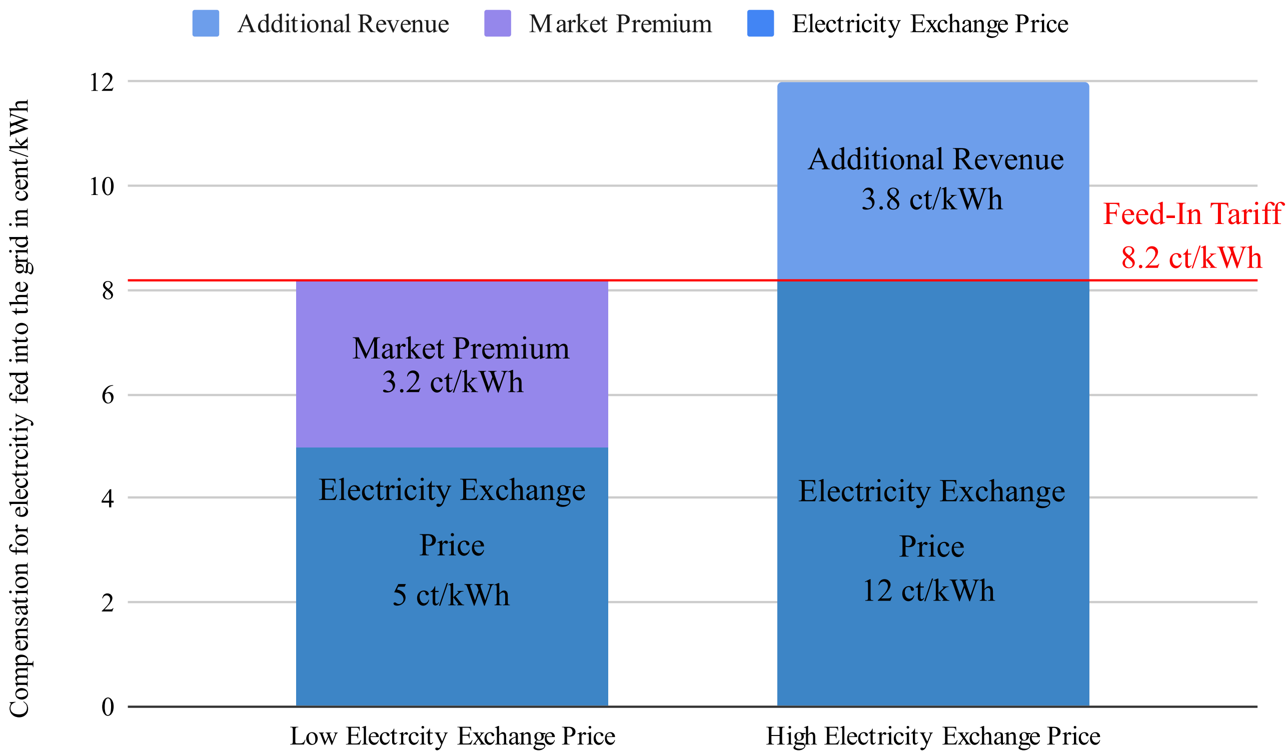

***Figure 11**: Own illustration of direct marketing model*

Furthermore, the issue of inequitable funding programmes persists. Subsidizing PVS, when combined with an electric vehicle purchase is mainly targeted at high-income individuals, which could likely install PVS without the government funding. Even though high-income individuals are usually consuming more electricity, low-income households must be included in the transition to renewable energy to boost public perception and democratise PVS. One option of including a wider range of individuals, regardless of their income, is TE. Considering tenants make up most of the German population, intensive funding programs and eliminating regulatory barriers for TE companies can result in higher levels of diffusion of PVS and broader accessibility. While communal building supply could theoretically provide similar benefits, expert assessment judged this initiative as too complex to be extensively applied.

Reducing financial assistance for fossil fuel-based electricity, such as price controls, may lead to increased adoption of PVS, or green electricity tariff options. This would adversely impact tenants who do not benefit from PVS, which comprises most of the German housing market, indicating inequitable treatment. The raising grid fees affect non-PVS equipped households more, as the grid fee is applied to every consumed kWh, compared to only those sourced from the grid. While inequitable treatment could once again be argued, inclination to adopt PVS should rise according to the gathered findings.

Enabling broader public access to PVS can be achieved by implementing laws and regulations that provide extrinsic incentives to building owners. Furthermore, utility companies losing their high-income customers presents a risk, as low-income customers are more sensitive to changes in electricity prices (Cai et al., 2013).

Adapting the CO_2 tax may encourage the adoption of PVS by real estate owners. As of the 1st of January 2024, each ton of CO_2 emission of a building costs the real estate owner 45 €. Applying CO_2 savings from the PVS to the building's total emissions, when taxing the real estate owner can lead to increased willingness to adopt PVS. TE models, as well as self-financed PVS, might be a more cost-effective solution to paying the tax.

Nonetheless, policymakers need to account for heterogeneity in their decision making, as personal differences and motivations can vary drastically (Schulte et al., 2022).

5.5.2 Bottom-Up Initiatives

From a business standpoint, bottom-up strategies for the PVS market encompass referral programmes, enhancing online interfaces, and simplifying PVS installation. When examining companies operating in the market from a bottom-up perspective, it is crucial to recognise that some companies depend on top-down initiatives for their survival. The TE model relies on the EEG for its existence. Therefore, evaluating grassroots efforts requires thoughtful examination of the current conditions.

According to the survey (Appendix 3), experts and literature, peer referrals strongly encourage higher PV adoption rates, which aligns with diffusion of innovation theory. Therefore, it is recommended to incorporate referral programmes into business practices for both the SFH and TE markets. Persuading fellow tenants to switch to the TE provider reduces emissions, increases project profitability, and accelerates the model's expansion.

Additionally, it is recommended to conduct awareness campaigns regarding CO2 savings and their impact to enhance public perception of PVS. Survey participants and experts considered this measure valuable for increasing likelihood of adopting PVS. Integrating electricity consumption and potentially incorporating gamification into user interfaces could aid in achieving this objective.

Vonovia, a real estate group with over 540,000 apartments, views the installation of PVS in suitable buildings as a strategy to reduce carbon emissions in their portfolio (Hartwig et al., 2022). The widespread adoption of PVS by a real estate group of this size can significantly impact public perception of PVS, given their influential role. Competitors are likely to adopt PVS to maintain competitiveness in the market.

The main driver for the adoption of PV technology in the SFH, as indicated by the survey, was the reduced initial cost. Moreover, it is crucial to have a heightened awareness of funding programmes. This suggests that cost remains a major concern among the public. Experts predict that the price will soon decline due to a small number of competitors in the market who are expected to lower prices to attract customers.

6. Conclusion

This study examined factors influencing the diffusion of PVS in Germany within the SFH market and AB sector. To do this, the existing PVS and management literature were analysed and expert interviews conducted, which were compared and validated with survey data.

