Swiss PV Circle

Work package 5 - Resale

Market analysis for second-hand photovoltaic modules

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Author	Roger Nyffenegger
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Executive Summary

The findings from the Swiss PV Circle project show that the market for second-hand PV modules in Switzerland is currently underdeveloped, but harbours promising niche and development potential. Potential market segments, challenges and opportunities were identified on the basis of interviews with industry representatives, pilot projects carried out and a comparative European analysis.

Possible market segments can be divided into three areas: Individual modules, entire systems and foreign markets. In the case of individual modules, there is particular potential with private customers (e.g. for small systems on balconies or in allotment gardens), installation companies with replacement requirements and solar community projects. The reuse of complete PV systems is relevant for environmentally conscious private individuals, commercial "first movers" with ambitious sustainability goals and the public sector. The latter often acts as an enabler and role model for circular solutions, which makes this segment particularly attractive. There is considerable sales potential outside Switzerland, particularly in Eastern Europe, Africa and the Middle East, where quality requirements are lower. However, exports require stable partnerships as well as traceability and recycling strategies.

A workshop with leading European players showed that reuse is gaining momentum throughout Europe, but is still a niche phenomenon. Securing demand remains the biggest challenge. European business models range from traditional retailers to social orchestrators and recycling companies offering reuse services. Standardised test procedures are being developed, guarantees are usually short (1-2 years) and sustainability calculations vary greatly in their validity.

Estimating the market potential in Switzerland is difficult. Only around 7% of the solar power potential of Swiss roofs is currently utilised, so there is still a lot of available space. Demand for PV modules will therefore remain high, with around 4.5 million new modules being installed each year. In contrast, around 114,000 second-hand modules could be available annually by 2030, which covers only 2.7% of the 4.5 million newly installed modules, but is still a considerable number of modules. Based on current installation rates, there is therefore a realistic time window for the next 20 years with enough free roofs and enough available second-hand modules to establish the reuse market.

Across all considerations, Swiss PV Circle expects a moderate market potential for the reuse of PV modules until 2030 and significant growth thereafter. The development of a viable market requires targeted initial investments, co-operation networks and successful pilot projects in order to create trust and visibility. Embedding this in a European strategy and regulatory impetus could further accelerate market momentum.

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1. Overview of possible market segments

The market for second-hand modules in Switzerland is currently underdeveloped and there are only a few market segments that already utilise used modules. However, in the event of damage, there is occasionally a need for replacement modules to avoid the complete replacement of a PV system. Such replacement modules are often procured via platforms such as Secondsol, Tutti or Ricardo. These modules can be both second-hand and from stock. In addition, there are local reuse activities in which installation companies use dismantled but as-new modules for new projects or store them as leftover stock for service purposes. Although these activities are difficult to quantify, they occur regularly. In particular, such activities can occur as a result of a system expansion and replacement of the previous PV modules after a few years of operation or in the event of damage caused by a hailstorm.

As part of work package 5 of the Swiss PV Circle project, potential market segments for the sale of second-hand modules and their respective potential were analysed. The results are based on discussions with industry representatives and the findings from two pilots conducted as part of the project.

1.1 Market segments for individual modules

Our analysis identifies three main market segments for individual modules:

Private customers with demand for small quantities of modules

There is demand from private individuals who would like to equip their rusticos, allotments or balconies with one or a few PV modules, for example. This demand exists and can be usefully met with second-hand modules. Transactions mainly take place via online platforms, where used modules are usually offered untested. For trustworthy suppliers (e.g. with certification), however, there is moderate sales potential for tested second-hand modules by selling them in small quantities on these platforms.

Replacement demand from installation companies

Installation companies often look for individual replacement modules to repair defective systems. This market is well established, as specific module types - including tested used modules - are often in demand. Due to this specificity, high sales prices can be achieved in this segment. In terms of volume, however, this market is small and requires a large stock and a wide selection of module types. Focussing exclusively on this segment is not very lucrative for the sale of second-hand modules, but can be an interesting addition to other market segments.

