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Product-service-system business models in the photovoltaic industry – A comprehensive analysis

Roger Nyffenegger[a,b,*], Ässia Boukhatmi[b,c], Nancy Bocken[a], Stefan Grösser[b]

[a] Maastricht Sustainability Institute, School of Business and Economics, Maastricht University, Tapijn 11 Building D, P.O. Box 616, 6200 MD, Maastricht, the Netherlands
[b] Management Science, Innovation, Sustainability and Entrepreneurship (MISE), School of Engineering and Computer Science, Bern University of Applied Science, Quellgasse 21, CH-2502, Biel/Bienne, Switzerland
[c] Faculty III Process Sciences, Chair for Circular Economy, TU Berlin, Building Z, Straße des 17. Juni 135, 10623, Berlin, Germany

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ABSTRACT

The solar industry is experiencing rapid growth, driving fundamental changes in business models and value creation strategies. While research has examined "solar photovoltaics (PV) business models" as catalysts for transformation, it has primarily approached this topic from a technology diffusion and energy policy perspective. As a result, the focus has been on deployment models, providing insights into how, by whom, and where PV systems are installed, rather than exploring the underlying value logic. Consequently, an understanding of how solar companies are doing business remains underdeveloped. This study addresses this gap by examining a subcategory of solar PV business models in which ownership remains with a third-party or community entity rather than the property owner. Commonly referred to as product-service-systems (PSS), these models integrate products and services to fulfil customer needs. They are relevant as they align financial incentives with system performance, encouraging the use of high-quality PV products and maximizing system lifespan. Employing an exploratory sequential research approach, this study combines qualitative data from focus groups with quantitative survey analysis. The findings highlight the advantages and disadvantages of PV PSS business models compared to traditional purchasing models with subsequent self-ownership. They further reveal that these models are driven primarily by financial considerations, with limited emphasis on circular economy principles. Building on these insights, the study develops six key decision criteria – cost structure, revenue opportunity, investment requirements, flexibility in property development, competency distribution, and life cycle management – essential for evaluating solar PV business models. These insights aim to guide procurement departments in selecting PV installation models and support policymakers in creating enabling regulatory frameworks. Theoretically, this study contributes by examining the underlying value logic of solar PV business models, complementing demand-side research in this field, and bridging insights between solar PV business models and PSS concepts.

1. Introduction

The world is in the middle of a transition from predominantly fossil fuel-based energy systems to a low-carbon energy system dominated by renewables (IRENA, 2024). As a key renewable energy source, the global solar photovoltaic (PV) industry is undergoing profound transformation and has experienced tremendous growth (SolarPower Europe, 2023). The Swiss solar PV industry, for example, has experienced growth over the last few years with the installed performance increasing from 271 MW in 2018 to 1′698 in 2023 (Swiss Federal Office of Energy, 2024). Upcoming regulations to meet the Paris Climate Agreements will provide incentives for the expansion of solar PV systems and influence solar PV business model design, as they are deeply embedded in political and regulatory frameworks (Burger and Luke, 2017; Huijben et al., 2016). Again, using Switzerland as an example, this means a politically driven increase in annual solar electricity production from the current 2.8 TWh

* Corresponding author. Management Science, Innovation, Sustainability and Entrepreneurship (MISE), School of Engineering and Computer Science, Bern University of Applied Science, Quellgasse 21, CH-2502, Biel/Bienne, Switzerland.

E-mail addresses: roger.nyffenegger@bfh.ch (R. Nyffenegger), aessia.boukhatmi@bfh.ch (Ä. Boukhatmi), nancy.bocken@maastrichtuniversity.nl (N. Bocken), stefan.groesser@bfh.ch (S. Grösser).

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to 34 in 2050 (Swiss Federal Office of Energy, 2022). Such a fundamental upheaval in an industry is accompanied by major changes in the business models applied, as new ways of value creation, delivery, and caption emerge (Giehl et al., 2020).

As a result, research has explored the role of so called “solar PV business models” as catalysts for driving these transformations (Ford et al., 2017), investigating how solar companies have experimented with and innovated their business models to adapt to this evolving market (Frantzis et al., 2008). Scholars have analysed various types of solar PV business models, including turnkey, third-party ownership, community solar, host-owned, solar lease, or rental business models (Altunay et al., 2021; Horváth and Szabó, 2018). However, the term ‘business model’ has not been fully employed in its appropriate conceptual framework, as existing research has primarily positioned it within the domains of technology diffusion or energy policy, rather than within a value logic perspective (Bankel and Mignon, 2022). As a result, little attention has been given to the value creation, delivery, and capture mechanisms of solar PV business models, as well as their advantages and disadvantages in a circular economy context.

This study seeks to address this gap by focusing on a specific sub category of solar PV business models, where ownership resides not with property owner but is with third-party or community entities (Bankel and Mignon, 2022; Strupeit and Palm, 2016; Van Opstal and Smeets, 2022). These business models exhibit characteristics of Product-Service Systems (PSS) which are combinations of products and services to fulfil customer needs (Tukker, 2004, 2015). Such PV PSS business models are particularly valuable from a circular economy perspective, as they align financial incentives with system performance. Because PSS providers are financially linked to the performance of the PV system, their revenues increase with higher energy output, creating strong incentives to use good-quality PV systems and maximize their lifetime through proper maintenance, digital tracking, and monitoring (Boukhatmi et al., 2023; Lundqvist, 2020; Schmidt-Costa et al., 2019). In this way, economic and environmental goals are effectively aligned.

Therefore, this study offers a comprehensive analysis of PSS-related solar PV business models by examining both the demand and supply sides. This approach contrasts with previous research, which has predominantly concentrated on the demand side (Van Opstal and Smeets, 2022), thereby providing a more holistic understanding of the dynamics that influence the adoption and implementation of these business models. Given the immaturity of the concepts under investigation, an exploratory sequential research approach was employed, involving an initial phase of qualitative data examination through focus groups followed by quantitative analysis via survey.

The findings of this study provide a comprehensive analysis of the advantages and disadvantages of solar PV PSS business models in comparison with traditional purchasing models characterized by self-ownership (Table 3). Furthermore, the study examines how organizations offering solar PV PSS business models create, deliver, and capture value, while also identifying the key components of their value proposition (Figs. 3–7). Building on these insights, this study draws theoretical, industrial, and policy-related conclusions, including the formulation of six key decision criteria essential for evaluating solar PV business models (Fig. 8). These criteria are intended, first, to support procurement departments in the decision-making process when selecting a PV installation and, second, to enhance policymakers’ understanding of the underlying value logic of PV PSS business models, thereby fostering the development of more favourable regulatory frameworks.

2. Theoretical background

The following theoretical analysis begins by situating *PSS business models* within the broader framework of circular economy research. Subsequently, *solar business models* are systematically conceptualized, presenting relevant research developments in a chronological manner. Finally, the third section establishes the *connection between PSS business models and solar business models*, thereby identifying and delineating the research gap addressed in this study.

2.1. Product-service-system business models

Business models describe the rationale for how an organization creates, delivers, and captures value in a value logic framework (Osterwalder and Pigneur, 2010; Richardson, 2008). Three major components reflect the logic of strategic thinking about value: (1) the *value proposition* – what an organization will offer and why customers will be paying for it; (2) the *value creation and delivery* system – with which resources and capabilities the organization creates and delivers that value to its customers; and (3) *value capture* – how an organization generates revenue and profit (Osterwalder and Pigneur, 2010; Richardson, 2008).

Circular business models are a new type of business model that focus on delivering superior customer value propositions while narrowing, slowing, and closing resource loops and regenerating resources (Bocken, 2024; Konietzko et al., 2020). Such circular business models holistically examine the way organizations operate in relation to their ecosystem, deliberately including the environment and society as key stakeholders (Stubbs and Cocklin, 2008). While circularity is an integral part of circular business model design, the value logic framework still follows the rationale of value proposition, creation and delivery, and capture (Geissdoerfer et al., 2020). Organizations therefore need to consider circularity, namely, how to slow, narrow, and close resource loops, when designing the value logic framework of their business models (Bocken, 2024).

Product-service-system (PSS) business models, in turn, can be considered a sub-category or archetype of circular business models because they are commonly understood as a means of realizing circular economy (Henriques et al., 2023; Tukker, 2015). A PSS is defined as an integrated combination of tangible products and intangible services that are jointly capable of fulfilling customer needs (Goedkoop et al., 1999; Tukker and Tischner, 2006). The ratio between product and service components in a PSS can vary significantly but is typically classified into three categories (Baines et al., 2007; Tukker, 2004). *Product-oriented PSS* focus on selling products with added service offerings, such as maintenance and repair. Ownership is transferred to the customer, and the primary revenue comes from product sales. Services are typically offered as standalone, unconnected transactions throughout the product lifecycle, with no shift in incentives for the provider to reduce product sales. *Use-oriented PSS* provide access to a product through renting, leasing, or sharing, whereas ownership remains with the provider. Customers pay for access, while the provider is responsible for maintenance and repair and is incentivized to design the product for durability and reuse. Given the longer payback periods, substantial financial resources are essential to cover the initial capital investments. *Result-oriented PSS* sell a specific outcome rather than a product. The provider delivers an integrated solution of products and services, taking responsibility for all lifecycle costs. Payments are based on achieving the agreed-upon result, incentivizing the provider to minimize costs and extend product lifespan (Adrodegari and Saccani, 2017; Barquet et al., 2013; Bressanelli et al., 2018; Reim et al., 2015).