The SFH market is shifting from a fragmented market with local solution providers to a consolidated market backed by investments. According to experts, the market has reached peak growth and is expected to stabilise soon. Therefore, existing market participants must adapt their offerings to tackle the forthcoming challenges of price competition, market saturation, and limited financial advantages for customers. The main drivers of adoption are: financial incentives, autonomy from conventional electricity providers and CO_2 savings.

The emerging AB market shows promising growth potential. Exploring strategies to engage tenants in the transition to renewable energy is vital due to its significance among a substantial portion of the German population. TE provides a solution for installing PVS in ABs. Tenants are motivated to adopt TE due to lower cost and informative interfaces. The real estate owner is driven by potential cost savings from reducing CO_2 emissions, benefiting tenants, and increasing real estate value.

To promote the widespread adoption of PV technology in Germany, it is crucial for the government and firms to raise awareness about its benefits.

7. Outlook

Interest in PV technology rises during global or national crises, as indicated by insights from experts. To gain a deeper understanding of this phenomenon, it would be beneficial to conduct a comprehensive, long-term study that examines the impact of significant events on the demand for PVS and investigating whether there is a decline in PVS interest in response to positive events or news. Additionally, future research on this subject could examine potential shifts in government incentives and their effects on the PV industry in Germany, particularly in relation to grid fees, the FiT and infrastructure.

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Appendices

Appendix 1

Coding of interview data

Category	**Codes**	**Number of mentions**
The Past and Status Quo	- Covid-19 / Energy Crisis / Russia-Ukraine War - Module production - Market potential - Grid parity	- 13 - 6 - 10 - 5
Solution Providers	- Tenant electricity - Surge in demand - Marketing efforts - Municipal utilities - Leasing model	- 13 - 15 - 8 - 3 - 7
The Customers	- Single family home market - Housing cooperatives - B2C - Customer needs - Customer profile	- 20 - 17 - 6 - 24 - 4
Driving Forces of the Industry	- Manufacturers - Installers - Solution providers - Government / Policies - Investment firms	- 6 - 10 - 13 - 23 - 4
Future of the Industry	- CO_2 tax - Adaption to the market - PV regulations - Apartment building sector expansion	- 14 - 10 - 10 - 18
Problems with PVS diffusion	- Labour shortage - Storage solutions - Inequitable solutions - Incentive criticism - Readiness for PV expansion in the housing sector	- 4 - 5 - 9 - 7 - 11

Appendix 2

Main arguments from the interviews were summarised.

Interview 1 - Multi-Tenant Solar, Founder of PV Startup

Please describe the current PV industry from your perspective.

- **Upstream Hardware Production and Logistics:**

- Three categories: upstream hardware production and logistics.
    - Strong push from China, especially from manufacturers, leading to increased capacity.
    - The market is growing significantly, and there is enough material available.
    - This wasn't the case in the past due to factors like the Corona pandemic, the Suez Canal blockage, and energy crises.
    - Hardware is becoming more affordable due to overcapacity causing excessive price drops.
- **Installer Industry:**
    - Many local craftsmen are present.
    - A few champions have grown big but have largely remained local.
    - Solution providers entered with venture capital and scaled through digitization.
    - The industry was fragmented before and has now consolidated.
    - This year reached a peak due to the solar hype because of the energy crisis.
    - High interest rates have made the capital market stricter.
- **Solution Providers:**
    - Make it easier to use PV.
    - Enpal introduced a leasing model.
    - More marketing and branding.
    - Financing solutions.
    - Multi-tenant is just starting.
    - The overall solution takes precedence.

Where do you see the industry in the next 10 years?

- **Single-Family Home (EFH) Sector:**
    - Approaching saturation phase.
    - 20-25% of houses already have installations.
    - Future installations will be increasingly challenging.
    - Linear growth observed.
- **Multi-Family Homes (MFH), Offices, Logistics, etc.:**
    - Only 1% equipped.
    - Regulations, construction requirements, certifications.
    - Solar packages make it easier.
    - The case becomes more attractive due to high energy prices.
    - Owners of MFH are challenging because they are property companies.
    - EFH can do it out of personal motivation.
    - The German industry is not innovative or investment-friendly.
    - The commercial building share will increase dramatically over several years.

To what extent and which laws have aided the expansion of the PV market?

- The EEG is a German invention and one of the most successful laws worldwide.
- Adopted by 100 countries.
- High feed-ins ensured that the global learning curve was supported.
- Boosted the strong PV industry in Germany.
- A significant push was observed in 2015/16 when PV electricity from rooftops became cheaper than grid electricity.

- Battery storage solutions emerged.
- No network charges for rooftop solar (network operators aim to change this).
- The electricity needs to be free for a viable case.
- Apart from the tenant electricity law, not much positive action was taken.
- Previous policies weren't interested in pushing the topic.
- Raised funding rates.
- Smart meter rollout and virtual totalizers.
- The government gathers opinions and incorporates them into laws.
- Network connection is made easier

How does competition within the tenant electricity market affect the industry?

- Currently very small.
- Still complex, requiring specialized knowledge.
- Software players aim to enable landlords to offer tenant electricity.
- They have also faced challenges so far.
- Slow customers and industries.
- Customers think they can handle it themselves but often cannot.
- Landlords seek new income sources, many are frustrated they handed over the billing for heating and water.
- They don't want to deal with electricity either.
- Value needs to be offered through cheaper prices - competition can drive growth.
- Affordable rates for heat pumps, e-charging stations.
- PV systems are a central component, but the rest comes from the grid (especially for heat pumps).
- Requires energy management and smart electricity purchasing

How to approach new customers?

- Limited knowledge about end customers.
- Different regions have different demands - segmentation is crucial.
- EFH owners are well-off, have environmental concerns, and seek social recognition.
- In the rental segment: unemployed, non-German speakers.
- Prefer digital solutions via smartphones, especially price-sensitive, less focused on the eco-story, more on convenience.

How do external factors affect PV penetration?

- Trust is essential; people observe others' actions.
- The same applies to neighbors.
- Especially true in Germany, where they aren't innovators or early adopters in the German market (see iPhone).
- The narrative promotes the wave more positively than wind power.
- Energy has two streams: fans vs. supporters of nuclear, coal, etc.
- Hard facts need to be presented; it's cheaper and better for the environment.
- Technically, it's the cheapest way to generate electricity.
- Nobody wants to wait for modules in five years because they were late.
- Few understand the energy market.
- Trust, education, and facts would lead to more demand.

Interview 2 - Solar Startup / Federal Ministry for Economic Affairs and Climate Protection, Founder of PV Startup & working for the government as a guide for PV expansion

Describe the current PV industry from your perspective

- Regulation focus on support schemes and grid fee issues.
- Economic incentives for building owners.
- Societal incentive to be part of decarbonization and maintain a good reputation.
- Political pressure; local politicians demand compliance, especially from those with good political standing.
- PV obligation for commercial entities (already in law) or forthcoming.
- Individual desires for participation, energy sharing, and self-efficacy.
- Companies' existence is a result of regulations.
- Offers act as enabling factors.
- Barriers to action are significantly reduced.
- Germany was the first to introduce feed-in tariffs, setting an example for the world.

