SolarSwift — Accelerating Solar Transition

Expansion of personal competences - MCCf186 / MCCf256 / MCCf356

Course of study	MSc in Circular Innovation and Sustainability
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Abstract

Switzerland needs to increase its solar production from 4TWh today to 34TWh in 2050, in order to ensure the country's energy transition. To achieve this, the decentralized nature of solar production requires the participation of a large proportion of the population and institutions, including property owners, where photovoltaic systems will be installed, and the investors who finance them. As the majority of the population are not experts in solar energy, and don't have the time or money to invest in it, a solution in needed to enable them to simply make their resources available, without other investment. This study therefore looked at ways of facilitating the participation of property owners and investors in the solar transition. As a result of this research, the Solar Swift platform was designed. With an accessible interface and a clear separation of tasks for each stakeholder, it allows them to focus only on the aspects that are most relevant to them, such as making their surface available or investing in solar projects.

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MSc Circular Innovation and Sustainability

Contents

Glossary

PLC	Power Line Communication
GO	Guarantee of Origin
TPO	Third-Party Ownership
F-TPO	Fractional Third-Party Ownership
ROI	Return on Investment
PV	Photovoltaic
O&M	Operational and Maintenance
DeFi	Decentralized Financial
dApp	Decentralized Application
F-NFT	Fractional Non Fungible Token
Surface	Any space where a PV system can be installed (roof, façade, field, mountain, lake, etc.)

Introduction

1 Project’s Goals

This project is an integral part of the Master's program in Circular Innovation and Sustainability at the Berne University of Applied Sciences (BFH), encapsulating three distinct modules—termed "Expansion Modules"—which collectively contribute 18 ECTS over a span of 14 working weeks. These modules are designed to foster knowledge acquisition and creation through transdisciplinary methods (MCCf356), to develop the conception of products and processes related to our project (MCCf186), and to construct a business model for the proposed solution (MCCf256).

Having no knowledge of the Swiss solar industry and ecosystem, a subject that interests me deeply, **the main goal of this project is on a personal level and is to expand my knowledge in this area**, as the name of the modules, "Expansion Modules", suggests. In other words, the aim is to explore the subject from many different angles, rather than to carry out scientific research. If my interest in the subject is confirmed, I will continue with it in a more scientific way for my Master's thesis.

This extension of my knowledge will be through the SolarSwift project, which will be discussed in this report. This research aims to answer the question "**How can we facilitate the participation of investors and property owners in the solar transition in Switzerland?**" and to design a product and its business model to address this issue.

2 Problem Statement

Switzerland generates 61TWh of electricity annually but faces a significant transformation in its energy sector. With a national commitment to carbon neutrality by 2050 (Federal Office for the Environment, 2021) and a public decision to phase out nuclear energy (Federal Department of the Environment, Transport, Energy and Communications, 2017), the country must navigate a changing energy landscape. This transition includes a projected increase in electricity demand by 23TWh to support the electrification of the transport and building sectors (Nordmann, 2019), coupled with the replacement of 23TWh from nuclear sources. Consequently, Switzerland needs to identify new means to produce an additional 46TWh by 2050.

Options for scaling up energy production are constrained. Dams are already operating at more than 90% capacity (Swiss Federal Office of Energy, 2022a), and the country faces limitations in expanding wind power and biomass capacity (Nordmann, 2019). Solar energy emerges as the viable alternative, underscored by the national long-term climate strategy 2050.

The energy production paradigm is shifting from a centralized model reliant on large-scale nuclear, gas, coal, or hydro plants, towards a decentralized network of prosumers (International Renewable Energy Agency, 2019). This shift, while promising, encounters varied and significant barriers—including technical, regulatory, political, societal, managerial, and economic challenges—that slow the transition.

For this project, it was decided to focus on the issues of financing solar energy, and creating demand for new solar projects, recognizing these factors as pivotal in accelerating the solar transition. Economic theory suggests that capital and demand influx can catalyze market development and solution generation across sectors (North, 1990). For example, increased demand for solar energy could lead to improvements to the electricity grid, regulatory adjustments, and the training of new installers.

However, solar energy's decentralized nature necessitates broad participation from individuals, legal entities, and both private and public sectors, to boost funding and demand for new projects. This involves mobilizing thousands of property owners to authorize land use and investors to secure project financing. Yet, widespread participation is hindered by barriers such as reluctance to invest time or money in the solar transition, and a lack of necessary knowledge and network.

Thus, our research question is crafted to address these challenges:

"How can we facilitate the participation of investors and property owners in the solar transition in Switzerland?"

We therefore set out to understand what holds investors and property owners back from participating in the solar transition, then to identify the key features to facilitate their participation, and finally to develop the concept of a project offering a solution to help solve this problem.

3 Solution Overview

Addressing the identified challenges, the SolarSwift platform, along with its innovative business model, has been developed. SolarSwift stands as a pioneering digital platform designed to bridge the gap between property owners, investors, and service providers, orchestrating the establishment of new photovoltaic (PV) systems across Switzerland. It distinguishes itself by offering an intuitive, user-friendly interface coupled with a clear role separation among stakeholders. This design principle allows each party to concentrate on their specific interests, effectively reducing the time, money, and knowledge barriers that previously deterred their participation.

SolarSwift directly tackles the two primary hindrances that have kept property owners from leveraging their solar potential: the complexities of financing and managing PV systems. By assuming complete responsibility for these aspects, SolarSwift enables property owners to effortlessly contribute their property for PV system installation in exchange for a share of the production revenue. Concurrently, the platform opens new avenues for investors by allowing them to acquire ownership stakes in PV installations on others' properties, thus generating income from the electricity produced. This arrangement not only benefits the property owner and investor but also offers the advantage of lowering electricity bills for tenants, creating a win-win-win scenario, for the property owner, investor, and tenant.

Central to SolarSwift's approach is the Fractional Third-Party Ownership (F-TPO) model, which permits multiple investors to collectively own portions of a PV system. This model ensures that property owners can participate without facing financial risks or the burden of system maintenance and reduce risk for investors in case of SolarSwift bankruptcy. Moreover, SolarSwift encourages transparency and third-party participation by being open-source, public, interoperable, and decentralized. This architecture fosters an open market for solar projects, inviting a wide range of service providers, investors, and property owners to engage and exchange information.

Through these strategic measures, SolarSwift aims to streamline the transition to solar energy in Switzerland, making it more accessible, financially viable, and manageable for all involved parties.

4 Paper Structure

This paper is divided into chapters. Some chapters are general and concern all modules, while three specific chapters correspond to each module. Each of these three chapters contains its own methodology and conclusion, in addition to the general conclusion.

Introduction	
Project methodology	Given the size of the project and its distribution over several modules, a certain organization had to be put in place. This chapter explains the research design, the links between the different modules, deadlines, and planning.
Transdisciplinary methods	This chapter presents the transdisciplinary methods used to acquire and create knowledge on the topic, reply to the RQ, and review by peers our solution.
Product and Processes	This chapter presents the concepts of the processes acting within the platform, and the platform itself is also introduced.
Business Model	This chapter presents the business model behind this solution.
Conclusion	This final chapter reviews the work carried out, analyses the results, draws conclusions, present the limitations, and propose further studies.

Project Methodology

1 Work Packages

The management of this work is based on the principle of work packages, which were defined in the first weeks of the project. Each of the three modules has different work packages, which are described in the three Terms of Reference documents, available in Appendix 4.1.

2 Research Design

This study forms an integral part of a project that encompasses three distinct "Expansion Modules": one focusing on transdisciplinary methods (Module 1), another centering on product and process (Module 2), and the final module dedicated to the business model (Module 3). These modules are intricately connected, with certain work packages depending on, or influencing other work packages.

The structure of this research, illustrated in Figure 1, is the following:

1. Starting from no knowledge on the solar industry, new knowledge was acquired through a literature review to better understand the solar industry, and to reply to various questions coming from the design of the business model and the product. In parallel, a stakeholder analysis was conducted (WP1.1, 1.2).
2. During the entire project, 8 Interviews with professionals in the solar industry were conducted, to reply to our research question, and to reply to various questions coming from the design of the business model and the product (WP1.3, 1.5).
3. Once initial knowledge has been created on this research question, the design of a first Business Model (WP3.1, 3.4) and its Market analysis (WP3.2), in parallel with the design of a Product (WP2.1, 2.2) responding to the problem, was carried out. Also, a cost/revenue simulator (WP2.3) has been developed to check the viability and Accounting (WP3.3) of our business model. The questions arising from the design of the business model and the product influenced our literature review and interviews.
4. Our final result was then reviewed during a Focus Group Discussion (WP1.4) including citizens involved in associations, cooperatives, and Swiss politics active in the solar transition.

It should be noted that an iterative research design approach was highly necessary, since the acquisition and creation of new knowledge with transdisciplinary methods was carried out over the entire duration of the project, leading to constant reconsideration and modification of the business model and product.

Precis methodology for each module is described in respective chapters, and more details about the dependencies between each Work Packages, the influences of one WP to another, and the work needed to review a WP are mentioned in the table in annex 4.2.

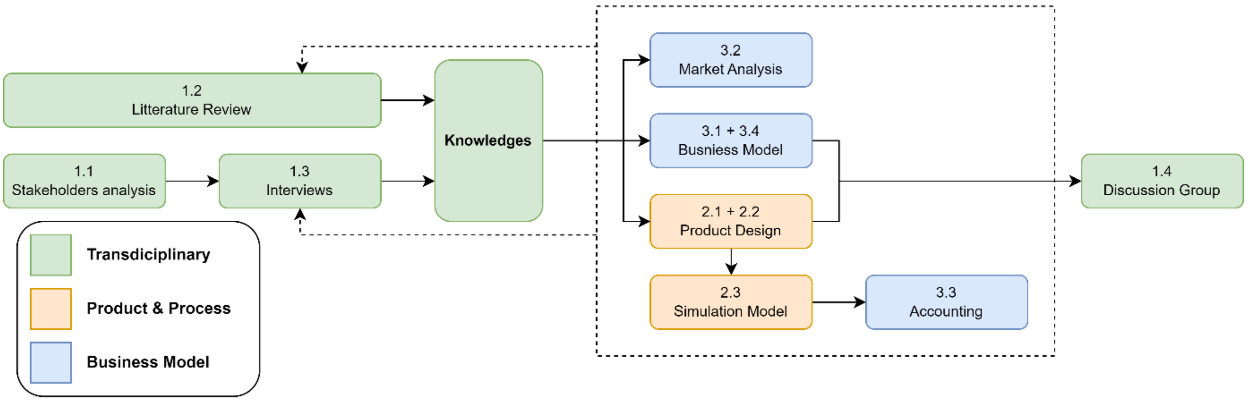


Figure 1 Dependencies between work packages

3 Planning

The planning with deadlines, tasks, workload and worked hours can be accessed here → Planning.xlsx

Official hard deadlines

These deadlines are mandatory to pass the modules:

- 12.10.2023 Submission of ToR.
- 25.01.2024 Oral presentation.
- 04.02.2024 Submission of Reports.

Personal hard deadline:

This deadline is personal, to have time at the end for the oral presentation and reports:

- 14.01.2024 Finish all practical work.

Work packages deadlines:

Table 1 Personal deadlines, for the Transdisciplinary module

	Comment	Deadline
WP1.1 Stakeholders Analysis		29.10.2023
WP1.2 Literature Review	Continuous work until Christmas.	24.12.2023
WP1.3 Interviews	Expected 1 interview every 2 weeks. Last interview maximum before Christmas. One addition week for the retranscription and summary of last interview.	24.12.2023 31.12.2023
WP1.4 Focus Group Discussion	Clarify the purpose for the FGD. Recruit participants. Prapare and host FGD before Christmas.	19.11.2023 03.12.2023 24.12.2023
WP1.5 Data analysis	Finish analysis before the personal deadline.	14.01.2024

Table 2 Personal deadlines, for the Product & Process module

	Definition	Deadline
WP2.1 Process Design	Design of the concept and diagrams The visual mock-up must be finished for the day of the FGD, to validate the concept.	26.11.2023 24.12.2023
WP2.2 Tech & Admin Concerns	Same as the design of the concept and diagrams, as it's done in parallel.	26.11.2023
WP2.3 Simulation Model		10.12.2023

Table 3 Personal deadlines, for the Business Model module

	Definition	Deadline
WP3.1 Value Proposition		14.01.2024
WP3.2 Market Analysis		14.01.2024
WP3.3 Accounting	Tasks related to the simulation model (WP2.3) have the same deadline, as it's done in parallel. Other tasks.	10.12.2023 14.01.2024
WP3.4 Business Model		14.01.2024

Transdisciplinary methods

This chapter presents the transdisciplinary methods used to acquire and create knowledge on the topic, as well as the results obtained. Three sources of knowledge were used. Firstly, to gain knowledge and understanding of the solar industry, the scientific literature on the subject was reviewed. In parallel, a stakeholder analysis was carried out, to understand the ecosystem around the SolarSwift project. This analysis led to 8 interviews with professional stakeholders working in the solar industry, to reply to our research question. Finally, a focus group including volunteers involved in associations, cooperatives, and Swiss politics active in the solar transition was held, to review our solution.

At the end of this chapter, results are discussed in a section. The methodology for each transdisciplinary method is addressed in each section.

1 Literature Review

1.1 Methodology

The methodology chosen for this literature review is to conduct a Traditional (Exploratory) Review, and not a Systematic Review or Meta Analysis. There are several reasons for this choice:

- First of all, the aim of this work is to extend our knowledge of a subject, while developing a project, and not to carry out scientific research on a precise research question, as will be the case for the master's thesis. It is therefore preferable to carry out exploratory learning rather than systemic research on a single research question.
- Secondly, as this literature review is being conducted by someone with no experience in the solar industry, it is necessary to start this literature review with the basics of the solar industry.
- This literature review was carried out before the research question was known, so it does not focus specifically on the research question, but on related topics.

It is important to note, however, that such a literature review may be biased and incomplete, as this is not a Systematic Review.

1.2 Goal of the literature review

This literature review is therefore intended to acquire knowledge, not to answer the research question. It starts with the basics of solar energy, and moves in the direction of the topics we need to know to develop our project. This literature review covers the following topics:

- Overview of the Swiss electricity market today,
- Swiss goal and strategy for energy transition,
- Switzerland's solar potential,
- Challenges and barriers in the solar transition,
- Solar financing methods,
- Solar energy regulation and subsidies,
- Sustainability and the circular economy of solar energy.

1.3 Background on the Swiss electricity market

Switzerland consumes 61 TWh of electricity a year. Only 1.9% of this electricity is generated from fossil fuels, mainly thanks to its mountainous topology, which guarantees substantial hydroelectricity production. In 2022, 52.8% of the electricity produced will come from hydroelectric power (33.5 TWh), 36.4% from nuclear power (23.1 TWh) and 6.8% from solar power (3.8 TWh), with the latter showing a sharp increase of 60% between 2021 and 2022 (Pronovo, 2023a; Swiss Federal Office of Energy, 2022b; Swissolar, 2022a).

Table 4 Share of origin of electricity produced and consumed in Switzerland in 2022. Sources: (Pronovo, 2023a; Swiss Federal Office of Energy, 2022b; Swissolar, 2022a)

	National production	**National consumption** (Import and export included)
Hydropower	52.8% (33.5 TWh)	64.9%
Solar	6.8% (3.8 TWh)	2.4%
Wind	0.2%	3.6%
Nuclear	36.4% (23.1 TWh)	19.6%
Fossil	1.4%	1.9%

1.4 Energy transition

However, a number of factors are putting pressure on Switzerland's electricity supply in the future. Firstly, Switzerland wants to achieve carbon neutrality by 2050, in line with the Paris agreements (Federal Office for the Environment, 2021). However, in 2022, 71% of the energy consumed in Switzerland was non-renewable, mainly due to the transport sector (36.2% of energy consumption) and the building sector (27.6%) (Federal Statistical Office, 2022). To change this, an electrification strategy is being put in place, involving the electrification of heating systems using heat pumps (Swiss Federal Office of Energy, 2023c), and the electrification of transport (Swiss Federal Office of Energy, 2023f).

This strategy would require an additional 6 TWh of electricity to decarbonise building heating, and 17 TWh to decarbonise mobility. Taking into account an increase in the efficiency of appliances, a fall in consumption and an increase in the population, Switzerland's electricity consumption is set to rise by 38% to 84 TWh by 2050, according to the President of Swissolar (Nordmann, 2019).

In addition, the Swiss people decided in 2017 to phase out nuclear power (Federal Department of the Environment, Transport, Energy and Communications, 2017), calling for the 23TWh of electricity currently produced to be replaced by another source.

This means that over the next few years we will have to cope with an increase in demand (+23TWh), along with a decrease in current supply (-23TWh). Switzerland will therefore gradually face a supply challenge of 46 TWh, and will have to find alternative electricity sources.

Solar power is a solution that is widely promoted in the various scenarios of the 2050 energy strategy. This is because our hydroelectric capacity has reached saturation point, and other renewable energy sources such as wind and biomass have far too little potential in Switzerland. According to the Swiss Federal Office of Energy, solar power production should increase from 3 to 34 TWh by 2050, and even 45 TWh according to the President of Swissolar (Federal Department of the Environment, Transport, Energy and Communications, 2017; Nordmann, 2019).

1.5 Solar potential in Switzerland

Solar systems in Switzerland can be installed on a variety of surfaces, such as lakes, mountains or fields. However, as Switzerland is densely populated, the priority is to use the surfaces of buildings to produce heat and electricity from the sun.

The Swiss Federal Office of Energy estimates that Swiss roofs and facades have a solar potential of 50 and 17 TWh/year respectively, based on the results of the sonnendach.ch and sonnenfassade.ch simulators (Swiss Federal Office of Energy, 2019). However, the economic feasibility of all these installations has not been proven.

Meteotest goes into detail about the calculations. While the potential is technically 260 TWh, economic and technical constraints reduce this value to an exploitable potential of 118 TWh. This takes into account the viability of exploitation and the complexity of realisation. Finally, the realistic potential is

45 TWh, considering subjective parameters such as a property owner's unwillingness to install a solar system (Remund et al., 2019).

However, a meta-analysis by the ZHAW considers that this potential can vary greatly depending on the study hypotheses, such as the quality of the roofs, the economic viability of an installation, or the actual exploitable surface area of a roof. Their results show a potential ranging from 16 to 53 TWh for roofs (Anderegg et al., 2022).

As for other types of surfaces, the potential of infrastructures (car parks, noise barriers, etc.) is estimated at 10 TWh, that of alpine surfaces (excluding lakes) at 5 TWh, and that of pastures at 3 TWh (Meyer et al., 2023; Remund et al., 2019).

This brings us to a total potential of 34 to 71 TWh of electricity production from solar energy, which could make a major contribution to the energy transition. In order to achieve this production, and taking into account the seasonal and daily profiles of solar production, as well as assumptions about future storage techniques, the director of Swissolar estimates that 50GW of photovoltaic power needs to be installed by 2050 (Nordmann, 2019), multiplying current capacity by 25.

1.6 Challenges and barriers in the solar transition

When reading the literature, or during discussions with players in the sector, many subjective opinions on different barriers were identified, sometimes contradicting each other. Some barriers concern the global solar transition, others are specific to Switzerland. In this section, a brief summary of the barriers encountered in the literature is presented.

1.6.1 Policy and Regulatory Barriers

Regulatory and Administrative Challenges

In the Swiss system, each institution will request additional authorisations and information when designing a solar system. This means that, according to Stéphane Genoud, professor at the HES-So Valais, every solar project is a pilot project, requiring a lot of administrative procedures, planning and project design. Up to 20 applications and forms have to be filled in, different for each municipality, canton and utility company. This makes it difficult to scale up the creation of new solar projects. In 2022, for a solar installation company, 40% of working time was allocated to installing solar systems, 40% to administrative costs, and 20% to purchasing materials and logistics. If it were possible to allocate 80% of resources to installing panels, and 20% to administration, planning and logistics, the efficiency of installers would be greatly increased (Haeberli, 2022).

Reluctance of municipalities

The decentralised nature of renewable energies, and solar power in particular, means that every municipality is concerned by the subject. Each municipality therefore has to make a decision and establish a strategy for the development of this energy in its area, enabling it to block developments in the event of disagreement. Switzerland's federal system, which gives a great amount of power to the cantons and municipalities, complicates and slows down the development of a unified national strategy for the development of renewable energies, such as solar power (energyscope.ch, n.d.).

1.6.2 Social and Environmental Barriers

Reluctance of the population

In Switzerland, public reluctance is a major obstacle to the energy transition. As mentioned in the section on municipal reluctance, the decentralised nature of renewable energies means that the subject directly affects the entire population. PV production systems will be an integral part of the daily life of the local population, unlike the current power plants, such as nuclear and hydro, which are only present in limited numbers. Issues such as the impact on the landscape, noise, odour and the risk of having a PV system on your own property all contribute to this reluctance (energyscope.ch, n.d.).

Public unawareness and fear

According to Ms Perret-Aebi, a researcher at the EPFL, people see solar energy as something complicated and not yet mature. This is holding them back from considering solar energy for their homes or businesses. However, according to her, the obstacles are no longer technological; we now need to succeed in making people understand that PV is a viable solution and that simple solutions exist (Perret-Aebi, 2021).

Environmental concerns

Environmental concerns about solar systems and their life cycle, which we will see in Section 1.10, could have an impact on the enthusiasm for a solar transition. But above all, the impact of the land use of large solar projects, for example in the Alps or on lakes, is an issue that is often debated, slowing down their development. Valais, for example, rejected a decree on alpine solar parks in 2023 (Swissolar, 2023b).

1.6.3 Technical and Infrastructure Barriers

Geographic limitations

Not all regions of the world benefit from sufficient sunshine, which limits the effectiveness of solar energy in these areas. Switzerland receives a marginal amount of solar irradiation, from 1200-1400 kWh/m2 per year, but this is still of interest for solar production. By comparison, Spain receives 1600-1800 kWh/m2, while Saharan Africa receives more than 2200 kWh/m2 (Prăvălie et al., 2019).

Grid management

The decentralisation of production with solar energy, as well as the increase in electricity consumption, is putting pressure on the infrastructure of the current electricity grid, which needs to be greatly developed, being designed for centralised production. In Switzerland, Swissgrid and the local grid operators are aware of this problem and are already working on changes to the grid to adapt to tomorrow's consumption and production. These developments include the creation of smart-grids, micro-grids and dynamic pricing by region and by time (The Federal Council, 2022).

Delays in the supply chain

Given that the photovoltaic sector is growing rapidly, and that market demand can fluctuate greatly from one year to another, waiting times and delays in the delivery of equipment can be significant. The shortage of manpower we will see also increases the waiting time for the installation of a solar system (Haeberli, 2022).

Complexity in solar project planning and creation

Today's solar market requires the property owner to be interested, invest time, educate themselves and make technical decisions about the installation of their solar system (Franco & Groesser, 2021). Although installers are increasingly providing turnkey solutions, the initial investment by the property owner still requires a fair amount of motivation (Karakaya & Sriwannawit, 2015).

1.6.4 Economic and Financial Barriers

Missing workforce

There are currently 13,000 people working in the solar sector in Switzerland (IEA PVPS, 2022). However, in order to meet the Confederation's targets, 50-80,000 people would need to work in this field (RTS, 2022). The sector requires a wide range of skills, such as roofing, electricians and tinsmiths, although no training existed at the time. This is changing, however, with the arrival of the first apprenticeships in Western Switzerland in September 2023 (Groupe E, 2022), and in German-speaking Switzerland in September 2024 (Swissolar, 2023a).

Closed electricity market

The electricity market in Switzerland is closed to prosumers. They cannot sell their electricity directly to another consumer at the market price. Instead, they have to go through the local utility, which sets its own buy-back prices. Given that the peer-to-peer market price would be much more advantageous financially than resale on the grid, opening up this market between prosumers would provide an incentive for the solar transition (Haeberli, 2022).

High up-front costs

The economic barrier most often discussed in the literature often refers to the high up-front costs required to create a solar system (Karakaya & Sriwannawit, 2015). This concerns private individuals who do not have the means to invest on their roof, a new building project that often abandons the installation of solar panels to fit within the building's budget, or a public institution that does not include this type of installation in their budget.

Lack of investments

Investment in solar power may not be very attractive at present. The high initial investment cost is said to be irrecoverable, because it only loses value over the years. Investors must therefore rely solely on production revenues to generate profits, which are currently unstable due to fluctuating electricity market prices and uncertainty about future regulations (Nordmann, 2019). Periods when the price of competing energies rises have seen investments in solar power rise, such as during the energy crisis of 2022.

1.7 Financing new solar systems

As we will see in the conclusion, for this project we have chosen to focus on the problem of investment in solar energy and the availability of surface area in order to increase demand. This is because economic theory shows that the influx of capital and demand in a market, in this case photovoltaics, will drive its development, and consequently the development of technical and regulatory solutions. The opposite will not be the case (North, 1990).

In order to finance the large number of solar systems that need to be installed, innovative business models need to be created. The state cannot finance the entire transition on its own. On the contrary, it is essential that other types of investors, such as private companies, households and associations, also participate in this transition, while also gaining from it (Bankel & Mignon, 2022).

This section delves into the various existing business models for financing solar projects, which meet the diverse needs and preferences of property owners, the specificities of the installations, and the interests of investors. Our analysis will particularly focus on the Third Party Ownership (TPO) model, given its relevance to our project. We identify the following financing models as part of our study (Franco & Groesser, 2021; IEA PVPS, 2022):

1.7.1 Self-financing

The property owner finances the solar system out of his own resources and becomes the owner, either directly out of his own savings or indirectly through a bank loan.

1.7.2 Third Party Ownership - Power Purchase Agreements

With the TPO model, a third party, often a single entity such as an installer, finances the PV system on a landowner's property, and becomes the owner of the PV system. It then takes charge of all the work and costs, in exchange for rights to the electricity produced by the PV system. This electricity will be sold back to the property owner and to the grid. The buy-back price to the property owner may be fixed for 20 to 30 years, or may depend on the market. Sometimes, a minimum quantity of self-consumed electricity can be fixed in the contract, reducing the risk for the investor. Companies implementing this business model transform any surface into a service. Users only buy electricity when they need it, at a reduced price (Overholm, 2015). In America, the creation of this business model has opened up the solar market to younger, less affluent and less educated people than those who normally buy photovoltaic systems, giving the market a boost (Drury et al., 2012). This model is currently the most widespread in the US, and is starting to arrive in Europe. It eliminates several major barriers to PV adoption, including initial financing, initial learning costs related to the complexity of the technology, initial time investment for planning, design, and administration, fear of solar system risks, and investment required for operation and maintenance time and costs (Overholm, 2015). Because of its simplicity, reduced barriers, and lack of risk and liability, the TPO model is suitable for more customers than the traditional ownership model (Drury et al., 2012). However, the biggest challenge for all companies implementing this model, interviewed in a study by Harald Overholm, was finding funding. As one CEO said, "Managing a TPO business is not a technical business, it's a banking business" (Overholm, 2015).

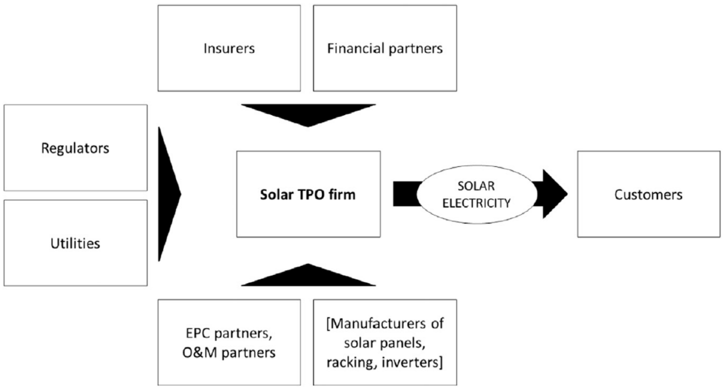


Figure 2 TPO ecosystem (Overholm, 2015).

1.7.3 Third Party Ownership – Leasing

Here, a third party also finances and owns the solar system, but the property owner pays a fixed monthly price to use the PV system at will, regardless of how much electricity is consumed. At the end of the contract, the owner can buy back the system at a preferential price.

1.7.4 Financing through public fund (utilities or municipalities)

Municipalities and especially utilities finance large numbers of solar systems for their own portfolios. This may be on land they own, or on surfaces they lease. They are now actively integrating this sector into their strategy.

1.7.5 Community – Subscription

With community financing, various people participate in the financing of a solar project. These projects can be local, such as in a residential area, or further afield, in a PV park for example, or on a large roof of a public building. It can be in the form of a subscription, where the community pays monthly for the right to use the electricity, similar to the leasing principle seen above.

1.7.6 Community – Solar Cooperative

Here the system is based around a cooperative. A group of citizens, called cooperators, will buy shares in it, often at 500CHF per share. The cooperative has a committee and each member has one vote. The money from the shares will be used to finance solar projects. The solar system and the income from production will belong to the cooperative, and this income will be used to finance other projects, or to pay dividends to the members of the cooperative. Cooperatives have a strong community approach, limited in size to a small region or town. 85% of cooperatives are only active in one municipality (Klopfstein & Wachtarczyk, 2023). This means that a large number of cooperatives are needed. In Switzerland, more than 140 solar cooperatives exist, with an average of 93 members (Klopfstein &

Wachtarczyk, 2023). Cooperators generally do not expect any ROI, and sometimes work for free on the cooperative's projects.

1.7.7 Community – Crowd funding

Here, a call for funds is made to a community in order to finance a solar project. The community does not become the owner of the project, and will not get back its initial investment, but can sometimes be rewarded with anything from a simple thank you to a share of the production revenue.