PSS are often heralded as circular business models with the potential to enhance circularity by moving beyond the traditional product-as-commodity model and offering comprehensive solutions that meet customer needs while delivering added value (Tukker, 2015). Yet, the extent of their contribution to circularity remains contested (Henriques et al., 2023; Moro et al., 2020). The degree to which PSS models enhance the circular economy depends largely on the specific type of PSS – whether product-, use-, or result-oriented (Tukker, 2015). Research indicates that use- and result-oriented PSS are particularly well suited for circular business models because manufacturers retain ownership of the product, thereby maintaining control over its lifecycle (Henriques et al., 2023; Tukker, 2015). This ownership structure incentivizes manufacturers to minimize environmental impacts throughout the entire product lifetime (Bocken et al., 2014; Yang et al., 2018).

2.2. Solar photovoltaic business models

Coinciding with significant advancements in the solar industry, the term "solar photovoltaic business model" began to gain prominence in the late 2000s, as companies increasingly experimented with and innovated business models within the sector (Frantzis et al., 2008; Lüdeke-Freund, 2013). Since then, scholars have examined numerous solar PV business model types under various labels, such as turnkey, host-owned, third-party ownership, community solar, solar lease, power purchase agreement (PPA), and rental business models (Altunay et al., 2021; Horváth and Szabó, 2018). Solar PV business models are inherently influenced by the regulatory frameworks within which they operate, highlighting the critical role of regulatory contexts in shaping their development and adoption (Huijben et al., 2016; Strupeit and Palm, 2016). Consequently, the evolution of solar PV business models varies across different jurisdictions, reflecting distinct geographic, economic, cultural, and social conditions, as exemplified by analyses conducted in diverse contexts, including Brazil (Faria et al., 2024), the United States (Overholm, 2015), Austria (Gsodam et al., 2015), the Netherlands (Huijben and Verbong, 2013), Malawi (Kamende and Munthali, 2017), and China (Zhang, 2016).

Following Bankel and Mignon (2022), solar PV business models can be categorized into three types: host-owned, third-party-owned, and community-owned business models (Fig. 1). In the *host-owned model,* often referred to as turnkey, the building owner, who installs the PV system, also owns the system and serves as the primary consumer of the generated energy (Horváth and Szabó, 2018). In contrast, the *third-party-owned model* involves a third party – which is neither the property owner nor the electricity consumer – who owns and operates the solar PV system installed on a customer's roof or land (Bankel and Mignon, 2022; Franco and Groesser, 2021). Finally, the *community-owned solar business model* allows multiple users, typically without access to suitable roofs for a PV system or ownership rights, to acquire a share of the output of a solar PV system installed elsewhere by a utility or other organization (Chan et al., 2017; Nolden et al., 2020). The third-party ownership model can be further differentiated into two types. First, power-purchase agreements that are long-term agreements to purchase renewable electricity from a specific asset (on- or off-site) at a predetermined price. Second, solar leases function as rental agreements, where a PV system is installed on the customer's roof with zero or little upfront costs, in exchange for the electricity generated by the system (Douglas et al., 2020; Lundqvist, 2020). In Switzerland, third-party ownership models are often referred to as "contracting", which is similar to solar lease, as property owners provide their roofs to contractors for the installation of PV systems in exchange for reduced and contractually fixed electricity prices (Ribi and Perch-Nielsen, 2021; Strickelberger et al., 2022).

When dividing the solar industry into upstream, midstream, and downstream segments (Nyffenegger et al., 2024), solar PV business models typically occur at the transition between the up- and midstream phases when PV modules are integrated into a complete PV system – including fastening structures, inverters, string boxes, and meters – and then put into operation (Garlet et al., 2020). Once the PV system is operational, maintenance and monitoring services become central activities throughout the midstream phase, until the system is dismantled (Schoettl and Lehmann-Ortega, 2011). Activities in this phase are closely related to the end customer and often include service-oriented components (Frantzis et al., 2008; Garlet et al., 2020).

2.3. Circular product-service-system business models in the solar industry

In the literature the outlined solar PV business models – host-owned, third-party-owned, and community-owned – are usually classified based on the relationship between the ownership of the PV system, ownership of the property where it is installed, the party that sells, and the party that consumes the generated electricity. These role-based models, therefore, resemble deployment frameworks descriptive insights on how, by whom, and where a PV system is installed, but they fail to address the underlying value logic (Bankel and Mignon, 2022). As a result, the term 'business model' is not fully applied in its proper sense, which entails how an organization creates, delivers, and captures value (Osterwalder and Pigneur, 2010; Richardson, 2008). This limitation hinders the ability to systematically analyse and compare the fundamental mechanisms through which host-owned, third-party-owned, and community-owned business models create, deliver, and capture value. To date, only a limited number of studies have explored the value logic framework of solar PV business models. For instance, Altunay et al. (2021) examined five solar PV business models from a utility perspective, while Bankel and Mignon (2022) identified six types of solar PV business models from a firm perspective. However, research remains scarce, particularly concerning PSS business models – a specific archetype of circular business models that are expected to play a crucial role in advancing the transition towards a circular economy.

This study seeks to address this research gap by adopting a business

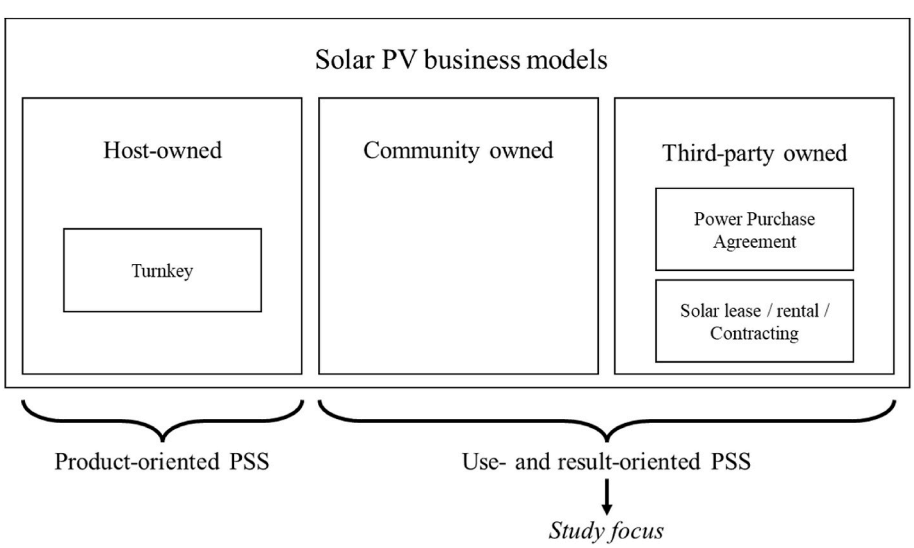


Fig. 1. Overview of solar PV business models in relation to PSS categorization, defining the study focus (based on Bankel and Mignon, 2022).

model perspective with a particular focus on PSS business models in the solar industry. The analysis concentrates on third-party-owned and community-owned solar PV business models (Fig. 1). In contrast to the more widely adopted host-owned business model, in which ownership of the PV system is transferred to the end consumer, in third-party and community-owned settings ownership does not reside with the property owner. This holds particular relevance for the circular economy as this ownership structure incentivizes the optimization of system dimensions, performance, and end-of-life processing of the product, shifting the business focus from short-term sales improvements to long-term asset management (Overholm, 2015; Van Opstal and Smeets, 2022). Consequently, they align closely with the core principles of the circular economy to narrow resource loops (production efficiencies; using fewer resources per product), slow resource loops (durable products; using products longer), and close resource loops (using materials again; recycling) (Bocken et al., 2016).

3. Research design

3.1. Research approach and context

This research was conducted as part of the European Union's Horizon 2020 Research Project on Circular Business Models for the Solar Power Industry (CIRCUSOL, circusol.eu). An exploratory sequential research approach was employed (Fig. 2), consisting of an initial qualitative followed by quantitative analysis. This methodology is particularly suitable for investigating underdeveloped concepts that require thorough exploration and description (Creswell, 2014; Morse, 1991).

First, a qualitative research method is employed, as it is well-suited for exploratory, open-ended investigations (Easterby-Smith et al., 2015), and provides a comprehensive approach to investigate phenomena (Corbin and Strauss, 2015). Focus groups have been utilized to capture a range of opinions on the topic and to identify factors that influence opinions, behaviours, and motivations (Bohnsach and Przyborski, 2009; Krueger and Casey, 2015). In the context of energy transition, characterized by rapid development and urgency to act, focus groups are particularly valuable for gaining insights into social dynamics related to the energy transition (Gailing and Naumann, 2018).