Where do you see the industry in the next 10 years?

- Continued growth expected across all sectors.
- Possible significant PV crash; companies could fail.
- Next 3 years will likely be a stabilization phase.
- Demand expected to decline.
- Installers will need to offer reasonable prices.
- If prices align with electricity costs, demand will rise.
- Significant boom expected for commercial buildings.

How have laws aided the expansion of the PV market?

- Feed-in tariffs less relevant for small systems.
- High self-consumption rates; electrification; heat pumps; and electric vehicles (also a driving force).
- Not heavily influenced by subsidies, more by grid fees.
- For multi-family homes (MFH), solar packages are significant.
- Expansion to commercial properties.
- Virtual totalizer as a significant relief.
- Growth Opportunities Act - removes tax barriers (business tax infection).
- Simplifying grid connections; partly in solar packages, partly by the federal network agency.
- Quarterly balancing will become mandatory; the federal network agency will intervene.
- New wind with a new boss.

What needs to happen for Germany to produce more PV domestically?

- Industrial promotion is crucial (similar to chip production).

- Many roadblocks; limited budgetary resources.
- Demand-side support is advocated by BSW.
- Bonuses should be included.

How to approach new customers? How can a larger market be tapped? What needs to be done, and what are the current obstacles?

- Address technical challenges (damaged roofs, etc.).
- Increase awareness of climate change.
- PV should be positively positioned in society.
- More information needed from a business perspective.
- During house renovations, PV installation should be a primary consideration.
- Broad offerings

Interview 3 - Multi-Tenant Solar, Regulation expert

Describe the current PV industry from your perspective

- Full-service packages like enpal 1komma5 are significant drivers.
- PV systems with storage, energy management systems, and electricity supply contracts.
- Attractive price guarantees that convince even the hesitant.
- Less hassle, cheaper electricity.

Distinctive Shift from Previous Models

- Dramatically reduced hardware costs; e.g., 10 kW with installation and storage is around 20k.
- A year and a half ago, it was at least double the price.
- Energy management systems are becoming increasingly relevant.

Transport Ministry's Funding Program

- €300 million in funding, with up to 10k support, provided one buys/leases an electric car.
- Massive demand; all funds were exhausted within a day.
- Criticized for being a waste of money due to the immediate depletion of funds.

Roadblocks

- Simplifying virtual totalizer systems can help significantly.
- Infrastructure upgrades are challenging; the current infrastructure, including meters, is subpar.
- Upgrades to roofs and electrical installations are costly.
- Grants are beneficial as they incentivize renovations.
- Standardization is needed for energy processes.

- Challenges with the exchange of network operators; standardization would help existing companies scale and offer better prices.
- Shared building supply is currently vague and poorly standardized.
- Simplification of processes, infrastructure funding, and balcony solar systems highlight the topic's relevance.
- Engaging with WEGs (residential property owner associations) is currently challenging but has significant potential.

Where do you see the industry in the next 10 years?

- Politically desired: Significant expansion is necessary.
- The single-family home market cannot grow as robustly.
- Open space and agricultural PV are growing sectors.
- The multi-family home (MFH) sector must expand; otherwise, there will be issues.
- Financing rounds indicate increasing investments in the MFH sector.
- Performance indicators show strong growth over recent years, though still niche.
- Unexpected events, such as tariffs on modules or hardware, pose challenges.

How have laws aided the expansion of the PV market?

- Virtual totalizers have been introduced.
- Smart metering systems are crucial, but the need for individual metering points can be reduced, saving costs and simplifying matters.
- Collective building energy supply: Owners don't need to procure residual current.

How must companies adapt to address the market

- Obligation for MSB sub-meters for tenants.
- Necessity for installing smart meters.
- Standardization is crucial.
- Companies need to become economically more attractive.
- Drawing ideas from the single-family home market, optimizing battery storage, and purchasing electricity when it's cheap can lead to offering cheaper tariffs or higher returns to B2B customers.
- Addressing these issues is more complex in the MFH sector than in the single-family home sector.
- If PV systems had a more significant impact on energy efficiency ratings, they would be the most cost-effective measure, leading to a significant boom.
- Mandatory renovations for poor energy efficiency ratings could further stimulate growth.

Interview 4 - PV Startup, Energy product expert

Describe the current PV industry from your perspective

- Industry is overheated.
- Module prices have plummeted.

- Many companies purchased expensive modules and stocked them, incurring additional storage costs.
- Predictions of numerous companies going bankrupt due to inability to handle price pressures.
- Demand is expected to decline as many potential customers already have systems.
- Residential sector demand will decline, while the multi-family housing (MFH) sector will rise.
- Strong consolidation expected; not all major players will survive, but they have a better chance of acquiring customers.
- Commercial sector expected to grow due to declining module prices.

Where do you see the industry in the next 10 years?

- Not optimistic about expansion goals.
- Emphasized the importance of storage; without it, systems may not be viable in 20 years.
- Concerns about managing excess summer production.
- Business case challenges primarily due to high storage costs.
- Regulation plays a significant role; exceptions for battery storage network fees have been extended.

What is the influence of Companies on Development?

- Companies like Enpal streamline processes, focus on digitalization, reduce sales costs, and optimize processes.
- Local solar installers face extinction due to such companies.
- Word-of-mouth is currently the most significant driver for customers.
- Sustainable business models are questioned.
- PV knowledge is widespread; marketing efforts might be secondary.
- Emphasis on showcasing the business case, especially concerning electric storage and e-vehicles.
- PV rentals may offer a consistent revenue stream but may not make financial sense for customers.

Who are currently PV Customers?

- Standard customers are single-family homeowners, often male, tech-savvy, and interested in experimentation.
- Renting PV is challenging as costs significantly outweigh benefits.
- Previously, customers preferred loans to finance installations.

How to approach new customers?

- The single-family home market is saturated; innovations are needed for businesses and multi-family housing (MFH).
- Challenges in reaching non-property owners.
- Good MFH products can significantly boost PV acceptance.
- Price reduction through PV is a primary advantage.
- Reforms in network fees may complicate matters; a balance is needed to maintain system integrity.

To what extent and which laws have aided the expansion of the PV market?

- Faster and more affordable network connections are required.
- Conditions and requirements for connections need clarity.
- Network fees must be eliminated for viable PV operations.
- Concerns about the value of PV-generated electricity compared to other sources.
- Feed-in tariffs remain crucial; concerns about the financial burden on taxpayers and potential reduced acceptance if wealthy individuals are compensated

Interview 5 - Consumer Protection, 15+ Years experience

What are reasons clients seek consultation?