1.7.8 Community – Crowd lending

In this case, a citizen provides money over a given period to a company that will finance solar projects. They will receive annual interest on their loan, and will be repaid at the end of the contract. Some cities are introducing such a system, such as the city of Fribourg with the public company Particip SA (Particip SA, 2023). Citizens can then lend money over 10 years to the company, which will finance solar projects.

1.8 Other source of income

As part of this project, it is important to understand the possible sources of income for a PV system. In addition to the sale of the electricity produced to the occupier and the utility, there are other sources, which are presented here.

1.8.1 Electricity labelling and Guarantee of Origin

The principle of guarantees of origin is an important one in our project, as it can be a source of additional income. Since 2006, any electricity supplier with an installation of more than 30 kVA has been required to generate and sell a guarantee of origin. Installations with a lower output are free to do so. This contains information such as the type of energy source used to produce the electricity. This makes it possible to identify the origin of the electricity, and thus to trace the type of electricity produced in order to promote renewable energies (Swiss Federal Office of Energy, 2021). These guarantees are not linked to the corresponding physical electricity, and can therefore be sold anywhere. In fact, Swiss Guarantees of Origin are compatible with the corresponding European system, the European Energy Certificate System (Pronovo, 2023b). They can therefore also be traded on the European market. They are bought by utilities throughout Europe, so that they can prove to their customers the origin of the electricity they supply. They can therefore generate income by selling them. Generally they can be resold directly to the local utility at a fixed price, or they can be resold on third-party markets, where the price may be more attractive.

1.8.2 Subsidie

Another important point to be aware of is the Swiss subsidy system for solar energy. In 2023, Switzerland has released CHF 600 million to encourage photovoltaics (Swiss Federal Office of Energy, 2022c). Several subsidy systems exist (Pronovo, 2023c):

Feed-in remuneration (SRI)

This system paid electricity producers according to their production, every 3 months. This system was discontinued in 2022 due to the excessively long waiting list for subsidy applications. This was due to the system's excessive administrative burden.

Single subsidy for small photovoltaic system (PRU)

For solar systems of less than 100kWp, this subsidy applies, and is awarded only once at the start of the project. For solar systems above this power, this subsidy can still be requested for a system equivalent to 100kWp.

The amount of the subsidy is calculated as follows: a basic amount of 200CHF (only for small systems of 2-5kWp), then an amount per kWp installed of 400CHF/kWp. This subsidy will cover a maximum of 30% of the cost of the PV system.

Single subsidy for large-scale photovoltaic system (GRU)

The same principle applies as for the previous subsidy, only for systems over 100kWp. An amount of 330CHF/kWh is paid out.

Single subsidy for small photovoltaic system without self-consumption (RUE)

A subsidy of 450CHF/kWp is paid out for solar systems of less than 150kWp without self-consumption, i.e. feeding all the output into the grid, up to 60% of the initial cost of the installation.

Auctions for large-scale photovoltaic system without self-consumption

For solar systems over 150kWp without self-consumption, an auction system will be introduced every quarter, with a variable price per kWp. For the first quarter of 2024, the subsidy will amount to 640CHF/kWp, for a total of 60MWp that can be subsidised.

Angle bonus

A bonus of 250CHF/kWp is paid for installations with an angle of 75° or more. This subsidy encourages winter production.

Altitude bonus

A bonus of 250CHF/kWp is paid for installations at an altitude of more than 1500m, outside any building zone and without own consumption. This subsidy favours projects in the Alps.

Municipal and canton subsidies

Some municipalities and cantons have added their own subsidy systems. These cannot be analysed in detail here, due to the number of communes and the differences between the subsidy systems.

1.9 Sustainability, Circular economy, and End-of-life of PV panels

An important point to bear in mind is the environmental impact of solar panels. The aim is not to create an environmental disaster by massively pushing the installation of new solar systems.

Generally speaking, the emissions of electricity produced by photovoltaics, taking into account its entire life cycle, are low. It is of the order of 14-73 gCO2eq/kWh, well below oil (742 gCO2eq/kWh), or the Swiss electricity mix (112 gCO2eq/kWh) (Tawalbeh et al., 2021; VSE, 2023).

In terms of raw materials, the environmental and social impact, although not negligible, is acceptable compared with other electricity generation technologies. The basic elements - glass, which comes from sand, silicon, the second most abundant element on our planet, as well as aluminium and copper - are accessible under acceptable environmental and social conditions. Doubts remain, however, about certain rare metals, present in small quantities in panels and electronics, and requiring further research (Tawalbeh et al., 2021).

However, the energy required to produce PV modules is substantial, particularly for silicon wafers, the central components of PV modules, and for the aluminium frame. Most of this energy currently comes from fossil fuels, with 61.8% from coal and 8.3% from gas. This is due to the fact that 96.8% of wafers and 74.7% of modules are currently imported from China, a country that mainly uses fossil fuels. On the other hand, these production emissions are generally offset in 4 to 10 months of electricity generation, whereas this will provide emission-free energy for more than 30 years (IEA, 2021).

As far as end-of-life is concerned, little is known for the moment, due to the youth of the market. However, this is an important point to consider, as 9 million tonnes of waste from the photovoltaic market could be produced in Europe by 2050 (Vellini et al., 2017). However, provided that the end-of-life phase is properly managed, its impact would be acceptable. A solar panel can theoretically be 95% recycled, with the main components being aluminium, which can be reused or recycled easily, silicon and glass, two inert minerals that can be reused in construction or buried without much impact, and copper, which can also be recycled (Swissolar, 2022b). Doubts remain, however, regarding electronic devices such as inverters, and certain parts of the panel, containing certain rare materials in small quantities, the consequences of which are little known and recycling of which is technically and economically impossible (Vellini et al., 2017). It is important to note that the infrastructure for managing the end-of-life of solar modules is currently inadequate or even non-existent in Switzerland. Major efforts need to be made in this area (Franco & Groesser, 2021).

Finally, in general terms, there are still many challenges to integrating solar systems into a circular economy. Panels and inverters are not currently designed to be part of a circular economy. Dismantling, repairing, renovating, reusing and recycling them is currently a complicated, if not impossible, task (Franco & Groesser, 2021). Digital solutions such as product passports, information sharing and a panel resale platform could contribute to the circular economy in this field (Boukhatmi et al., 2023).

2 Stakeholders’ analysis

2.1 Definition of a Stakeholder

In the context of any project, the term 'stakeholder' encompasses a wide range of individuals and groups that interact with, influence, or are influenced by the project within its social and economic environment. These actors may be directly involved in the project or may exert an indirect impact through their status, resources, or interests. Stakeholders are identified as those who possess a potential interest in the project and its objectives, motivated by the desire to safeguard these interests and prevent any potential losses. The unique combination of material resources, social standing, and knowledge that stakeholders bring to the table grants them considerable power. This influence is pivotal in shaping the project’s direction, including its design, planning, and execution phases.

2.2 The Importance of Conducting a Stakeholder Analysis

A Stakeholder Analysis helps to identify actors relevant to a project and to get to know their perceptions, interests and influence. Each party involved has a different perception and perspective about their environment. Persons act upon their world, and try to change it. When changing it, they are in turn changed by the consequences of their action. As the goal of our project is to change part of our environment, it's crucial to understand the different actors, their perception of the project and how this one will change their own environment. As the changes will impact differently each Stakeholder, they adopt different positions towards our objectives.

With a good understanding of the economic landscape, collaboration between Stakeholder leading to positive outcomes for every side is possible.

To a small extent, the project's impact will shift power and market share in the economic landscape, from near to far from the project. So, the impacted actors will face up to these changes and in turn take measures that will impact us.

A profound understanding of the actors and their interests, goals and relationships is therefore crucial for planning and steering a project. Stakeholder analysis can be the backbone of a cooperation strategy and have to be done at the beginning of the project, and updated regularly.

2.3 Methodology

The following stakeholder analysis is based on the "STAKEHOLDER ANALYSIS" tool published by the Swiss Agency for Development and Cooperation in 2011 (Federal Department of Foreign Affairs, 2011). This tool was originally created by the Federal Department of Foreign Affairs to analyze stakeholders with a view to social and economic development and political cooperation, not directly for stakeholder analysis of an entrepreneurial project. For this reason, certain modifications to the methodology have been made and will be described, where applicable, at each step.

2.4 Step 1: Scope of the Mapping

In conducting this stakeholder analysis, it is important to define the scope and limitations of this initial mapping process. The following points provide an overview of the scope of this analysis:

1. This is the initial mapping of stakeholders for the project. It is recognized that as the project evolves, the stakeholder landscape may change. Therefore, this mapping serves as a foundational step and should be subject to recurring updates and improvements as the project progresses.
2. The current mapping has been carried out by the author independently, without the involvement of a well-performing and interdisciplinary working group. It is essential to acknowledge that this individual perspective may introduce biases and limitations in the stakeholder map. Future iterations of this analysis should aim to involve a broader range of perspectives to ensure a more comprehensive and objective understanding of stakeholders.

3. The primary objective of this mapping is to identify and categorize stakeholders into four main groups: veto stakeholders, key stakeholders, primary stakeholders, and secondary stakeholders. The analysis focuses on the identification of these groups and their relevance to the project. Detailed assessments of the interrelationships, strengths, influences, resources, and networks of these stakeholders are beyond the current scope of this analysis.
4. It is important to note that this stakeholder analysis is based on market conditions as of Q3 2023. Given the dynamic nature of the solar industry and the rapid changes it is currently undergoing, it is advisable to repeat this stakeholder mapping process in approximately one year's time to ensure that the analysis remains relevant and accurate.

2.5 Step 2: Stakeholder Identification

First, it is necessary to identify and list all the stakeholders relevant to the project. It's also interesting to draw a small profile of each stakeholder to make a first statement regarding the relative importance of certain stakeholders for the project. To get this overview, the method of the 4 A's can be used:

1. **Actor**: What is the actor's name, what is his function?
2. **Arena**: In what field is the actor active, where is he present for our project?
3. **Agenda**: What is the actor's mandate, what is his mission?
4. **Alliances**: With which other actors is the actor allied, how is he interconnected?

As explained in the point 3 of section 2.4, the "Alliances" between stakeholders is beyond the current scope of this analysis and will not be discussed.

The stakeholders have been classified in 8 different "Arenas" (categories), based on the field in which the stakeholder is present for our project:

1. Investor
2. Property owner
3. Service provider
4. Occupant
5. Competitor
6. Supporter to the project
7. Regulatory Bodie
8. Others

A stakeholder can be categorized in multiple arenas. For example, a school is a surface owner, in order to place a PV system on its roof, but it's also a possible investor funding part of its own PV system.

The Figure 3 list the identified stakeholders (Actor), and their category (Arena).

The categories of investor, property owner, service provider and occupier are the most important for a project like ours (coloured in Figure 3). We will not go into the mission (agenda) of each stakeholder in this report, as 55 have been identified. We will only describe and discuss the interests of these 4 main categories.

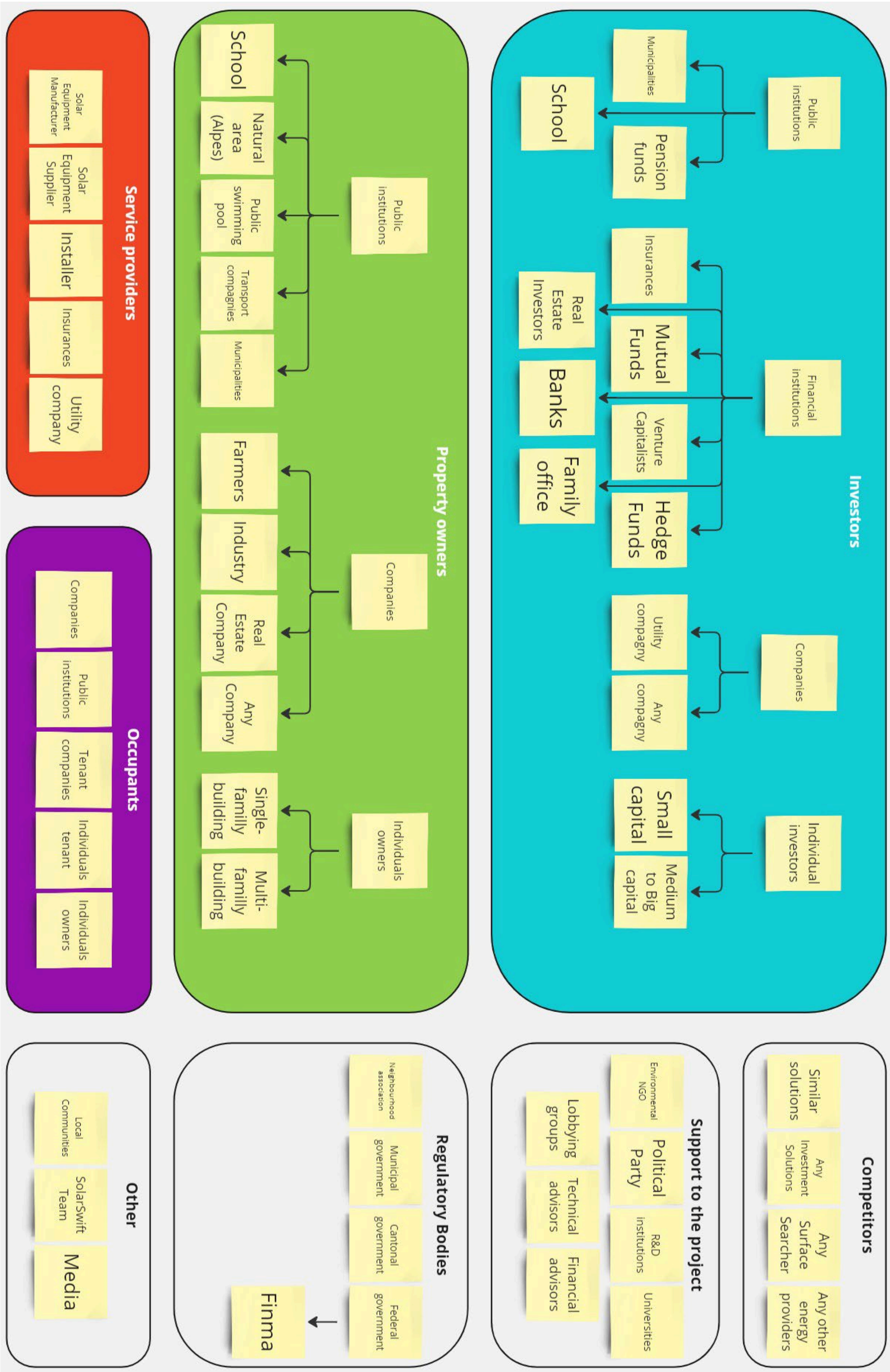


Figure 3 Stakeholders identification

2.5.1 Investors

Investors are the natural and legal persons who will buy a share in a solar system, become its owner and receive the income from it.

Who are the investors ?

In today's economy, there are many different types of investor. Figure 3 provides an overview of those of interest to us. First of all, we have public institutions, such as municipalities or pension funds, investing public money in the local energy transition. Then there are the financial institutions, such as banks, insurance companies, investment funds, family offices and so on. Companies also finance solar projects. These are mainly public utilities, but can also be any type of company. Finally, there are individuals who want to invest their savings.

What are their interests ?

Our interviews showed that financial institutions, companies and, to a lesser extent, individuals, all have a financial interest. However, it is not present for public institutions. There is also a desire to make investments that will contribute to the energy transition, with a sustainable impact. However, no correlation was expressed between this interest and the type of investor. This interest depends on the values of each individual and institution, and not its type. Private companies and financial institutions are also interested in receiving Carbon Certificates, which they can then use to communicate their environmental commitments.

2.5.2 Property owners

Property owners are the natural or legal persons who can decide whether to accept the installation of PV systems on their property, and who receive a share of the income generated for the rental.

Who are the surface owners ?

Their type can be very diverse, and broadly consists of any type of property owner. Our stakeholder analysis shows that we have, for example, public institutions, which generally own quite a few large, electricity-intensive buildings, such as schools, swimming pools, public transport company buildings, etc. Any company owning property can be of interest for us, such as farmers, industries, real estate companies, etc. Finally, individual owning a single or multi-family house can also host a PV system.

What are their interests ?

The interests of property owners in a solar system have been classified into three categories. Firstly, making their surface area available enables them to earn income by renting out the roof (1). Secondly, installing a PV system allows the owner to significantly reduce the electricity bill of the building's occupant (2), as the solar-generated electricity is sold to the occupant at a lower price than the grid price. If the owner is himself the occupier of the property, he will therefore see his bill reduced. If the owner rents out the property, the occupants' charges will fall, allowing the owner to increase the rent. The final benefit is an ethical one, for owners seeking to participate in the solar transition (3).

2.5.3 Building occupant

“Occupant” is the term given to the legal or natural persons living or working in the building where the PV system is located. They may be tenants, or directly the property owners.

Who are the surface owners ?

Our stakeholder analysis shows that we can have individual private owners, tenants in flats, business owners, business tenants, public services, or even no occupiers if the PV surface is not connected to an occupied building.

What are their interests ?

The interest in solar power for occupiers of a property is that they can buy PV electricity at a price lower than the grid price.

2.5.4 Service provider

Service providers are any companies or institutions required for the design, installation and operation of a PV system, and for the smooth running of our project.

Who are the service providers ?

We have PV panel manufacturers and installers, essential to the design and installation of PV systems. Insurance is also very important in our case, as the other stakeholders don't have to pay for the operation and maintenance of the PV system. Finally, the more than 600 public utilities (Swiss Federal Office of Energy, 2023d) will be needed to buy back surplus electricity.

What are their interests ?

Suppliers' interests depend on their respective business models. It may be linked to the economic growth of their business, by increasing their number of mandates, for example for installers or insurance. It may also be a legal obligation, as in the case of public utilities.

2.6 Step 3: Stakeholder Classification

The listed stakeholders should then each be assigned to one of the four groups, namely veto stakeholders, key stakeholders, primary stakeholders, and secondary stakeholders. Here, stakeholders were classified only into Key stakeholders, and Secondary stakeholders, for the sake of simplicity.

The classification between key stakeholders and secondary stakeholders is a result of interviews and market analysis. For example, some property owners, such as public institutions will be more interested in our project than individual property owners. This classification is exposed in detail the section "Customers Segment and Relationships" of the Chapter Business Model, and illustrated in Figure 4.

2.7 Step 4: Stakeholder Mapping

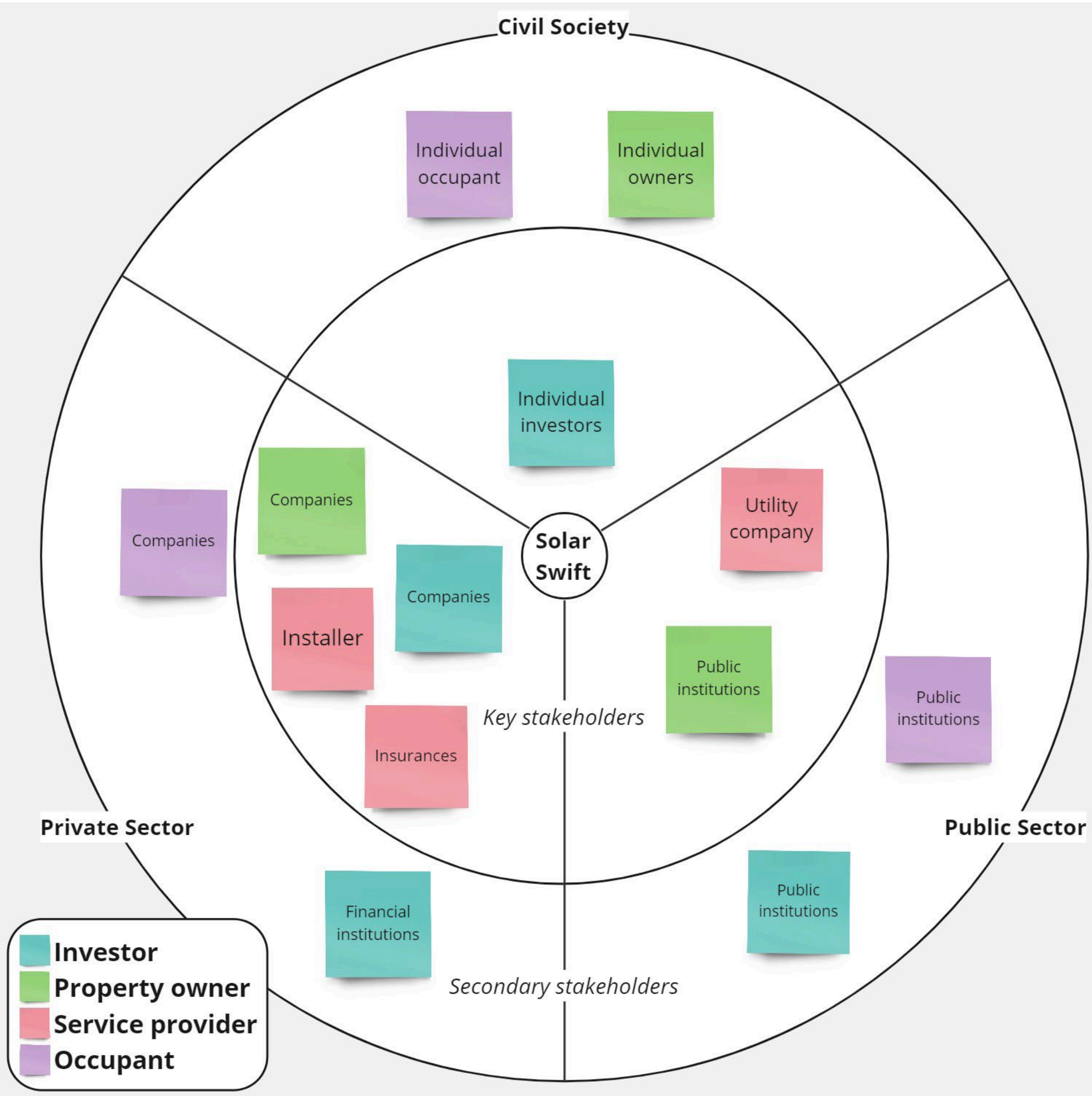


Figure 4 Stakeholders mapping, classified between key and secondary stakeholders, and grouped into Private, Public, and Civil Sector.

2.8 Step 5: Gender Trap

Given that this stakeholder analysis is for entrepreneurial purposes, and not for a social reform project, the step concerning the identification of gender gaps in our stakeholder analysis will not be carried out.

2.9 Step 6: Stakeholder Relationships

As explained in the point 3 of section 2.4, the relationships between stakeholders is beyond the current scope of this analysis and will not be discussed.

2.10 Step 7: Stakeholder Map Review

The stakeholder map should have been presented to several key stakeholders during the WP1.4 Focus Group Discussion for feedback. However, it was subsequently decided not to do so, to focus on more important topics during this discussion.

3 Interviews

As part of this project, interviews are an essential element in the acquisition and creation of knowledge about the solar energy sector, with stakeholders representing different sectors, in order to understand the challenges, interests and points of view of each stakeholder, as well as the functioning of the Swiss photovoltaic ecosystem. As I am not personally from the solar energy sector, interacting with experts who have been working in this field for many years provides invaluable knowledge. In fact, reading the literature and learning online alone have their limitations, such as the risk of getting stuck on subjects that are far from reality, and of having information that is not recent and local.

Also, these interviews provide an initial understanding of the Swiss solar market, enabling us to identify needs and reorientate the project's business model in line with the market. However, no interviews will be conducted with non-initiated private individuals, such as potential end customers. This is because the interview sample would be too small in the time available for the study to have a meaningful result and representation of end-customer views. It is therefore preferable to talk to professionals who are already in contact with dozens of customers similar to our own, in order to get their feedback.

3.1 Goal of interviews

The primary goal of these interviews is to answer the research question **“How can we facilitate the participation of investors and property owners in the solar transition in Switzerland ?”,** to identify the key features our product and business model should include to help this transition.

Another question that was asked, and whose answers turned out to be decisive in the choice of our product design and business model, was **"Is it easier to find investors for solar energy, or property owners willing to make their land available?”.** This question helps us to understand the state of the market in terms of supply and demand from investors and property owners.

Other questions were also asked in some of the interviews, specific to issues identified during the product design and business model phases, such as:

- « What is a fair depreciation model for a PV system ? », to choose our depreciation model.
- « What growth are you seeing in the market, and who are your typical customers? », to analyze the market.
- « What is the interest of investors and property owners in the solar transition? », to define our value proposition.
- « Which stakeholders are interested in a Third-Party Ownership business model? », to determine our target customers.
- “Do you think it's possible to generate carbon credits by financing solar projects in Switzerland?”, to consider this additional possibility of income.
- Etc.

3.2 Methodology

The interviews are one-to-one and are conducted in a semi-structured manner. An interview guide is written in advance with a short biography of the interviewer and the corresponding questions. These can be found in the appendix. Open questions are asked, and follow-up questions are sometimes asked. If the participant authorises it, a recording and transcript are made, which can be found in the appendix. The interviews are conducted by a single interviewer, and take place in various locations, whether face-to-face, by telephone or by video. The interviews are not coded, but a summary of each one with the topics covered is provided in the appendix. Finally, these interviews and their results are discussed in the “5 Results and Discussion” section.

It should be noted that for the spontaneous telephone interviews, the method is unstructured, and transcription is not possible. As a result, only a written summary of the interview is made, either following or during the call.

3.3 Participant selection

As described at the beginning of section 3, only experienced professionals with advanced knowledge of our field of interest were selected. Their choice was made on the basis of whether their contact could be obtained, the knowledge they could contribute, and their availability. They come from a variety of disciplines and occupations, so as to have different points of view.

The list of 8 interviewees, spread over 9 interviews, is provided in Table 5. This summarises practical information about the interviews conducted, such as the name of the interviewee, their position, the date on which the interview was conducted, its location, the language, and finally whether it was recorded and transcribed.

A presentation of the interviewees, and the reason for their choice, is presented in the remainder of this section.

Table 5 Information about conducted interviews.

	Name	Fonction	Date	Time	Location	Lang.	Trans.
1	**Ässia Boukhatmi & Roger Nyffenegger**	Research Associates at BFH in the solar industry	09.10.2023	1h	Teams	En	Yes
2	**Aurel Schmid**	CEO of Solarify	16.10.2023	1h	Phone	En	No
3			15.11.2023	30min	Teams	En	Yes
4	**Emanuele Cimino**	Customer Acquisition in the Oikos Solar NPO	22.11.2023	25min	Teams	En	Yes
5	**Jean-Louis Guillet**	Fonder of Soleol SA, installation compagny	29.11.2023	1h20	Estavayer-le-Lac	Fr	Yes
6	**Virginie Cavalli**	Lausanne Municipal Councillor (Vert'libéraux)	11.12.2023	15min	Phone	Fr	No
7	**Francois Calame**	Solar project manager at Eco Energie Etoy	11.12.2023	15min	Phone	Fr	No
8	**Rianne Roshier**	Project manager at Seeland Solar Platform	11.12.2023	15min	Phone	Fr	No
9	**Christoph Giger**	Director at Seeland Solar Platform	10.01.2024	50min	Teams	En	Yes

3.3.1 Ässia Boukhatmi & Roger Nyffenegger - Research Associate at BFH in the solar industry

A. Boukhatmi & R. Nyffenegger are two young research assistants to Professor Stefan Grösser. They were chosen for their work in the field of solar energy, in particular their collaboration with the European Union on the CircuSol project, a project to develop a circular business model for solar energy. The aim was to gain an initial understanding of the solar market and to get their feedback on my project.

3.3.2 Aurel Schmid - CEO of Solarify

Aurel Schmid is CEO of Solarify, a company that enables private individuals to purchase a photovoltaic surface and receive a return on their investment. He was chosen because the business model used by Solarify, Third Party Ownership (TPO) financed by private individuals, is similar to that of our project. His knowledge of the market, the barriers and his advice can be invaluable. He was first interviewed by Julian Kölbler, a professor at the University of St. Gallen, an interview I was able to attend and which answered many of my questions (A. Schmid, personal communication, October 16, 2023). I then interviewed him myself in a second interview.

3.3.3 Emanuele Cimino - Customer Acquisition in Oikos Solar

Emanuele Cimino is a student at the University of St. Gallen and works on customer acquisition at Oikos Solar. Oikos Solar is a non-profit student association whose aim is to finance solar projects with capital from investors. They are currently focusing on the possibility of working with financial institutions such as family offices, banks and 2nd pillar funds. They also handle all the operational aspects of setting up solar projects. Their economic knowledge and their business model, which is similar to that of our project, are interesting for us.

3.3.4 Jean-Louis Guillet - Fonder of Soleol SA

Jean-Louis Guillet is the founder of Soleol SA, a leading solar installation company in the French-speaking part of Switzerland, offering a complete range of solar energy services, including financing, installation, monitoring, maintenance and more. He was chosen for his expertise and experience in the solar market, particularly as an installer, as well as for his use of the TPO model, which is close to the one proposed in our project.

3.3.5 Virginie Cavalli - Lausanne Municipal Councillor (Vert'libéraux)

Virginie Cavalli is a lawyer and a Lausanne municipal councillor for the Vert'libéraux, who is very active in the field of energy transition in French-speaking Switzerland. She was contacted as a politician and co-founder of the Cellios solar cooperative, which operates in French-speaking Switzerland. As a reminder, a solar cooperative allows a community to pay for shares in the cooperative, which are used to finance solar projects. She was therefore selected for her political knowledge, and because the cooperative business model is close to the one proposed in this report.