Second, a quantitative research method was implemented to contextualize and validate the findings of the initial qualitative phase. To this end, a cross-sectional survey was conducted using purposive sampling, which is a non-probability sampling technique (Easterby-Smith et al., 2015; Eichhorn, 2021). Focus groups can serve as a foundation for subsequent survey research, by identifying concepts or factors that can then be analysed in larger samples. Therefore, surveys are an appropriate research method for complementing the exploratory sequential research approach (Creswell, 2014).

3.2. Data collection

Initial data collection was conducted through two demand-side focus groups. Participants were chosen based on specific criteria, including ownership of at least one large PV system – some with a cumulative capacity of up to 30 MW – preferably in a PSS model, their net electricity consumption, and their presence in Switzerland. Given the varying procurement frameworks and policy dependencies, participants were divided into two more homogeneous focus groups: one for businesses and the other for governmental and quasi-governmental organizations. Tables 1 and 2 provide an overview of the participants from the business and government sectors, respectively.

In preparation for the focus groups, the relevant literature and policy documents were reviewed, and semi-structured interviews were conducted with industry experts. The focus groups were held on April 6, 2022 (business) and April 13, 2022 (governmental), each lasting for 2 h. Due to COVID-19 restrictions and to facilitate participation, the sessions were conducted using Microsoft Teams and were recorded for accuracy. A Miro Board was utilized, allowing participants to provide comments before the discussions commenced. This approach helped mitigate the risk of dominant voices potentially leading to group thinking. Both focus groups covered the same topics, were moderated by the same facilitator, and observed by three researchers to ensure data validity and methodological rigor.

Based on the focus group findings, a questionnaire was developed as a survey instrument to validate the results on the supply side. Given the specific target group for the survey, purposive sampling was employed, including only organizations offering solar PV PSS in Switzerland (Easterby-Smith et al., 2015; Eichhorn, 2021). The organizations were identified in collaboration with the national Swiss Solar Industry Association, Swissolar, which maintains a comprehensive database of solar PV entities operating in Switzerland. The online questionnaire was designed by two researchers using SurveyMonkey and initially sent to 15 randomly selected pilot organizations by email for validation (Eichhorn, 2021). Among these pilot organizations, one did not offer PSS, and six completed the survey, resulting in a response rate of 43 %. Since there were no significant issues related to non-responses or dropout rates, the questionnaire was slightly refined and subsequently distributed to the full sample in May 2023. The full sample comprised 92 organizations identified through the Swissolar database as offering solar PV PSS business models in Switzerland. The survey was cross-sectional and data collected at a single point in time (Creswell, 2014). A follow-up reminder was sent after two weeks. Of the 92 organizations contacted (including the pilot organizations), six indicated that they did not offer PSS, and 23 completed the survey, yielding a response rate of 26 %. For Switzerland, the 23 responding organizations represent a geographically diverse sample encompassing all regions. They also vary significantly in size, ranging from organizations with fewer than ten employees to those with more than 500 employees. Additionally, the duration of their involvement in the PSS market varies, with some organizations having entered the market less than two years ago, while others have been engaged for over a decade. Consequently, the sample includes a broad spectrum of organizations, ranging from start-ups to established companies, and wholly or partly publicly owned utilities. This response rate is considered adequate for a purposive survey, given the low non-response error and the fact that all respondents fully completed the survey, often providing additional comments (Dillman et al., 2014; Eichhorn, 2021). Potential factors limiting the response rate may

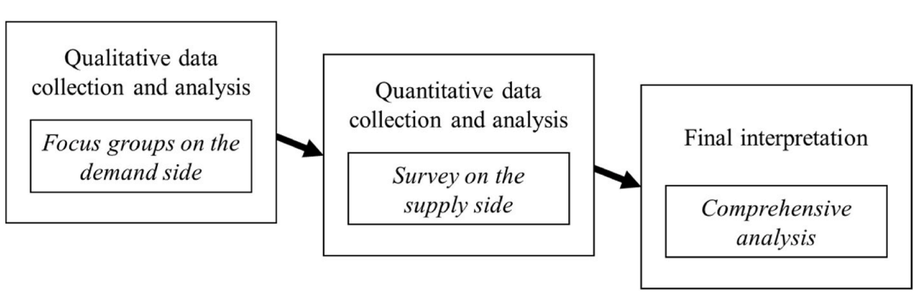


Fig. 2. Process visualization of the applied exploratory sequential research approach (based on Creswell, 2014).

Table 1
Overview of participants in the business focus group conducted for data collection.

No.	Position	Organization	Industry	Turnover	No. of employees
B-A	Owner and Chairman of the Board of Directors	Building material supplier	Construction	N/A	200
B-B	Project Manager Buildings	Privat insurer	Insurance	4.3 B CHF	6′000
B-C	Head of Energy/Technology	Retail and wholesale company	Retail	30 B CHF	95′000
B-D	Chief Operating Officer	Chocolate producer	Food	60 M CHF	200
B-E	Project Manager	Window producer	Construction	20 M CHF	120
B-F	Head of Environment Unit	Real Estate Management	Real Estate	N/A	100
B-G	Project Manager Energy Efficiency & Climate Protection Projects	Retail and wholesale company	Retail	30 B CHF	99′000
B-H	Architect & Business Unit Manager	Transport and warehouse logistics company	Logistics	1 B CHF	5′600
B-I	Operations Manager	Conveyor technology manufacturer	Machinery	N/A	130

Table 2
Overview of participants in the governmental focus group conducted for data collection.

No.	Position	Organization	Industry	Turnover	No. of employees
G-A	Deputy Head of Department Municipal Buildings	Municipality	Public sector	230 M CHF	N/A
G-B	Head of the Circular Economy Business Unit	Logistics and postal service provider	Logistics	7 B CHF	7′300
G-C	Project Manager Sustainable Development	Municipality	Public sector	116 M CHF	N/A
G-D	Head of Sustainability Department Building Construction Office	Cantonal administration	Public sector	16 B CHF	32′000
G-E	Senior Manager Business Development Mobility	Bus company	Transport	800 M CHF	840
G-F	Head of Sustainability Real Estate	Railway company	Transport	9 B CHF	9′500
G-G	Project Manager Energy Management	Cantonal administration	Public sector	6 B CHF	8′000
G-H	Chairperson of the Board	Building Cooperative	Real Estate	N/A	N/A
G-I	Sustainability consultant	National administration	Public sector	N/A	900

include time constraints due to the competitive market environment and the varying interpretation and minor role of PSS within these organizations. To validate and clarify the responses, follow-up interviews were conducted with survey participants and representatives from Swissolar.

3.3. Data analysis

Data analysis was conducted in two phases, with findings from the initial exploratory phase indicating the subsequent quantitative phase. For the data analysis and interpretation of the first data collection, six phases of reflexive thematic analysis were employed: (1) familiarization with the data, including the recordings and notes from the focus groups; (2) coding the data into initial segments of interest; (3) identifying broader themes based on the codes; (4) reviewing and refining themes to ensure viability and reliability; (5) defining and naming themes; and (6) synthesizing the structured content of the dataset (Braun and Clarke, 2021). Steps 1–3 were independently carried out by two researchers, who then collaboratively discussed the remaining steps. Each focus group was initially analysed separately to identify specific characteristics between business and governmental settings before the themes were consolidated. The identified themes were categorized into advantages and disadvantages of the PSS business model and the conventional purchase business model with self-ownership.

Subsequently, the survey, serving as the second data source, was analysed using Excel. Two researchers independently reviewed the data to determine the most informative ways to present the survey results in graphical form. The analysis followed the elements of value proposition, value creation and delivery, and value capture.

4. Results

4.1. Focus group results about the demand side

The focus groups examined the advantages and disadvantages of solar PV PSS business models compared with traditional ownership models for PV systems. Participants provided insights based on their experiences in the planning, acquisition, and utilization of PV systems, addressing multiple perspectives, including operational, legal, and financial aspects. In general, most focus group participants were critical of the PSS-based PV installation models, with a few exceptions.

Solar PV PSS business models have several advantages (Table 3). First, the "all-inclusive package" allows clients to outsource responsibilities such as repair and maintenance of the PV system, alleviating the need for financial, personnel, or expertise investments. Clients would benefit from the competences of the PSS provider without needing to develop their own expertise. Synergies in monitoring, maintenance, and repair, as well as greater purchasing power owing to larger purchasing needs, were also noted as key advantages. Additionally, the focus group participants expected that PSS providers would have incentives to operate resource-efficient systems with high availability, minimal repair needs, and better synchronization of component lifecycles (e.g., inverters, meters, and software). From a financial perspective, participants emphasized the benefit of no upfront investment or equity capital requirements as the PSS provider assumes the investment risk. This arrangement allows the client to allocate capital to other investments, whereas the fixed cost structure ensures the long-term predictability of electricity costs.