- Three variants: full feed-in, use + feed-in, use + storage.
- Questions about costs: "How much for the installation? What about with storage?"
- Queries about electricity usage for cars and heat pumps.
- Current focus on price sensitivity.
- Desire to compare offers without the expertise to evaluate them.
- Uncertainty about products: module types, inverters, etc.
- CO_2 savings not a decisive factor; viewed as a bonus.
- Main motivation: future-proofing and saving money.
- Concern about inadequate supply, especially for those using electricity for heating.
- Most consultations are with individuals aged 50-65, with a surprising number of those 80+.
- Many consider legacy and inheritance.
- Clients seek independent advice; skepticism towards companies pushing sales.
- Word-of-mouth from neighbors is a common reason for inquiries.
- Many have electric vehicles (E-Autos).
- A PV system increases a home's value.

How has the industry developed?

- Noted a significant increase in PV interest in recent years.
- During the Ukraine crisis and initial energy crisis, the interest surged.
- Current main topics: PV and heating.
- Those financially able wish to become independent from the electricity market.
- Security during crises was unforeseen; foundational supplies are no longer guaranteed.
- Those with surplus funds aim for greater autonomy; a more significant argument now than 3-4 years ago.
- A surge in inquiries due to the Ukraine crisis.
- Winter sees a rise in demand, with legal uncertainties leading to consultations.

What are the purchase vs. lease trends?

- No significant trend towards renting; preference for ownership remains.
- Rent-to-own options are notably more expensive.

- Enpal experienced high demand during material shortages, offering all-in-one solutions.
- Public interest leans towards rental models, possibly due to well-explained offers from companies like Enpal.

What are roadblocks and uncertainties?

- Complexities in insurance, procurement, and technology.
- Budgetary constraints and outdated heating systems hinder adoption.
- PV is still viewed as a luxury.

What impact do subsidies have?

- Subsidies targeting electric cars missed their mark.
- Incentives often just get factored into the offer price.
- Subsidies have driven prices up.
- Current incentives are sufficient; the high electricity price further justifies investments.
- Subsidies are still in demand, especially for plug-in systems.
- They play a role but aren't the sole deciding factor.
- Subsidies should target those who currently can't afford such systems.

What do you wish for to expand PV adoption

- More transparent communication and cost transparency.
- Warnings about overestimating system capabilities.
- Concerns about the authenticity of energy sourced from one's roof.
- Calls for the government to support consumer centers and promote bidirectional charging.
- The industry is becoming complex, underscoring the need for straightforward consultations.
- Emphasis on user behavior, direct consumption of generated power, and challenges for users.

Interview 6 - Energy Consultancy, 10+ Years experience

Description of the Current PV Industry from Your Perspective

- The industry is primarily driven by major players.
- Previously, numerous small companies existed; now, there are many large ones backed by investment funds.
- Manufacturing remains dominated by Asia, particularly China.
- Some German manufacturers have a strong reputation but often come at a higher cost.
- The market has a plethora of installers, with varying levels of expertise.
- Many enter the installation business without adequate prior knowledge.
- Projects frequently face setbacks due to poor execution by inexperienced installers.
- Solution providers are expanding their offerings, including tenant electricity, billing software, and visual interfaces.

- Overall costs are decreasing, but rising interest rates make contracting options more appealing.

Where Do You See the Industry in the Next 10 Years?

- PV will become an increasingly significant topic.
- The housing sector will see substantial growth in PV adoption.
- Regulations and guidelines will steer the direction.
- Some cities have already mandated PV installations; more will likely follow.
- Single-family homes might see stagnation.
- Solar packages introduce community building supply concepts.
- While many find it overwhelming, larger companies are starting to manage it in-house.
- Major housing developers are forming energy companies to produce tenant electricity, but they still often collaborate with specialized firms.

How Have Laws Supported the PV Market Expansion?

- The Tenant Electricity Act provided a framework where companies didn't need to invest upfront.
- The impact of communal building supply regulations is still evolving.
- Feed-in tariffs remain crucial, with some housing developers setting up full feed-in systems early on, leaving tenants with no direct benefits.
- If housing developers could save on high CO2 taxes, there would be even more interest in PV.

What Are Your Clients Asking For?

- Many companies have a sustainability roadmap but lack the resources to fully implement it.
- There's a significant demand for expertise in the industry—not just in PV but also in areas like heat pumps and renovations.
- Concerns often arise regarding upcoming PV mandates.
- During crises, there's a heightened focus on ensuring energy security, with housing developers aiming for more autonomous buildings.
- Some clients are resistant to balcony power plants, seeking alternative solutions that still benefit their tenants.
- Increasingly, tenants inquire about PV installations after observing neighboring buildings adopting them.
- Buildings are usually worth more with a PVS

Interview 7 - PV Startup, Contact to many investors

Who are the main players in the PV Industry?

- B2C market and B2B market differ.
- B2C players with substantial investor funds: Zolar, Enpal, 1.5 – various approaches.

- Tenant model, 1.5 offers complete handling + digitalization and flexible electricity tariff.
- B2B sector lagging, especially PV in city centers.
- Smaller players with less financing.
- Balcony power plants simplified in Solar Package 1.
- Highly relevant – PV for everyone.

Where Do You See the Industry in the Next 10 Years?

- Short-term view: Strong development.
- Most single-family homeowners already approached.
- Marketing strategies seem to have reached most.
- Focus in single-family home (EFH) market shifting to heat pumps and energy management systems.
- Total product is in focus; systems control consumption.
- Expected 30-50% annual growth in multi-family housing (MFH) sector.
- Overall market for green power.
- Our product needs to diversify.

What are investor‘s focusing on when deciding to invest

- IT landscape crucial; legal topics and GDPR compliance.
- Product not for everyone; handling is challenging.
- Digital presentation, smart metering, and grid connection not straightforward.
- Unique selling proposition makes one interesting.
- B2C market not easily accessible.
- Scalability due to expertise.
- Grid connection a significant topic.

How has the government helped the diffusion of tenant electricity?

- Major topic in investor discussions.
- Virtual totalizer law relevant.
- Collective building supply can be “relatively” passed to customers.
- Not financially attractive.
- Government seeking new ways to promote PV for tenants.
- Smart meter rollout law.
- Balcony power plants also promising.
- Supply chain may face challenges.
- More internal steps expected.
- Offer expansion needed.
- Tenant electricity grants already available.

How can new customers be targeted?

- Customers want energy values clearly presented.
- Only pay for what they consume.
- Customers need to understand added value.
- B2C market needs to improve tenant electricity consumption representation.

- Market data: 56.4% live in MFH; 3.3 million multi-tenant buildings; 600,000 suitable for tenant electricity; significant potential.
- Reduced CAPEX allows more buildings to be included.
- Midday tariffs part of energy management system.
- From a marketing perspective, tenants must see PV benefits.
- Otherwise, it's just electricity from the socket.
- Many tenants don't switch electricity tariffs often; offer a complete solution and tenant event.

What are B2B considerations?

- Focus on large clients.
- Most customers want to start with pilot projects and then scale.
- New customer acquisition is primary.
- References from the housing sector are vital.
- Heat pump tariff.
- CO2 reduction.
- More energy used, more CO2 savings.
- Building becomes more attractive.
- CO2 compliance crucial.
- Buildings not in compliance can be worth up to 30% less.
- Provide all energy consumption data (source, CO2 emissions) to companies.
- CO2 savings can be credited to the portfolio.