Solar community projects

Solar communities could also generate demand for second-hand modules. These projects are characterised by the fact that groups jointly finance solar projects that they could not or did not want to realise alone, such as a PV system on a club building in which all members participate financially. Such projects are often characterised by limited financial resources and are not designed for maximum energy yields. Tested second-hand modules, at best with certification, could certainly arouse interest here. Although this market segment is also small in terms of volume, it offers increased visibility due to its community orientation. As only a few installation companies offer such solutions, it is worth looking into direct cooperation with companies to realise projects that would not normally be realised due to financial constraints.

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1.2 Market segments for complete systems

Three key market segments can be identified for the reuse of entire PV systems, including modules, substructures, weights, cables, inverters and similar components.

Private property owners with environmental awareness

There is a moderate demand for second-hand systems among private property owners with a strong environmental awareness. This demand is often closely linked to architectural objectives, such as the increased use of second-hand materials in new buildings or renovations. Although this segment is currently still small, the trend towards secondary materials is becoming increasingly important in the architecture and construction industry, partly as a result of the new ordinance on the prevention and treatment of waste[1] or the new SIA 430:2023 standard from the Swiss Society of Engineers and Architects (SIA)[2] . Targeted cooperation with relevant stakeholders could create sales opportunities for tested second-hand modules that can also be used for communication purposes. However, a key challenge lies in coordinating the timing between the dismantling of suitable PV systems and the planning of the reuse project. In addition, specifications such as substructures and cables of the system to be dismantled should be included in the planning process at an early stage. This may require sufficient storage capacity and a high level of coordination.

Commercial "first movers"

Companies pursuing ambitious sustainability goals, particularly with regard to Scope 3 emissions or the circular economy, are showing increasing interest in second-hand systems. The use of second-hand materials, including PV systems, is increasingly seen as a strategic measure to achieve these goals. In the property sector in particular, the use of sub-optimally located roofs or façades can open up interesting application opportunities. However, this market segment is still young and developing. The "Ordinance on Reporting on Climate Issues", which will come into force on 1 January 2024 as part of the indirect counter-proposal to the so-called Corporate Responsibility Initiative in the Swiss Code of Obligations (Art. 964a-964c CO), is expected to further strengthen this dynamic. As the market cannot be served purely transactionally, an accompanying consulting or realisation offer is crucial, whereby the safety, performance and longevity of the tested second-hand modules must be guaranteed. Initial successful projects could trigger positive imitation effects. Here too, coordinating the timing between dismantling and reassembly remains a challenge.

Public sector

The public sector is also showing interest in second-hand systems, particularly through legal requirements to promote the circular economy (e.g. as part of public procurement) or through solar obligations, as one of the pilots carried out in the Swiss PV Circle project showed. In this context , the public sector positions itself as an "enabler" and often prioritises its pioneering role over cost efficiency. This segment also requires intensive consultation during the planning and realisation phases; a purely transactional sale is unlikely. Due to the large volume in the public sector and the lower cost sensitivity, this segment is an attractive starting point for market development with tested second-hand modules. With its shareholding in electricity companies, the public sector may also have access to information on potential end-of-life plants, which can be included in the planning process for reuse projects in an anticipatory manner.

[1] Ordinance on the Prevention and Disposal of Waste (Waste Ordinance, VVEA).

[2] Angst et al, "Information sheet on the reuse of components."