However, solar PV PSS business models were found to have several drawbacks (Table 3), the most significant being their heavy reliance on a single partner, which can lead to significant financial and legal implications. From a financial perspective, fixed electricity prices in PSS contracts can create dependency; while organizations benefit when market prices rise, they incur higher costs when prices fall, as the fixed rate may exceed the current market price. Legally, the long-term nature of these contracts' limits flexibility in property development, particularly for publicly owned property. Additionally, complex contractual arrangements, such as cancellation clauses, contract duration, and property-related rights and obligations, present challenges, especially for public sector projects. Some participants also pointed out that PSS providers capitalize on the ecosystem by diverting revenue streams that would otherwise benefit existing players outside of the PSS model.

Traditional purchasing business models with subsequent self-ownership offer several advantages (Table 3). First, once the amortization period is reached, the PV system generates income that accrues entirely to the organization that owns it. Additionally, electricity costs are reduced through self-produced power, although this benefit is contingent on the size of the PV installations and the organization's electricity demand. Several participants also highlighted the typically low maintenance costs during the first ten years – roughly the lifespan of the inverter – making the purchase more attractive, as minimal upkeep

Table 3
Comparison of advantages and drawbacks of PSS and traditional purchasing business models.

		Advantage/ disadvantage name	Description
Solar PV PSS business models	**Advantage**	All-inclusive package	All tasks related to the PV installation, such as maintenance and inverter replacement, are handled by the PSS provider.
		Operational efficiency through synergies	PSS provider can leverage synergies across multiple projects, particularly in areas such as PV model procurement, maintenance, or monitoring.
		Optimized resource utilization	High system availability, minimal repairs, and the inclusion of end-of-life management options are aligned with the interests of the PSS provider. This includes synchronizing the lifecycles of various PV system components, such as PV modules, inverters, and meters.
		Elimination of upfront investment	No upfront investment is required, eliminating the need for equity capital.
		Preserved financial flexibility	Without the need for investment, the capital remains available for other uses.
		Predictable and transparent costs	The tariff is fixed, and compensation for feeding surplus energy into the grid is pre-determined.
	Drawbacks	Reliance on PSS provider	Significant reliance on the PSS provider.
		Potential cost disadvantages in market fluctuations	The fixed electricity price may be advantageous when market prices are high but can seem unfavourable when market prices drop below the fixed rate.
		Limited flexibility due to long-term contracts	Limited flexibility property development due to long-term contractual commitments.
		Complex contractual obligations	The duration, exit clauses, and rights and obligation to the property make contractual agreement for PSS complex.
		Reduced profit potential	PSS provider also “wants a piece of the pie”, reducing overall returns.
Traditional purchasing business models	**Advantages**	Revenue generation through electricity sales	The sale of self-produced electricity generates income and offers a strong return on investment.
		Low initial maintenance costs	Maintenance costs are generally low during the first ten years, resulting in minimal expenses.
		Energy independence	Increased self-sufficiency through independent electricity production.
		Flexibility in property modifications	Greater flexibility in making property modifications, such as refurbishment or building extensions.
		Straightforward legal ownership	The legal framework is straightforward, as the property owner is also the registered owner of the PV system, simplifying property sales.
	Drawbacks	Upfront investment requirements	High investment needs, which often require extensive internal approvement processes.
		Capital immobilization	Invested capital is tied to the PV system.
		Ongoing maintenance expenses	Maintenance costs arise due to regular washing and cleaning or snow clearing.
		Ownership risks and liabilities	Being the owner bears risks in the realm of weather events (e.g., hail or wind), inverter replacements, identification of defective PV modules, or problems with PV system monitoring.
		Need for technical expertise	Need for basic competence in PV systems is necessary within the organization.

is expected during this period. Beyond financial benefits, self-ownership offers advantages related to self-sufficiency and independence. The focus groups participants noted greater autonomy in planning and executing structural changes, such as roof renovations or property modifications, as well as flexibility in the event of a property sale. Furthermore, participants emphasized that self-ownership provides a clearer legal framework.

However, traditional purchasing business models with subsequent self-ownership have several drawbacks (Table 3). The focus group participants primarily noted the high upfront investment costs required to finance PV installations. In larger organizations, the internal approval process for such significant capital expenditures may present an additional challenge, and capital becomes tied up, limiting its availability for other investments. Moreover, the participants pointed out that operational costs related to maintenance and repair can be unpredictable. Routine maintenance, such as cleaning and snow removal during winter, was highlighted, whereas repairs following extreme weather events – such as heavy hail or strong winds – along with the replacement of inverters, defective modules, or monitoring systems, were noted as potential cost drivers. These expenses can be further exacerbated by the need to develop such competencies internally. Alternatively, reliance on external providers for maintenance and repair services may create dependencies. Additionally, participants indicated that purchased PV systems are often scaled according to the property’s energy consumption, which may limit their contribution to broader energy-transition goals.

4.2. Survey results about the supply side

This study also explored the supply side by conducting a survey among PSS providers (see Appendix A for the full list of questions). Unlike the demand-side analysis, the supply side survey focused exclusively on PSS business models. The findings highlight how organizations offering solar PV PSS business models create, deliver, and capture value as well as key components of their value proposition. The following sections outline each aspect of the business model in detail. However, to provide context and facilitate the interpretation of the results, the surveyed organizations are first categorized by number of employees, total turnover, number of PSS installations, and whether they are utilities (e.g., a wholly or partly publicly owned electricity providers), as shown in Fig. 3.

A significant portion of the surveyed PSS providers, totalling nine, reported having fewer than ten PSS installations. This can be attributed to the fact that only eight of the 23 organizations have been in the market for over five years, whereas eight have entered the solar PV PSS market within the past two years. Moreover, only two non-utility solar PV PSS providers report revenues exceeding 50 million Swiss Francs. Overall, 19 organizations anticipate strong or very strong growth in the PSS market, while only four foresee limited or no growth. As illustrated in Fig. 3, these findings suggest that the market is relatively young, with most organizations still in the growth phase.

The survey provides insights into diverse value-creation activities within the solar PV PSS sector. Most organizations engage in a comprehensive range of activities, from initial consulting to end-of-life management. As illustrated in Fig. 4, these activities were either conducted in-house (represented by the light blue bar) or outsourced to third parties (dark blue bar). Insurances, ongoing energy management, securing power supply, and end-of-life management are among the least commonly offered activities. Most activities are performed in-house, with insurance and installation frequently outsourced to a third party. Notably, seven organizations carry out all the activities in-house, significantly reducing need for key partnerships in value creation. The survey results indicate that solar PV PSS organizations create value by delivering all the necessary services to customers throughout the lifecycle of a PV system, from planning to operation and end-of-life. While many of these activities are managed in-house, some are outsourced to partner organizations. Consequently, solar PV PSS organizations require a wide array of resources, ranging from intellectual capital (such as expertise in PV system planning and subsidy applications) to human capital (such as skilled installers) and financial resources for pre-financing systems, as evidenced by follow-up interviews. Therefore, sourcing investors is crucial to the solar PV PSS business model.

With respect to value delivery, the survey provides insights into the significance of various customer segments. As illustrated in Fig. 5, most solar PV PSS organizations identify commercial customers, particularly for PV installations on large industrial or commercial buildings, as their main target group. However, five solar PV PSS organizations specifically focus on residential customers, a segment served by most other organizations. Public institutions, such as schools and hospitals, represent a niche market that is of interest to many organizations, although only two consider this segment to be highly important. Special PV installations, such as those on car parks, infrastructure like rail baffles, or open spaces, are not (yet) viewed as key customer segments, and none of the organizations rank them as a first or second priority. Post-survey interviews highlighted the different channels used to engage these customer segments. For residential customers, the digital calculation tools available on websites serve as direct channels for generating awareness. By contrast, dedicated sales teams play a crucial role in customer acquisition for commercial and public customer segment. Given that the solar PV PSS market is relatively young, and most organizations have only been operational for a few years, customer acquisition strategies are prioritized over customer retention or upselling, as confirmed by the interviews.