3.3.6 Francois Calame - Project manager at Eco Energie Etoy

Francois Calame is a PV installer and entrepreneur in the French-speaking part of Switzerland, and co-founder of several companies, associations and cooperatives involved in solar energy. He was approached because of his knowledge of the solar economy in Switzerland and Europe, as well as his work as project manager for the Eco Energie Etoy solar cooperative, a cooperative with over 700 members specialising in agricultural PV projects.

3.3.7 Rianne Roshier - Project manager at Seeland Solar Platform

Rianne Roshier is a project manager and contact person for the platform promoting solar energy in the Seeland region, supported by public authorities in the region. She was called in as the first contact person for the Seeland Solar Platform, and her knowledge led to an interesting telephone interview.

3.3.8 Christoph Giger - Director at Seeland Solar Platform

Christoph Giger is the director of the platform promoting solar energy in the Seeland region, supported by public authorities in the region. He was contacted as part of their new "Energy Sharing" test project, which is very similar to our project. It's designed to connect property owners who want to make their roofs available for solar power generation with third parties who want to invest in solar energy. The project is supported by the canton of Berne and the Swiss Confederation.

3.4 Interview guide, summary, and transcript

The interview guide, written transcripts and summary of each interview are available in the appendix.

4 Focus group discussion

The focus group was conducted at the end of the process of co-creating knowledge and designing the platform, in order to receive feedback on it from initiated participants from different disciplines. This discussion also served to receive more input concerning our research question.

4.1 Goal of the focus group discussion

The primary aim of this focus group is to present my problem, and then my platform, to a group of stakeholders from different disciplines, in order to gather their opinions on this solution. Before doing so, we also go back over the questions discussed during the various interviews, available in Section 3.1 of this chapter, in order to share knowledge on these questions between the participants present.

4.2 Methodology

This discussion group follows the "Multi-stakeholder discussion group" methodology proposed by Patricia Fry (Fry, 2021). It is described as follows: "The multi-stakeholder discussion group brings together representatives from science, civil society, the private sector and the public sector to work on the development and implementation of a project."

This methodology is normally used for the entire creation process of a project, from the idea, through development, to implementation, requiring several meetings. In the context of this work, the discussion group will only meet once, due to the logistical difficulties of bringing everyone together several times. As seen in the previous section, it will therefore focus on knowledge sharing and feedback on the proposed platform.

The following steps were taken to set up this discussion group:

1. Identifying potential participants of interest to the project, through stakeholder analysis.
2. Selecting a facilitator to facilitate and record the social interactions between participants. Ultimately, this was not possible.
3. Find, contact and invite participants.
4. Organise the meeting. Define the goal, prepare the questions (discussion guide available in appendix), a presentation (slides available in appendix), define a didactic means of gathering ideas (mind-map on Miro used), define a date, define the location (Teams).
5. Meet the participants.
6. Draw up a summary of the meeting, by theme (available in the appendix).
7. Record the participants' interactions, the atmosphere and the social relations observed during the discussion.
8. Incorporate what is learned from this focus group into the final discussion in section 5.

This focus group will have the following characteristics:

- Number of leaders: 1
- Number of external participants: 8
- Language: French
- Duration: 1h30
- Location: Teams (to facilitate the participation of people from all over French-speaking Switzerland)
- Transcription : Yes

4.3 Participant selection

The participants in this discussion group are 8 members of cooperative committees, associations and political groups active in the field of solar energy.

The choice was made not to select participants who were not experts in solar energy, nor professionals. The first choice was made because the project is not yet sufficiently advanced to benefit from feedback from ordinary users, and it is preferable to use our resources to talk to experts with several years' experience in the solar industry, who can teach us more. The second choice is made for logistical reasons. It will be more difficult to find a common schedule between several professionals than between people in the voluntary sector. What's more, at this stage of the project, if contact is made with a professional, it's preferable to interview them one by one to get the most out of the exchange.

The search for participants began with solar cooperative committees in French-speaking Switzerland, because their business model is close to ours. In a solar cooperative, a community of people finance solar projects on the surface area of another owner, which is managed by the cooperative. They therefore face the same stakeholders and challenges as our project, whether it's finding the various property owners, investors, installers. A discussion with them could prove very valuable.

23 participants were contacted in French- and German-speaking Switzerland, of whom 8 were able to take part. Their presentation, including their education, professional activity and involvement in associations and politics, is available in Table 6.

4.4 Focus group discussion guide, summary, and transcript

The focus group guide, written transcript and summary are available in the appendix.

4.5 Reflections on the Discussion Dynamics

The participants seemed enthusiastic about the opportunity to take part in a student project. However, of the 8 participants, only 3 took an active part in the discussion. It was necessary to address the other participants directly in order to gather their opinions, which was done in order to balance the speaking time of each person. This may be due to a number of factors, but for me it seems that the fact that the discussion was online reduced the involvement of the participants.

Furthermore, the project's proposition of developing a digital platform to facilitate investments in solar projects as a means to scale-up the solar transition in Switzerland seemed to diverge from the philosophy of solar cooperatives. Solar cooperatives typically pride themselves on a model of cooperation that does not prioritize financial returns. They value the human connection and local engagement inherent in cooperative ventures, instead of dematerialised links. This may have put off a number of participants.

Table 6 Focus Group Discussion participants.

	Name	Formation	Profession	Associative commitment	Politic commitment
	**Francois Calame**	PV installer Solar energy expert	- PV Project Manager for Eco Energie Etoy - Founder Solarmobility Sarl	- Co-founder of the Court-Circuit association	
	**Virginie Cavalli**	Master in Law in Public Law	- Health Lawyer	- Co-founder of the Cellios solar cooperative	- Municipal Councillor for Lausanne (Les Vert'libéraux) - Co-President of the Lausanne Vert'libéraux
	**Syril Eberhart**	Master of Engineering in Power Generation and Transmission	- Co-founder, solar planner and course director at E-Wende (Energie Wendegenossenschaft)	- Member of the Spiez solar cooperative	
	**Leonard Farine**	Bachelor's degree in communication	- Co-founder of “Tandem 100% électrique”	- President and co-founder of the OptimaSolar Chablais solar cooperative	- Municipal councillor for Ollon (Les Vert.e.s)

	**Jean-Luc Nagel**	PhD in Micro-technology	- Expert and project leader at Csem (ultra low-power processor architectures)	- Co-president of the Coopsol solar cooperative	
	**Karine Roch**	Master of Science in Geological and Earth Sciences	- Project coordinator at the SSES -	- Co-president of the Swiss Association for Citizen Energy - Co-founder of the Court-Circuit association - Vice-President of the Association for the Development of Renewable Energies	- Municipal Councillor for Lausanne (Les Vert.e.s)
	**François Roquier**	Mechanical engineer	- Consultant at Precitrame Machines SA	- Co-president of the EcooSol solar cooperative	- President Les Vert.e.s Jura bernois
	**Philippe Vollichardt**	Master of Science in Forestry	- Head of Sustainable Development EPFL	- Co-founder of the Newatts solar cooperative - Co-founder of Action Climat Ecublens - Co-founder of Ecubike - Co-founder of the Ecublens Transition Festival	

5 Results and Discussion

In this section, we will review what we learned from the interviews and focus group discussion about our research question "How can we facilitate the participation of investors and property owners in the solar transition in Switzerland? This question serves to highlight the key features that a solution must have in order to help address this issue.

However, as we asked the question "Is it easier to find investors in solar energy, or property owners willing to make their surface available?", in order to understand the current supply and demand market for surface area and investors, we noticed that an additional feature was needed in the solution, in order to connect the PV project market to the investor market. We will therefore come back to this issue.

Finally, we'll be analysing the feedback we received from various stakeholders at the end of our work regarding our platform.

It should be noted that other questions were asked to several stakeholders, some examples of which can be seen in Section 3.1 of this chapter, or in the guide interviews in the appendix. These questions are specific to issues identified during the product design and business model phases. Their results are not summarised here, and are used directly in their respective sections of the product or business model.

5.1 How can we facilitate the participation of investors and property owners in the solar transition in Switzerland?

The following themes have been identified.

5.1.1 Reducing barriers to entry

For Virginie Cavalli, a Vert'liberal politician, the major obstacle to bringing the solar transition to the masses is the complexity of the solar industry. She says, "Now, you need to be an exert in solar, invest time, lot of money, and take risk, to participate in the solar transition". It is therefore necessary to find solutions that reduce all the barriers faced by investors and property owners in order to participate in the solar transition. According to Jean-Louis Guillet, founder of the installation company Soleol SA, any investment of time, initial costs and necessary knowledge must be reduced to a minimum, so that the stakeholder only has to deal with what concerns him in the ecosystem, whether it be providing funds, a surface area or a service.

It would therefore seem that the barriers to entry holding back investors and property owners are :

- **Up front cost**. The cause that came up most often.
- **Time investment**, for example for project management
- **Knowledge needed**, to make decisions about the project.
- **Networking needed**, to know who to ask for a service or funds.
- **Fear of risk**.

The speakers were also unanimous on one point. It is vital to be **the sole point of contact for any stakeholder**. It is necessary to provide all services, or to appoint an external service provider yourself, so that the customer doesn't have to worry about anything.

5.1.2 Informing and establishing a relationship of trust

The key to facilitating participation in the solar transition lies in building a robust relationship of trust and adequately informing stakeholders, especially if we provide services over the long term. Ässia Boukhatmi, a doctoral student focused on the circular economy within the solar sector, emphasizes that business models requiring customers to use a service instead of being an owner can often face resistance due to trust issues. This is the case in the solar industry, where the property owner has to make 30-year contracts with service providers, fearing risk-taking and a loss of freedom. Similarly, investors may be sceptical about financing PV systems on properties they do not own. To mitigate these concerns, establishing trust is crucial. This can be achieved through transparent communication, demonstrating the security and reliability of the business model, and how it works, offering responsive support, and potentially partnering with trusted public institutions or established companies, according to François Roquier.

Additionally, providing stakeholders with flexible exit strategies, such as the option for investors to sell their shares or for owners to buy back the PV system, can further enhance trust.

Christoph Giger, Director of Plateforme Solaire Seeland, also points out the necessity of a significant marketing effort to educate the public on solar energy's benefits and viability. Many still view solar technology as unproven and are skeptical of its benefits, often misinterpreting no-upfront-cost models as scams. By clearly explaining how property owners can generate income by leasing their rooftops for solar installations without bearing the installation and management costs, stakeholders can be more effectively encouraged to participate in the solar transition, realizing the technology's potential for savings and environmental impact.

5.1.3 Enabling investors to own their investment – TPO business model

To address investor concerns, as outlined in section 5.1.2, Solarify CEO Aurel Schmid proposes to strengthen investor confidence by issuing a legal certificate of ownership for their share in the PV system. This approach, which is an integral part of the TPO (Third Party Ownership) model, guarantees investors the security of their investment, even in scenarios such as SolarSwift's insolvency. Jean-Louis Guillet, founder and director of the installation company Soleol, shared with us that in recent years, many property owners have been using their TPO offer, where Soleol will own the PV system in place of the property owner, reaching now 2/3 of their installed capacity. TPO is the majority business model in the US solar industry. And according to Roger Nyffenegger, a doctoral student in solar energy research, this model could become standard in Europe too.

However, the conventional TPO model typically involves a direct, one-to-one contract where a single investor funds an entire PV system, which might limit participation to only those with significant financial resources. To democratize access to solar investments and cater to a broader investor base, including those with limited capital, we propose a hybrid approach: Fractional Third Party Ownership (F-TPO). This model allows investors to own a portion of the PV system, thereby reducing the entry barrier and encouraging wider participation in the solar transition.

5.1.4 Changing legislation and incentives

Problems with legislation, cumbersome administrative procedures and an inappropriate solar incentive system have often been cited as obstacles to stakeholder participation in the solar transition. However, given that such obstacles cannot be resolved within the framework of this project by a product, process and business model, only a brief summary is presented.

According to Virginie Cavalli, heavy administrative procedures, the subsidy system and Swiss regulations are the main obstacles. Legislation needs to change, so that property owners are obliged to make their surface available and investors are more encouraged to invest.

For Francois Calame and Christoph Giger, the lack of long-term contracts on the resale price of electricity with utility companies, as is the case in France over 15 years, increases the risk for investors. Also, the way electricity is priced in Switzerland means that only PV systems with a high level of self-consumption are profitable. These complications make Swiss projects unattractive to large investors. This pushes all the big investors, such as financial institutions or utility companies, to develop projects abroad.

5.2 Is it easier to find investors in solar energy, or property owners willing to make their surface available?

During the focus group, Francois Calame told us that "I have dozens of large surfaces to offer you, on farms, industries and stables. There are just no interested investors, as current conditions are unfavourable for them". This was also the case for Emanuele Cimino, from the University of St Gallen's Oikos Solar association, who pointed out that their biggest obstacle was project financing. An architect, whose testimony was external to this work, commented that many projects for PV systems in new buildings are abandoned to fit within already tight budgets. Other interviews mentioned this lack of funding.

However, on the other hand, finding funding seems simple for some. Leonard Farine, president of a solar cooperative, tells us: "Finding investors is not the problem. For a solar project on a school costing 200kCHF, the financing was done in 30 minutes". The other members of the cooperatives, Roger Nyffenegger and Christoph Giger, confirm this. Their feedback shows that the biggest obstacle is the lack of interested private or industrial property owners willing to make their surface available.

After these discussions, the current state of the market and the balance between supply and demand for available surfaces and investors remain confused and unresolved. This may be due to the fact that the market is opaque or illiquid, meaning that it is complicated to bring the various players into contact with each other, due to the lack of a market, and that it is therefore difficult to buy or sell a resource. The result is that some players have surface areas but can't find financing, and on the other hand, interested investors can't find surface areas.

This means that hundreds of players, such as co-operatives and installers, are working on their own to find surface areas and investors, without exchanging information with each other, leading to a waste of resources, as everyone is doing the same job.

For Christoph Giger, creating a new solution for finding surfaces and investors to install new solar systems would simply add another player to a market where everyone is already doing the same thing without exchanging information. He therefore suggests creating an open marketplace to coordinate the connection between property owners, investors and installers. This could be an open, standardised and interoperable platform, managed by the public sector or an NPO, so that as many private players as possible join in, and to eliminate competition between different information channels. After discussion with him, he agrees that a decentralised public and open platform, running on a blockchain, could also be a solution for exchanging this information and creating an open market.

5.3 What are the pros and cons of the SolarSwift digital platform?

Once the product, processes and business model had been designed, it was possible to present our solution during various interviews, and especially during the focus group, in order to obtain feedback. This enabled us to receive positive opinions, criticism and advice. These are presented here by theme.

5.3.1 Designing a PV system isn't easy

The most common criticism is that it is complicated to design a PV system, and that this has to be done in collaboration with the property owner, in the course of numerous discussions. For Rianne Roshier, it's impossible that the property owner doesn't have to invest any time, and that my solution is utopian. It will be necessary to go on site to analyse the state of the roof, the type of electrical connection, measure self-consumption, etc.

For Jean-Luc Nagel, a lot of information needs to be provided by the owner, and papers signed. Just providing an address is not an option. After I compared my solution to an online bank, Uber or AirBnb, he told us: "Designing a PV system is much more complicated than simply opening a bank account. I'm interested if your solution can work, but I'm sceptical".

5.3.2 Automated and numeric platform

People understand the desire to provide a digital platform that is as automated as possible in order to be able to scale-up the creation of new PV systems by limiting the need for human interaction. However, they are sceptical about the possibility of doing so. For Aurel Schmid, CEO of Solarify, this is impossible, because even if high-quality digital simulations are carried out to determine the potential of a PV system, in the end the final design and installation on site will still have to be done by humans. The administrative procedures are also non-standardised and have to be done by hand. In contrast, for Emanuele Cimino, the automation of many processes is necessary because today only 1/3 of the time of installers is spent on site for the installation, and the rest is spent on designing a project, researching funds, and managing administrative procedures.

5.3.3 Using a user-friendly application

A number of participants pointed out that it may not be a good idea to offer a digital application that is easy to use, purified and minimises human interaction. For Leonard Farine, a solar project is complex and involves 30-year contracts. It is therefore necessary to establish a relationship of trust with each stakeholder, by taking the time and communicating extensively with them in person. François Roquier explains that for each solar project, they "have to sit down several times around a table with all the stakeholders during the design phase, and then again during the life of the installation when there are problems",... "a digital platform will hardly be able to replace these human interactions".

Philippe Vollichardt advises: "You need to know in your business model whether the user needs to feel confident, receiving explanations from a consultant who will take time for them, or whether you want an easy-to-use system with an application, but where the user won't really know or understand where the money is going".

Conversely, Francois Calame believes that Switzerland is a country where people love technology, and they would like to have an application to manage their portfolio of solar projects. He has noticed that it is a trend for many services to move from a qualitative service with human interaction to a simple application, such as the hotel industry (AirBnb), taxis (Uber), banks (N26, Revolut, Trade Republic), the post office, travel agencies and so on. People are starting to trust an app too.

5.3.4 Using Blockchain

There has been little feedback on the use of blockchain as the backbone of the project, managing transactions and proofs of ownership transparently and securely. This is mainly due to the fact that this technology is still relatively unknown.

Generally speaking, the feedback was rather critical. According to Christoph Giger, the use of blockchain would open up solar energy to a niche market of private individuals enthusiastic about decentralised solutions, but would close the doors to all public and financial institutions. He also has doubts about the legal feasibility of using a blockchain.

All the same, he suggests testing the use of blockchain for the financing and management of PV systems, in particular by working in collaboration with players testing its use for smart grid management, as Group-E is doing on a pilot project.

5.3.5 Fractional Third Party Ownership

The Fractional Third Party Ownership (F-TPO) financing model received unanimous approval from the stakeholders engaged during our discussions. It's important to note that this consensus might carry a bias, considering that these stakeholders—comprising installers, cooperative members, and project managers—have adopted similar models in their business.

Syril Eberhart highlighted a potential cultural barrier to the adoption of TPO in Europe, contrasting with its popularity in the USA. The difference stems from a cultural preference in Europe for ownership and control over property, as opposed to the American comfort with borrowing and renting. This distinction suggests that European property owners might be hesitant to lease their surfaces for solar systems, pointing to the need for careful consideration of cultural nuances when implementing F-TPO in Europe.

5.3.6 Projet pool

On this point, François Roquier, co-director of a solar cooperative, says: "I like the feeling you get in a solar cooperative, where people finance projects that they are going to be able to see. Your project pool option for a small region can be interesting because it allows you to invest locally, for a community".

6 Conclusion

Firstly, we were able to understand Switzerland's current energy situation, and why PV is central to its 2050 energy strategy. The barriers to the solar transition were then identified, thanks to a literature review. The issue of barriers to the participation of investors and property owners in the solar transition was then selected. This enabled us to draw up our research question:

"How can we facilitate the participation of investors and property owners in the solar transition in Switzerland?"

In order to understand what is holding investors and property owners back from participating in the solar transition, and then to identify the key elements that can facilitate their participation, interviews were conducted with professionals in the field. These came from different fields in order to vary the points of view, such as researchers, installers, members of NPOs, politicians, public solar accelerators, solar project managers, direct competitors and members of cooperatives.

This has enabled us to draw up the key characteristics that a solution must contain in order to facilitate the participation of investors and property owners in the solar transition, which are as follows:

- Eliminates up-front costs for property owners.
- Reduce time investment for every stakeholder.
- Reduce knowledge and networking needed for property owners and investors.
- Be the single point of contact for all stakeholders.
- Enable investors to own their PV system.
- Clearly communicate on a long-term risk reduction strategy for property owners and investors.
- Enable stakeholders to withdraw from contracts at any time.
- Conduct marketing campaigns, provide clear explanations and educate people about the potential of solar energy.
- Listen to stakeholders, providing good and responsive support.

We were also able to understand that one problem was that each stakeholder was looking for other resources in their own corner. For example, a property owner will have to find financing and service providers on his own, and conversely, a solar project manager will have to find property owners on which to build PV systems. It's not just a question of facilitating the participation of new investors and property owners, but of connecting all the stakeholders, and thus making the solar market more fluid. A last feature is therefore:

- Create an open, public and interoperable marketplace, managed by a public institution, an NPO or decentralised, to enable stakeholders to exchange information and collaborate.

Finally, having designed the concept of the product and its business model, the peer reviews carried out during the discussion group, and also during some interviews, highlighted these positive points and these criticisms:

PROS

- TPO's financial model and a user-friendly interface can transform the solar market from a niche to mass sector by removing the up-front cost barrier. It's a promising business model, that is the most popular in the USA.
- An application to invest in solar, manage, and monitor its solar portfolio can work well in Switzerland, where people like this kind of application replacing human interaction (AirBnb, Uber, N26, Revolut, Trade Republic).
- Daily revenue payment, instead of every 3 months, provides dopamine and encourages involvement.
- Blockchain is an interesting solution to explore for solar financing and revenue management, especially if it is directly integrated into Smart Grid networks.
- The "project pool" option is a good idea, and enables investors to have a local impact, as a cooperative.

CONS

- Automatically designing a solar project with only the address is utopian. Property owners will have to invest time, you'll have to go on site, etc.
- A digital platform lacks the human interaction that is essential in the solar industry, where projects are complex and long-term. Also, it's essential to explain to a new user how a solar project works, to gain their trust, which a digital platform can lack.
- Property owners can be afraid to make their surface available for 30+ years, owned by different unknown investors.
- Blockchain will make collaboration with public and financial institutions impossible.
- It's unlikely that blockchain will be the solution in Switzerland to create an open marketplace, making the solar industry open and interoperable.

Product and Processes

In this chapter, the concept of the product and processes designed to help facilitate the participation of investors and property owners in the solar transition is presented.

1 Methodology

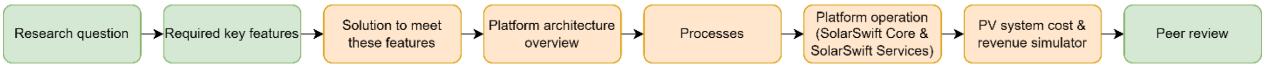


Figure 5 Product and processes design steps (Green: Transdisciplinary Methods, Orange: Product & Processes)

By answering our research question using transdisciplinary methods, we have obtained the key features that a solution must have in order to facilitate the participation of investors and property owners in the solar transition. These are presented in section 5.1 of the "Transdisciplinary Methods" chapter, summarised here:

- Eliminates up-front costs for property owner.
- Reduce time investment.
- Reduce knowledge and networking needed.
- Be the single point of contact for all stakeholders.
- Enabling investors to own their investment.
- Enable stakeholders to withdraw from contracts at any time.
- Clearly have and communicate on a risk reduction strategy.
- Conduct marketing campaigns, provide clear explanations and educate people about the potential of solar energy.
- Listening to stakeholders, providing good and responsive support.
- Create an open, public and interoperable marketplace, managed by a public institution, an NGO or decentralized.

Firstly, we will outline the solutions selected to meet these features. Next, an overview of the architecture of our platform will be provided, in order to understand how it works, before outlining the processes that take place during the lifecycle of the PV system, whether during the design and financing phase, or during its production phase. We will then go into more detail about the functioning of the platform, with a section on the backbone of the platform, called "SolarSwift Core", and another on the services that the platform must provide in order to function, called "SolarSwift Services".

In parallel, a PV system cost and revenue simulator was developed, to explore the possibility of analysing the economic viability of a solar project based on its address alone, and to be able to carry out the PV system accounting required for the "Business Model" chapter.

Finally, the results of the peer-review of our platform by various stakeholders are presented at the end.

2 Solutions to meet these features

In order to facilitate the participation of property owners and investors in the solar transition, it was decided to design a digital platform, where property owners can make their surface available, so that SolarSwift can plan a new PV system on it, which will then be published on the platform's marketplace, and where investors can buy a share of this PV system.

The key features will be answered with the following solutions. Note that we will come back to the technical realisation of these solutions in more detail later in the chapter.

Eliminates up-front costs for property owner

To ensure that the property owner does not have to invest anything, it is necessary to find a business model where all the funding comes from a third-party stakeholder. The property owner should only receive money from the provision of his roof, and never spend any of it. We will see that the "Fractional Third Party Ownership" business model was chosen to finance a solar system.

Reduce time investment and expertise needed

We want to design a platform that's easy to use, with a user-friendly interface, where the user is clearly guided, and only asked to do what's relevant to them. They will never have to take actions or make decisions that require knowledge and time.

For example, on the property owner's side, they will only need to enter the minimum information required to make their surface available, such as their address and contact details. SolarSwift takes care of analysing the solar potential of the surface, designing the project, finding installers, financing it and managing all the maintenance.

The same goes for investors, who only have to buy shares in a solar project of interest to them, without having to carry out all the work involved in designing and maintaining the project.

The platform offers a clear separation of roles between stakeholders, i.e. between investors, property owners, and service providers (installer, surface and financing finder, PV system designer, maintenance company, insurance, etc.).

Be the single point of contact for all stakeholders

Following on from the previous section, the platform must provide all the services required to create and maintain a solar project. These services can be provided directly by SolarSwift, or indirectly by commissioning third-party service providers. Our platform will mainly use third-party service providers, in order to act solely as an orchestrator. The aim of the platform is precisely to be able to easily connect different external service providers, as a platform like AirBnb or Uber can do.

Enabling investors to own their investment

As explained in the results of the "Transdisciplinary Methods" chapter, investors want proof of ownership of their share of the PV system in order to reduce their risk. We saw that the F-TPO financing model was the one to use. The platform therefore needs to implement a solution where investors can purchase a share of the PV system for a no minimum amount, and receive legal proof of possession of their purchase. This will be done through an official and legal contract of possession, and through Fractional Non Fungible Tokens on the blockchain, a smart-contract proving possession of part of an asset, but legally invalid.

Enable stakeholders to withdraw from contracts at any time

In order to reduce risk and allow stakeholders to withdraw at any time, the platform should allow investors to resell their shares in a PV system, or buy-back all shares as a property owner in order to regain control of its surface. This increases stakeholder trust in the platform.

For investors, this is possible by reselling their shares on the SolarSwift marketplace. Property owners can issue a buy-back deed for all shares at the current value of the PV system.

Clearly have and communicate on a risk reduction strategy.

Firstly, solar is a low-risk option due to the longevity and low operational and maintenance (O&M) costs of a PV system. In addition, the previous two points reinforce this risk reduction for property owners and investors, as they legally own their assets and can withdraw at any time. Also, the use of a public blockchain, connected to decentralised smart electricity meters, guaranteeing automatic remuneration of stakeholders according to electricity production, even if SolarSwift goes bankrupt, also reduces risk. Finally, our platform guarantees the insurance protection of the PV system, and also guarantees the transparent and automatic saving of funds to cover O&M costs.

The communication of the risks of solar to stakeholders and the measures taken by SolarSwift to reduce them are not considered in this work.

Conduct marketing campaigns, provide clear explanations and educate people about the potential of solar energy

This feature has not yet been included in the platform.

Listening to stakeholders, providing good and responsive support.

This is not directly part of the product, but is discussed in detail in the "Customer Relationship" section (Section 3.2 of the "Business Model" chapter).

Create an open, public and interoperable marketplace, managed by a public institution, an NGO or decentralized.

It has been decided to base SolarSwift Core on the EnergyWeb public blockchain. Solar projects will then be published, managed and financed on a decentralised public platform, and not dependent on an entity like SolarSwift. This allows any solar project manager to publish a project, in order to find investors and service providers. On the other hand, any service provider, such as an installer, can come to the platform to find projects to work on, or any investor can come and buy shares in a solar project, without being dependent on SolarSwift.

3 Platform architecture overview

SolarSwift consists of two layers. A core infrastructure (1), serving as the backbone of the project, and the services offered by SolarSwift (2), guaranteeing the good operations of the project. This distinction serves to guarantee the payment and operation of solar systems already installed over the long term, independently of a third-party player like SolarSwift.

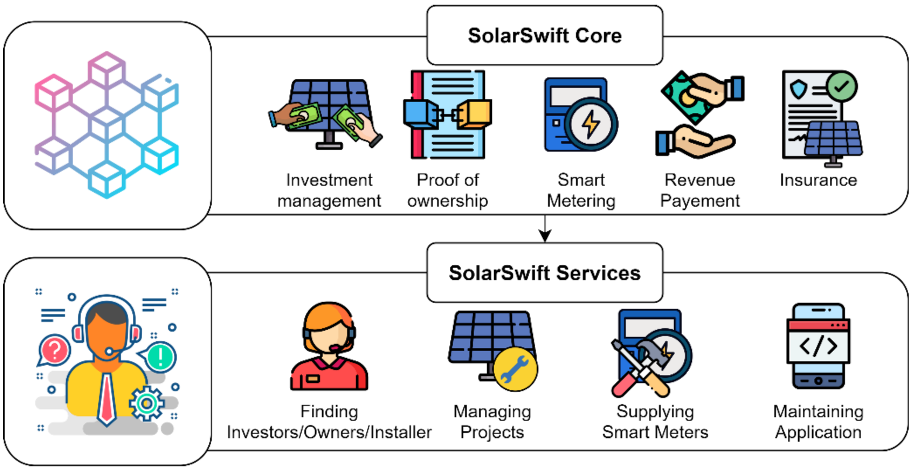


Figure 6 Layers of the SoalrSwift project

3.1 SolarSwift Core

The first layer is a standardized, secure, and long-lasting infrastructure, based on the EnergyWeb blockchain, that guarantees the operation of the investment platform's vital functions, even if SolarSwift goes bankrupt. The use of a blockchain allows to:

1. Automate execution of transactions based on PV production,
2. Secure proof of ownership and transactions,
3. Transparent revenue distribution among stakeholders,
4. Decentralize the platform to be independent from a third-party entity,
5. The interoperability open up the platform to any third-party entity, so that it can participate in the solar transition and provide its services.