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1.3 Market segments outside Switzerland

In addition to domestic demand, there is significant demand for individual modules or complete PV systems abroad. The legal framework for the export of modules is dealt with separately (see deliverable AP5.2). In the long term, the development of export opportunities should not be neglected for the success of business models in the area of reuse. Firstly, because a significant increase in end-of-life plants is expected after 2030 (see Deliverable 3.1). This is due in particular to the fact that the systems installed in the years of strong expansion will become increasingly interesting for re-powering projects and the demand for suitable reuse projects in Switzerland is not expected to be sufficient to fully absorb this supply. Secondly, because modules that cannot find a suitable reutilisation project in Switzerland - for example modules with an output of less than 250 Wp - could still be marketed abroad. Even today, a considerable quantity of modules uninstalled in Switzerland are exported, mostly untested and without clear destinations (see Deliverable AP5.2). These modules often end up in Africa or the Middle East.[3] However, there is also considerable demand for low-cost modules in Eastern Europe[4] and, to a lesser extent, in Southern Europe, as one of our pilots with Ukraine showed. These markets are characterised by lower quality and performance requirements and therefore complement the sales market in Switzerland. Stable partnerships are of key importance for exports in order to be able to track the modules and systems in the long term during their second utilisation phase and ensure their recycling. A key challenge in this context is the limited purchasing power of many target markets. In Eastern European countries in particular, however, approaches could be developed to combine such offers with development and construction aid, which could expand sales opportunities.

2. Customer acceptance

We were able to gain some insights into customer acceptance of reuse through a survey conducted by project partner Helion. The survey was sent to all their customers in Helion's newsletter. 83 customers took part in the survey, both private and commercial. The majority of participants were male, over 65 years old and had an installation capacity of less than 30kWp. In this respect, the survey cannot be considered representative. Nevertheless, it gives a fascinating insight into the acceptance of reuse from the perspective of end consumers, which has never been recorded in this way in Switzerland before.

In the first part of the survey, participants are asked to rate attributes regarding the installation of Seconhand modules on a scale of 1 to 100. The order in which the attributes are rated is from left to right. Testing the second-hand modules is rated as the most relevant with an average of 82.6 points. The price (Ø 74.3) and performance (Ø 72.9) attributes also scored over 70 points, while the product (Ø 62.1) and age (Ø 65.1) attributes were rated as less important. In the comments, efficiency was also mentioned several times as an important attribute, which correlates with age. It is possible that a different formulation of the age attribute with reference to the efficiency or the maximum electrical output (Wp) would have led to even higher values here.

[3] Agyeman et al, "Toward a Circular Economy in Ghana's Renewable Energy Sector."

[4] Bilek, Stubbe, and Weser, "A Solar Marshall Plan for Ukraine - Empowering Ukraine's Brighter Future: Bottlenecks and Key Policy Reforms Needed to Boost Solar PV Deployment."

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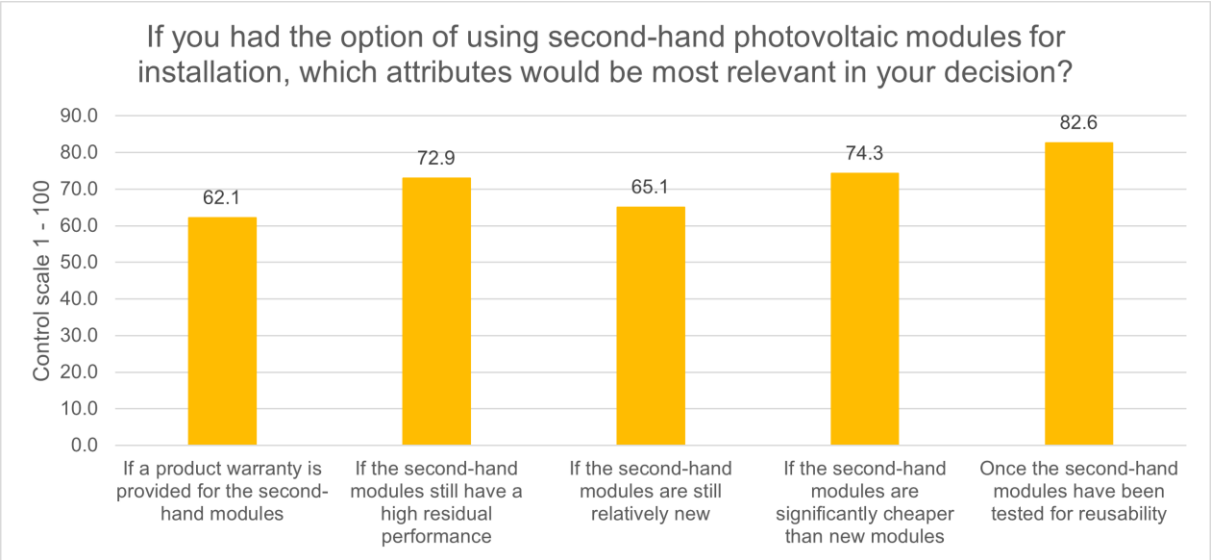