To evaluate the value capture mechanisms of solar PV PSS business models, it is essential to first analyse the ownership structures (Fig. 6). According to the survey, more than 60 % of solar PV PSS organizations retain ownership of the PV system post-installation, allowing them to manage a portfolio of PV installations over time. Approximately 13 % transfer ownership to a third party, such as an investor, while another 13 % determine ownership on a case-by-case basis, choosing between retaining it or using a third party. The remaining 13 % transfer ownership to a community, where individuals can purchase a specific number of PV modules. Regardless of the ownership structure, most solar PV PSS organizations (91 %) generate revenue through the sale of electricity to the property owners where the PV systems are installed, as well as to the grid. The remaining 9 % are exclusively involved in planning and consulting services. Notably, PV systems owned by the PSS provider, or a

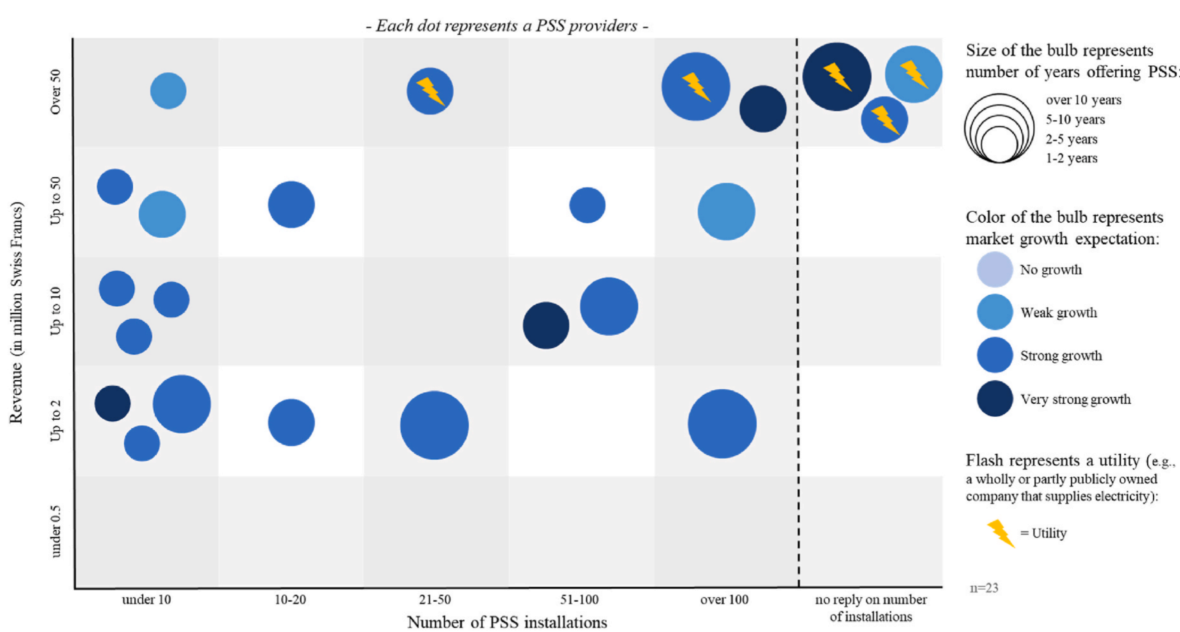


Fig. 3. Categorization of surveyed solar PV PSS providers for context and better interpretation of results.

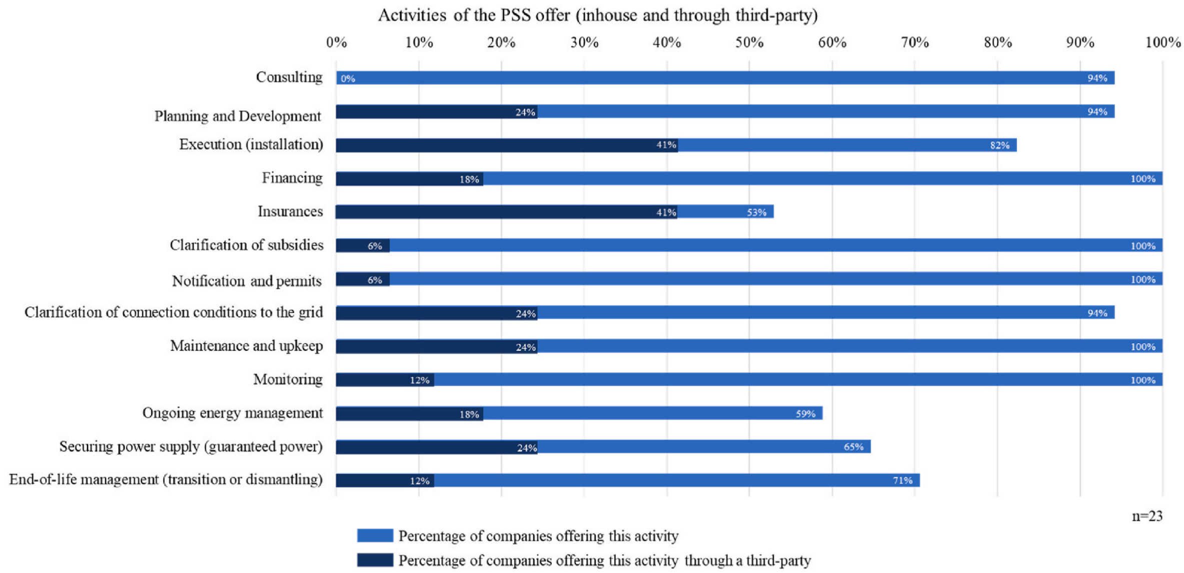
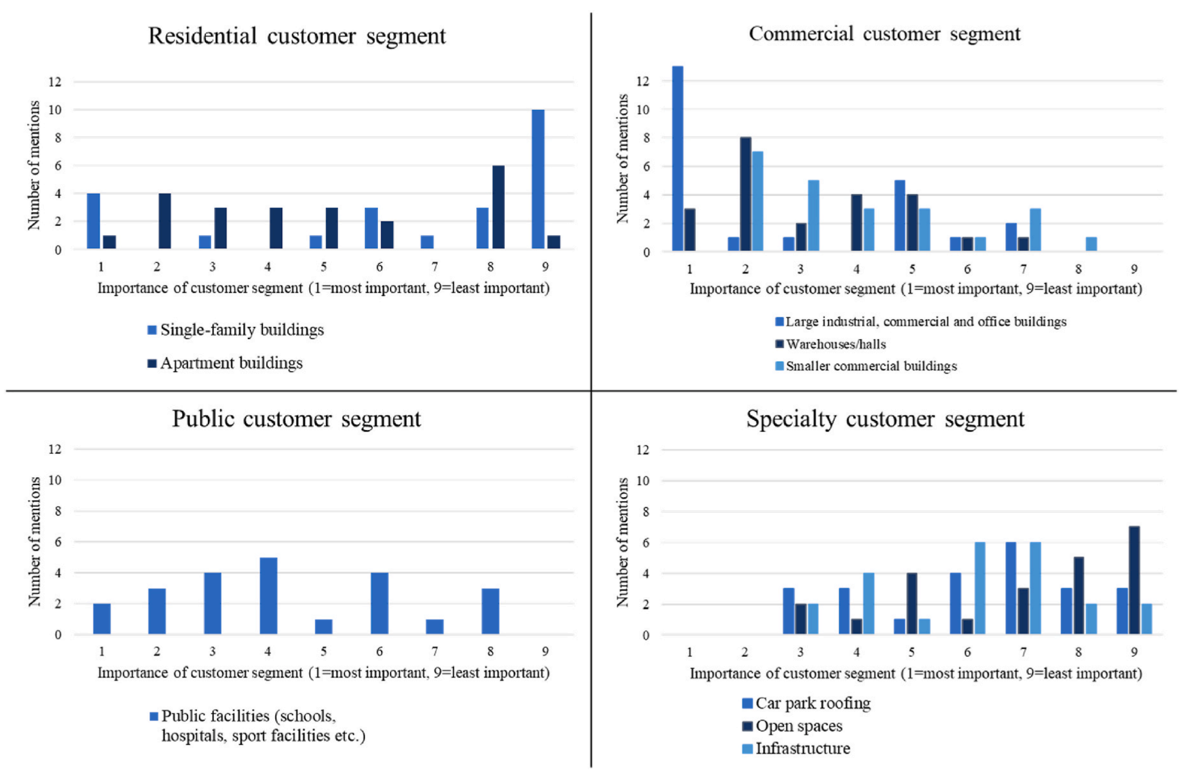


Fig. 4. Value creation activities and outsourcing practices of solar PV PSS organizations, presented in relative terms.



n=23, all 23 answers are displayed in each of the four segments (e.g., single-family buildings are most important (= 1) for four of the 23 companies, while they are least important (= 9) for ten other companies in the residential customer segment).

Fig. 5. Importance of residential, commercial, public, and speciality customer segments to solar PV PSS organizations, presented in absolute terms.

third party typically charge fees for planning and installation, whereas no such fees are applied to community-owned PV systems. Consultancy fees are charged by 48 % of solar PV PSS organizations, independent of the ownership model. On the cost side, the key factors include the activities and resources necessary for value creation that solar PV PSS providers must possess. As these costs are relatively stable and predictable, the primary factor influencing profit margins is the fluctuating electricity price.