This core infrastructure must manage the features explained in Table 7.

Table 7 Features managed by SolarSwift Core.

During the investment phase	- Manage the registration of a new solar system project. - Manage the investment in a solar system project (purchase of a share in the solar system). - Freeze the investments until the solar system project is fully financed. Then pay the installer for the construction of the solar system, or reimburse investors if the system is not fully financed. - Secure storage of contracts of ownership of a PV system. - Resale and buy-back of contracts of ownership of a PV system, respectively by an investor and by the property owner.
During the production phase	- Automatic reading and storing electricity meter data periodically. - Automatic billing of electricity sold to consumers and utility companies periodically. - Automatic payment to each stakeholder based on production revenue periodically. - Automatic payment of insurance and O&M fees periodically.

3.2 SolarSwift Services

The second layer concerns the services offered on top of the SolarSwift Core backbone. This is used to guarantee the smooth running of the project and provide all the services requiring human intervention. If SolarSwift goes bankrupt, these services will no longer be guaranteed. These services include the services presented in Table 8.

Table 8 Services provided by SolarSwife Services

During the investment phase	- Find new property owners. - Find new investors. - Find and assign an installer to a new solar system project. - Develop and maintain the platform and decentralized application (dApp). - Propose pool of projects for investors. - Provide support for the smooth running of PV system. - Provide smart electricity meters that can connect to SolarSwift Core blockchain. - Provide standard contracts similar to smart contracts to meet legal requirements.
During the production phase	- Provide certificate of sustainable investment. - Acting as a bridge between the standard banking system and Decentralized Financial (DeFi) systems for stakeholders without a DeFi account. - Manage solar system maintenance and repairs. - Read, store and monitor continuous production data from solar systems.

The long-term goal is to make the project as independent as possible of the services provided by SolarSwift, in order to create a completely autonomous, secure, standardized and sustainable platform open to everyone. To achieve this, we are implementing two strategies.

1. Firstly, we want to integrate as many of the functions currently provided by SolarSwift Services as possible into the Core infrastructure using decentralized and automated tools,
2. Secondly, we want to make it possible for any third-party service provider to interact with the Core infrastructure to provide alternative services.

4 Processes

This section describes the basic concepts behind the SolarSwift platform. There are a number of processes that enable a solar project to exist. These processes are divided into two phases. First there is the investment phase, where a new solar system is designed and financed, and then there is the production phase, where the energy produced is sold.

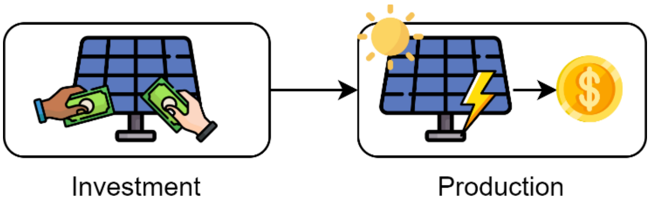


Figure 7 Phases of a solar system project.

4.1 Investment phase processes

The investment phase consists of all the steps to develop a new solar system, before it goes into production for 30+ years. In this section, we will first illustrate the **flow of assets, services and contracts between stakeholders**, during the investment phase. Then, the different **steps to go from the registration of a new surface to the finishing of the construction**, will be explained.

4.1.1 Flow of assets, services and contracts

Figure 8 illustrate the flow of assets, services, and contracts, between property owner, investors, and service providers. The illustration is explained in Table 9.

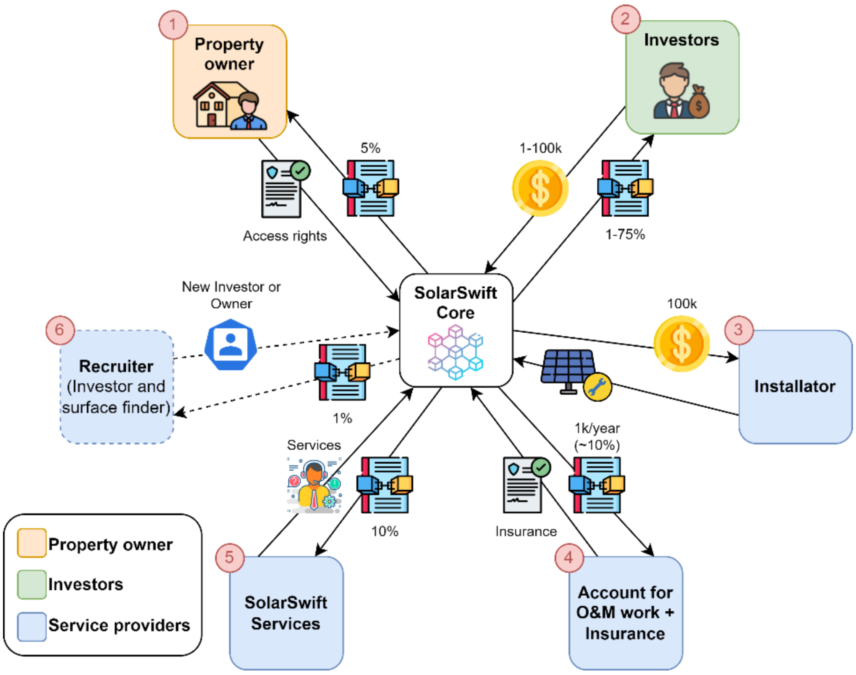


Figure 8 Illustration of assets, services, and contracts flows during the investment phase (the "%" represent each stakeholder's share of the income generated by production)

Table 9 Explanation of assets, services, and contracts flows during the investment phase.

1.	Contracts are signed with the surface owner to have access to his roof in exchange for a smart contract guaranteeing 5% of revenues

2.	Investors bought part of the solar system (via F-NFT) guaranteeing them the distribution of the income generated.
3.	Installer is paid to construct the solar system.
4.	A smart contract is signed to send the necessary amount (1% of the PV system price per year, so around 10% of revenue) on an account to pay O&M costs and insurance. At the same time, a contract is signed with an insurance provider.
5.	The service providers, so the player managing solar system construction, reparations, and maintenance, doing marketing, networking, providing monitoring application, etc. get up to 10% of the revenue in exchange of their services during the lifetime of the solar system. For now, all these services are provided by SolarSwift Services.
6.	As an example of an external provider replacing SolarSwift Services, we see that if an external recruiter provides the contact of an investor or property owner, they will receive 1% of the revenue from that PV system, instead of SolarSwift.

4.1.2 Steps to create a solar system

Figure 9 and Table 10 describe the necessary steps to create a new solar system.

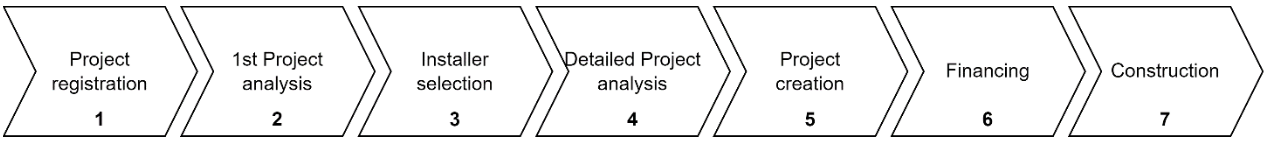


Figure 9 Step in creating a new solar project.

Table 10 Step in creating a new solar project.

1. Project registration	First, a surface owner registers his address on the SolarSwift platform.
2. 1st project analysis	An initial automatic potential analysis of the project is carried out.
3. Installer selection	If the potential is interesting, a local installer is chosen for the rest of the project, based on certain criteria. The installer's geographical location, the type of installation he can handle, his price and his availability. Particular care is taken when choosing the installer, to ensure that his supply chain complies with our sustainability criteria.
4. Detailed project analysis	A detailed analysis is carried out by the installers, defining its viability and price of the PV project.
5. Project creation	If the project is viable, it is created. When the project is created, few things happen: - A Fractional Non-Fungible Token (F-NFT) representing the ownership of the solar system is minted on the EnergyWeb blockchain, worth the total value of the solar system. - A contract is signed with the surface owner, granting SolarSwift access rights to his surface, and ensuring that 5% of the income generated by the sale of electricity is paid to the owner of the surface. - The project is published on the platform to let investors buy a part of the solar system.
6. Financing	Then the financing phase begins. Investors can buy a part of the solar system, which they then actually and legally own. In fact, they buy a Fraction of the NFT representing the ownership of the total PV system (called F-NFT). This F-NFT is a smart contract ensuring that the investor will receive in his wallet the income generated by his solar panels.

	During the financing phase, the investments are not held by SolarSwift, but are frozen in the anonymous account of a smart contract, which will automatically pay the full amount to the installer if the financing is completed, or reimburse the investors if the financing is not complete.
7. Construction	Once the project has been financed, the installer previously chosen receives the invested money and is commissioned to build the solar system. An insurance policy is also set up to ensure the funds in the event of an accident or maintenance work on the solar system.

4.2 Production phase processes

Once the solar system has been installed, it enters the production phase. The flow of energy, money, and data during the production phase between the various stakeholders and ecosystem elements is illustrated in Figure 10.

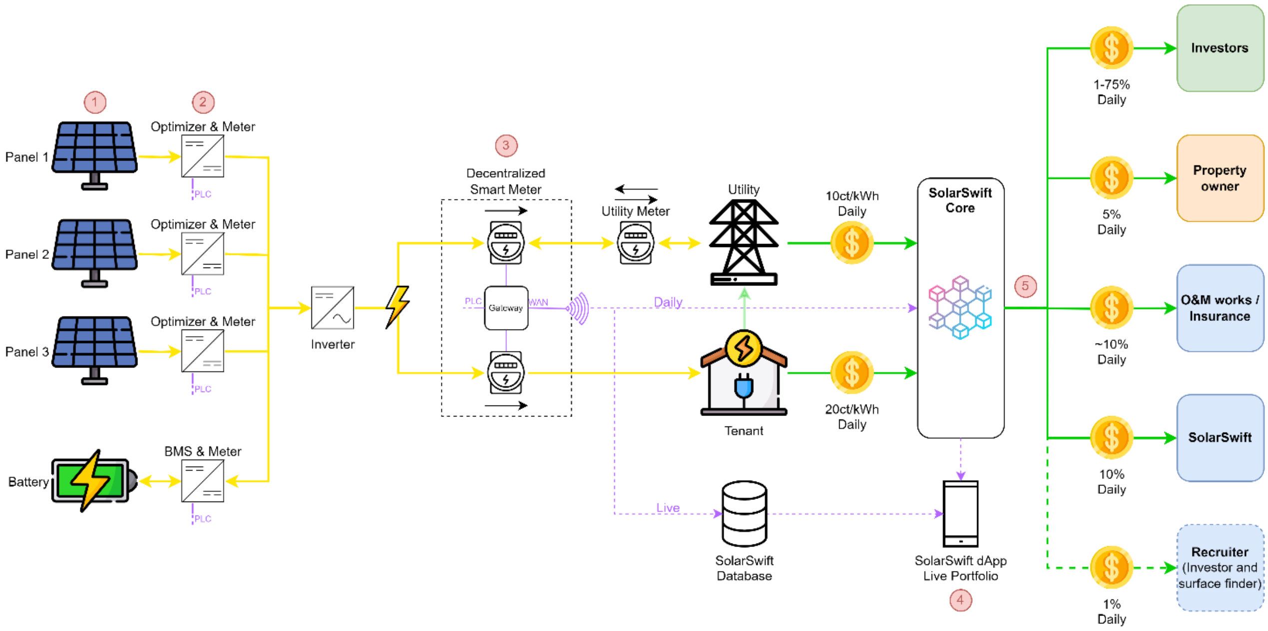


Figure 10 Production phase process.

This production phase can be broken down into several steps, from electricity production (on the left in Figure 10) to stakeholder payment (on the right).

Table 11 Steps during the production phase

1. Electricity production	The panels generate current when there's enough sunlight.
2. Individual metering	[optional] This current is measured individually for each panel for fault detection, and this information is sent to the central meter (3), through Power Line Communication (PLC).
3. Output metering	Energy sold to utilities and tenants is metered. A first design of the Decentralized Smart Meter used is given in Section 5.3.
4. Live monitoring	Data from all meters are continuously sent to a centralized SolarSwift Database. This information can be viewed on the platform to provide investors with an overview of their installation's production and income, detect faults and analyse solar system performance.
5. Payment	Once a day, the Decentralized Smart Meter automatically executes a smart contract with information on the energy produced during the day. These contracts transfer money from the electricity buyers' accounts to the various beneficiaries, so those with proof of ownership on the blockchain (F-NFT). This step does not require SolarSwift's services, and runs automatically on the EnergyWeb blockchain.

The use of a decentralized platform running Smart Contracts makes it possible to redistribute an installation's revenues to numerous investors, securely and without the need for an intermediary.

As some individuals and institutions will be reluctant to use a decentralized finance platform, a bridge service is set up to enable them to use the standard finance system, to pay and receive income from a standard bank account, as explained in Section 6.9 of this chapter.

5 SolarSwift Core

This section looks at the technical aspects that enable the backbone of the SolarSwift platform to deliver the features presented in Table 7. We will answer the following questions:

- What is the EnergyWeb Blockchain?
- How to provide proof of ownership to investors?
- How to register a new PV system project on the blockchain?
- How to invest in a PV project?
- How to temporarily freeze, manage, and release the invested funds?
- How to resale and buy-back a proof of ownership of a PV system?
- How is production measured, monitored and transactions self-executed?
- How are Insurance and Operation & Maintenance (O&M) work paid and managed?

5.1 What is the EnergyWeb Blockchain?

The EnergyWeb blockchain is a public blockchain, based on Ethereum, using the Proof-of-Authority principle. Energy Web is a mission-driven, nonprofit organization. Their solutions are free, open-source software with no licensing fees, obligations, or vendor lock-in. They were created on the initiative of 42 major energy companies, including EDF, Engie, E.ON, Austrian Power Grid or Shell, but also Volkswagen, General Electric or Deloitte (EnergyWeb, 2023b). They have active projects with a large number of private companies, utility companies, or even in the public sector, such as 6 projects under the European research programme 'Horizon Europe' (EnergyWeb, 2023c).

This blockchain is built around three solutions.

1. One, called "Asset Management", enables the management of Decentralized Energy Resources (DER), i.e. decentralized devices that produce, transform or consume energy. This could be PV panels, wind turbines, a biogas plant, batteries, electric cars, inverters, etc.
2. Another, "Data Exchange", enables the exchange of data, which is essential in a circular and decentralised economy, for example in a Smart Grid.
3. The last, "Green Proof", enables information on the origin of energy to be traced, by providing it with certificates.

In terms of price, and based on historical values, transaction costs are generally of the order of $0.0001 or less (EnergyWeb, 2023d). This price may vary depending on the complexity of the transaction or smart-contract, and the current price of the EW token, but generally remains low. This is because the blockchain uses the Proof-of-Authority principle, and verifiers do not seek payment for this work. EnergyWeb's business model is based on consulting services for countries and companies, and not on the charging of fees for transactions.

5.2 How to provide proof of ownership to investors?

There are several ways of providing a certificate that an individual owns a share in a PV system, and we will look at these methods in more detail in this section. Standard contracts and Fractional Non-Fungible Tokens (F-NFTs) have been chosen as proof of ownership for our platform.

5.2.1 Standard Contract

Standard ownership contracts have the advantage of being familiar to all individuals and financial institutions, are legally recognized, and are very flexible in their written terms. However, creating and managing the contract, verifying its authenticity, and above all automating its execution in a decentralized manner is complex.

5.2.2 Token

It might be possible to create a fungible token. The investor buys a certain quantity of token, representing an equivalent quantity of solar panels, installed anywhere in the world. The money invested is then put into a common pot, which is used to finance various solar projects. All investors are then remunerated by the production of electricity on all projects worldwide, according to their number of tokens. The disadvantage of this solution is the inability to know precisely which solar system an investor owns. This is problematic, as some investors want to finance a specific solar system, for example on the roof of a school. Also, not all solar systems in the world have the same price, yield and risk, so it's not possible to lump them all together.

5.2.3 Non-Fungible Token (NFT)

NFTs are non-fungible tokens and are therefore proofs of ownership linked to a specific solar system. When a new solar project is conceived, an NFT is minted, and its price is set at the construction price of the new solar system. When purchased by an investor, this NFT provides clear and transparent proof of ownership of the solar system. It can then be easily used, via a smart contract, to automatically transfer electricity generation revenues to its owner on a decentralized basis. It can also be easily resold or transferred to another owner. However, an NFT has the disadvantage of still being little recognized by legal institutions, users and financial institutions. Also, an NFT cannot, by definition, be divided up, forcing an investor to buy the whole PV system, not just a share. This runs counter to our mission, which is to reduce the barriers for investors by enabling them to invest any amount, even a small one.

5.2.4 Fractional Non-Fungible Token (F-NFT)

Fractional NFTs, as the name suggests, enable you to own a portion of an NFT. Thus, the NFT, always representing an entire PV system, can be owned by a multitude of investors. It still has the advantage of offering clear, transparent proof of ownership, simple buy-back and, above all, automated, decentralized payment of revenue to its owner. However, it is still little recognized by legal institutions and users as a true proof of ownership.

Note that the F-NFT protocol allows anyone to buy back NFT fractions from other owners, which may be necessary if the surface owner wants to regain control of the solar system on his surface. This is done through a buyout auction system.

5.3 How to register a new PV system project on the blockchain?

When a new solar project has been designed, we know its price, and we want to publish it on the platform, an F-NFT is minted on the EnergyWeb blockchain (EnergyWeb, 2023a), for a value equal to that of the PV system. This is done through a temporary account managed by SolarSwift, which will receive money from investors when they buy a fraction of this NFT.

5.4 How to invest in a PV project?

Investors can buy a share in a PV system, either via the dApp made available by SolarSwift (see Section 6.3 of this chapter), or directly via the EnergyWeb blockchain. They will then own a fraction of the NFT representing the PV system. Their invested money will go into the temporary account created specifically for this solar project. If the project is fully funded and built, standard and legal contracts of ownership will be established and sent by SolarSwift to the investors.

5.5 How to temporarily freeze, manage, and release the invested funds?

As explained in the previous section, the funds invested are held in a temporary account. So, what happens to this money? This temporary account is accompanied by a smart-contract, specifying that if the financing of the PV project is completed within the allotted time, the funds are automatically transferred to the account of the selected installer, who will start the work. If not, the funds are automatically transferred back to the investors' accounts.

5.6 How to resale and buy-back a proof of ownership of a PV system?

If an investor wants to sell his share of a PV system, for example because he is short of cash or production is unsatisfactory, he can put his F-NFT back up for sale via the SolarSwift dApp. It will then be visible to other investors, who will be able to buy it back. SolarSwift could guarantee investors the buy-back of their shares, as Solarify does, in order to reduce the risks for investors. However, we would first have to analyse the risks for SolarSwift of guaranteeing this buy-back, which has not been done in this report.

If the property owner wants to regain the right to his surface, it may be possible for him to buy out the shares of the other investors at any time. As explained in Section 5.2.4, the N-NFT allows for a buyout auction system, in order to be able to automatically buy out the shares of other NFT owners.

5.7 How is production measured, monitored and transactions self-executed?

To measure the amount of electricity sold to the grid operator and occupant, as well as send monitoring data and execute transactions, our system needs a decentralized smart power meter at the solar system site. This data is then used primarily to bill the utility company and the tenants, and to remunerate the stakeholders. It can also be used to monitor production and consumption remotely, for example for fail detection. In the case of a decentralized infrastructure based on blockchain, the smart meter must be able to interact with it autonomously in order to execute smart contracts.

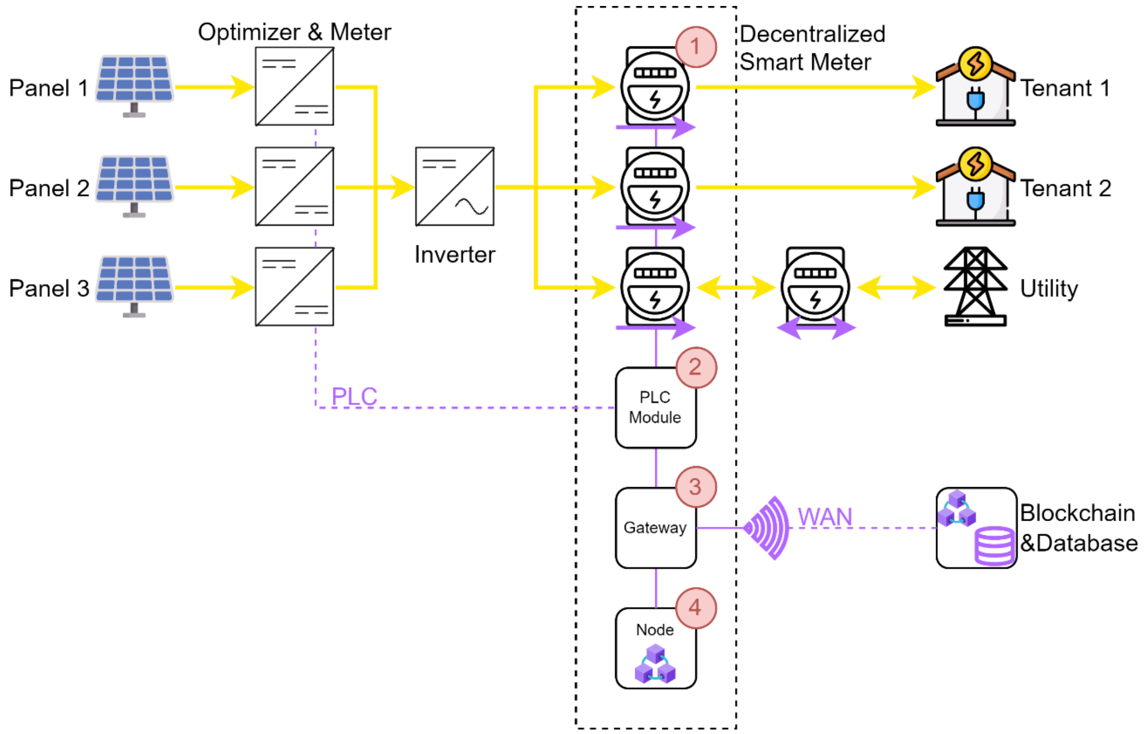


Figure 11 Concept architecture of the decentralized smart meter

5.7.1 Literature review

If we carry out a literature review on smart meters and their interoperability with blockchain, we find a fair number of references. First Rahman et al. (2015), and then Prathik et al. (2018), introduced a new smart energy meter that might be used to establish a self-contained, improved metering and billing system. Owing to the Arduino and GSM short message service (SMS) interfaces, the meter reading system provides a wide range of predefined automatic capabilities. The suggested energy meter system may convey data such as utilized energy in kWh, generated invoices, and security services (line cut/on) through a GSM mobile network. Barman et al. (2018) proposed a smart energy meter based on the IoT with full duplex communication, based on Wi-Fi. It enables energy analyzation by the consumer, and helps in detecting power theft. Avancini et al. (2021) described and exhibited a new smart energy meter that uses an IoT technique, as well as the associated costs and benefits. The meter has a multi-protocol connection that makes it simple to integrate with any monitoring software. Finally, the proposed solution has been validated and demonstrated in real-world circumstances, and is now being implemented. Other alternatives are proposed in numerous articles (Muralidhara et al., 2020; Srivatchan & Rangarajan, 2020; Tahir et al., 2022; Tuyishime et al., 2021).

Concerning the integration of smart meter with blockchain, studies also exist on the subject. Natarajan and Vinayak (2020) present El DApp, a power consumption tracking application solution that combines IoT and blockchain. El DApp uses a Raspberry Pi based Ethereum network to provide a secure and cost-effective decentralized real-time power usage record for users. Also, Mukherjee et al. (2021) presented an eChain architecture for smart energy usage, employing smart contracts and the Ethereum blockchain. The article also discusses how combining blockchain technology with smart energy consumption techniques improves security and privacy. Finally, Tahir et al. (2022) propose a practical implementation of a smart energy meter using blockchain and IoT.

5.7.2 Smart meter design

This literature will enable us, to design the first concept of the smart meter. However, this development will not be discussed in detail here, only the basic concept. Figure 11 shows the basic components of this Decentralized Smart Meter, which are the following:

1. The central elements are the meters, counting the power sent to the utility's network in real time, and the consumption of each tenant in the building.
2. A Power Line Communication (PLC) module to read the production of each solar panel, sent by small meter directly installed under the panels. PLC is used because it is a communication system that uses existing electrical wiring, so no additional infrastructure is required. Wireless communication is also excluded here, as the Smart Meter and PV panels can be a long way apart.
3. A Wireless Wide Area Network (WWAN) gateway (Cellular or LPWAN) is used to send this data continuously to the SolarSwift server, so that monitoring and fault detection can be carried out. An IoT SIM card costs ~1-3 CHF/month (Swisscom, 2023), which is acceptable. WiFi is not used here because it is not necessarily accessible where the Smart Meter is installed, and above all, we don’t want to depend on the building occupant's network.
4. Finally, the Decentralized Smart Meter contains its own node on the blockchain with its own address, to issue transactions automatically once a day through smart contracts, between electricity sellers (investors) and buyers (occupant/utility company), in function of the electricity produced. This node is connected to the blockchain through the previously mentioned gateway.

5.8 How are Insurance and O&M work paid and managed?

Although a solar system presents few risks and requires little maintenance and operational costs, it is still necessary to take them into account. In Section 7.2 of this chapter, we'll look in detail at the amount to allow for these costs, which is around 1% per annum of the initial price of the PV system. This amount includes insurance costs, which will cover the costs in the event of damage (breakage, theft, hail, fire, etc.), and operational and maintenance costs, such as the charges for connecting the system to the grid, changing faulty equipment, cleaning the panels, etc. This amount will be paid into an account on a daily basis.

This amount will be paid daily into a savings account specifically for this solar project, managed by SolarSwift, at a rate of 10% of income. If the amount paid is higher in one year than 1% of the initial price of the PV system, the surplus is redistributed among the investors.

6 SolarSwift Services

This section looks at the technical and administrative aspects of setting up the services provided by SolarSwift Services, presented in Table 8. We will answer the questions:

- How to find new investors and property owners?
- How to select an installer for a project?
- What is the SolarSwift dApp?
- What is a pool of projects?
- How to provide quality support?
- How to manufacture and distribute Smart Electricity Meter?
- How to provide a legal contract of ownership to investors?
- How to provide a certificate of sustainable investment?
- How to make the bridge between DeFi and traditional financing?

6.1 How to find new investors and property owners?

This subject is covered in the "3 Customers Segment and Relationships" section of the Business Model chapter.

6.2 How to select an installer for a project?

As the platform is intended to be open and interoperable, so that any service provider (such as installers) can participate, it is possible for any user to register as an installer on the platform. Installers are asked to fill in a form, giving details of the services they provide, their region of operation, their expertise, a report on their environmental strategy and impact, and so on. SolarSwift will then accredit the installers if they meet our requirements. In addition, SolarSwift will also actively seek out installers in each region to work with, so that we can add them to the platform ourselves.

Then, when a new solar project is accepted onto the platform, a call for tenders is sent out to all the local installers. These are then put into competition to determine which installer will be responsible for installing the PV system.

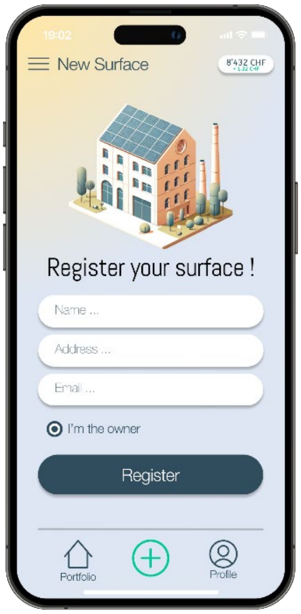
6.3 What is the SolarSwift dApp?

The SolarSwift application is a mobile and web application used as an interface with the SolarSwift platform. It is said to be "decentralised" because it displays and interacts with the EnergyWeb public blockchain. As illustrated in Figure 10 (p. 47), this application will communicate with the blockchain for everything to do with wallet and asset management, transaction management, proof-of-ownership (NFT) management and contract signing. But it will also communicate with a centralised server held by SolarSwift to retrieve and store any other type of information, or to run the various simulation algorithms.

In our business model, as we shall see, we want the application to be the main channel of interaction with our stakeholders. Like online banks such as N26 or Revolut, or applications such as AirBnb or Uber, it must be possible to carry out and control everything from the application, and it must be easy to use.

In this section, we'll look at a few examples of use cases with illustrations of the application.

6.3.1 New surface registration



For property owners, our mission is to provide a solution that puts up the fewest obstacles and makes it as easy as possible for them to make their surface available. As we saw in Section 2, we need to "Reduce time investment and expertise needed" and "Be the single point of contact for all stakeholders".

To achieve this, we first need to offer the simplest possible interface, asking them for only the essential information. Once they have shown an interest in accepting a solar system on their surface, the process explained in Section 4.1.2 of this chapter is carried out. The property owner will then be asked for as little information as possible. They will, however, be notified regularly of the progress of the project.