Interview 8 – Strategy Manager at Housing Cooperative with >3000 flats in Germany

What has your cooperative done for your sustainability path so far?

- **Past (Last 10 years):** Emphasis on building physics and system technology (windows, floors, insulation). Comprehensive measures from 2008 onwards.
- **2019 with the Climate Protection Act:** Aim to achieve CO2 targets. Strategic orientation towards climate strategy.
    - **5 Areas of Impact:**
        1. Building physics
        2. System technology (heating systems, heat pumps, district heating priority)
        3. Renewable energies
        4. Consumer awareness (tenant communication, tenant participation in climate protection, strong e-mobility promotion, bike sharing)
        5. Energy source usage (fossil fuels, future handling, hydrogen heating)

Why tenant electricity?

- **Since 2019:**
    - Initially considered building assets but realized it would be too much work.
    - Too many duties as energy supplier and system operator.
    - Focus on core processes, so no time for this.

- 2020: sudden price escalation made it economically unviable.
- Monitoring supply chain as prices drop.
- Learned from experts due to these challenges.

What's important for your tenants?

- Subsidized tenant electricity systems: 10% below basic supply rate.
- Monetary benefit.
- Social focus as a cooperative – secure, good, and future-proof electricity supply.
- Transparency of consumption (tenant portal).
- Ability for tenants to consume electricity from the roof.
- Not just giving away the roof without benefits.
- Participation in the energy transition.
- No electricity trading.

Did tenants push for PV?

- Occasional push: waves.
- Media attention leads to increased inquiries.
- Negative sentiment towards balcony power plants.
- Preference for comprehensive systems over individual solutions.
- Neighbors inquire about tenant electricity, growing interest.
- Many are unsure, haven't engaged with the topic.
- Concerns about supply.
- Demand surged due to the Ukraine conflict, including for balcony power plants.
- Basic suppliers increased rates, many customers still on cheaper tariffs.

What are roadblocks and incentives for PV expansion?

- No profit; often a loss – renovations accompanying PV solutions.
- Buildings not previously considered are renovated.
- PV is considered during maintenance measures.
- Emphasis on synergy, usually no risks taken.
- Grants often benefit providers, enabling lower prices for tenants.
- Electricity sales regulations should be streamlined for self-management.
- Renovation grants are welcome.
- Climate fund in Hanover offers similar incentives.
- Grant conditions often exclude tenant electricity.
- Positive view on BAFA grants – future potential to be seen

Interview 9 - PV Startup, 7+ Years experience

Please describe the current PV industry from your perspective.

- The industry is flooded with numerous companies.
- In the single-family home market, installation and module prices are at a new low.

- Many modules are currently produced in China, and there's no longer a shortage of resources.
- Those who seriously considered an installation tend to have one.
- Leasing options for PV installations don't make sense.
- While prices are inflated, the initial investment isn't particularly high anymore.
- Larger solution providers often offer a complete package of installation, setup, and connection.
- They also frequently provide maintenance packages and useful apps.
- When people think of PV, they think of companies like Enpal or 1Komma5.
- In the tenant electricity market, companies should strive for similar recognition.
- Many different providers currently share a relatively small market.
- Rising grid fees drive housing cooperatives to install PVS through tenant electricity to lower cost for their tenants.
- Adoption amongst residents is ~40%, which is enough to make projects profitable, but is anticipated to grow over the years.
- Registering smart meters takes a long time and prolongs the customer acquisition process.

Where do you see the industry in the next 10 years?

- The industry will be dominated by a few major players.
- Public interest will increase, especially with falling prices.
- Due to new regulations, more buildings will be required to install PV, leading to a significant increase in demand.
- Massive marketing and branding efforts are already prevalent and will continue.
- The multi-family housing sector has significant growth ahead.
- It's crucial to establish a market position now to capture this sector.
- The goal should be for Enpal to become synonymous with tenant electricity.

How have laws aided in the expansion of the PV market?

- Foremost among these is the EEG.
- Feed-in tariffs were previously the main driver for installing PV systems.
- The Tenant Electricity Act is vital for tenant electricity.
- The Solar Package introduces several simplifications and improvements.
- The decision to eliminate EEG surcharges and grid fees is crucial as grid fees continue to rise.
- As PV penetration increases, grid fees will rise even more for non-PV households.
- CO_2-based laws will become increasingly important.
- Companies want to save money without making significant upfront investments.
- Contracting solutions fit well as they allow for CO_2 savings without the financial commitment.

How does competition within the tenant electricity market impact businesses?

- Competition within the tenant electricity market is limited and complex.
- Entry barriers are high, preventing easy market access.
- Companies from the single-family home sector haven't entered yet as they can earn more in their current domains.
- Long-term, competition will increase once the single-family home market is saturated.

- Software solutions, however, are more prevalent.
- They require less operational effort.
- The real estate sector is still slow to adapt, often relying on outdated values and fears.
- Many are content with cheaper green energy from other providers.
- There's considerable skepticism among businesses.

How do you approach acquiring new customers?

- Marketing is key.
- More attention can be drawn to the topic within the single-family home market.
- Referral programs among customers can be particularly effective.
- The same holds true for the tenant electricity market.
- Referral programs within a building's tenants demonstrate high efficiency.
- The multi-family housing sector will inevitably adopt PV over time.
- Hence, it's essential to gather good reference customers now.
- For end customers, digital solutions are paramount.
- We carried out a survey of TE customers and the main findings were that they want to track consumption, see the production, CO2 savings, and understand their bills. However, first and foremost, the price per kW/h was the most important motivator.

How do external factors influence PV penetration?

- Reference customers are incredibly influential.
- Projects with large companies significantly increase the likelihood of securing further projects.
- The industry is well-connected.
- Providing accurate CO2 savings data is crucial; the topic must resonate with people.
- Many don't grasp the technical aspects, so having a technician present is vital.
- There are numerous doubts and questions.
- Energy, in general, isn't a particularly emotional topic, especially electricity.

Interview 10 - PV Installation, Leading role in solar installation firm for 5+ years

Please describe the current PV industry from your perspective.

- Many small companies are currently going bankrupt.
- Large companies advertise that they have larger reserves than smaller ones.
- PV is a long-term commitment, so it's crucial for companies to remain in business.
- Especially due to maintenance and software contracts.
- The market is flooded with new installers with poor knowledge.
- However, there is still a shortage of personnel.
- If there were more installers, more orders could be processed as demand is high enough.
- Prices for materials are continually dropping, but labor costs are rising.
- Customers are reluctant to pay high prices and sometimes opt for rental solutions instead.

Where do you see the industry in the next 10 years?