Drawing on the insights gained from value creation, delivery, and capture, the value proposition of solar PV PSS organizations can be further elaborated. Although the survey results do not point to a singular value proposition applicable to all organizations, certain key elements are consistently observed across different business models (Fig. 7). The most compelling offering in the sales and contracting process is the 'good electricity price' achievable through a solar PV PSS solution. Key elements of the value proposition include 'long-term fixed electricity costs' and the 'all-in-one carefree package'. Of the ten most important elements, five pertain to financial aspects, indicating that the value

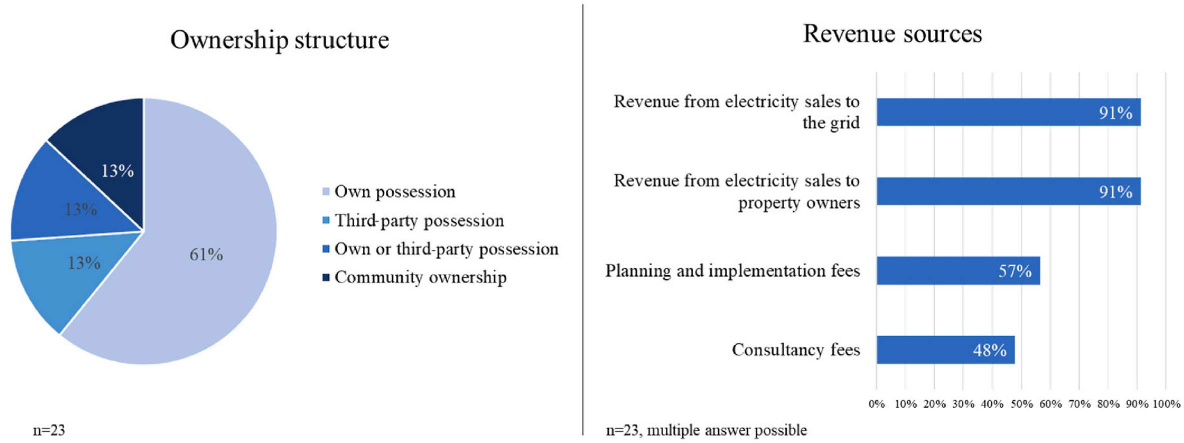


Fig. 6. Ownership structure of PV systems installed in a PSS setting (left) and revenue sources of solar PV PSS organizations (right).

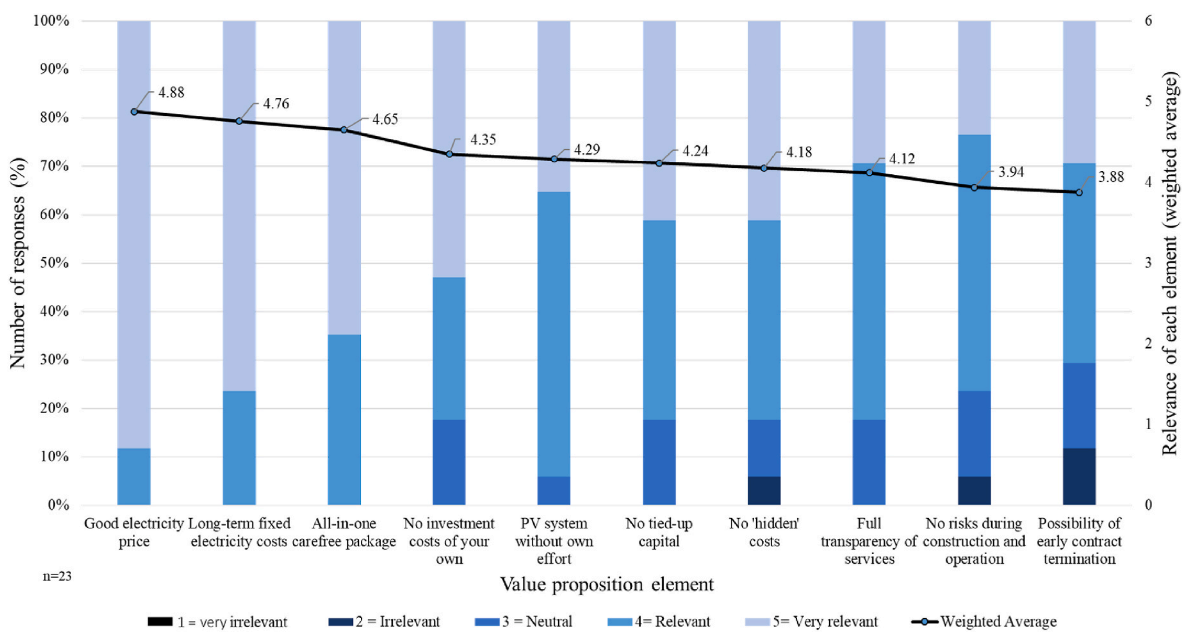


Fig. 7. Top 10 value proposition elements of solar PV PSS organizations, presented as percentages and weighted averages.

propositions of solar PV PSS organizations are primarily financially driven. In contrast, elements related to climate change or sustainability – such as the 'contribution to the energy transition' (weighted average: 3.76) or the 'promotion of sustainability' (3.41) – along with those linked to energy independence – such as the 'possibility to increase self-sufficiency' (3.53) and 'ensuring a constant energy supply' (3.41) – are not seen as primary drivers of value. This highlights the secondary role of environmental and energy independence in the overall value proposition.

The terminology used to describe PSS offerings provides further insights into the value proposition of solar PV PSS organizations. The survey reveals variations in how organizations label their offerings: 16 organizations refer to their PSS offering as 'Contracting', while eight use terms such as 'Roof rental' or 'Power Purchase Agreement'. Notably, special emphasis is placed on specific attributes, such as 'Citizen financing' or 'Solar subscription', particularly in cases where community-based financing models are involved. These variations in naming reflect different strategic focuses within the value proposition of solar PV PSS organizations.

5. Discussion

In the context of the global energy system transformation, the PV industry is experiencing significant changes and rapid growth, accompanied by major shifts in the business models employed. This study explores novel approaches to value creation, delivery, and capture by examining solar PV business models from both demand and supply perspectives, with a particular focus on use- and result-oriented PSS. Therefore, this study has theoretical, industrial, and political contributions.

5.1. Theoretical contributions

This study contributes to the theoretical discourse by expanding the knowledge on solar PV business models, with a particular emphasis on use- and result-oriented PSS. Recent literature has mainly examined PV business models from the perspectives of technology diffusion or energy policy, with some exceptions (e.g., Altunay et al., 2021; Bankel and Mignon, 2022). Much of this research has focused on role-based models that describe how, by whom, and where a PV system is installed (e.g., Burger and Luke, 2017; Drury et al., 2012; Frantzis et al., 2008;

Overholm, 2015). This study adopts a different approach, advancing the solar PV business model literature in three ways.

First, this study extends previous work by examining the underlying value logic of PV business models, particularly those based on use- and result-oriented PSS. Our findings reveal a *value proposition* in which organizations provide customers with solar electricity at a competitive fixed price for a specified period, generated by PV modules installed on the customer's property, without requiring customer involvement in installation or electricity generation. Such business models *create value* for customers by managing activities along the entire value network, from initial consultation to ongoing monitoring and maintenance during operation, and end-of-life management. This comprehensive range of activities, spanning the pre-installation, operational, and post-deinstallation phases, requires a diverse array of physical, financial, intellectual, and human resources, including expertise in PV system planning, securing subsidies, installation skills, and access to funding sources. Developing such a broad set of resources is complex, time-consuming, and costly because it demands establishing closer client relationships, addressing complex legal issues, adopting a service-oriented mindset, and navigating legal standards and financial partnerships that are not yet fully developed (Altunay et al., 2021). In terms of *value delivery*, our findings strongly emphasize the industrial and commercial facilities segment, which is driven by focused customer-acquisition strategies. Supportive evidence from Sweden confirms that such projects are not only complex and capital-intensive, but also more financially rewarding due to the higher electricity output generated from a single project (Bankel and Mignon, 2022). Similarly, Swissolar, the Swiss Solar Industry Association identifies these segments as most suitable, particularly for large roof owners with high levels of self-consumption (Strickelberger et al., 2022). However, our survey also indicated that the residential segment is gaining increasing attention from PSS providers. Some PSS providers appear to target this underdeveloped niche, challenging the previously low potential assessed for residual customers. Although this market is well established in the United States, it remains less prevalent in Europe (Bolinger and Holt, 2015; Overholm, 2015). In this context, alternative financing models, such as crowdfunding and community financing, are also being experimented with (Bankel and Mignon, 2022). Finally, *value* is *captured* through recurring revenues from electricity sales to property owners and the grid, as well as one-time fees for consulting, planning, and implementation. These recurring income streams differentiate the business model from traditional models that focus primarily on the planning and installation of PV systems (Bankel and Mignon, 2022). Notably, electricity is often supplied directly to the end user, bypassing the grid and avoiding grid fees, provided the end consumer has a considerable level of electricity consumption (Strickelberger et al., 2022). However, these recurring revenues are subject to external factors such as feed-in tariffs and fluctuations in electricity prices, both of which can change over time (Strupeit and Palm, 2016).