Figure 12 Illustration of the page to register a new surface

6.3.2 Investing

Figure 13 Illustration of the page to invest in a solar project

The platform displays all the projects for which financing is available in a marketplace. Projects can be viewed individually in a list or on a map. By clearly displaying the simulated ROI, this enables projects to be compared, and encourages investment. It is also possible to choose to invest in pools of projects, for example for all projects in a specific city, as explained in Section 6.4 of this chapter.

Once on the project page, you can access all the information and purchase a share in the PV system. It is possible to have basic information such as its location, the size of the project, its total price, the planned commissioning date, the chosen installer, the owner of the surface, and so on. It is also possible to have a map of the surface, with the different owners (if they have agreed to be displayed publicly) and the remaining free surface. It is also possible to display the predicted daily ROI and the predicted environmental impact of the PV system. A media area is also available for viewing photos of the installation, a video of the project or a 3D simulation of the project.

6.3.3 Portfolio

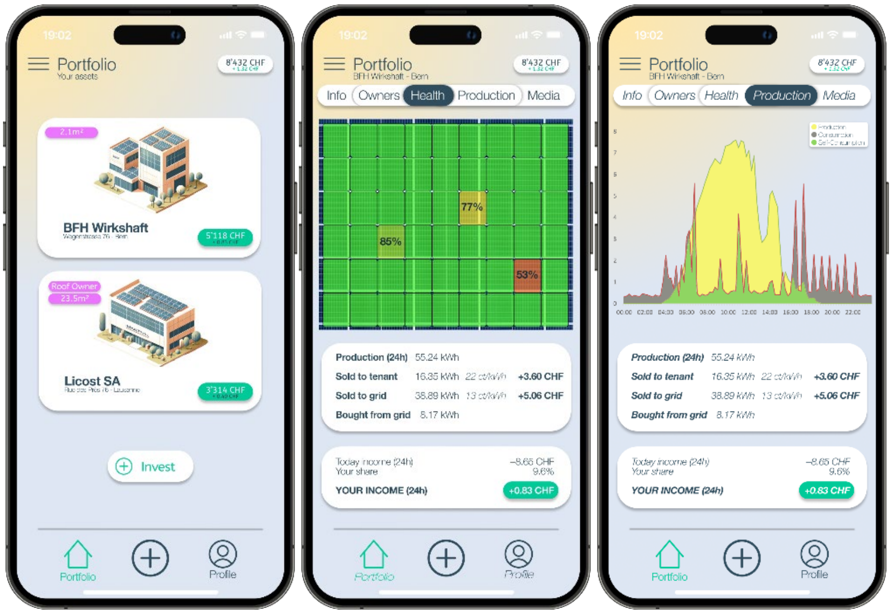


Figure 14 Illustration of the page to manage portfolio.

The portfolio groups together the assets linked to the user. This may be the PV systems he owns as an investor, or those where he is the property owner.

This portfolio shows the total daily income from each PV system, and the share belonging to the user. It is possible to display the health of each panel in the installation, as well as its production curves.

It's also possible to place one of your assets for resale, so that it can return to the marketplace, as described in the previous point. It will then be possible for another investor to buy it directly at a preferential price, without having to wait for the project to be built, as it already exists.

6.3.4 Gamification

By clearly showing the revenue generated each day, the amount of electricity produced and the CO2e avoided, this application activates the production of dopamine in the user, who will want to invest even more to boost these figures.

It may also be possible to provide virtual badges in the form of NFTs, or real trophies, for achievements such as owning 10, 100, 1000m2, or finding 10 surfaces as a recruiter, etc.

6.4 What is a pool of projects?

As illustrated in the presentation of the application, SolarSwift Services offers project pools. This consists of a group of several projects with a common denominator, comparable to ETFs in the world of finance. This could be a similar geographical region, such as all the projects in the same town, canton or country.

There are many advantages to having project pools:

– For the investor, you don't have to take the time to analyse each project. Simply choose a region, and SolarSwift will finance the most appropriate projects.

- Diversifies the portfolio, and therefore spreads the risk over several projects, in case one performs less well or has problems.
- Allows SolarSwift to have an investment fund in which to take in order to finalise the financing of the projects almost at 100% of their financing.

6.5 How to provide quality support?

This topic is covered in the "3 Customers Segment and Relationships" section of the Business Model chapter. In addition to this, the fact that SolarSwift has access to remote data from all PV systems means that faults can be predicted. The use of technology and algorithms such as those proposed by SmartHelio seems promising for fault prediction (Smarthelio, n.d.). SolarSwift can provide this service in order to limit future support requests.

6.6 How to manufacture and distribute Smart Electricity Meter?

The construction, production and distribution of SolarSwift's Smart Electricity Meter, which must interface with the EnergyWeb blockchain and SolarSwift's servers, was not covered in this work.

However, the concept of this meter was discussed in section 5.7 of this chapter.

6.7 How to provide a legal contract of ownership to investors?

Normally, proof of ownership of an asset on another property owner's surface is provided by the "surface right", explained in Articles 675 and 779 of the Swiss Civil Code. However, such a contract must be drawn up for a minimum of 30 years and a maximum of 100 years, must be registered in the "land register" by a notary, and only applies to a given surface, so does not include the rest of the installation that is not on that surface, such as the inverter or the batteries.

It would be better to draw up a "lease contract", as explained in Articles 253 and 274 of the Swiss Code of Obligations, between the investors and the property owner. This contract can be drawn up without a notary.

It may be necessary to distinguish between an installation installed on a surface, in which case it may belong to the investors, and an installation incorporated into the roof or facade of a building, in which case it forms part of its envelope, and cannot legally belong to the investor. In this case, the investor will not acquire the solar panels as such, but only the right to the income, as Solarify does (Solarify, 2020).

It should be noted that no notary or lawyer has been consulted in the course of this work on this point, and that it would be necessary to do so. We simply know that this is possible, as Solarify is already doing it.

6.8 How to provide a certificate of sustainable investment?

Companies and financial institutions may be interested in receiving a certificate of the impact of their investment in PV projects, in order to improve their scope 3 impact. This may enable them to have a better ESG score, or to communicate to their clients about the impact investments they are making.

By measuring the difference between the environmental impact of the local electricity mix and that of the PV system they own, it is possible to determine the impact of their investment.

The EnergyWeb blockchain can already be used to provide these certificates, with their solution called "Green Proof".

6.9 How to make the bridge between DeFi and traditional financing?

We saw that if the SolarSwift Core infrastructure uses a decentralized system on a blockchain, the various stakeholders will need to have a decentralized wallet (such as MetaMask or Trust Wallet), so that the smart contracts can transfer the revenues generated by the sale of electricity between the

buyers' and sellers' accounts on a daily basis. This can greatly reduce the platform's user-friendliness, and therefore hinder its expansion, as not all users, be they private investors, banks, the property owner or the utility company, will agree to interact with the Decentralized Finance (DeFi) system. In order to reduce the barriers to the use of our platform, it must be possible for any user to use the standard banking system to invest in solar, pay for the purchase of electricity, or receive income from the sale of electricity. To this end, SolarSwift offers a bridge service, illustrated with blue boxes in Figure 15. This allows the user to use payment networks such as Twint, PayPal, Visa, MasterCard, Bitcoin, or the standard bank network.
Transactions are still carried out automatically on the EnergyWeb, however the amounts are stored in accounts on the blockchain managed by SolarSwift (in blue boxes), and not by the stakeholder. They can send money to SolarSwift, which will fill their account. The stakeholders are able to view their balance in their account using the dApp, and can use it to invest in new solar projects, or request a withdrawal of this amount to their standard bank account.

Also, any user can ask to take back possession of this account at any time, as it belongs to them. They can then manage the funds themselves.

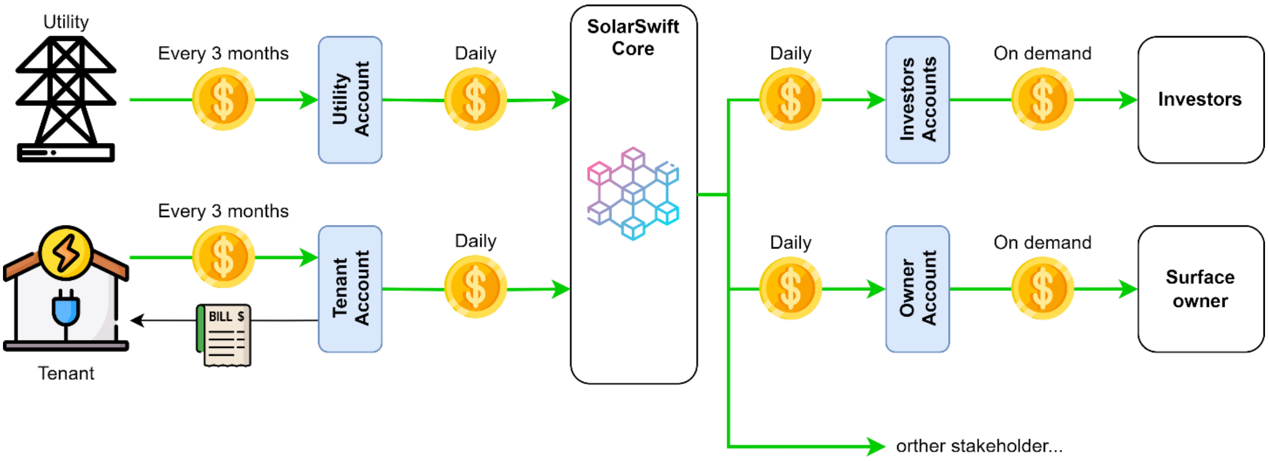


Figure 15 Bridges between standard bank account and DeFi account.

7 PV System Cost & Revenue Simulator

As part of this work, three cost and revenue prediction tools are required. The first tool concerns the prediction of the installation costs of a new solar system. A second tool concerns the operational and maintenance costs of the solar system during its lifetime. The last tool is used to predict the production and revenue of an installation. These have several purposes:

- To learn and understand the revenue and cost structure of a PV system.
- Simulate the viability and financial attractiveness of a solar system.
- Display in the marketplace of our application, the ROI of a PV system and its accounting.
- Draw up the accounting for the SolarSwft project in the "Business Model" chapter.

Also, if we want to automate the design of new solar projects as much as possible in order to scale up the solar transition, we need simulators that are as autonomous and accurate as possible, so that we need to rely on human consultants as little as possible.

In this chapter, the operation and formulas of these three prediction tools will be demonstrated, followed by a conclusion to summarise the final result.

7.1 Installation Cost Simulator

This first prediction concerns the cost of installing a solar system. It is necessary in order to be able to judge the extent of the fund-raising required to finance an installation, as well as to calculate the Return on Investment (ROI) of the project.

7.1.1 Methodology

For the purposes of this report, a 2022 market study will be used as a reference to predict the costs of a new solar system. This was commissioned by SuisseEnergy to the consulting firm Planair SA (Swiss Federal Office of Energy, 2023b), based on the costs of new solar systems installed in Switzerland in 2022 (4,161 observations). This will enable us to calculate an estimate of the cost of a new solar system, as a function of its size alone.

It was therefore decided not to develop a complete cost simulator, taking into account every parameter of a solar installation. This decision is due to the fact that many of these parameters, presented in the next section, are highly variable, unknown and dependent on the current market price. For the sake of simplicity, the statistical results of the market study have therefore been preferred.

7.1.2 Parameters influencing the cost

The simplification in the statistical model used means that we lose the possibility of modifying the cost of a solar system according to its features. It is therefore important to bear in mind that the following elements will influence the final price of the installation (Swiss Federal Office of Energy, 2023b; Younergy, 2023a):

- Price, technology and number of PV panels,
- Price and number of optimisers (optional),
- Price and size of inverter,
- Price and size of battery (optional),
- Price of the mounting system,
- Price of electrical equipment,
- Price of surface renovation (optional),
- Administrative costs,
- Price of system installation + installer's margin.
- Subsidies.

7.1.3 Descriptive statistics

In this section, an first form of the results of the study is presented, using descriptive statistics. The price per kWp of a solar system, according to its size category, is presented in Table 12. The median price as well as the low (25%) and high (75%) statistical ranges are given. In Figure 16, a box plot illustrates these results, and clearly shows the decrease in specific costs (CHF/kWp) as the size of the installation increases. A centralised installation can cost up to 3 times less (982 CHF/kWp) than a residential installation (3,032 CHF/kWp). This is due to economies of scale, allowing large volumes of equipment to be ordered, and savings on fixed costs such as administration, planning and design. We can also observe the consequent range of uncertainty in costs for small solar systems, making it complicated to estimate costs accurately using this method.

Table 12 Size and price statistics of solar systems added in 2022 in Switzerland (Swiss Federal Office of Energy, 2023b).

Size	Typical applications	2022 prices stats [CHF/Wp]
Residential 2-10 kWp (11-53 m2)	Typically roof-mounted systems on villas and single-family homes	Median: 3.03 25–75%: 2.6 – 3.6
Small commercial 10-30 kWp (53-158 m2)	Public buildings, multi-family houses, agriculture barns, grocery stores, etc.	Median: 2.38 25–75%: 2.1 – 2.8
Medium commercial 30-100 kWp (158-526 m2)	Public buildings, multi-family houses, agriculture barns, grocery stores, etc.	Median: 1.76 25–75%: 1.5 – 2.1
Large commercial 100-300 kWp (526-1578 m2)	Public buildings, multi-family houses, agriculture barns, grocery stores, etc.	Median: 1.31 25–75%: 1.0 – 1.5
Industrial 300-1000 kWp (1578-5260 m2)	Industrial buildings, warehouses, etc.	Median: 1.10 25–75%: 0.9 – 1.3
Centralized plant 1000+ kWp (5260+ m2)	Central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	Median: 0.98 25–75%: 0.9 – 1.2

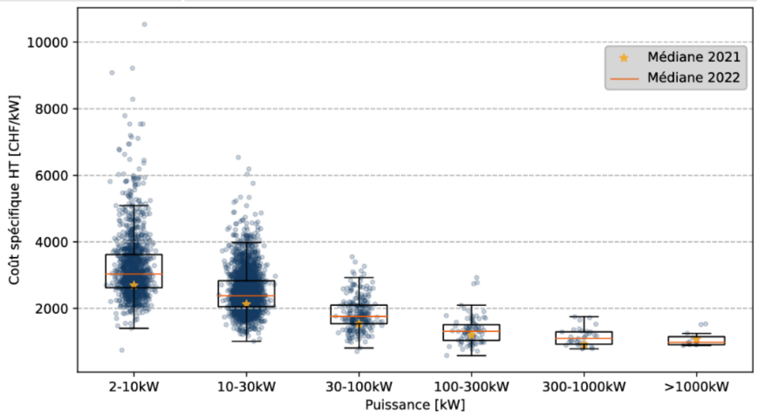


Figure 16 Box plot of solar system price, by size categories. Min, 25%, Median, 75% and Max are presented.

7.1.4 Linear regression

In this section, a second form of the study results is presented, in the form of a linear regression by part. The illustration in Figure 17 plots the cost of solar systems installed in 2022 as a function of their size (up to 300kWp), then a regression by part is carried out, according to the size categories seen previously. The advantage of the partial regression is that it takes into account both the fixed and variable costs of an installation, whereas the median does not consider any fixed costs. With the latter, a more accurate result can be calculated than with the median. The coefficients of the piecewise linear regression are given in Table 13. We note that the variable part (a) is strictly decreasing and that, on the contrary, the fixed part (b) is strictly increasing.

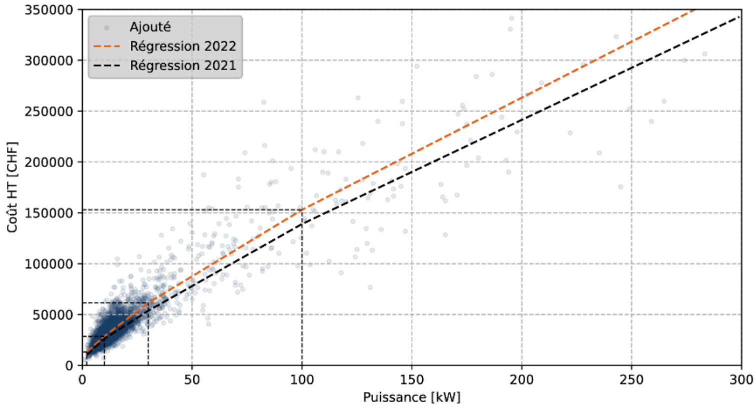


Figure 17 Cost of solar systems added in 2022 up to 300 kW. The orange curve is a piecewise linear regression of these costs, by size categories. The black curve corresponds to the regression given in the previous year (Swiss Federal Office of Energy, 2023b).

Table 13 Parameters of piecewise linear regressions of solar system costs added in 2022.

Size [kWp]	a [CHF/kWp]	b [CHF]	R2
2-10	1'930	9'240	0.23
10-30	1'646	12'072	0.38
30-100	1'307	22'241	0.51
100-300	1'102	42'753	0.43

This linear regression gives us the formula for a statistical prediction of the price of a solar system, as a function of its size, presented in Equation 1.

$$Cost\ [CHF] = \min_k \left(a_k \left[\frac{CHF}{kWp}\right] * P[kWp] + b_k[CHF] \right) \qquad \text{Equation 1}$$

However, as we do not have access to the raw data, it is not possible to calculate the Standard Prediction Error (SEP) of the regression by part, which would allow us to calculate an expected price range ($cost(x) = y \pm SEP_x$). We must therefore use the low (25%) and high (75%) limits presented in Table 12 in order to obtain a price range. Figure 18 illustrates this range, and the linear regression, for each category up to 300kWp.

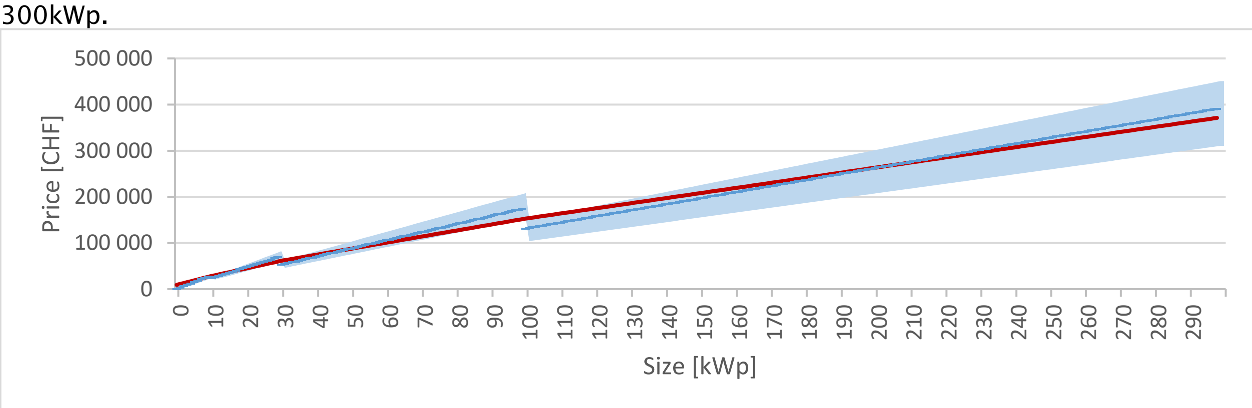


Figure 18 Static predictions of the price of a solar installation as a function of its size. In red, prediction by linear regression per part. In blue, prediction by the median of each category, with the interval between its low (25%) and high (75%) limit.

7.1.5 Result

For the purposes of this report, the result of the stepwise regression, being the most accurate, will be used as the basis for all cost calculations, with an indication for information purposes of the upper and lower limits.

Subsidies, presented in the literature review in section 1.9 of the "Transdisciplinary methods" chapter, and whose amounts can be simulated on the Pronovo website (Pronovo, 2023c), must then be subtracted from this cost.

It is therefore important to note that with this solution, a manual cost estimate by a professional will always be necessary, before publishing the price of a solar project on the platform. If the cost estimate wants to be fully and accurately automated, in order to speed up administrative processes by making it unnecessary to create a quote manually, a simulator that takes into account all the parameters specific to an installation will have to be developed.

7.2 Operating and Maintenance Cost Simulation

For the SolarSwift project, accurately forecasting the operational and maintenance expenses throughout the lifespan of the solar installation is crucial. This encompasses costs associated with subscriptions, insurance, routine maintenance, and repairs. A distinctive aspect of our approach involves saving a monthly reserve for these expenditures, thus negating the need for investors to provide immediate funding for future maintenance activities. Given the multitude of investors for the solar system, pre-allocating funds for maintenance simplifies the process, ensuring that necessary work can be conducted without financial or logistical hurdles. This preventive financial planning is essential for the seamless operation of the project, requiring precise estimation of operational costs at the project's design.

7.2.1 Methodology

For the purposes of this report, a complete operating cost simulator, taking into account each parameter, has not been specifically developed. This is because solutions already exist, in particular a model presented by the National Renewable Energy Laboratory, an American public institution (H. Walker et al., 2020).

However, this model requires knowledge of all the details of a solar installation, as well as the current market prices of each component, making it impossible to use it before the complete development of a new solar system. For this reason, a second method is also proposed. This consists of a review of current recommendations on the annual savings to be expected, as a function solely of the size of the installation, which is simpler to implement.

7.2.2 Parameters influencing the cost :

If we want to use the NREL model, some parameters have to be taken into account to know the annual operation and maintenance costs of a solar installation. They are as follows (H. A. Walker, 2018):

- List of equipment present in the solar system,
- Life expectancy of the equipment before replacement,
- Duration of warranty on equipment,
- Price of equipment to be replaced,
- Frequency of maintenance work (cleaning, technical inspection, roof weeding),
- Price of periodic maintenance,
- Price of periodic charges (meter subscription, network connection),
- Price and cover of insurance.

7.2.3 NREL Model of Operating and Maintenance Costs

This model presents a method for calculating the costs associated with the operation and maintenance of photovoltaic systems. It gathers information on the cost and frequency of several maintenance services to estimate their annual costs. This will show the net costs over the years of the maintenance work, what has been saved, and what remains in the reserve account for possible additional maintenance. It can also be used to determine whether a minimum initial capital is required to finance any work in the early years, when the reserve has not yet been built up.

NREL can provide a spreadsheet incorporating this model on request. An example is shown in Figure 19. However, access to this spreadsheet has not yet been obtained.

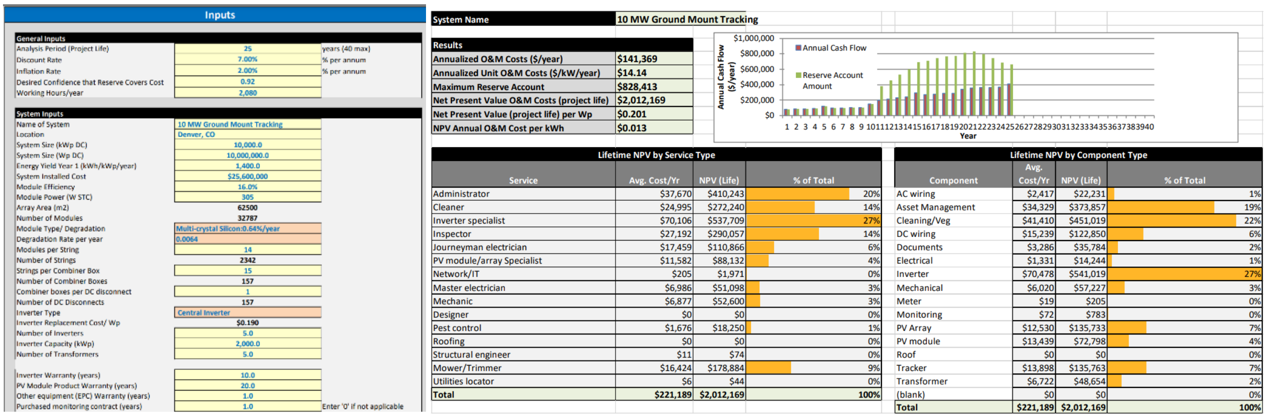


Figure 19 Partial list of inputs (left) and report (right) of the NREL Operating and Maintenance Cost Model spreadsheet.

7.2.4 Survey and trends in the Operating and Maintenance Costs

In a meta-analysis published by NREL in 2018 (H. A. Walker, 2018), based on several American surveys, it is recommended to allow 1% of the installation price per year for operational and maintenance costs, for small installations (residential and small industry). A saving of 0.5% is recommended for large installations.

For Switzerland, the solar company Voenergies also recommends allowing 1% of the base price per year for these costs (Voenergies, 2023).

7.2.5 Results

In the context of this project, it will be considered that 1% of the base price of the installation per year must be saved in order to pay for operational and maintenance costs, such as insurance, the various subscriptions, equipment replacement in the event of a fault, and cleaning.
The additional costs relating specifically to our solution are negligible, because the price of transactions on the EnergyWeb blockchain is $0.0001, and the price of the subscription to connect the Smart Metter to the internet is 1-3CHF per month. No other additional O&M costs have been detected.

7.3 Revenue Simulation

This prediction concerns the electricity production and revenue generated by a PV system. It is essential for calculating the viability and ROI of a solar project, particularly in the Business Model section.

7.3.1 Methodology

For Switzerland, a production simulator is available on the Confederation's website (Swiss Federal Office of Energy, 2023e). It can be used to simulate monthly electricity production for an installation of a given size, and to find out the self-consumption rate.

However, this simulator is based on the Tachion algorithm dating from 2008 (Solarcampus, 2008). This model lacks certain aspects, such as the degradation of panels over time, the effect of temperature, the detection of shadows from nearby trees or buildings, and the analysis of the roof to determine the surface that can actually be used. Furthermore, it does not take advantage of data recently produced by swisstopo, such as 2D and 3D imagery of the territory, which could be very powerful in improving the simulation. What's more, it is designed primarily for PV systems on individual homes, and not for industry or business.

That's why a first version of a complete production and revenue simulator was planned as part of this project, along the lines of what Google can offer with its Sunroof project (Google, 2023). This would also have enabled us to have total control over its operation, so as to better understand and control it. Several days of work were carried out on this simulator, but after reconsideration of the necessary workload, it had to be abandoned. It was therefore decided to go back to the simulator proposed by the confederation in order to simulate electricity production for a given surface, and then to calculate the income in a spreadsheet using local market values.

Nevertheless, in the next section we will come back to the important parameters to consider when simulating the production and revenue of a solar system, and we will suggest ways of improving the confederation's simulator. This can be used for future simulator development, even if this information is not actually used in our final solution.

7.3.2 Parameters influencing the production and revenues

Many parameters influence the production and revenues of a solar system. These parameters and their interactions are illustrated in Figure 20, and are explained in this section. Here we can see several important steps. Firstly, it is necessary to know the average solar irradiation energy per m2 for a given surface, by month of the year (in kWh/m2). Then, by knowing the size of the installation, we can determine its total irradiation energy (in kWh). Knowing the actual efficiency of the PV panels, it is finally possible to calculate the electrical energy produced by the solar system (in kWh). In order to calculate the revenue generated, it is necessary to divide this production between the electricity self-consumed by the occupant, and that sold to the grid, depending on the occupant's self-consumption profile.

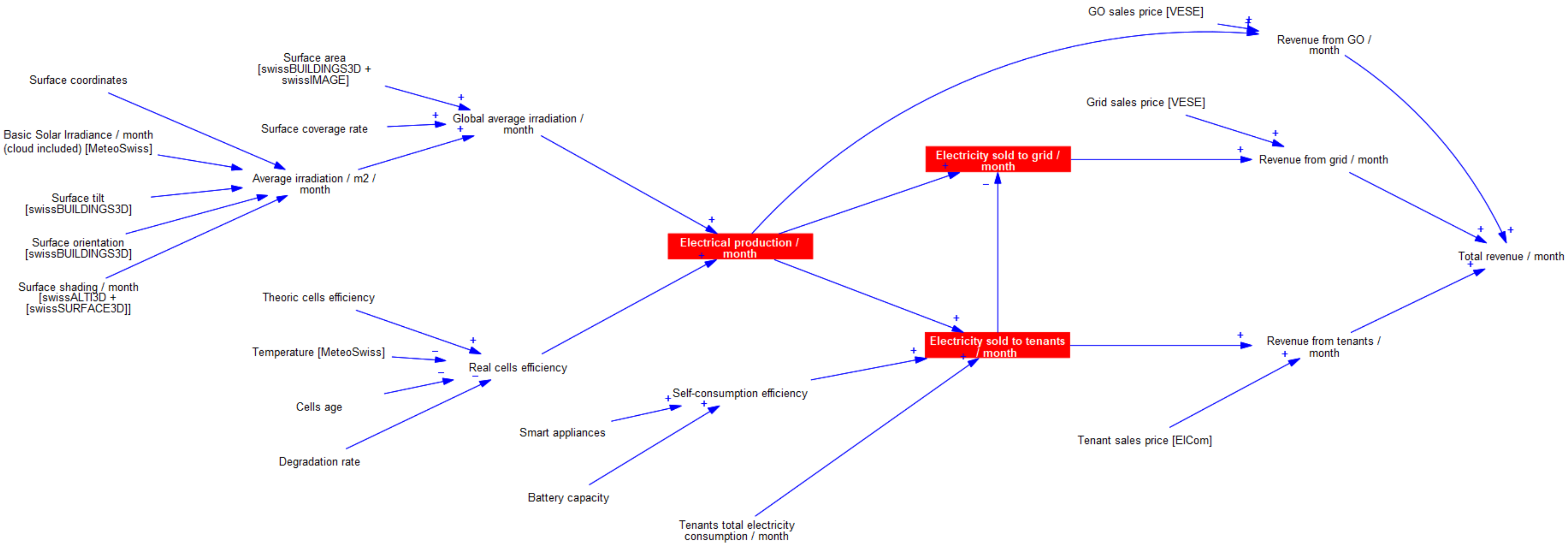


Figure 20 Dynamic system of photovoltaic production and revenue. In red, the data provided by the Tachion simulator.