- The single-family home sector will continue to grow steadily.
- We receive more inquiries every year but can't always handle them all.
- In the past, there was also a shortage of materials, but that seems to be changing for the future.
- The multi-family housing sector will see even more growth.
- Currently, many inquiries come from individual homeowners rather than large companies.
- However, installations are often planned during new construction.
- PV readiness for buildings is becoming increasingly important and plays a significant role in roof and basement planning.

How does competition within the installer market impact businesses?

- Many companies are trying to outdo each other.
- In the long run, it's possible that large companies will buy out smaller ones to acquire industry expertise.
- Prices continue to decline, sometimes giving the impression of price dumping.
- Despite this, many installers recommend products that are not tailored to the customer.

How do you approach acquiring new customers?

- Customers tend to approach us.
- Nonetheless, marketing is essential since there are so many installers, and one needs to stand out from the crowd.
- The local factor has a positive impact; many customers want a local contact person familiar with the area.
- Price reductions are primarily what interest customers.
- The origin of the modules is not very important to customers.

How do external factors influence PV penetration?

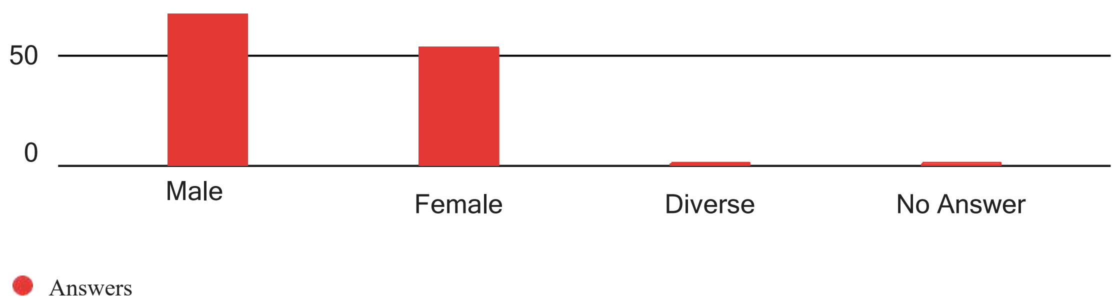
- Word-of-mouth is crucial for us.
- Most new customers come in through recommendations.
- There's a feeling that customers don't want to appear worse off than their acquaintances and therefore also want a PV system.
- Social pressure is significant.
- Advertising from large companies also benefits us.
- Awareness of PV is increasing, and people are starting to educate themselves.
- Government campaigns promoting PV also provide a strong boost to inquiries.
- Many customers could afford the systems even without subsidies.

Appendix 3

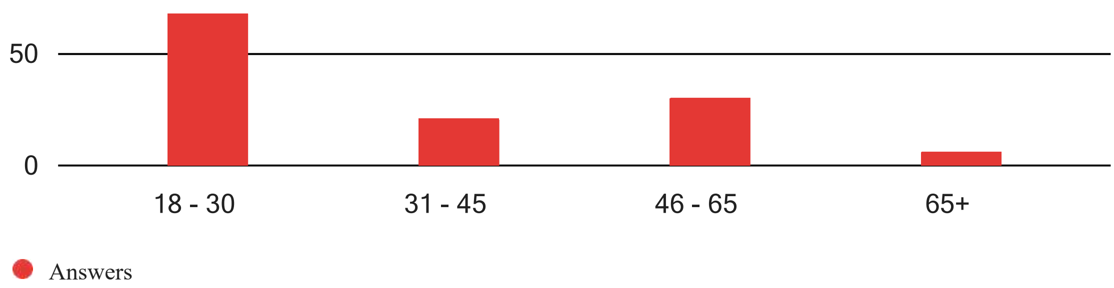
The Survey

https://ucpresearch.qualtrics.com/jfe/form/SV_3KIIwYh44rjHyOW - Link to the original German survey

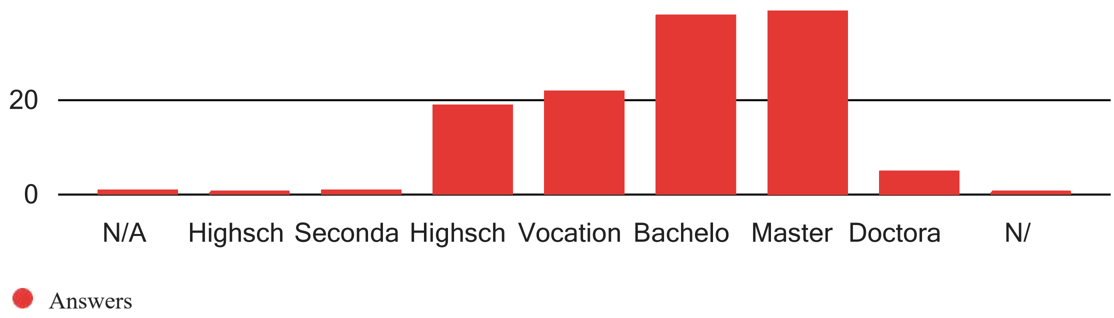
Q1 Please indicate your gender



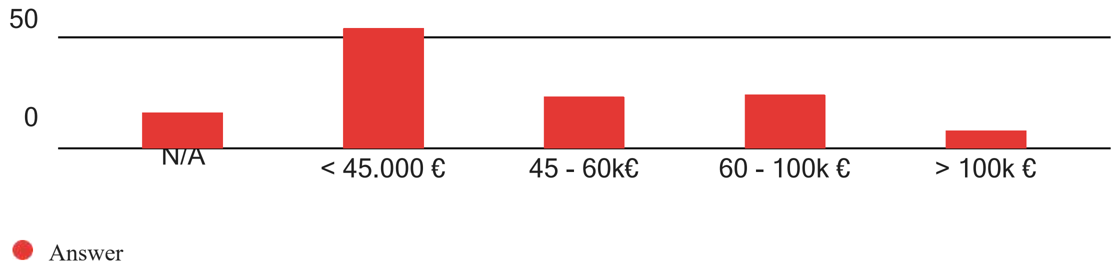
Q2 How old are you?



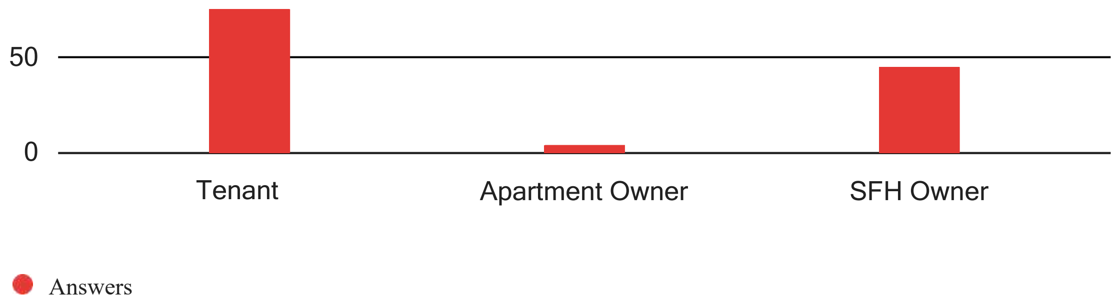
Q3 What is your highest level of education