Second, our findings from both the focus groups and the survey complement existing research that focuses on the *demand side of solar PV business models* (e.g., Bankel and Mignon, 2022; Van Opstal and Smeets, 2022). On the one hand, focus group participants generally expressed significant reservations about PV PSS business models in the context of a circular economy, often favouring traditional sales models. Traditional sales were generally perceived as less complex and more familiar, while PSS models were viewed as contractually and financially novel and untested. Similar studies underscore that trust is a critical factor in the acceptance of circular PV business models, such as PSS (Van Opstal and Manshoven, 2024). On the other hand, the survey results indicate that five of the ten most promising value proposition elements are financially oriented, reflecting a clear emphasis on financial arguments in the sales strategies of PSS providers. These findings suggest that financial arguments play a central role in customer decision-making. This aligns with other research, which highlights the importance of low transaction costs and immediate electricity bill savings as key drivers for the adoption of PV PSS business models (Shakeel and Rajala, 2020; Strupeit and Palm, 2016).

Lastly, our research contributes to the literature at the *intersection of solar PV business models and PSS*, a domain that has been relatively underexplored (see Altunay et al., 2021; Bankel and Mignon, 2022; Overholm, 2015 as exceptions). Our findings support the theoretical features of PSS, illustrating that the solar PV business models examined closely correspond to both use- and result-oriented PSS models, outlined by Tukker (2015). This alignment is particularly evident because the ownership of the PV modules remains with the PSS provider, while the customer purchases electricity alongside with a service package. In some cases, the business model predominantly exhibits features of a result-oriented PSS, where the provider sells the outcome (electricity) rather than the physical product (i.e., the PV module) (Baines et al., 2007; Tukker, 2015). The distinction between use- and result-oriented PSS models depends on the specific business context. For instance, a PSS provider that installs PV modules on the customer's property, covers all costs, and sells the generated electricity represents a more result-oriented PSS. By contrast, providers that rent PV modules without overseeing monitoring or end-of-life management reflect a more use-oriented approach. The greater the alignment with a result-oriented PSS, the higher the potential to advance circularity, as highlighted by Bocken et al. (2014) and Yang et al. (2018). However, the emphasis on financial elements within the value propositions of PSS providers, while circular economy principles, climate change, and energy independence remain secondary, indicates that PSS providers may either insufficiently communicate or undervalue the potential of their business models to enhance circularity. These findings are consistent with the idea-action gaps frequently observed in the implementation of circular economy business models, as highlighted by Blomsma and Brennan (2017) and Bocken et al. (2023). This suggests that the solar PV industry's use- and result-oriented PSS models face similar challenges when scaling circularity beyond initial pilots and demonstrators (Strupeit et al., 2024).

5.2. Industrial and political contributions

This study offers industrial and political implications. Based on our analysis we propose six key decision criteria that are crucial for evaluating solar PV business models. Fig. 8 illustrates the identified decision criteria, positioning them between the demand-side needs of customers and the value propositions offered by solar PV business model providers on the supply side. Three of the six decision criteria pertain to financial aspects (*italicized* in Fig. 8).

The first financial aspect is the *cost structure*. In a PSS offering, costs are typically distributed over the duration of the contract through a fixed monthly fee. By contrast, purchasing a PV system involves various unpredictable and hidden costs. These hidden costs include the need to develop internal expertise for system maintenance and repair, insurance expenses, and capital commitment for the initial investment. These costs are sometimes overlooked in the procurement process because they are either unknown at the time of purchase or are allocated to different departments. Moreover, while PSS models shield customers from electricity price fluctuations by offering fixed rates, these fixed prices may become less competitive over time, particularly as the energy market evolves quickly.

The second financial aspect among the six decision criteria is *revenue opportunity*, which complements the cost structure. When purchasing a PV system, owners have the potential to generate revenue in the long term by selling excess electricity once the system has been fully amortized. However, fluctuating electricity prices and the long operational lifespan of PV systems introduce significant uncertainty. This added complexity makes it challenging to accurately predict payback periods and profit margins, because these factors are subject to changes in the energy market over time.

The third finance-related decision criterion pertains to the *investment requirements*. When purchasing a PV system, organizations face

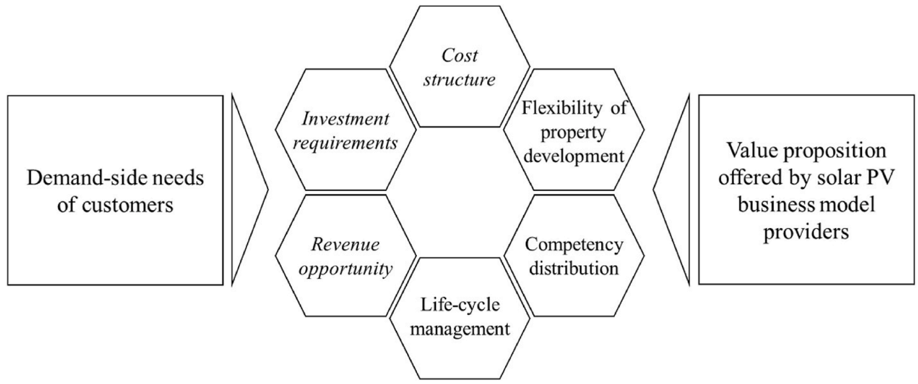


Fig. 8. Dominant decision criteria for assessing solar PV business models, embedded within demand- and supply side constraints.

substantial upfront capital investment. By contrast, a PSS model eliminates the need for direct investment, as the costs are typically integrated into a service fee. Consequently, organizations are not required to allocate equity to such an investment, which serves as a key selling point in the value proposition of PSS providers.

The fourth decision criterion is related to the *flexibility of property development.* A common concern regarding engagement in a PSS model is the potential imposition of significant restrictions on property modification. While this concern is partially valid, it can be contractually mitigated by establishing buy-back agreements over the lifetime of the installation. Moreover, even when a PV system is purchased and owned by a property owner, certain constraints on property development may still arise. In particular, the financial disincentives associated with dismantling and reinstalling the system can limit the flexibility of property modifications, irrespective of ownership status.

The fifth decision criterion concerns *competency distribution* and involves the broader "make or buy" decision. Organizations must determine whether to develop internal expertise in areas such as maintenance, upkeep, monitoring, and energy management when purchasing a PV system, or to outsource these functions to a PSS provider. Additionally, a third, frequently pursued option involves purchasing the PV system while outsourcing maintenance services over the course of its operational lifespan. While offering external expertise, this approach tends to be the costliest because of the ongoing service fees associated with external contracting for system maintenance and management.

The final decision criterion is the *life-cycle management* of the PV installation. A comprehensive evaluation of the entire life cycle of a PV module remains underdeveloped on both the demand and supply sides. Most PSS providers interpret end-of-life management merely as the transfer of ownership of the PV system to the property owner, with only one-third including dismantling and reinstallation at alternative locations (see Appendix B). Furthermore, the enhanced resource efficiency offered by PSS models due to extended utilization periods, which result from the synchronization of component life cycles, along with more efficient maintenance and knowledge accumulation over time, is rarely recognized.

Those six decision criteria have industrial and political relevance. From an industry perspective, the six decision criteria are designed to enhance the evaluation process for selecting a PV installation. They serve as a valuable starting point for procurement departments, particularly those with little knowledge of solar PV business models and their associated circularity potential. While some criteria will likely be addressed at some point during the evaluation, this framework helps streamline the decision-making process. Additionally, if certain criteria, such as end-of-life considerations, have not been previously accounted for, this overview encourages new perspectives and considerations. This framework thus provides practical guidance for organizations navigating the complexities of solar PV procurement options, helping them to make more informed and sustainable choices.

From a policy perspective, the six decision criteria aim to enhance policymakers' understanding by providing deeper insights into the underlying value logics of PV PSS business models. Policymaking, particularly when implemented through a top-down approach, often struggles to align with rapidly evolving industry developments, as is the case in the dynamic solar PV sector. As solar PV business models are inherently shaped by the regulatory frameworks in which they operate, the six identified decision criteria provide a foundational framework for assessing and shaping more effective policies that foster the adoption and scalability of PV PSS business models.

5.3. Limitations and future research

This study investigates new strategies for value creation, delivery, and capture by examining solar PV business models from both demand and supply perspectives, with a particular focus on PSS within a circular economy framework. However, this study comes with limitations. First, the data collection methods present constraints: on the demand side, focus groups provide in-depth but limited data breadth, whereas on the supply side, the survey offers broader data but lacks depth. As a result, insights into business models are restricted. Future studies can build on our findings by further exploring the value framework through qualitative research. The performance of PV PSS business models can be measured and benchmarked by evaluating key performance indicators such as customer acquisition costs or revenue per customer, while the financial viability might be evaluated by comparing the internal rate of return or the net present value of the PV PSS business models. Second, the findings are specific to Switzerland, a country characterized by limited land availability, strict environmental and spatial planning regulations, a partially liberalized energy market, and a relatively sustainable electricity, with approximately 60 % secured from hydropower (Swiss Federal Office of Energy, 2023). Comparative studies across different geographic contexts could offer a more nuanced understanding of the results and provide insights into how these findings might vary under different regulatory, environmental, and market conditions. Lastly, this study contributes valuable insights by linking business model research with solar PV studies, an area that remains underexplored. But while the primary focus has been on PV PSS business models, this study falls short in examining the value logic of other solar PV business models. Future research is necessary to broaden the understanding of how different business models in the solar industry create, deliver, and capture value. Expanding this research would enhance knowledge across a wider range of solar PV business models, offering a more comprehensive view of the industry's business landscape.