Average Irradiation / m2:

First of all, the average basic irradiance of the surface must be known. Although the sun's theoretical irradiance is 1000W/m2, this is much lower in Switzerland due to factors such as cloud cover, air transparency and humidity. This information for every region of Switzerland, and for every time of year, is publicly available on MeteoSwiss (MeteoSwiss, 2023).

The orientation and inclination of the surface is also very important. To maximise the radiation energy reaching the PV cells, the surface should be perpendicular to the sun's rays. For Switzerland, a southerly orientation and a tilt of 60° in winter and 20° in summer is optimal. Although mobile structures on 1 or 2 axes exist, in order to always maximise perpendicularity to the sun, they are still rarely used, mainly due to their cost and complexity (Rodríguez-Gallegos et al., 2020). It is therefore necessary to integrate the effect of these two parameters on the result. To find out the basic slope and orientation of a building's roof, the public database swissBUILDINGS3D can be used (swisstopo, 2023b).

A final important point to consider is the shading of the surface by external factors, such as a tree, a house or relief. However, this factor is not currently taken into account by the Confederation's simulator. Two techniques could be implemented to determine the shading of the surface over the course of the year and the day.

1. The first consists of taking a 360° image of the sky over the solar system and extracting the shading elements using image processing. Then, the sun's path can be simulated over the course of the year, and the direct exposure time of the panels over the course of the year can be deduced (Figure 22). The disadvantage of this technique is the need to visit the site in order to take the 360° image.
2. The second uses the 3D data provided by the Swiss Confederation for the entire surface of Switzerland, in order to simulate the shading elements. In this way, the shading of all Swiss roofs can be simulated, without having to go on site. The 3D relief is publicly accessible on swissALTI3D (swisstopo, 2023a) in order to model the shading of mountains, and a Lidar map of Switzerland is publicly accessible on swissSURFACE3D (swisstopo, 2023d) in order to model the shading of trees and buildings. An example of a simulated view of the sky from a roof, using the swissSURFACE3D point cloud, and simulated on QGIS, is available in Figure 23 (p. 67). The elements obstructing the sun, as well as its trajectory, can be observed.

PV system Irradiation

In order to know the total irradiation of the PV system, it is necessary to know its size. This can be obtained from swissBUILDINGS3D. However, in the Confederation's simulator, the state of the surface is not taken into account, such as the presence of a window, a chimney or air conditioning. It is therefore necessary to apply a reduction factor in order to determine the actual size of the installation. However, this factor is arbitrary.

One solution would be to use aerial imagery to analyse the condition of the roof and then use image processing to identify the areas that are actually accessible. These aerial images are publicly accessible on swissIMAGE (swisstopo, 2023c).

Real cells efficiency

The efficiency of a solar panel depends first and foremost on its design, and is provided by the supplier. It varies between 17-23%. Other factors are also taken into account, such as degradation and temperature. However, these factors are not taken into account by the Confederation's simulator.

The rate of degradation depends on a number of factors, such as the quality of the panel and local weather conditions. For conditions corresponding to Switzerland, a degradation rate of 0.6% per year is measured on average (Sharma & Chandel, 2013), meaning that the panel produces 82% of its capacity after 30 years.

With regard to temperature, the panels are tested for a temperature of 25°C. If this temperature changes, the output voltage will be affected linearly with temperature, altering its efficiency. There is a loss of 0.26% for each additional degree, and a similar gain for each lower degree (Fox, 2017).

Self-consomption

It can be complicated to predict how much electricity an occupant will be able to self-consume. This depends on their energy demand, but also on their consumption profile. It is important to be able to estimate this profile, because if the tenant consumes electricity when production is insufficient, for example at night, self-consumption will not be possible. To illustrate this case, PV production and self-consumption data for a PV system over one day are shown in Figure 21. Although the solar production (55kWh) could cover all the consumption (25kWh), only part is self-consumed (13kWh).

To improve self-consumption, two types of technology can be installed. A battery, which will store the energy produced for later use, and an intelligent appliance manager, which will start up consumers only when solar electricity is available.

The self-consumption profiles from the confederation's simulator were used for this report. There are 3 profiles. For family homes, for businesses working 5/7 days, and 7/7. However, the simulator does not support installations where consumption exceeds 100 MWh, corresponding to a small to medium-sized business.

Resale price

The revenue from a PV system comes from three sources. The resale of self-consumed electricity to the building's occupants, the resale to the grid, and the resale of guarantees of origin.

The resale price to the building's occupant is fixed in a contract at a lower price than the electricity purchase price from the grid. This will encourage property owners to make their roofs available and encourage self-consumption. For our simulator, this price will be set at 80% of the purchase price from the local utility, information that can be found on the Federal Electricity Commission website for each utility (ElCom, 2023).

The grid feed-in price is set by the utilities and cannot be traded. These tariffs are listed and made available on the website of the Association of Independent Energy Producers (VESE, 2023).

A final revenue stream concerns the sale of guarantees of origin, enabling an electricity supplier to guarantee the origin of the electricity it sells. It is possible to resell these guarantees directly to local utilities, or there are resale markets for these guarantees, where the price can be more attractive. For our simulator, the buy-back value offered by the public utility will be used, which can be found on the VESE website.

7.3.3 Results

The Confederation's simulator will be used to determine the monthly production of an installation, as well as its self-consumption. The self-consumed electricity will then be sold at 80% of the local electricity price to the occupier, which can be found on the Federal Electricity Commission website (ElCom, 2023). The surplus will be sold to the utility company, whose prices can be found on the Association of Independent Energy Producers (VESE, 2023) website, and finally the GOs will be sold at the local utility company price, also found on the VESE website.

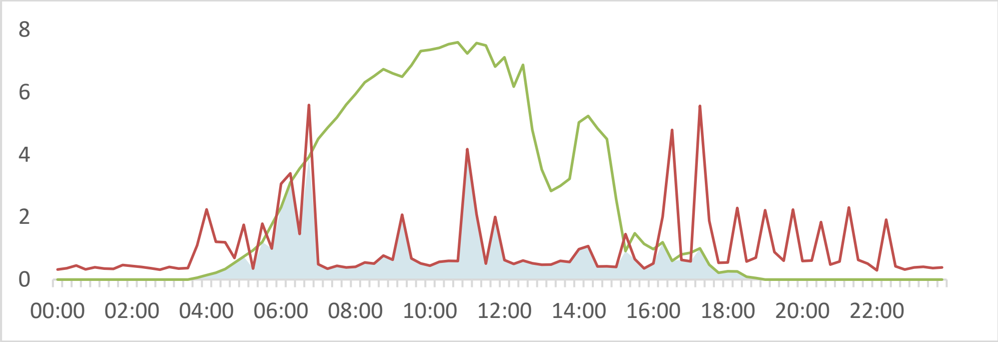


Figure 21 Production (green), consumption (red) and self-consumption (blue) profiles on 24h for a residential house.

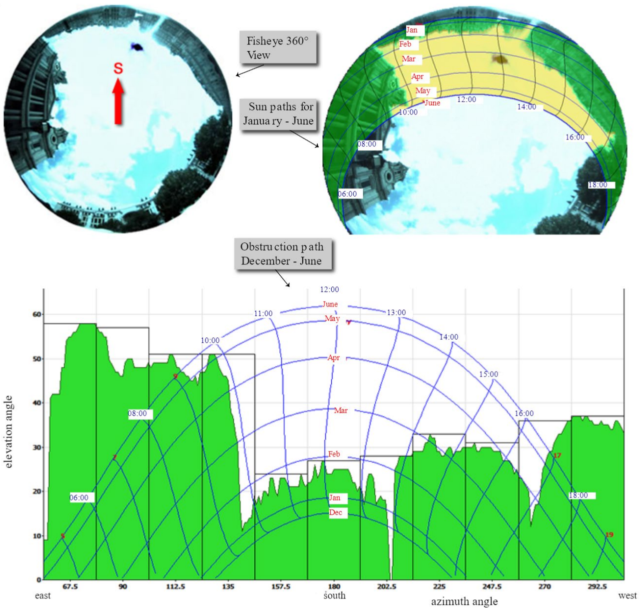


Figure 22 Shading determination with 360° picture (Baumgaertner, 2016)

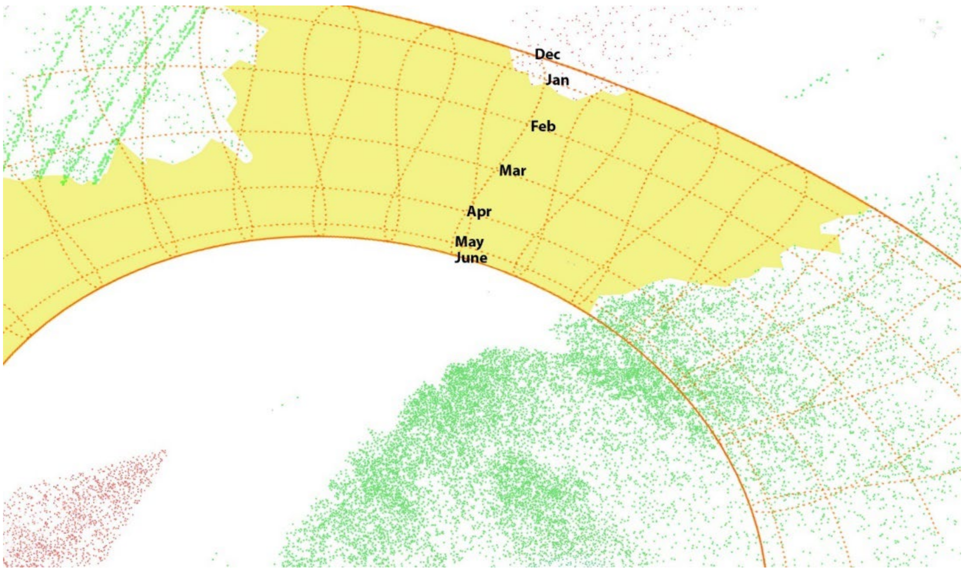


Figure 23 Shading determination with 3D simulation. View of the sky from a roof, with sun trajectory (orange), sun exposition (yellow), vegetation (green) and building (red). 3D data from swissSURFACE3D (swisstopo, 2023d), simulation done with QGIS.

7.4 Conclusion

To summarise, the design and installation costs of a PV system are simulated as a function of its power, using a linear regression whose parameters can be found in Table 13. To this must be subtracted the subsidies, presented in the literature review in section 1.9 of the "Transdisciplinary methods" chapter, and whose amounts can be simulated on the Pronovo website (Pronovo, 2023c).

Operational and maintenance costs are calculated at 1% of the total PV system price per year.

Revenues are calculated using the Confederation simulator for electricity production and self-consumption of a PV system, then local utility prices for electricity purchase and buy-back and GO buy-back are used to calculate the total monthly revenue of a PV system.

This information is finally used in a spreadsheet to do the accounting for a PV system. This spreadsheet is presented in Figure 28 (p. 92).

8 Validation by peers

Validation of the platform by external peers was carried out as part of the Transdiciplinary methods module. The results are available in Section 5.3 of the "Transdiciplinary methods" chapter.

9 Conclusion

Based on the key features, obtained by transdisciplinary methods, that our solution should have in order to facilitate the participation of investors and property owners in the solar transition, we have been able to design a platform that meets those features, with the following solutions:

- Eliminates up-front costs for property owner, using third-party investors,

- Reduce time investment and expertise needed for investors and property owners, by providing an accessible, user-friendly interface and a clear separation of roles between stakeholders, enabling them to focus solely on what's relevant to them, without having to invest time, money, or knowledge, and thus minimize their barriers to entry.

- Be the single point of contact for all stakeholders, providing all necessary services directly or indirectly.

- Enabling investors to own their investment, using the F-TPO model, allowing investors to own a fraction of a PV system on someone else's property.

- Enabling stakeholders to withdraw from contracts at any time, by providing a mechanism for resale of shares as an investor, or buy-back of all shares as a property owner.

- Providing good and responsive support, by offering support that provides an initial response within 10 minutes, and setting up communication communities.

- Create an open, public and interoperable solar marketplace, using the EnergyWeb public blockchain.

The platform would have a backbone, SolarSwift Core, based on the EnergyWeb blockchain, and using a decentralised smart meter to measure production. SolarSwift Core provides a standardised, transparent, secure and future-proof system for distributing and storing proof of ownership (F-NFT), and automatically redistributing PV system revenues between stakeholders. It also allows the sale and buy-back of proof of ownership of a share of the PV system. This would work even if SolarSwift went bankrupt.

On top of this, SolarSwift Services provides all the services needed to orchestrate the creation of new solar projects, as well as the monitoring and maintenance of PV systems in production. These include finding property owners, investors, installers, insurers, providing support, and developing and maintaining the decentralised application used to access the platform.

It will be possible to access all the platform's functions via this application, so that you don't have to go through a contact person. This includes, for example, registering a new surface, buying shares in a PV system, managing your portfolio, tracking your income on a daily basis, offering your services, etc.

At the same time, a solar system cost and revenue simulator has been developed, to provide its ROI, to understand its cost and revenue structure, and to be able to do the accounting for the SolarSwift project in the "Business Model" section.

Peer feedback on our solution was conducted, the results of which can be seen in the conclusion to the 'Transdisciplinary Methods' chapter.

Business Model

This chapter presents the business model accompanying the SolarSwift platform presented in the "Product & Process" chapter, and responding to the problem addressed by transdisciplinary methods in the "Transdisciplinary Methods" chapter.

The knowledge acquired in the transdisciplinary methods module will be essential in this chapter.

1 Methodology

The various sections of this chapter cover the themes addressed by Strategyzer's **Business Model Canvas** (Strategyzer, 2023a).

Firstly, our Value Proposition has been designed, using the **Value Proposition Canvas** for our different customers, also proposed by Strategyzer (Strategyzer, 2023b). Several value propositions have been made as they are different for each of our customer segments.

The description of our customer segments, our relationships with them, and the channels we maintain with them are then addressed in the "**Customers Segment and Relationships**" section.

The resources and partners we need, and the activities we carry out, are described in the "**Operational Framework and Resources**" section.

This is followed by information on the cost and revenue structure of the SolarSwift platform. A "**Market analysis**" is presented, as well as the "**Accounting of a PV system**", which is necessary in order to carry out the cost and revenue structure of our SolarSwift platform. This accounting requires the revenue and cost simulator developed in the Products & Processes module. In addition, several of the 55 Business Model Patterns proposed by the Business Model Innovation Lab, a spin-off from the University of St. Gallen, were selected for the design of our business model (Business Model Innovation Lab, 2023). These three sections finally enable us to propose a "**Revenues & Costs structure**" for our project.

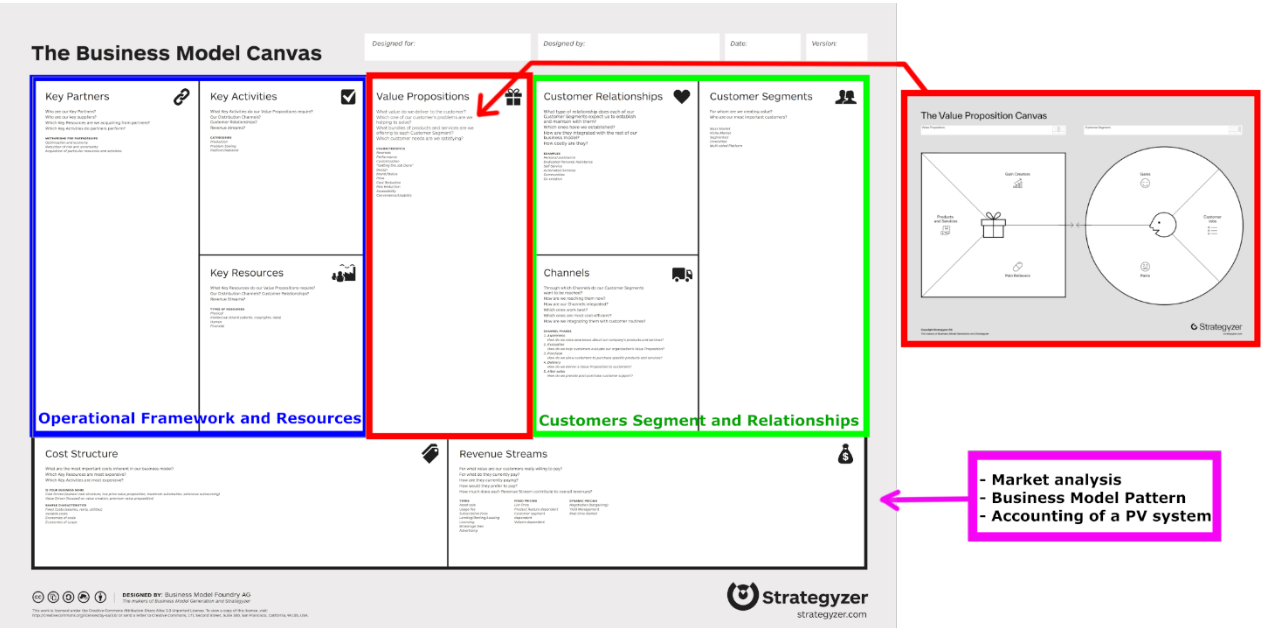


Figure 24 Methodology of the Business Analysis

2 Value proposition

The value proposition for each stakeholder is explained in the following sections.

2.1 Value proposition for investors

The SolarSwift digital platform offers new opportunities for investors seeking to participate in the energy transition, while having a positive and low-risk ROI, by allowing them to own part of a solar system on someone else's property, while removing the need to invest time and knowledge to find and manage a viable solar project.

The values of our business model for investors have been classified into the following categories:

- **Positive ROI and low-risk Investment** : Investing in solar energy provides a positive and low-risk ROI. This is possible thanks to the resale of the electricity and GOs generated by the panels. The investment is low-risk because the PV system will be maintained and generate income for the duration of the contract (30 years minimum), ensuring that even the most inefficient PV systems will repay the initial investment.
- **Simple Investment** : No knowledge, time or networking is required to invest in solar energy. By providing a marketplace of solar projects, the investor does not have to worry about finding a property, an installer, administrative procedures, and the management of a solar project. All they have to do is invest in the solar projects that interest them, in the same way as applications for buying stocks or cryptocurrencies. In addition, there is no minimum investment amount, making investment possible for all investor profiles.
- **Sustainable Investment** : The investor pushes the energy transition, enabling fossil fuel consumption to be reduced in favour of solar power. For companies and financial institutions, this participation can be attested by Green Certificates, enabling them to reduce their carbon footprint in order to achieve their ESG objectives, and show their customers the impact of their investments.
- **Transparent and Clear Investment** : Details of production, revenues and their sharing between stakeholders are visible in real time on the platform. These are paid daily into the investor's virtual wallet, and can be withdrawn at any time.
- **Safe Investment** : The F-TPO model guarantees that investors are officially the property owner of their share of the solar system, reducing their risk. This is particularly important in the event of SolarSwift going bankrupt, allowing the investor to retain ownership and income. The platform also allows investors to sell their shares at any time if they need liquidity.

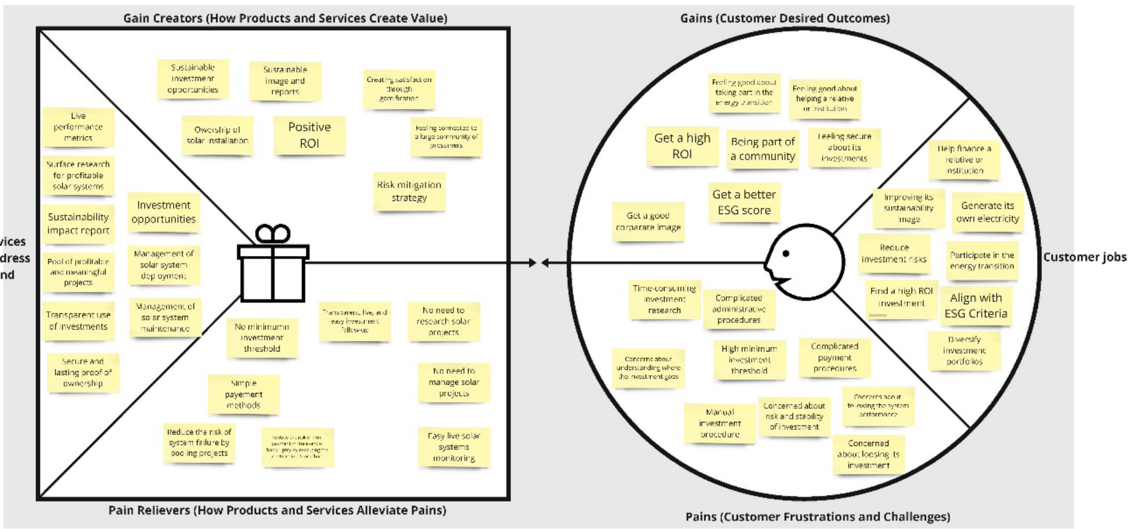


Figure 25 Value proposition canvas for investors

2.2 Value proposition for property owners

The SolarSwift digital platform enables property owners who want to participate in the energy transition to make their surface available, without having to invest money, time or knowledge, while earning an income and reducing the occupier's costs.

The values of our business model for property owners have been classified into the following categories:

- **Simple Registration**: No knowledge, contacts or investment of time or money is required to make your roof available. All you need to do is register to offer your roof as a surface.
- **Revenue**: If you make your surface available, you will receive 5% of the income generated by it.
- **Reduction and stabilisation of charges**: Electricity charges are greatly reduced and more stable for the occupier, as solar electricity is cheaper than grid electricity, and its price is fixed over 5 years. If the property owner is also the occupant, the PV system will directly reduce their charges. In the case of a tenant, the tenant's charges will fall, allowing the property owner to raise the rent to compensate.
- **Sustainable impact**: The property owner participates in the energy transition, reducing fossil fuel consumption in favour of solar energy.

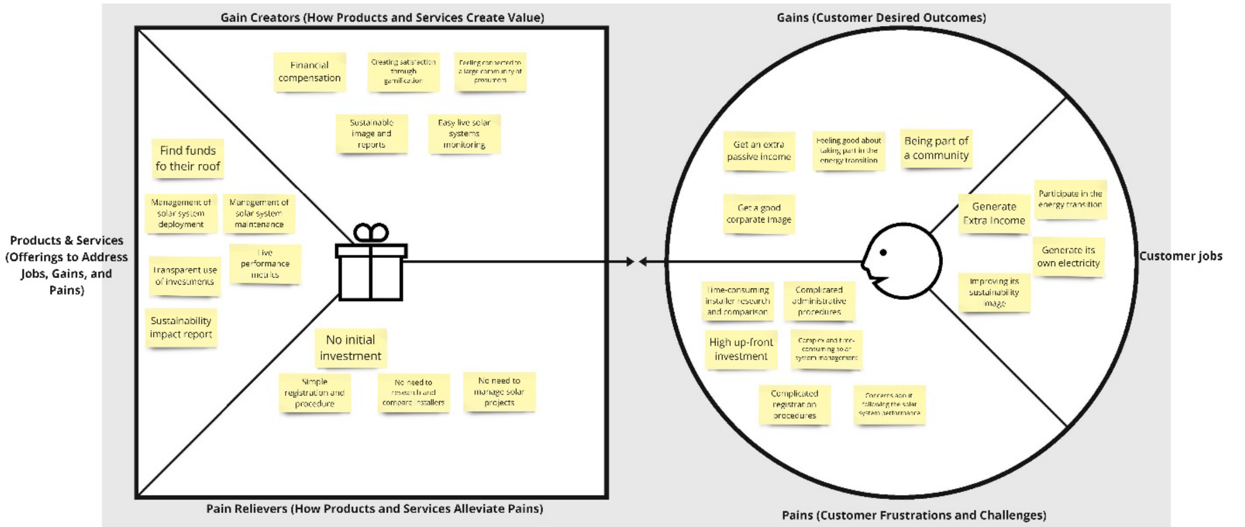


Figure 26 Value proposition canvas for property owner

2.3 Value proposition for occupants

The SolarSwift digital platform enables the occupants of a building equipped with a solar system to reduce and stabilise their electricity bills. This is because the solar electricity is sold at a lower price than the grid price, and on a 5-year contract, guaranteeing a stable price in the event of an energy crisis.

3 Customers Segment and Relationships

3.1 Customer segments

If we analyse the stakeholder map presented in Section 2 of the "Transdisciplinary methods" chapter, we can identify that our clients are investors, surface owners, building occupiers and utility companies. The others will be key partners.

It would be interesting to have a standard platform allowing any type of investor to buy part of a PV system, and to be open to any type of property owner, in order to create a platform open to any situation. However, in reality, not all types of investor or property owner would be interested in it. We therefore need to determine who our target customers are. The same applies to our project's region of action. Although it would be interesting to open up the project internationally, it's important to concentrate on Switzerland initially to develop the product and get initial feedback, and then to open it up quickly to international projects and investors.

3.1.1 Investors

Investors are the natural and legal persons who will buy a share in a solar system, become its owner and receive the income from it.

Who are the investors ?

In today's economy, there are many different types of investor. Our stakeholder analysis (Section 2 of the "Transdisciplinary methods" chapter) provides an overview. First of all, there are citizens who want to invest their savings. Then we have public institutions, such as municipalities or pension funds, investing public money in the local energy transition. Companies also finance solar projects. Most of these are public utilities, but they can also be any type of company. Finally, a large category are financial institutions, such as banks, insurance companies, investment funds, family offices, etc.

What are their interests ?

The interests of our business model for investors have been described in Section 2.1 of this chapter. However, not all types of investor are interested in this value proposition.

Transdisciplinary methods have shown us that financial interest is notably the case for financial institutions, companies and, to a lesser extent, individuals. However, public institutions have no financial interest.

In terms of interest in making investments that seek to participate in the energy transition, no correlation has been found between this interest and the type of investor. This interest depends on the values of each individual and institution.

The interest in Green Certificates relates exclusively to private companies and financial institutions, which can then communicate their environmental commitments.

The availability of a user-friendly application to interact with the platform is mainly of interest to individuals, small businesses and cooperatives. Financial and public institutions will not use this channel, and will want to interact with salespeople.

Who are our target investors ?

In our case, the most interesting investors at first are private individuals and companies. They recognise the financial potential and environmental impact of our type of business model. Our transdisciplinary work has shown that, for the time being, the enthusiasm of these two categories of investor has made it easy to finance solar projects. Financial institutions have great potential, and could accelerate the energy transition. However, they will not be considered in the first phase of the project, as it is complicated to work with financial institutions as well as being regulated by FINMA (FINMA, 2023). The feasibility of enabling financial institutions to invest in solar projects may however be considered for future research.

To sum up, private investors and companies are our target investors for the time being.

3.1.2 Property owners

Surface owners are the natural or legal persons who can decide whether to accept the installation of PV systems on their property, and who receive a share of the revenue generated.

Who are the property owners ?

Their type can be very diverse, and broadly consists of any type of property owner. Our stakeholder analysis shows that we have, for example, private owners of family homes, landlords renting flats, farmers owning agricultural land or roofs, real estate companies, all types of businesses, public institutions, etc.

What are their interests ?

The benefits of our business model for property owners have been classified into three categories. Firstly, by making their surface available, owners can earn 5% of their income from renting out the roof (1). Secondly, installing a solar system enables the property owner to significantly reduce the electricity bill of the building's occupants (2). As we have seen, the solar-generated electricity is sold to the occupant at a lower price than the grid price, and at fixed rates for 5 years. If the property owner is himself the occupier of the property, his bill will therefore be reduced and stabilised. If the property owner rents out the property, the occupants' charges will fall and stabilise, allowing the owner to increase the rent to compensate. The final interest is ethical, for property owners seeking to participate in the solar transition (3).

Who are our target property owners ?

The cross-disciplinary analyses showed us which property owners would be most interested. Public institutions, such as municipalities, appreciate TPO's business model. They don't always have the budget to finance solar installations on their surfaces, and they are also enthusiastic about the idea of offering the population the possibility of using public surfaces for solar installations. In fact, they account for the majority of solar cooperative projects. They are therefore potential customers.

Farmers and industry are also property owners who are more open to the TPO business model. What's more, the large surface area of their buildings is all the more interesting for us.

On the other hand, it has been found that private owners of family homes generally have the interest and the means to finance their PV systems themselves, and therefore have no need for our financing system. What's more, the small size and complexity of family home projects makes them less attractive to us in the first instance.

However, there is still a question mark over the interest of rental flat landlords for our financing system. Their potential is great, as 60% of the Swiss population are tenants, but research needs to be carried out into their interests (Federal Statistical Office, 2021).

Concerning whether we want to target only buildings with high self-consumption, most players in the solar industry seem to be moving in that direction. These are currently more financially attractive in Switzerland. This would mean targeting only property owners with high self-consumption. However, the mission of the project is not to make more profit, but first and foremost to produce as much solar-generated electricity as possible. And as this can be easily transported, there's no need to favour buildings with high self-consumption. What's more, Mr Calame says that current legislation, which strongly favours self-consumption because people don't have to pay any tax, is likely to change and make self-consumption less attractive in the future.

To sum up, public institutions, farmers and industries are the property owners targeted first and foremost, while remaining open to any type of project, as the aim is to democratise the installation of PV systems.

3.1.3 Building occupant

The "occupants" is the term given to the legal entities or individuals living or working in the building where the PV system is located. They can be tenants, or directly the owners of the surface. They are important players in our business model, and our customers, as they will pay for the use of the electricity self-consumed from our PV systems.