Figure 1: Results of the attribute evaluation for an installation of second-hand modules.

In the second part of the survey, participants are asked to rate attributes on a scale of 1 to 100 with regard to the submission of installed modules for reuse. The order in which the attributes are rated is from left to right. Compared to the attributes for installation, the attributes for disposal are rated lower on average, which generally indicates less relevance. The most important attribute is the extension of the service life, therefore an attribute in the area of sustainability. The cost attribute (Ø 66.6) and function attribute (Ø 65.2) are also relevant. The compensation attribute (Ø 56.3) and the reuse location attribute (Ø 45.7) are significantly less relevant. Use abroad is therefore seen as less critical. The fact that compensation is not very relevant is also promising for reuse business models.

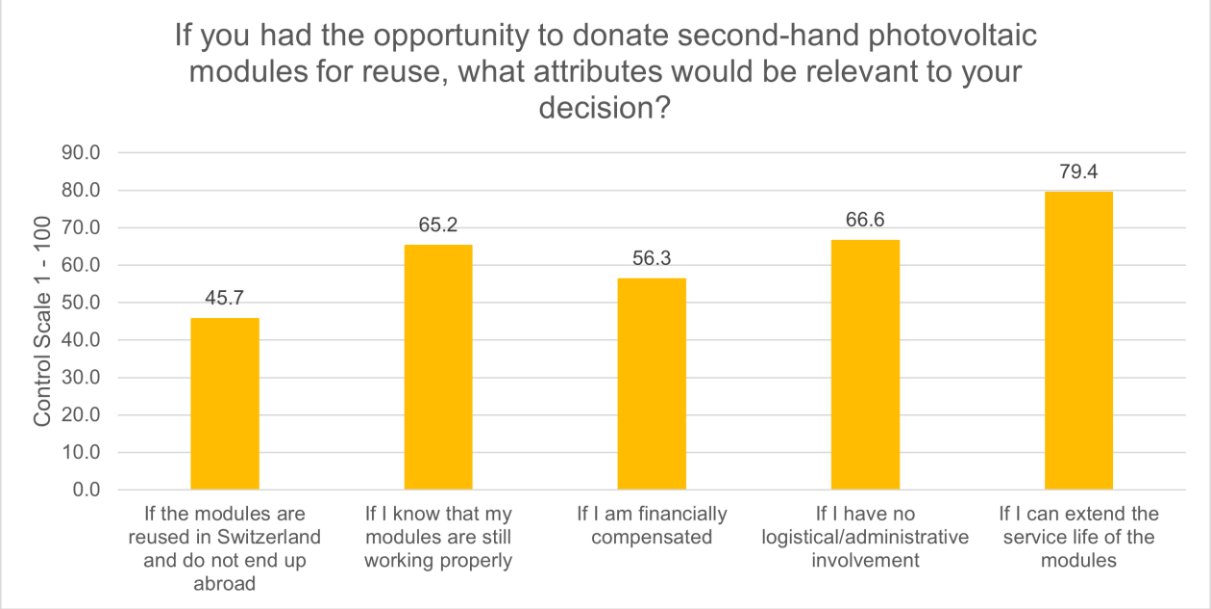

Figure 2: Results of the attribute evaluation for the sale of second-hand modules.