6. Conclusion

To date, research has focused on the role of solar PV business models as catalysts for the upheavals in the solar PV industry. However, much of this research has examined business models primarily through the lens of technology diffusion and energy policy, overlooking the fundamental processes by which these business models create, deliver, and capture value. Our study addresses this gap by adopting a business model perspective, focusing on PSS business models, that are relevant to the circular economy framework. In the context of the solar PV industry, this study focuses on PV PSS business models, in which the ownership of PV modules remains with the provider, not the customer. A deeper understanding of the advantages and disadvantages of solar PV PSS business models is sought, along with an exploration of the mechanisms through which value is created, delivered, and captured.

This study reveals that potential customers remain critical of PV PSS business models within the context of a circular economy, often preferring traditional sales models, perceived as less complex in terms of legal structure and less restrictive regarding property development compared to PSS offerings. Additionally, they are considered financially attractive because of the limited maintenance costs and the potential for revenue generation once the system has been amortized. This perceived financial attractiveness persists despite the acknowledged drawbacks of high upfront investment, tied-up capital, and often hidden maintenance and repair costs. Moreover, the value propositions of the analysed PSS providers exhibit a strong financial focus, while aspects related to climate change, sustainability, and energy independence play a minor role. Thus, the supply side is also promoting mostly along a financial value proposition, leaving circularity aspects out of the picture. This suggests that PSS providers may either deliberately undercommunicate or inadvertently underestimate the potential of their business models to foster a circular economy, as there seems to be a limited market demand for such attributes. More critically, it might highlight the structural limitations of PV PSS business models, which may be fundamentally constrained in fully realizing their potential within the existing linear economic framework.

This finding contrasts with the existing literature, which often theoretically positions PSS as a key enabler for circular economy principles. It also highlights the ongoing difficulty in bridging the gap between conceptualization and practical implementation of circular business models, particularly beyond initial pilots and demonstrators. In this context, policy support may be essential. By offering deeper insights into the underlying value logic of PV PSS business models, this research contributes to policymakers' understanding and informs regulatory decision making. Moreover, the six identified decision criteria serve as a foundation for evaluating a more conducive regulatory environment. Furthermore, as the findings indicate that PV PSS business models are primarily financially driven, policy measures should be designed to enhance their role as enablers of climate change mitigation, the circular economy, and energy independence, thereby addressing the structural limitations inherent to PV PSS business models operating within linear economic frameworks. Notably, PV PSS business models offer particular value by aligning financial incentives with system performance, encouraging owners to invest in high-quality PV products and extending their operational lifespan. This, in turn, has the potential to drive social change towards greater circularity.

This study, situated at the intersection of solar PV business models and PSS within the circular economy framework, illustrates how business model research can be applied to the solar PV sector. Specifically, it highlights the potential of solar PV business models to function as both use-oriented and result-oriented PSS models, offering valuable insights into their roles in value creation, delivery, and capture. By conceptualizing six decision criteria as an orientation framework, this study moreover assists organizations in navigating the procurement process for PV installations and enhances policymakers' comprehension of PV PSS business models within the broader context of the energy transition.

CRediT authorship contribution statement

Roger Nyffenegger: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ässia Boukhatmi:** Writing – review & editing, Writing – original draft, Project administration, Investigation, Formal analysis, Conceptualization. **Nancy Bocken:** Writing – review & editing, Validation, Supervision, Conceptualization. **Stefan Grösser:** Writing – review & editing, Validation, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Survey questions

No.	Question	Question type	Answer options
1	What is the name of your organization?	Free field	
2	How many employees work in the organization?	Single choice	- under 10 employees – 11–50 employees – 51–100 employees – 101–500 employees - over 500 employees
3	How much turnover does the organization generate?	Single choice	- under 0.5 million Swiss Francs - up to 2 million Swiss Francs - up to 10 million Swiss Francs - up to 50 million Swiss Francs - over 50 million Swiss Francs
4	Where is the organization located (zip code & town)?	Free field	
5	What does your organization call its product-service-system (PSS) offering?	Multiple choice	- (Energy supply) contracting - (Roof) rental - (Solar) leasing - On-site power purchase agreement (PPA) - Power purchase agreement (PPA) - Other name (please specify)
6	How long has your organization been offering PSS solutions?	Single choice	- less than 1 year

(*continued on next page*)

(*continued*)

No.	Question	Question type	Answer options
			- 1–2 years - 2–5 years - 5–10 years - over 10 years
7	What services does your organization's PSS offer include?	Multiple choice	- Consulting - Planning and development - Execution (installation) - Financing - Insurance - Clarification of subsidies - Notification and permits - Clarification of connection conditions to the grid - Maintenance and upkeep - Monitoring - Ongoing energy management - Securing power supply (guaranteed power) - End-of-life management (transition or dismantling) - Other services or comments/precisions (please specify)
8	For which of these services do you involve external partners to provide the PSS service?	Multiple choice	- Non, all in-house - Consulting - Planning and development - Execution (installation) - Financing - Insurance - Clarification of subsidies - Notification and permits - Clarification of connection conditions to the grid - Maintenance and upkeep - Monitoring - Ongoing energy management - Securing power supply (guaranteed power) - End-of-life management (transition or dismantling) - Comments/precisions (please specify)
9	For which use cases does your organization offer PSS solutions? Please sort by frequency of use cases in your organization	Ranking	- Single-family buildings - Apartment buildings - Large industrial, commercial or office buildings - Warehouses/halls - Smaller commercial buildings - Public facilities (e.g., schools, hospitals, sport facilities) - Car park roofing - Open spaces - Infrastructure
10	Who is the owner of the PV system?	Multiple choice	- Own possession - Third-party possession - Community ownership - Other owners or comments/precisions (please specify)
11	What sources of income does your organization have from the PSS offering?	Multiple choice	- Consultancy fees - Planning and implementation fees - Revenue from electricity sales to property owners - Revenue from electricity sales to the grid - Other sources of income or comments/preferences (please specify)
12	What options does your organization offer at the end of the contract?	Multiple choice	- Transfer of PV system to property owner - Transfer of PV system to new PSS provider - Dismantling and disposal by PSS provider - Dismantling and reinstallation of PV system on new property by PSS provider - Further options or comments/precisions (please specify)
13	How do you rate the relevance of the following aspects in the sales and contract process?	Likert scale (very irrelevant, irrelevant, neutral, relevant, very relevant)	- Upgrading of the property - Ensuring a steady energy supply - Promotion of sustainability - Possibility to increase self-sufficiency - New income opportunities through surplus feed-in - Economical use of roof space - Possibility to benefit from experience - Fast planning and implementation - Contractor has incentive for resource-efficient system - Contribution to the energy transition - Possibility of early contract termination

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(*continued*)

No.	Question	Question type	Answer options
			- No risks during construction and operation - Full transparency of services - No 'hidden' costs - No tied-up capital - PV system without own effort - No investment costs of your own - All-in-one carefree package - Long-term fixed electricity costs - Good electricity price - Other aspects (please specify)
14	Which type of argument has the highest relevance in the sales and contract process? Please rank the four categories in order of relevance.	Ranking	- Ecological arguments (energy transition, promotion of sustainability, reuse, …) - Technical arguments (simplified planning, quick implementation, …) - Economic arguments (investment costs, upgrading of property, fixed electricity price, …) - Supply-related arguments (self-sufficiency, securing energy supply, …)
15	How often are the following aspects mentioned when customers decide to buy a system and not a PSS solution?	Likert scale (very frequently, frequently, occasionally, rarely, very rarely)	- Long contract commitment - Dependence on the PSS provider - Complex contract design - Less flexibility with regard to Renovation/ conversion - No freedom in planning/realization - Legal situation unclear (e.g., if PSS provider goes bankrupt) - Desire for ownership of the system - Other aspects
16	How many PSS projects does your organization currently have (please state number and explanation if applicable)?	Free field	
17	How do you assess the market intensity on the PSS market?	Single choice	- Very high - High - Medium - Weak
18	How do you assess the market prospects for PSS offerings?	Single choice	- Very strong growth - Strong growth - Weak growth - No growth
19	Would you be interested in an in-depth study on PSS in the solar industry in Switzerland?	Single choice	- Yes - No
20	Do you have any comments/questions?	Free field	

Appendix B. End-of-life options

Survey question	Percentage of PSS organizations offering this end-of-life option
Transfer of PV system to property owner	100 %
Transfer of PV system to new PSS provider	30 %
Dismantling and disposal by PSS provider	61 %
Dismantling and reinstallation of PV system on new property by PSS provider	35 %
Further options or comments/precisions (please specify)	Contract extension *(mentioned by one organization)*

Data availability

Data will be made available on request.

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