The amount and profile of electricity self-consumed by the occupants will significantly affect the revenue of a PV system, since the self-consumed resale price is higher than the grid feed-in price.

Who are the surface owners ?

In terms of the types of building occupant, our stakeholder analysis shows that we can have individuals, companies, public institutions, either as property owners or tenants. It is even possible to have no occupant if the PV system is not connected to an occupied building.

What are their interests ?

The advantage of our business model for occupiers of property is that they can buy PV electricity at a lower price than the grid price, and have a fixed price for 5 years, limiting their exposure to spontaneous fluctuations in the energy market price.

Who are our target occupant ?

From a purely financial point of view, it would be preferable to favour occupants with a high level of self-consumption, such as factories, swimming pools, shopping centres and so on. However, this is not our vision, because we want to install as much solar power as possible, not make as much profit as possible. So we don't want to limit ourselves to any particular type of occupier.

3.1.4 Utility company

Utilities are companies that have a direct link with the end consumer for the sale and buy-back of electricity. Sometimes they are also the Distribution Network Operator. They are important players in our business model, and our customers, as they will pay for the buy-back of surplus electricity from our PV systems, as well as the purchase of Guarantees of Origin (GOs).

Who are the utility companies ?

In Switzerland, the management of electricity distribution is decentralised and divided into more than 600 companies, ranging in size from regional to national (Swiss Federal Office of Energy, 2023d). Each company manages a given region without competition for the sale and buy-back of electricity. GOs may, however, be sold back to this company, or on unofficial markets.

What are their interests ?

Utility companies are obliged to buy back the electricity produced by our PV systems. In the case of GOs, they are generally interested in buying them back so that they can guarantee their customers that their energy comes from a sustainable source.

Who are our target utility companies ?

All the utilities where we would have PV systems.

3.2 Relationship

The SolarSwift platform is intended to be the main link with customers, in the image of an online bank (e.g. Revolut, N26), which no longer has physical offices, but where everything is managed from their application. However, this is not always possible. Indeed, after discussions with various stakeholders in the solar sector (see Section 4 of the "Transdisciplinary methods" chapter), it emerged that the solar industry is not yet standardised and is still complex. As a result, each PV system project requires a great deal of monitoring and communication with each stakeholder. It can be dangerous, in a business like

SolarSwift seeking to automate and scale-up the implementation of new solar projects, to neglect communication and support with stakeholders. However, solutions do exist.

Indeed, several positive personal experiences with Indian and Chinese online service providers have shown me that solutions do exist. An initial response could be obtained within 5 minutes by simply contacting them using my favourite instant messaging application. This contrasts with the usual Western media, by e-mail or telephone, which are fairly slow and cumbersome.

So we want to maintain a close, responsive relationship with our various stakeholders. They must be able to contact us via the main current means of communication that they prefer, such as social networks, private instant messaging, forums dedicated to the platform, or even by email, and get an initial response within 10 minutes.

To do this, we first need to identify the different needs of each stakeholder, depending on who they are, what our relationship with them is, and what their habits and expectations are. Our relationship with a small investor, preferably communicating via instant messaging or social networks, will not be the same as our relationship with a financial institution, communicating by email or in person. The same applies to the various surface owners, installers or utility companies. Also, answering small questions, or managing larger problems will not be the same. While the former can be answered quickly on public channels such as a forum or social networks, by someone not working for SolarSwift, a larger problem will need a ticket number, and a private exchange via messaging or email, or even an on-site visit by an expert.

We have therefore identified several ways of maintaining relations with stakeholders, which are presented here.

3.2.1 Professional stakeholders Relationship

Generally, the relationship with professional stakeholders, whether customers or partners, will be via private channels, such as instant messaging (WhatsApp, Messenger, Telegram, Signal), professional messaging (Slack, Teams), email, or face-to-face meetings. This will depend on the relationship with each stakeholder.

3.2.2 Community Relationship

The community approach is increasingly present in new businesses. The use of forums or social networks dedicated to the platform enables a close relationship to be maintained with stakeholders, so that they can be kept informed of new developments and receive feedback. It also allows stakeholders to ask questions openly on the forum, and receive answers from the community or directly from SolarSwift members. It is worth creating communities on Reddit, Discord, Telegram Group, and opening the 'issues' section on the SolarSwift GitHub project.

In addition to a general community, it would be worth testing the creation of dedicated communities, for example for PV installers. This would enable them to raise and discuss concerns specific to their field.

3.2.3 Private support

Personal support is essential, because as we said, any PV project is complicated, and follow-up is necessary. This is especially true in a new market like PV, where there is a lot of uncertainty. Stakeholders can then write to us, using the private means of communication they prefer, such as private messages on social networks (Instagram, LinkedIn, X), private instant messaging (Telegram, Signal, WhatsApp, Messenger), or email. The use of a customer relationship management (CRM) tool, with ticket management, enables this support to be managed efficiently on a variety of platforms. The use of international staff, or an AI, can be used to answer questions reactively in less than 10 minutes, and then, if they cannot be dealt with, to pass the tickets on to the appropriate qualified staff.

3.3 Channels

We have several strategies for accessing stakeholders. These will depend on each target. Professional stakeholders, whether they are large investors, installers, utility companies or large property owners, will have to be reached via more qualitative channels, such as canvassing by our sales representatives, at exhibitions, or by presenting our solution at conferences. If we manage to offer quality services and a quality solution, word of mouth between professionals can also be very effective.

Small and medium-sized investors and property owners would be reached by strategies that reach more people. Marketing campaigns via social networks, billboards, Youtube and television are always an effective way of making your solution known. The blockchain and trading niche can be reached via specific communities, usually on Discord or Telegram, where collaborations with other projects can bring in new customers. This community also often uses ambassadors to spread the word about a project to their own community. The affiliation system we have in place, with remuneration for recruiters, can encourage the community to participate in recruitment.

One channel to try out is to go directly through the utilities companies' channels. These are already in contact with all the property owners in a region, who already have trust in this company. If it is possible to work with utility companies to use their communication channels, it would be possible, for example, to send a letter on behalf of the utility company proposing that the property owner make his surface available. What's more, according to Francois Calame, these companies have electricity consumption data for every home, enabling them to identify which properties are most suitable for maximising self-consumption. However, it would be necessary to analyse the probability of obtaining such cooperation, which must be low.

Finally, one last possibility is to work in partnership with architects or real-estate companies, to offer them a turnkey PV system for their new buildings that does not fit into their budget.

4 Operational Framework and Resources

This section summarises the essentials of what the business needs to operate effectively, including the activities it must undertake, the resources it requires and the partnerships it relies on.

4.1 Key partners

First of all, we need to establish trusted partnerships with local installers. As these are regional, we will need to contact and include several installers per region in the platform, so that they can receive calls for tender when a new solar project meeting their criteria is registered on the platform. In order to cover the largest possible area in Switzerland, and to reduce waiting times for the construction of a PV system, it is important to work in partnership with as many installers as possible.

It's also important to work with local utility companies. Although they are obliged to buy back any surplus electricity they produce, partnerships could help speed up the process. Indeed, if they know us and trust us, they might agree more quickly to validate the connection of our PV systems to the grid. What's more, utility companies are major players, long-established and well known to end customers. As we saw in the 'Channels' section, partnerships with them could enable us to make contact with their customers, the property owners, on their behalf, in order to acquire new customers.

The same applies to architects and real estate companies. As we have seen, partnerships need to be established in order to provide our services on their new building projects.

Also, a partnership with an insurance provider needs to be established to insure all our PV systems.

Finally, a collaboration with EnergyWeb, the NPO responsible for the namesake blockchain, is recommended to help us develop our platform on their blockchain.

4.2 Key activities

Our activities are explained in the "3 Platform architecture overview" section of the "Product & Processes" chapter. To summarise, these are our activities

- Developing and maintaining the platform for registering new projects, connecting the project with service providers (installers, insurance, utility company), managing the financing of the project, monitoring it, automatically executing transactions, managing contracts, etc.
- Develop and maintain the decentralised application, i.e. the interface with this platform.
- Develop and build the Decentralized Smart Meter
- Find property owners
- Find investors
- Find installers
- Orchestrate the creation of solar projects.
- Provide sustainable investment certificates annually to companies.
- Monitor the condition of PV systems during their lifetime
- Mandate companies to carry out O&M work.
- Create project pools for investors.
- Offer support to stakeholders.

4.3 Key resources

Here we will identify the resources needed to make the project work, focusing on the first 5 years.

4.3.1 Platform & Knowledge

In order to facilitate the participation of property owners and investors in the solar transition, we need to develop our solution, and acquire knowledge of the field by doing more research. This platform and knowledge are resources and added value for our core business model.

It was considered that in 2 years with 2 people it would be possible to set up a first version and test it on new PV systems. In order to create these initial resources, 200kCHF would be required (50k per person per year).

4.3.2 Employee

Once the project is up and running, employees will be needed. Given that SolarSwift offers services and a software solution, these are the most important.

In the context of this business model, we assume that employees will be paid 80k/year gross, to which must be added the employer's social security contributions, identified as between 10-20% (Prieur, 2023). We therefore set the cost of a 100% employee at 90k/year. A 100% occupancy rate corresponds to 42 hours/week, or 2,000 hours/year.

Some employees are needed regardless of the number of solar projects in a year, some employees vary according to the number of new projects in a year, and some employees vary according to the total number of projects managed since the start of SolarSwift.

Fix employees

First of all, we have fixed employees, necessary no matter how many solar projects are underway. The equivalent of 2.6 people is needed, for a total of 234k per year.

Description	Activity	Percentage	Cost/Year [CHF]
Management	Management of the company	60%	54k
Operational Engineer	Develop and maintain the SolarSwift platform. Find solutions to technical problems.	100%	90k
Marketing	Find new property owners, investors and installers.	100%	90k
TOTAL		**260%**	**234k**

Variable employees (depending on new PV systems)

For information purposes, to understand the following figures, if a position requires a percentage of 1% per project, this means that the employee will invest 20 hours per year on the new project. Here, a project manager who has to invest 5% per project, will invest 100h on one projet, and can therefore work on 20 new projects over the year.

On top of this, there are employees proportional to the number of new projects per year, to deal with them and orchestrate the project.

In total, we can see that 5,400CHF needs to be invested on our side for the management of a new PV system.

Description	Activity	Percentage (per project)	Cost/Year [CHF] (per project)
Lawyer	Settles legal issues, contracts, etc.	1% (20h/year)	900
Project manager and support	Oversee project progress, connect stakeholders, manage problems	5% (100h/year)	4500
TOTAL		**6%**	**5.4k**

Variable employees (depending on portfolio size)

And finally, we have the employees proportional to the total number of projects managed by SolarSwift over their lifetime. This is used to manage their monitoring, maintenance, and provide support to stakeholders. We can see that each year SolarSwift has to invest 540CHF in each PV system over its lifetime.

Description	Activity	Percentage (per project)	Cost/Year [CHF] (per project)
Inspector	Monitor and track faults on PV systems remotely.	0.1% (2h/year)	90
Support	Provides support in the event of questions from a stakeholder or problems with a PV system.	0.5% (10h/year)	450
TOTAL		**0.6%**	**540**

4.3.3 Other ressources

SolarSwift needs office space, the price of which in Bern is around 200CHF/m2 per year (immobilienmarkt, 2023). Employees also need to be able to travel on business. As no goods transport is required, these will be carried out exclusively by public transport. Office and computer equipment must be purchased, as well as software licences. SolarSwift will also need financial resources to carry out marketing campaigns. Finally, we need the "Les Pros du Solaire" label provided by the SwissSolar association to gain recognition and access to their network.

	Investment	Cost/Year [CHF]
Premises (200CHF/m2; 100m2)	0	20k
Charges (energy, water, internet)	0	10k
Transport (2xGA)	0	8k
Office furniture/ Informatic/Server	10k	2k
Licence	0	2k
Advertising	0	5k
SwissSolar membership fee	0	1.2k
TOTAL	**10k**	**48.2k**

4.4 Key metrics

The key metrics for measuring the performance of our business are as follows:

- Map of coverage of the Swiss territory with partner utilities, and installers
- Map of the number of solar projects per region,
- Total solar energy produced by our projects,
- Total CO_2 emissions reduced by our projects,
- Total new solar projects per year,
- Total annual investment obtained,
- Swiss market share of new PV systems managed and financed,
- Environmental impact of SolarSwift scope 1, 2 and 3,
- Acquisition cost of a new solar project, and new financing,
- Delta between simulated ROI and measured ROI,
- Average income for an investor, property owner and savings for occupiers.
- Time to wait between registering a property and it being put online on the platform,
- Time to finalise the financing of a project,
- Time taken to build the solar system,
- Stakeholder satisfaction, by qualitative or quantitative survey,

5 Market Analysis

In this section, we will analyse the current Swiss photovoltaic market. Then, the future potential of solar energy, as well as investments in solar energy will be analysed. Feedback on the potential of the TPO model in Switzerland will also be discussed. Finally, an analysis of direct and indirect competitors will be carried out.

5.1 Current photovoltaic market

The Swiss electricity market is explained in detail in the literature review, in section 1.3 of the "Transdisciplinary Methods" chapter.

In summary, since 2017, the PV market has only increased. As shown in Figure 27, between 2021 and 2022, the number of new PV installations in Switzerland increased by 60%, and between 2022 and 2023 by 40%.

In 2022, the total Swiss solar production was 3.8TWh, out of the total 57TWh of electricity produced (6.8%) (Swissolar, 2022a).

According to a 2022 study by the International Energy Agency, the Swiss photovoltaic market is worth 2’079 million, and 13’700 people are employed in it (IEA PVPS, 2022).

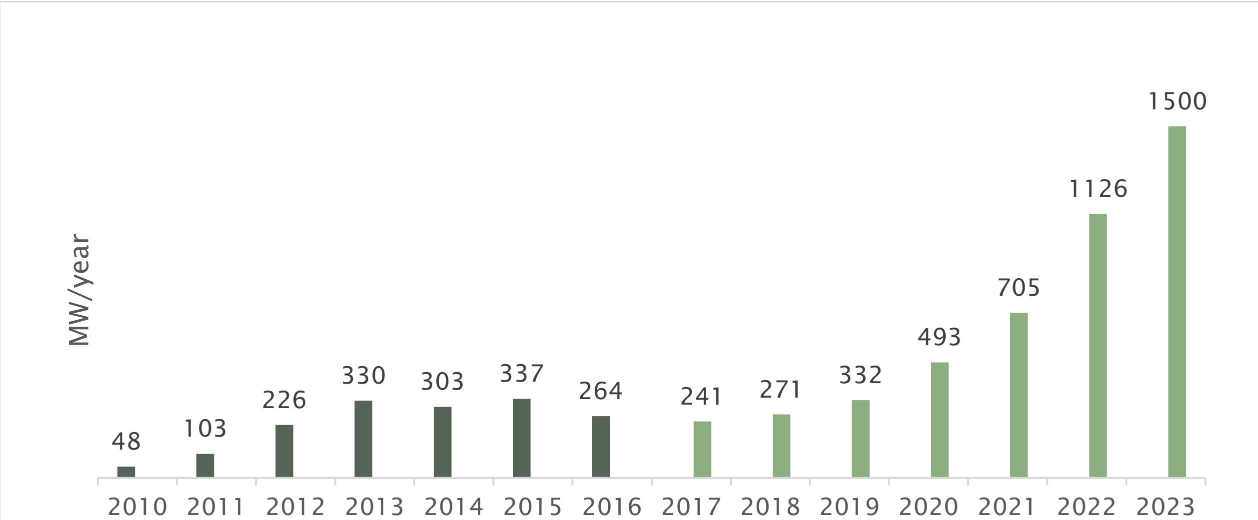


Figure 27 New installed PV power per year (Swissolar, 2022a)

5.2 Potential market for solar energy surfaces

The potential of surfaces in Switzerland is explained in detail in the literature review, in section 1.5 of the "Transdisciplinary Methods" chapter.

In short, these surfaces can be anything from lakes and mountains to fields and buildings. It is difficult to know the precise potential of surfaces, as many assumptions have to be taken into account. For example, one study shows that out of a technical potential of 260TWh, only 118TWh are exploitable, but if we take subjective parameters such as a property owner's unwillingness to install a PV system, we get a potential of 45TWh (Remund et al., 2019). A meta-analysis by ZHAW gives a potential range of 34 to 71 TWh (Anderegg et al., 2022).

By way of comparison, Switzerland will need to generate 46TWh more by 2050 to replace nuclear power and keep pace with rising electricity consumption, and the federal government plans to generate 36TWh from solar power, 10 times more than today.

At present, projects are divided roughly 1/3 on private individual houses, 1/3 on industrial buildings, and 1/3 on agricultural buildings and land (Interview with Jean-Louis Guillet, CEO of Soleol). Our project would focus on these last two types of surface.

The market for multi-family buildings is a sector with great potential, given that 60% of the Swiss population are tenants (Federal Statistical Office, 2021). However, the owners of these surfaces are not yet interested in PV.

5.3 Potential investors market

No figures on predicted investment in Switzerland for PV have been found. All information on the current investor market is explained in section "3.1.1 Customer Segment - Investors" of this chapter. Also, the results of the transdisciplinary analysis on this issue remain unclear. Some stakeholders say that it is easy to find investors, while others say that many projects are not carried out due to a lack of funding.

All the same, a Bloomberg study was found, specifying that by 2040, investment in solar energy should reach 3.7 trillion dollars worldwide, which represents 35% of capacity increases and results in a total of 8 trillion dollars devoted to all forms of renewable energy (BloombergNEF, 2022).

5.4 Potential of the Third Party Ownership model

In America, the creation of this business model has opened up the solar market to younger, less affluent and less educated populations than those who normally buy photovoltaic systems, giving the market a boost (Drury et al., 2012). This model is currently the most widespread in the US, and is beginning to arrive in Europe (Overholm, 2015).

This model could make it easier for tenants (60% of Swiss) and multi-family home property owners to participate in the solar transition.

Soleol SA, a solar installer that has been offering a TPO solution for several years, told us that currently 2/3 of their customers have used this model instead of financing the PV system themselves. These are mainly public institutions and businesses.

5.5 Competitors

In this section, we will identify and analyse the various indirect and direct competitors to our business model.

5.5.1 Indirect competitors

Indirect competitors are those offering a different service to ours, but with a similar goal, which is to install more PV installations in Switzerland. Although the business models of these competitors are quite different, involving different types of investors, their consideration is important. Indeed, any solar project financed and implemented by another business model will be one less project for us. The ultimate public utility goal, which is to push forward the solar transition, will be achieved, but not thanks to our solution.

All the business models looking for funding or surfaces to create new solar projects are indirect competitors. These different business models are presented in Section 1.7 of the "Transdisciplinary methods" chapter. As a reminder, here are the solar financing business models identified, with some of their players:

- **Self-financing**: The property owner finances his solar installation himself, using his savings or a bank loan, and becomes the owner.
- **Third Party Ownership**: A third-party company finances and designs a new PV system from start to finish, and takes care of installation and maintenance. It then becomes the owner of the system. This is usually done by an installer, such as Younergy or Soleol (Soleol, 2023; Younergy, 2023b).

- **Financing through public fund**: Utility companies, and some municipalities, finance solar projects themselves, on their own property, or on a surface they rent. For example, BKW plans to install 1GW of renewable energy between 2022 and 2026, in France, Spain, Germany, Denmark, Sweden, and also in Switzerland (BKW, 2022).
- **Solar Cooperative**: Cooperatives are groups of people who pay a share in the cooperative to finance PV systems. In Switzerland, more than 140 solar cooperatives exist, with an average of 93 members (Klopfstein & Wachtarczyk, 2023).
- **Crowd funding**: In crowd funding, several private individuals make a donation to a solar project. In exchange, sometimes for something in return. However, they are not the owner and will not get back the money they have contributed. Projects like the "Bourse Solaire Participative" in Renens are an example of this (Bourse Solaire, 2023).
- **Crowd lending**: In this case, a citizen provides money over a given period to a company that will finance solar projects. They receive interest on their loan. Some cities are introducing such a system, such as the city of Fribourg with the public company Particip SA (Particip SA, 2023). Citizens can then lend money to the company over a 10-year period, which will finance solar projects.

5.5.2 Solarify (https://solarify.ch/)

Solarify is a Swiss company that pioneered the Fractional Third Party Ownership model. It enables private individuals or companies to buy solar panels on someone else's surface. The investor then becomes the property owner of the panel, and receives the associated revenues. Although the company is open to the Swiss market, its projects are currently exclusively in German-speaking Switzerland. This project is very similar to ours. They propose ownership of the panels by the investor, with 80% of the revenue going to the investor, targeting the entire Swiss market, with the possibility for the investor to resell his share, or for the property owner to buy back the installation. An interview was conducted with the founder to find out more, a summary of which can be found in the 'Transdisciplinary methods' chapter. A number of different points were identified:

- For one customer, management of their asset, monitoring of electricity production performance and income, and gamification via an application are not available.
- Although the panel is owned by the investor, there is a contract between Solarify, the property owner and the investors, and Solarify is required to pay the income to the investors. This means that if Solarify goes bankrupt, a new service provider has to be found, increasing the risks. With smart contracts linking stakeholders, proof of ownership, and decentralised transactions, the third-party company that is SolarSwift is not needed to manage the remuneration of a solar system.
- It is compulsory to buy an entire panel, which means that the granularity of the investment is around 700CHF. It is not possible to invest any amount, unlike our project.
- Income payments are only made every three months, not every day.

5.5.3 Solergy (https://solergy.ch/)

Solergy is similar to Solarify in its business model. However, it is smaller, and little information is available about its operating conditions.

5.5.4 Energy Sharing Platform (https://www.plateformesolaireseeland.ch/energy-sharing/)

The Seeland Solar Platform has set up a three-year pilot project called the "Energy Sharing" digital platform. This project is in collaboration with the canton of Berne and the Confederation. This platform is also similar to our business model, and is designed to connect property owners who want to make their roofs available for solar energy production with third parties wishing to invest in solar energy. However, the platform was launched in June 2023, and little information or results are yet available to determine its potential. An interview was conducted with its director to find out more, a summary of which can be found in the 'Transdisciplinary methods' chapter.

5.5.5 Solar Split (https://www.solarsplit.com/)

Solar Split is a Neuchâtel-based start-up created in 2023 in the Microcity SA incubator. Its product has not yet been released, but it intends to offer an application to facilitate the connection between installers, property owners and investors. It will contain three services, one for finding an installer, one for raising finance, and one for monitoring your PV system. The way it works, and in particular one of their financing methods based on participative TPO, called 'Crowdinvesting', has certain similarities with our project. However, little information is available about the actual conditions of use of this financing system, and the large number of functions proposed in this project suggests that they are not yet complete. Here are some differences that have been observed:

- Their platform is aimed at the property owner, who will be able to use this application to facilitate the search for installers and funds. Our solution, on the other hand, allows the property owner not to have to manage anything in the solar project, and only to provide his agreement.
- It is not specified who owns the solar system between the surface owner, Solar Split and the investors, in the case of what they call "Crowdinvesting". Also, the duration of the contract is not specified.
- The investors do not seem to have access to their portfolio from the application, which was intended for the property owner.

5.5.6 Oikos Solar (https://oikos-solar.org/)

Oikos Solar is a young project run by the Oikos student association at the University of St Gallen, which we interviewed. It offers investors the chance to finance a share of a solar system, with a particular focus on projects in Ticino. Financial institutions are the main target for financing. The solar system will not belong to the investor, but to Oikos Solar. In return, investors should receive a 4% ROI per year. However, it is not stated whether this ROI is fixed or production-dependent. Once the investor has received the entire initial investment plus an additional 4%, the solar system is transferred to the property owner. According to them, this is possible after 10 to 15 years.

Their model is interesting, but too young to really understand its strengths and weaknesses. We'll be keeping an eye on their development.

5.5.7 Sunraising (https://sunraising.ch/)

Sunraising is a Bern-based association supported by the city, enabling a customer of the utility ewb to finance part of a solar project in the city, and to be able to deduct the electricity produced by this installation from their electricity bill. The main differences with our business model are as follows:

- Sunraising is only available to Berne and ewb customers, greatly limiting the number of potential customers.
- Sunraising does not allow you to earn money, only to lower your electricity bill. If the panels financed generate more than the customer consumes, the difference is lost. It is therefore not worth investing more than your own consumption.
- The square metres of PV panels do not belong to the buyer, but to Sunraising.
- The reduction in the electricity bill is only visible once a year on the final ewb bill, whereas with our business model, performance and revenue can be viewed at any time.

6 Business Model Patterns

In this section, we will present the business models integrated into our project. In addition to the model created for this project, the F-TPO, those listed among the 55 Business Model Patterns of the BMI Lab, related to our project, will also be presented (Business Model Innovation Lab, 2023).

6.1 Fractional Third Party Ownership

As explained in our Value proposition in section 2, F-TPO is the model where several investors can own the same asset on another property owner's surface.

6.2 Business Model Patterns from BMI Lab

By clicking on the BM names, more information is available on them.

Main BM

Orchestrator #34 : SolarSwift's goal is not to provide the services to design, install and maintain a PV system, but to act as an orchestrator between external service providers.

Solution Provider #47: SolarSwift offers a complete solution to its customers, so that they only need one point of contact.

Fractional Ownership #16 : A more general term for F-TPO, Fractional Ownership refers to the fact that several investors own the same asset, as in the case of SolarSwift..

Revenue Sharing #41: Revenue generated by PV systems is shared between stakeholders.

Open Business Model #32 : Our platform is open to any other service provider, and create as many collaborations as possible with players outside SolarSwift.

Open Source #33 : SolarSwift's code is open source, in order to create solutions that can be improved and used by the community.

Other related BM

Pay What You Want #36 : Investors can pay how much they want for a share in a PV system. No minimum amount is required.

Pay Per Use #35 : For occupants of a property, they only pay for the electricity they use, the rest being sold back to the grid. This is different from business models where the occupant pays a monthly subscription, regardless of their consumption, or is obliged to consume a minimum amount per month.

Prosumer #60 : SolarSwift allows any natural or legal person who consumes electricity to become a producer.

Affiliation #2 : If a user recruits a new property owner or investor, they will receive a share of the revenue generated by the PV systems concerned.

Leverage Customer Data #25 / Sensor As A Service #56 : Production data from the various PV systems connected to SolarSwift is used to improve the cost/revenue prediction model, as well as to offer a fault prediction service.

Customer Loyalty #10 : The attractive application, its gamification system with badges, and its ease of use, encourages users to participate even more in the ecosystem, either by investing more, offering a property, or recruiting acquaintances.

Digitization #11 : The platform offers a digital alternative to current solar project management solutions.

7 Accounting of a PV system

In this section, we will show the accounting around a PV system, namely its initial cost, its operational and maintenance (O&M) cost, and its revenue. All the points presented here have already been detailed in the "7 PV System Cost & Revenue Simulator" section of the "Product and Processes" chapter. For this reason, we will only summarise the final result, sometimes giving some additional information.

7.1 Installation Cost

To calculate the cost of a PV system, it was decided to use a market study on the price of Swiss PV systems commissioned by SuisseEnergy to the consulting firm Planair SA (Swiss Federal Office of Energy, 2023b). This provided a part-wise linear regression showing the gross price of a PV system as a function of its size. The parameters of this regression can be found in Table 13.

Subsidies must then be subtracted from this cost to obtain the net price, presented in the literature review in section 1.9 of the "Transdisciplinary methods" chapter, and the amounts of which can be simulated on the website of Pronovo, the administrator of energy subsidies in Switzerland (Pronovo, 2023c).

7.2 Operating and Maintenance Cost

We have seen that according to several market studies, 1% of the initial gross price of the solar system is required per year for O&M costs.

7.3 Revenue

The Confederation's simulator (Swiss Federal Office of Energy, 2023e) will be used to determine the monthly production of a PV system, as well as its self-consumption. The self-consumed electricity will then be sold at 80% of the local electricity price to the occupier, which can be found on the website of the Swiss Federal Electricity Commission (ElCom, 2023). The surplus will be sold to the public utility at a price that can be found on the website of the Association of Independent Energy Producers (VESE, 2023). Finally, the GOs will be sold at the price of the local utility companies, which can also be found on the VESE website.

7.4 Depreciation

It is important to know the depreciation of a PV system, in order to determine its value at a given time. This is necessary for calculating tax on the asset, and in the event of resale. In a fluid market, depreciation is simply the variation in the value of the asset over time on the market, and is not set arbitrarily. Given that the PV system resale market is not developed, it is difficult to estimate its value at a given time.

We can distinguish two different values for PV systems. One is important for tax purposes, in order to determine a person's capital. The other is important for determining the price of the PV system during a resale.

Tax value of PV system

Swiss law says nothing about the devaluation of a PV system over time. At present, the technique used to value a PV system for the purposes of calculating capital tax varies from one canton to another. Generally, two techniques are used. One is to set a fixed price per kWp installed, regardless of the age of the PV system. The other is to revalue the real estate periodically, taking into account the added PV system (Swiss Federal Office of Energy, 2023a). In the United States, for example, the Modified Accelerated Cost Recovery System (MACRS) stipulates that a solar system loses all its value in 5 years, thereby reducing taxes, in order to encourage investment (SEIA, 2023).

Resale value of PV system

It is common practice in Swiss TPO models to set a linear depreciation over 25 or 30 years, so that the value of the PV system is zero after this period. This is because the contracts are fixed over this period, and the investor loses ownership of the PV system at the end of the contract.