Even if the results of the survey are not representative, there are interesting trends in the responses. The fact that tested modules are the most important attribute when installing second-hand modules shows the importance of potential buyers ensuring functionality, durability and safety. This is a challenge for companies

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that want to offer reuse of PV modules, as systematic testing of all modules is more cost-intensive (see Deliverable 2.1).

Extending the service life of an early deinstallation is important to owners. So far, they have no options for this in Switzerland. In this context, the option discussed in Swiss PV Circle of also being able to specify authorisation for reuse when placing a collection order with SENS eRecycling is interesting.

3. Embedding and comparison with European markets

In autumn 2024, a Reuse workshop on the reuse of PV modules was held with leading European players such as SolReed (FR), Soren (FR), Baywa (IT), Resolar (UK), 2ndcycle (AT), Reiling (DE), 2ndlifesolar (DE), Innoboost (NL) and Zonnext (NL). The discussion centred on topics such as supply, demand, business models, testing procedures, guarantees and sustainability. These aspects were analysed in detail and compared with each other.

3.1 Offer

When it came to supply, the participants identified various sources for second-hand modules, including companies from the operations and maintenance sector, producer responsibility organisations (PROs), installation companies, recycling companies, platforms and the public sector. These sources also often simply act as whistleblowers or door openers. Good and institutionalised relationships with these sources are considered crucial in order to ensure a continuous inflow of modules. Some players have defined specific criteria for the acceptance of modules. For example, SolReed does not accept modules older than 15 years, while 2ndlifesolar only accepts modules with a minimum output of 250Wp.

3.2 Demand

The demand for second-hand modules was identified by the participants as the greatest challenge. In France, demand is driven in particular by green public procurement as well as private customers and solar developers with sustainability goals. In Germany, on the other hand, the market has almost completely stagnated at present, as second-hand modules are often more expensive than new ones. Nevertheless, there are niche markets, for example among private customers and start-ups. In England, second-hand modules are mainly used for community energy projects that prioritise low investment costs or ethical procurement criteria. In the Netherlands, there is demand from energy companies and organisations that focus on a low carbon footprint. The participants agreed that the market has become more price-sensitive and that domestic demand is not yet sufficient to absorb larger volumes.

3.3 Business model

In terms of business models, four main groups can be distinguished. Producer responsibility organisations operate take-back systems on behalf of manufacturers (extended producer responsibility) and in some cases actively promote reuse, in exceptional cases even financially via recycling fees (France). There are also "orchestrator companies", which coordinate the steps from dismantling, logistics and testing through to reassembly with a broad network of partners, without being operationally active themselves. They often operate in socially motivated niche markets. Recycling companies diversify their activities by testing reusable modules and marketing them as second-hand products. This allows them to tap into new sources of income and expand their portfolio. Finally, there are dealers who buy modules from

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various sources, load them and export them without carrying out tests. No traders were present at the workshop, as these business practices are in the regulatory grey area.

3.4 Test procedure

The test procedures used by the players have now been largely harmonised. There are also various efforts to standardise these at European level. The test procedures typically include visual inspections, electroluminescence tests, insulation resistance measurements and current-voltage measurements using flash tests. Some players carry out additional tests such as earthing or diode tests, while others take a situational approach and only test part of the modules. Initial assessments are sometimes also carried out on site, supported by drones and analyses of performance data.

3.5 Guarantee system

In the area of warranties, the players stated that they generally offer their second-hand modules with significantly lower warranties than new modules, usually with terms of one to two years. In Germany, there is a statutory guarantee of one year for used goods. All players reported that no warranty cases have been reported to date and emphasised that defects are handled pragmatically by replacing modules.