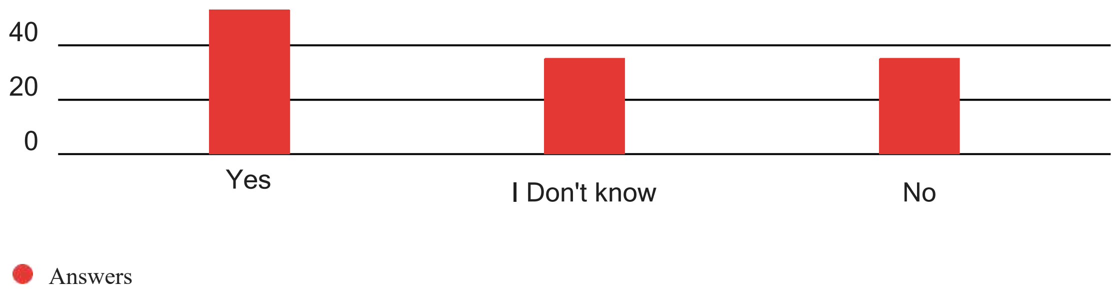
Q4 What is your annual gross income?



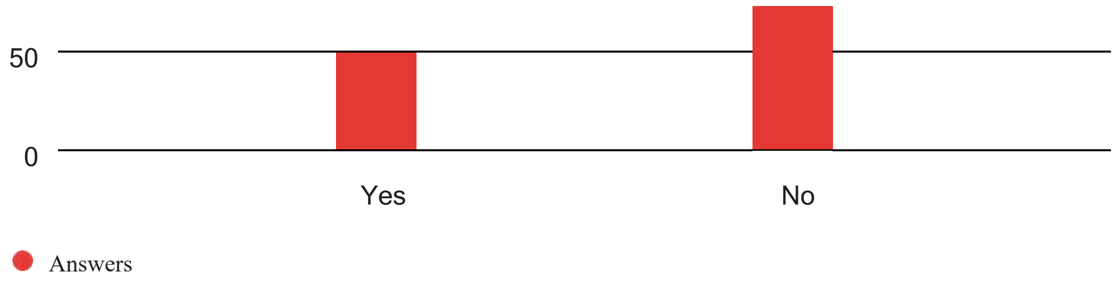
Q5 What is your living situation?



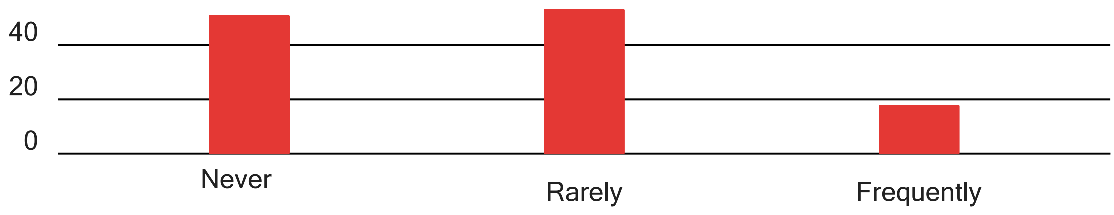
Q6 Do you have a green electricity tariff?



Q7 I am aware of my current electricity price per kilowatt-hour.



Q8 I switch my electricity provider.

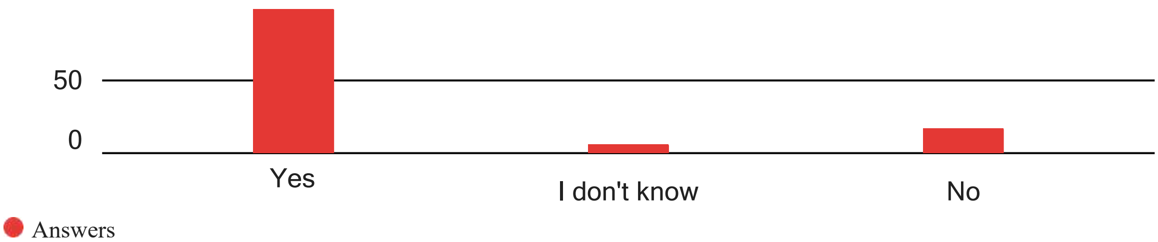


Answers

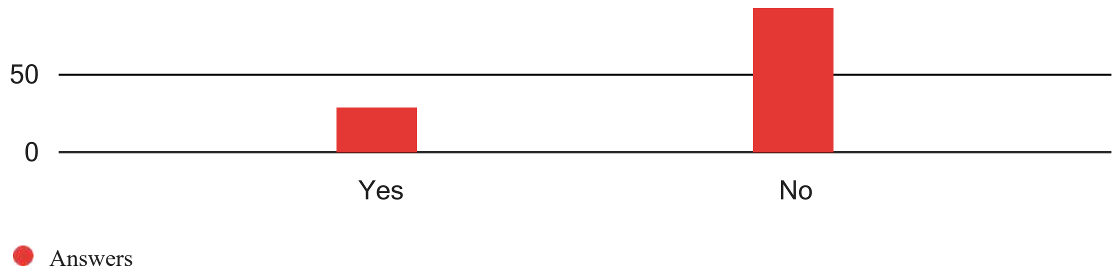
Q9 Please indicate the extent to which these statements apply to you.

Feld	Min	Max	Mean	SD	Answer
I pay attention to my electricity usage	1.00	5.00	3.51	1.11	121
I enjoy using new technologies	1.00	5.00	3.60	1.10	121
I inform myself about current electricity tariffs	1.00	5.00	2.28	1.20	122
Climate change is worrying me	1.00	5.00	4.09	1.06	122

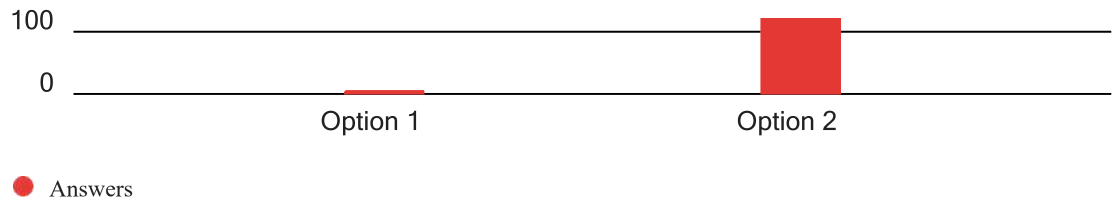
Q10 Do any of your acquaintances have a solar panel on their house roof?