At the beginning of this report, the intention was to determine the residual value of a PV system not arbitrarily, but according to its true potential value on the market at a given point in time. This would make it possible to avoid the situation where the investor loses possession of the asset after 30 years, even though it is still operating at over 80% efficiency and could still be generating income at no great cost for years to come.

This depreciation would take into account various parameters, such as :

- Loss of PV cell efficiency over time, reducing production.
- Increase in faults over time, increasing the risk of an old installation.
- Increase in the efficiency of new PV cells over time, reducing the value of an older, less efficient system.
- Reduction in the price of a new PV system over time, reducing the value of an older installation of similar power.
- Increase in the price of electricity on the grid, increasing the value of any PV system.

This solution makes it possible to simulate the value of a solar system as a function of the market and its age.

However, this poses the problem that the contracts between the stakeholders will never end, since a PV system will always have a residual value, even at the end of its life. We have seen in interviews that the stakeholders would never want to participate in a long contract, or even one without an end, especially the property owner making his surface available. Furthermore, during interviews, 3 stakeholders told us that they did not feel that linear depreciation over 30 years was a problem for investors.

We have therefore chosen to follow the existing model, and apply a linear depreciation over 30 years, starting from the net price of the installation, at 0.

7.5 Taxes

Taxes on capital and dividends are excluded from the ROI calculation, as is often the case in investment services, given that each region has a different taxation system and values. It is up to the user to take this into account.

The system for taxing a PV system, its value and revenue, has not yet been defined throughout Switzerland, and varies for each canton. A document explaining the situation is provided by SuisseEnergy (Swiss Federal Office of Energy, 2023a).

7.6 Final accounting, illustrated with the BFH Wirtschaft example

All this information is finally used in a spreadsheet to do the accounting for a PV system, shown in Figure 28. An installation on part of the roof of the BFH Wirtschaft building is used as an example, shown in Figure 29. On a roof surface of 620m2, it was decided that 80% would be covered with panels, for a surface area of 500m2.

The monthly production data for such an installation is provided by the Confederation's simulator, and pasted into the Excel spreadsheet.

For self-consumption information, it is necessary to know the building's electricity consumption and its consumption profile. It was not possible to obtain this information from BFH. We therefore used information from a study on the standard electricity consumption of a school building in Belgium, proposing a consumption of 24kWh/m2 per year (EnergiePlus, 2007), in order to have an order of magnitude. The BFH Wirtschaft has a floor area of 2,700m2 according to Googel Earth, spread over three floors, with a total surface area of 8,100m2. This gives a total consumption of 218 MWh per year.

However, as the Confederation's simulator only accepts self-consumption of up to 100 MWh, corresponding to a small to medium-sized business, the results may be greatly affected. With regard to the self-consumption profile, the profile provided by the simulator for a company working 5 days a week was chosen, given that the school is generally empty at weekends. The self-consumption results provided by the simulator are then pasted into the Excel spreadsheet.

The production and self-consumption profile can be seen in Figure 30.

By entering the local electricity purchase price, the grid buy-back price and the GO price, the spreadsheet automatically calculates the various revenues generated per month and in total. The resale price to the occupier corresponds to 80% of the grid price.

Next, the installation and O&M costs of the PV system are automatically estimated according to its size. Annual depreciation is also automatically calculated.

The subsidies must be calculated on the Pronovo website and entered into the spreadsheet (Pronovo, 2023c).

With this information, it is then possible to calculate the annual income for the property owner, SolarSwift, the investors, as well as the ROI:

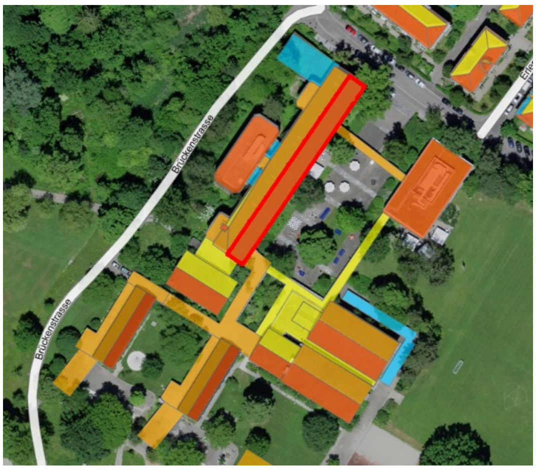
- The revenue for the property owner corresponds to 5% of the total revenue.
- The revenue for SolarSwift is 10% of the total revenue.
- Gross investor revenue is 85% of total revenue, less O&M costs (~10%).
- Net revenues to investors include deduction for depreciation.
- ROI is $net\ revenues\ /\ net\ investments$

Parameters	
Size [kWp]	**100**
Size [m2]	*500*
Cells efficiency	**20%**
Occupant electricity price discount	**20%**
Subsidies	**33’000 CHF**
Installation Cost (gross)	*152’941 CHF*
Installation Cost (net)	*119’941 CHF*
Depreciation / year	*3’998 CHF*
Operational Cost / year	*1’529 CHF*
Gride sale price [cts/kWh]	**22.73**
Gride buy-back price [cts/kWh]	**13.70**
Occupant sale price [cts/kWh]	*18.18*
GO price [cts/kWh]	**1.00**

Results	
Total revenue / year	*16’230 CHF*
SolarSwift revenue / year	*1’623 CHF*
Property owner revenue / year	*812 CHF*
Investors revenue / year (gross)	*12’266 CHF*
Investors revenue / year (net)	*8’268 CHF*
ROI	*6.9%*

Production (From simulation)		Sales sharing (From simulation)			Revenues		
Month	**Production [kWh]**	**Autoconsumption rate**	**Sold to occupant [kWh]**	**Sold to grid [kWh]**	**From occupant**	**From grid**	**From GO**
Jan	3063	83%	2553	511	464 CHF	70 CHF	31 CHF
Feb	4691	60%	2815	1876	512 CHF	257 CHF	47 CHF
Mar	8519	49%	4174	4345	759 CHF	595 CHF	85 CHF
Apr	10333	46%	4753	5580	864 CHF	764 CHF	103 CHF
May	12084	40%	4834	7250	879 CHF	993 CHF	121 CHF
Jun	13070	38%	4967	8103	903 CHF	1’110 CHF	131 CHF
Jul	12989	38%	4936	8053	898 CHF	1’103 CHF	130 CHF
Aug	11776	40%	4710	7066	857 CHF	968 CHF	118 CHF
Sep	8852	43%	3794	5058	690 CHF	693 CHF	89 CHF
Oct	5588	57%	3193	2395	581 CHF	328 CHF	56 CHF
Nov	3241	75%	2431	810	442 CHF	111 CHF	32 CHF
Dec	2444	80%	1955	489	356 CHF	67 CHF	24 CHF
Year	**96650**	**47%**	**45114**	**51536**	**8’203 CHF**	**7’060 CHF**	**967 CHF**

Figure 28 Cost/Revenue accounting of a PV system



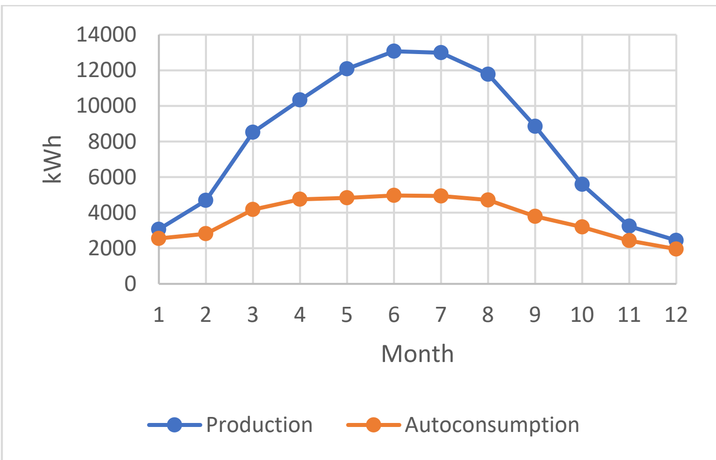


Figure 29 Selected roof from the BFH Wirtschaft (in red)
Figure 30 Production and self-consumption for the BFH Wirtschaft building

8 Revenues & Cost structure

In this chapter, we'll look at the structure of our revenue and costs. In the current context of the project, we will only look at the first 5 years of activity.

8.1 Revenue's structure

The SolarSwift project generates revenue in two distinct ways.

One-Time Revenue

The first revenue stream occurs when a new PV system is designed. A 10% fee is added to the project price. This means, for example, that on a PV system like the one at BFH Wirtschaft costing 150k, 15kCHF will accrue to SolarSwift. It should be noted that this value is arbitrary at present, as it has not been possible to determine the current margins of service providers in the solar sector, such as installers, planners, background researchers, etc., either through literature research or by interview.

Passive Annual Revenue

The second revenue stream is passive. SolarSwift receives 10% of the total revenue generated by each PV system managed. This value is based on what Solarify is currently doing. We have seen that for BFH Wirtschaft, this would amount to 1.6kCHF per year. Instead of charging investors for the various services provided by SolarSwift throughout the life of the PV system, it was decided that SolarSwift should receive a percentage of the revenue, and provide the services free of charge. This is simpler to manage in the relationship with investors.

These revenues are therefore proportional to the total value of new PV systems installed each year, and the total output of all solar systems already installed. This means that in SolarSwift's strategy, income can be increased by increasing the number of new mandates per year, but that if no new mandates are concluded, SolarSwift will continue to earn income on the installations already in place, in order to guarantee the service offer for their maintenance.

The 10% fee at the start of a project and the 10% deduction from revenue are arbitrary figures. More detailed cost analyses and the establishment of a clear marketing strategy should be carried out in order to define these values more precisely. It may be possible to play on these two values to modify our margins, make us more competitive and recover our costs.

Other possible stream of revenue

Certain strategies can be pursued to increase the revenues from each PV system, such as trading the resale of GOs and electricity on a third-party market, instead of reselling them directly to utilities, in order to increase the resale price. Soleol SA does this, and their CEO was able to share with us that this is very interesting, especially when the company manages a large number of PV systems. This would increase the total revenue, which would then be shared with all the stakeholders.

It might also be possible to study the possibility of issuing and reselling CO2 certificates on the voluntary certificate market. Projects that contribute to reducing CO2e emissions can receive certificates, which they can then resell to polluting companies that exceed their quota. However, little information was found on the feasibility of this, and none of the players interviewed had any knowledge of CO2 certificates. Only Oikos Solar offers investors the opportunity to receive them on their website, but we were unable to obtain any information on how they work, either on the website or through interviews. We are therefore only offering 'Green Proofs' that enable companies to prove the impact of their investment, but which have no monetary value.

It could also be possible for SolarSwift itself to invest in solar projects, as installers are currently doing. These investments would then generate additional income.

8.2 Cost's structure

The SolarSwift project has four types of costs. Note that the costs considered here are specific to SolarSwift, and not to the PV installations managed by SolarSwift. This is due to the fact that each project has its own accounting system, as discussed in section 7 of this chapter. The design, installation, operational and maintenance costs of a PV system are covered in each project's own accounting.

This cost analysis is strongly linked to the resources required by SolarSwift, the costs of which are presented in section 4.3 of this chapter. Only a summary is shown here.

Initial investment

Any new project needs a basic investment in order to function. Fortunately, as the project is focused on providing a service and an IT solution, the initial investment is low, at 10kCHF. However, the creation of a first version of our solution and the acquisition of knowledge will require an investment of 200kCHF in order to finance two people over 2 years. 210kCHF of funds will therefore have to be found in order to launch the project.

Fix cost

Fixed costs do not depend on the number of projects created or managed. These cover the payment of premises, public service charges for the premises, fixed salaries, employee social security contributions, taxes, licence payments, equipment purchases and transport costs. The details, presented in section 4.3, show fixed costs of 234kCHF/year for salaries, and 49kCHF/year for the rest.

Variable cost (depending on new PV systems)

These variable costs will increase in proportion to the number of new PV systems managed each year. This includes the resources to be provided by SolarSwift to set up each new installation. SolarSwift is based on an "Orchestrator" business model, meaning that it will not carry out the work itself to create new projects, but will delegate to other service providers, the cost of which is included in the accounting for each project. This reduces SolarSwift's costs per new project. However, 5.4kCHF will still have to be invested for each new PV system, mainly in labour time.

Variable cost (depending on portfolio size)

These variable costs will increase in proportion to the total number of PV systems managed by SolarSwift from the start of its activity. This number will therefore increase each year. We have seen that to carry out monitoring, fault detection and provide support, 540CHF must be invested per year per PV system.

8.3 Revenue/Cost balance

To find out whether the project is viable, we can compare our annual costs with our revenues. As we have revenues and costs based on the number of new projects managed each year, and based on the size of our portfolio, we know that these two variables are important. We will therefore first analyse the number of projects we need to have per year in order to be viable.

Note: For these analyses, the example of BFH Wirtshaft will be used as the reference project, which is a 100kWp project, i.e. 500m2. It is important to note that a smaller project will be less profitable, because the variable costs will be similar for lower revenues, and vice versa for a larger project.

8.3.1 Number of new projet required per year

By displaying the cashflow at the end of the first year of activity, according to the number of projects managed that year, we can see that we become profitable by finding 26 projects of 100kWp in the year. This corresponds to 2.6MWp in total, i.e. 0.17% of the 1500MWp installed in total in 2023 in Switzerland, which seems reasonable.

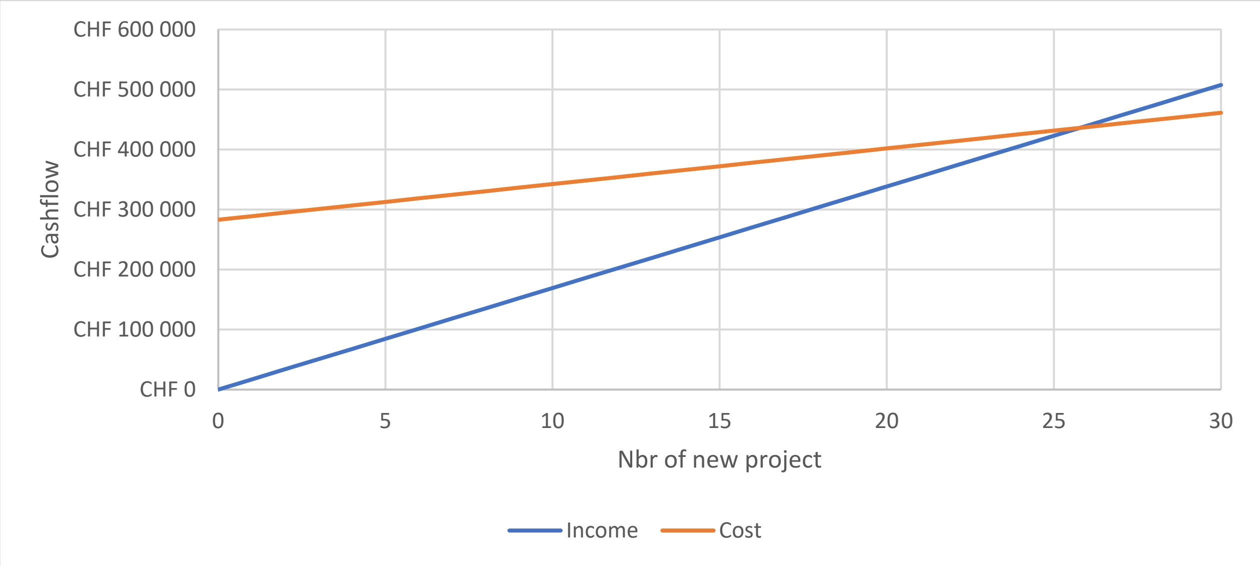


Figure 31 Cashflow at year 1, in function of the number of new projet managed in the year

8.3.2 Evolution of cashflow over time

If we consider managing 26 projects per year, i.e. just over 2 per month, we would need 4.3 full-time employees in the first year, and 5 in year 5.

With this target, the project would be just breaking even at the end of the first year with a profit of 2.4kCHF, and at +115kCHF profit at the end of the 5th year thanks to passive income from installed PV systems. An increase in the number of new projects managed would significantly increase profits.

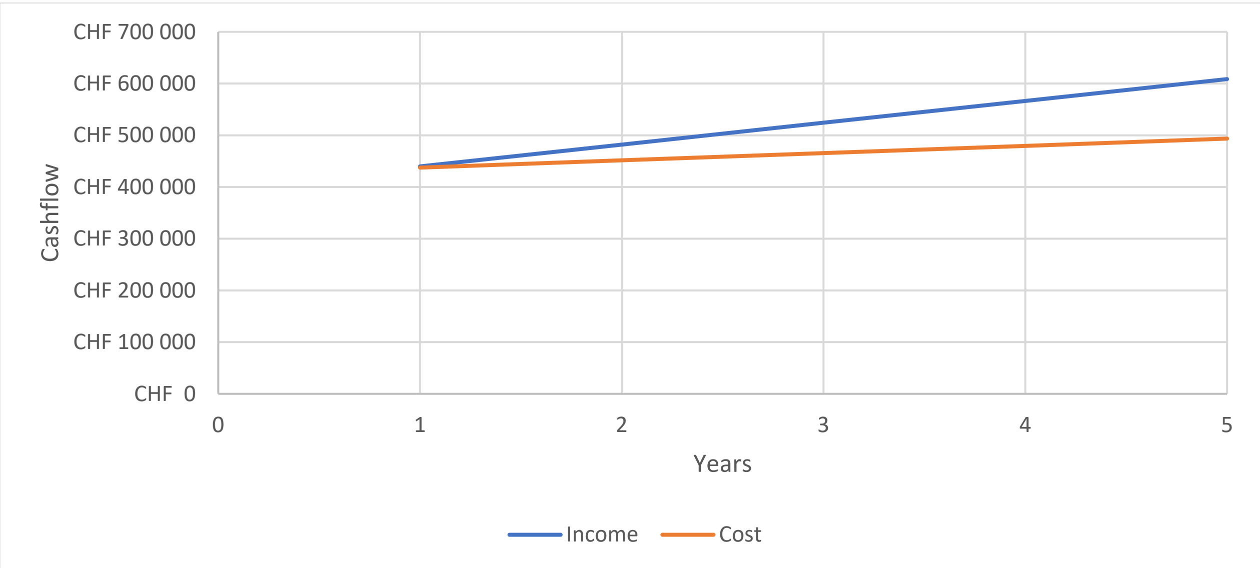


Figure 32 Cashflow bewteen year 1 to 5, if 26 projects are managed per year.

9 Conclusion

In terms of the different business model patterns used, we have seen that this digital platform uses the orchestrator business model, finding and bringing together property owners, investors and service providers to develop new PV systems. The Third Party Ownership model is used to allow investors to legally own their PV system on someone else's surface. Also, the platform offers the full range of services so that each customer only needs to be in contact with one service provider. The platform also uses an open source business model and is open to any other service provider. Investors pay for what they want, so there is no minimum amount, and electricity consumers pay for what they use, so they are not forced to consume for a minimum amount or pay a subscription.

For value propositions, our platform offers investors a low-risk investment opportunity with a positive ROI. The investment is simple to make, the use of the investment and the distribution of income are transparent, and also, this investment helps the energy transition. Finally, thanks to the F-TPO, investors are guaranteed to keep their procession, even if SolarSwift goes bankrupt, reducing risk.

For property owners, the platform enables them simply to make their surface available, in order to receive 5% of the income generated, to lower and stabilise their electricity prices, and to participate in the energy transition.

Our target investors are individuals and businesses. It would also be interesting to target financial institutions, but it has not been possible to determine this feasibility.

On the property owner side, public institutions, farmers and industries are the priority target owners, while remaining open to any type of project.

Our revenue structure is based on two sources of income. A 10% margin on each new PV system price charged, so it's a one-off income. And a fee of 10% taken from the income generated by the PV systems managed by SolarSwift, so income arriving throughout the life of these systems.

On the cost side, we have fixed costs, regardless of the number of solar projects managed, variable costs depending on the number of new projects managed in the year, and variable costs depending on the total number of PV systems in our portfolio.

To carry out this project, 2 people would first have to work for 2 years to acquire knowledge, test prototypes and set up a first version of the platform, for a total of 200kCHF. Then, a team of 4 to 5 people would have to work on it and find at least 26 new 100kWp projects per year, i.e. just over 2 per month, in order to be profitable. This corresponds to a Swiss market share of 0.17%, which is feasible.

What's more, this is a fast-growing and promising market, with demand for new installations higher than the current supply of solutions. Demand for new installations has risen by 60% in 2022, and 40% in 2023.

Conclusion

As Switzerland aims to boost its solar energy production from 4TWh today to at least 34TWh by 2050 to secure its energy transition, it confronts several challenges. Among them, the search for new financing and the acquisition of rights of access to property surfaces are major challenges. These issues are pivotal for advancing a solar industry that leans towards decentralized production and financing, a shift from the traditional centralized energy model.

Through transdisciplinary research, we've identified barriers hindering property owners and investors from engaging in the solar transition and outlined essential features for solutions to overcome these obstacles. Key solutions include :

- Eliminates up-front costs for property owners.
- Reduce time investment for every stakeholder.
- Reduce knowledge and networking needed for property owners and investors.
- Be the single point of contact for all stakeholders.
- Enable investors to own their PV system.
- Clearly communicate on a long-term risk reduction strategy for property owners and investors.
- Enable stakeholders to withdraw from contracts at any time.
- Conduct marketing campaigns, provide clear explanations and educate people about the potential of solar energy.
- Listen to stakeholders, providing good and responsive support.

A recurring issue is the isolated efforts of stakeholders in locating resources. A property owner seeking financing and service providers, and a project manager finding suitable locations for PV systems, highlight the market's fragmentation. Addressing not just the facilitation of participation but also enhancing stakeholder connectivity and information exchange is crucial. A last feature is therefore:

- Create an open, public and interoperable marketplace, managed by a public institution, an NPO or decentralised, to enable stakeholders to exchange information and collaborate.

Therefore, to facilitate the participation of investors and property owners in the solar transition, we designed Solar Swift, a digital platform connecting property owners, investors and service providers to orchestrate the creation of new PV systems in Switzerland. It provides an accessible, user-friendly interface and a clear separation of roles between stakeholders, enabling them to focus solely on what's relevant to them, without having to invest time, money, or knowledge, and thus minimize their barriers to entry.

SolarSwift solves the two major reasons why property owners haven't taken advantage of their solar potential yet, by financing and managing completely the PV system, so that all they have to do is grant access to their property, in return of a percentage of production revenue. On the other hand, it offers new opportunities to investors, by enabling them to buy and own part of a PV system on someone else's property and receive income from electricity production. All this also reduces the tenant's electricity bill, creating a win-win-win situation for the property owner, investor, and tenant.

This platform enables several investors to truly buy and own shares in a PV system, by using the Fractional Third Party Ownership (F-TPO) model, reducing risk for investors in case of SolarSwift bankruptcy, and risks for property owners in case of issue with the PV system.

It is also open-source, public, interoperable, and decentralized, based on the EnergyWeb public blockchain, creating an open marketplace for solar projects, enabling any service provider, investor or property owner to take part, and exchange information.

After feedback from the peers, the use of the TPO model, which allows property owners to have no upfront costs, seems very promising, and allows a clear separation between property owners and investors. Also, reducing barriers for property owners, by reducing any investment of time and money, and using a simple tool such as a smartphone, is interesting. What's more, being able to manage everything from an application, without the need for human interaction, could be in line with the mentality of the Swiss population. The distribution of daily income visible on the application, live portfolio monitoring and gamification are also interesting ideas to try out in order to reach a wider population.

However, a digital platform is greatly lacking in human interaction and discussion, which is essential in the solar industry. Indeed, every project are complex, different and involves long-term contracts. It's not easy to gain the trust of stakeholders, and it's essential to take the time to explain how things work. What's more, the proposed solution for acquiring new property owners, based on designing a project using only the address and some basic information, is too utopian. With regard to the use of blockchain, feedback has been critical. Although this solution is interesting and should be tested, particularly by integrating it with a future Smart Grid system, it would reduce the trust of many stakeholders and close the doors of the project to public and financial institutions.

1 Limitation

It is important to note that this report was conducted by someone with no initial knowledge of the solar industry, limiting the hindsight needed to develop an ideal solution. Also, the idea for the project, as a digital platform to simply make your surface available and invest in solar, was set up before any knowledge of the solar industry had been acquired and the research question posed. This means that the choice of solution may be biased, as it was chosen before the research began. This reverse structure is due to the fact that we had to register for the Expansion Modules already with a project idea.

It was also decided not to spend time learning the processes involved in creating a new PV system, from project conception to commissioning. This made it difficult to incorporate the complexity of these processes into our solution, and it is simply considered that the creation of a new solar project is provided to an installer.

Given the decentralised nature of the solar production system, the choice of using a blockchain was made relatively automatically, out of personal interest. However, this is not necessarily the best solution. This work lacks research into the real benefits and feasibility of creating a blockchain-based platform.

Although the proposed solution focuses on simplifying the participation of property owners and investors in the solar transition, the project has concentrated more on the financial side. Research into setting up a financing solution has been more extensive than that into facilitating the provision of surface area. For example, no research has been done into the possibility of creating a solar project based solely on the address and some basic information. As a result, the solution proposed here to facilitate the participation of property owners is utopian and unfeasible.

In terms of knowledge acquisition and creation, our solution has not been tested on end-users, which limits our knowledge of its real potential. Also, no utility company, an essential stakeholder in our project, has been contacted. This greatly limits our knowledge of the feasibility of our solution. All legal questions were also not answered and supervised by a lawyer or notary, making the feasibility of our project uncertain on the legal side. This includes, for example, the actual conditions for legally owning an asset on someone else's property, or what are the legal conditions of the contracts binding each stakeholde. Finally, our focus group was mainly made up of members of solar cooperatives, a structure similar in some respects to our project, but philosophically different, being geared towards the local community approach, whereas our project seeks to scale-up the solar transition. This has limited the feedback.

There are still many grey areas in terms of technical, administrative and regulatory challenges. For example, the real feasibility of setting up an open, interoperable platform where any property owner, investor or service provider can come and exchange resources was not analysed in detail. Also, it has not been decided who should pay if work needs to be carried out on the roof structure, or if the cost of a PV system is exceeded. Also, it is not certain that SolarSwift Core will work in all circumstances, even if SolarSwift goes bankrupt. For example, although money is set aside daily to pay the O&M costs, who will look after them if SolarSwift is no longer there? What will happen to the insurance contracts?

SolarSwift's cost and revenue structure and the accounting for SolarSwift and PV systems are still very sketchy, and the results can only give orders of magnitude. It would be necessary to re-do these calculations more precisely when more concrete information on the project is available.

Finally, on the point of sustainability, this project makes no mention of a strategy for integrating it into a circular economy, for example by using second-hand panels and batteries, and managing the end-of-life of installations, or by promoting the extension of the life of installations.

2 Further studies

In the course of this work, a number of interesting questions have been raised but not answered. These questions require further study. They are presented here.

The first relates specifically to the barriers for property owners, which were not fully explored in this study: ***"What are the barriers preventing property owners from making their surface available, and what solution would reduce these barriers?"***

Following on from this, the question of the potential of tenants also came up: "Switzerland is a country where 60% of the population are tenants, but where very few flats have PV. **How can we make PV attractive to property owners with rented flats?**"

On the investment side, we had decided not to consider financial institutions, which are more complicated to reach, for administrative and legal reasons. We therefore wanted to know: "**What are the conditions, potential and feasibility of working with financial institutions?**" and "**What are the legal conditions for becoming regulated as an investment platform?"**

Blockchain could prove to be an interesting tool, but further research would be required: "**What is the potential and feasibility of using blockchain in the financing and management of PV systems?"**

Other questions also came up:

- "What is the feasibility of working with utility companies to use their customer data, such as self-consumption, and their communication channels?"
- "How can we create a public, standard and interoperable network for the exchange of resources and information between stakeholders in the Swiss solar industry, in order to join forces?"
- "How does the trading of electricity and guarantees of origin work in Switzerland, in order to maximise profits on their sale?"
- "How does the solar industry work abroad, and what strengths do we need to bring to Switzerland?"
- "Could this platform be used to finance and manage all types of Distributed Energy Resources like electric vehicles, rooftop solar systems, batteries, heat-pumps, and other flexible electric loads?"
- "The financing of electricity production has always been centralised, supported and managed by the state. Is it a good thing that this funding is now being provided on a decentralised basis, by the public and businesses?"

3 Personal Reflections

The subject chosen and the topics covered were very broad, confusing the work and making it difficult to demonstrate clear results. However, I'm glad I carried out the project in this way, as it allowed me to explore many different solar topics, and to learn more than if I'd concentrated on one specific research question. In addition, this exploration was necessary because I first needed to get a big picture of the Swiss PV industry before I could focus on a particular topic. So, for me, the 'Expansion' of my knowledge on a personal subject has been successful, and now gives me the knowledge to focus on a specific research question in my master's thesis.

The fact that the Work Package, and the ToRs were decided in the first few weeks, when my knowledge of the field was non-existent, meant that their definitions did not correspond to the real useful work to be done in order to answer the research question. For example, a lot of time and effort was spent creating a PV system production simulator, when it was clearly not necessary for this project. However, all this 'unhelpful' work has enabled me to learn a lot about how solar energy and the solar industry work.

Therefore, the main challenge encountered on a management level was the continual evolution of the business model and product. Every new knowledge gained from transdisciplinary methods led to the reconsideration and modification of the project. This repeated change of project made it challenging to settle on a final business model and a consistent product for development, thereby impeding my ability to produce concrete results and move the project forward.

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1 List of illustrations

2 List of tables

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4 List of Appendix

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