3.6 Sustainability

In terms of sustainability, the stakeholders presented their own calculations. Zonnext estimates that reuse can save 79 euros in ecological shadow costs per module. Soren presented scenarios in which reuse emerges as the most environmentally favourable option, while 2ndlifesolar calculated a saving of 300 kilograms of CO_2 per module compared to new modules. However, such calculations depend heavily on the assumptions made and comparison scenarios, which is why they should be viewed critically. The ecological sense of reuse is not given in all cases.

4. Estimation of market potential

Before estimating the market potential on the basis of the previous chapters, we first want to make a rudimentary numerical categorisation of the market potential. To this end, various rough calculations will be carried out in order to obtain an idea of the respective orders of magnitude. It should be noted that all of the quantities presented should be interpreted with caution and must always be placed in the respective context. In addition, the underlying parameters can change dynamically, which can influence the validity of the estimates.

The Swiss Federal Office of Energy (SFOE) estimates the annual solar power potential on Swiss building roofs at around 50 terawatt hours (TWh) and that on moderately to extremely suitable building façades at around 17 TWh[5] . In 2023, the 245,390 PV systems installed in Switzerland produced around 4.6 TWh of solar power[6] , which corresponds to around 6.9% of the total solar power potential (67 TWh). Potentially, around 3,417,000 buildings, i.e. 93.1% of the potential, are therefore still untapped. This indicates a

[5] Klauser, Albrecht-Widler, and Matti, "Solar Potential Analysis For Sonnendach.Ch - Final Report."

[6] Swiss Federal Office of Energy, "Statistics on solar energy reference year 2023."

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considerable market potential, as many suitable areas on and around Swiss buildings are not yet being utilised.

In 2023, 58,142 new systems with an estimated total output of around 0.0016 terawatts (1,600 megawatts) were installed. As the average output of PV modules sold in 2023 is 352Wp[7] , this expansion required around 4.5 million modules. It is expected that similar installation rates will be achieved in the coming years. At an average module price of CHF 150, this results in an annual market potential of around CHF 686 million for the procurement of modules alone. Part of this potential could also be covered by second-hand modules.

In order to estimate the available second-hand quantities, we use end-of-life volume estimates (see deliverable AP3-1). According to their forecasts, the annual volumes of end-of-life PV modules will increase from the current level (2023) of less than 1,000 tonnes[8] to an average of 4,800 tonnes per year in the period from 2026 to 2030. With an average module weight of 21 kilograms[9] , this corresponds to around 228,000 modules per year. Assuming that half of these modules are reusable[10] , around 114,000 second-hand modules could be available each year. However, this would only cover around 2.7% of the estimated 4.5 million modules required annually for further expansion. If we assume a linear expansion over the next few years, the market will reach saturation around 2042, as the vast majority of suitable areas will be equipped with PV systems (see Deliverable 3.1). Accordingly, a promising window of opportunity for the reuse of PV modules will open up over the next 20 years or so. On the one hand, sufficient PV modules will be deinstalled during this period, while on the other hand there are still numerous suitable roofs and façades available that are not yet equipped with PV systems.

5. Conclusion

Taking into account these numerical considerations, the market segments mentioned and the aforementioned customer acceptance, Swiss PV Circle forecasts a moderate market potential for the reuse of PV modules and systems until 2030 and a considerable market potential from 2030 onwards. Quantifying this potential is difficult given the known figures. It is clear that this potential requires a significant initial investment in order to publicise the reuse offer and gain the trust of market participants. Initial pilot projects in collaboration with key players in the solar industry are of crucial importance here.

[7] Fischer, Woodhouse, and Baliozian, "International Technology Roadmap for Photovoltaic (ITRP) - 2023 Results."
[8] "SENS eRecycling Annual Report 2023 - Facts & Figures."
[9] Fischer, Woodhouse, and Baliozian, "International Technology Roadmap for Photovoltaic (ITRP) - 2023 Results."
[10] Tsanakas et al, "Toward Reuse-Ready PV."

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