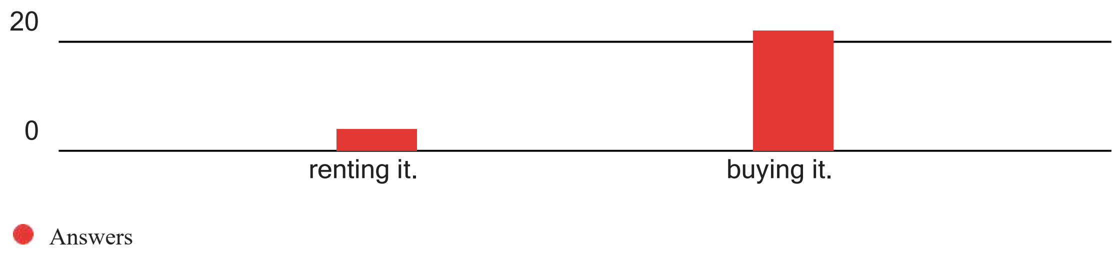
Q11 Do you have a solar panel on the roof of your residential building?



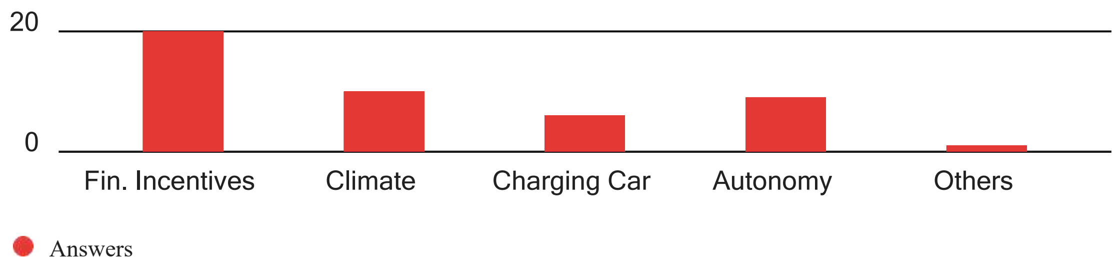
Q11 - Please select Option 2. This helps evaluating the answers.



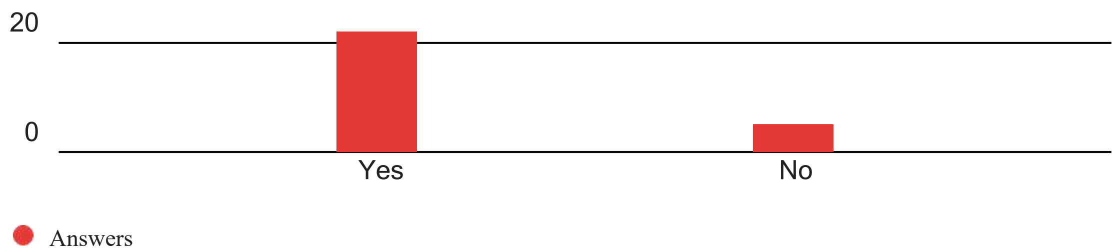
Q12 I acquired my solar panel by



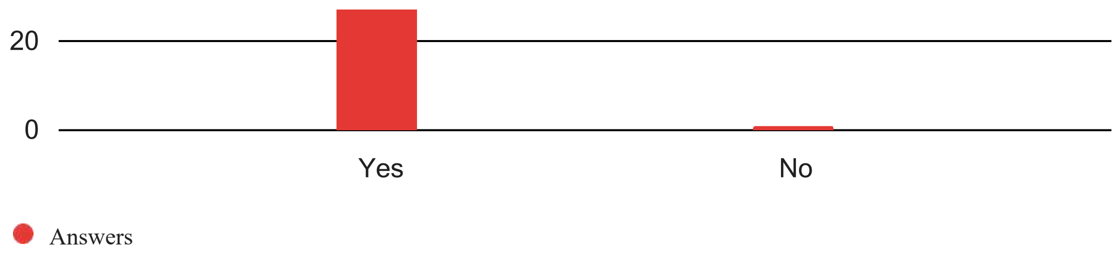
Q13 What was your primary motivation for installing a solar panel on your roof?



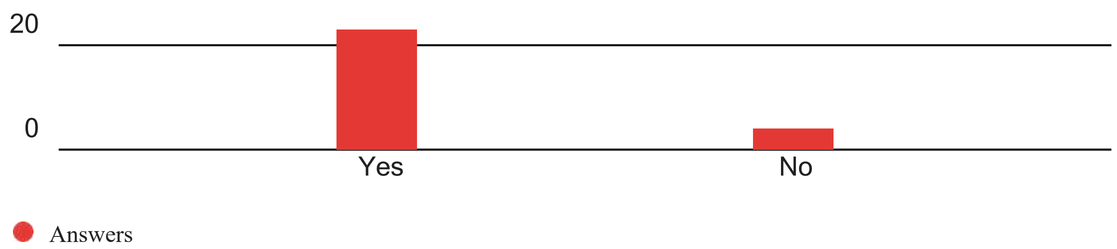
Q14 Do you have a battery storage?



Q15 Are you satisfied with the decision to install a solar panel?



Q16 Are your expectations regarding electricity cost savings being met?



Q17 Why haven't you currently installed a solar panel on your roof?

	Min	Max	Mean	SD	Answers
Too high initial cost	2.00	5.00	3.55	0.99	22
No interest in PV	1.00	5.00	2.14	1.22	22
No trust in PV-Technology	1.00	4.00	2.00	1.17	22
Unfit Roof	1.00	5.00	2.82	1.56	22
Too low Feed-in-Tariff	1.00	5.00	2.95	1.02	22
Too much effort	1.00	4.00	2.82	1.19	22
Aesthetic concerns	1.00	4.00	1.73	1.14	22

Q18 Display this question: If your living situation is 'Tenant' is selected: Scenario: Imagine you own a residential building. Please indicate the extent to which these statements apply to you.

Please indicate the extent to which these statements apply to you

	Min	Max	Mean	SD	Answers
Too high intitial cost	1.00	5.00	3.68	1.13	72
No interest in PV	1.00	5.00	1.79	1.07	72
No trust in PV-Technology	1.00	5.00	1.93	1.10	71
Too low financial incentives	1.00	5.00	3.03	1.15	71
Too much effort	1.00	5.00	2.69	1.28	72
Aesthetic concerns	1.00	5.00	1.68	1.15	72

Q19 Display this question: If you don't have a solar panel on the roof of your residential building and 'No' is selected: Please rate to what extent the factors below would motivate you to install a solar panel

	Min	Max	Mean	SD	Answers
Lower initial cost	2.00	5.00	4.18	0.75	95
Accurate information about environmental impact	1.00	5.00	3.39	1.23	95
Social recognition	1.00	5.00	2.64	1.31	95
More peer referrals	1.00	5.00	3.33	1.33	95
More knowledge about funding programs	2.00	5.00	3.80	0.96	95

Appendix 4

Quantitative calculations that aim to validate interview data.

Correlation Matrix of behaviour:

	I pay attention to my electricity consumption	I enjoy using new technologies	I inform myself about current electricity prices	Climate change is worrying me
I pay attention to my electricity consumption	1	0.32	0.44	0.38
I enjoy using new technologies	0.32	1	0.11	0.44
I inform myself about current electricity prices	0.44	0.11	1	0.14
Climate change is worrying me	0.38	0.44	0.14	1