Swiss PV Circle

Work package 2 - Business model

Economic and ecological aspects of the reuse of photovoltaic systems

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Author	Michael Gasser
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Executive Summary

The reuse of modules and other components of PV systems that are dismantled at an early stage has significant economic and ecological potential. The Swiss PV Circle project aims to promote the reuse of PV systems and has analysed when reuse can make economic and ecological sense.

The results of the project show that there are circumstances in which reuse can make economic and ecological sense. From an ecological point of view, reuse makes sense under many conditions and depends in particular on how long a reused system can be operated compared to a new system.

From an economic point of view, reuse is more challenging. A major obstacle here is the cost of testing used PV modules. Today, modules tend to have to be tested and recertified individually. The development and acceptance of alternative test methods with lower costs would enable significant cost savings in reuse and thus reinforce the economic advantages of reuse or make it possible in the first place.

From both an economic and ecological point of view, reuse makes particular sense if not only PV modules but also other components (e.g. inverters and substructures) are reused. In practice, it is difficult to reuse these components as they are specifically adapted to the location and the system. In order to promote reuse and take all components into account as far as possible, the Swiss PV Circle project has developed a form that summarises the information required to assess the reusability of systems (see Deliverable 2.3). In addition, a guide to reuse was created for installation companies (see Deliverable 2.2).

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1. Introduction

Installing a PV system involves financial and environmental costs. The components have to be manufactured and installed, which has both financial and environmental implications.

During the operation of a system, electricity is produced, which has an economic and ecological value. From an ecological and economic point of view, it makes sense to utilise an existing system for as long as possible. Nowadays, life cycle assessments and profitability calculations assume that PV installations have a service life of around 25-30 years.[1]

Due to technological developments, the efficiency of PV modules is increasing. For this reason, it can make economic sense to dismantle existing and functioning systems before the end of their technical life if space is limited. External circumstances can also cause the earlier dismantling of functioning PV systems and components (e.g. roof renovation, addition of storeys, hail damage). The majority of these systems and components are not reused today, but are sent for recycling via the industry solution from SENS eRecycling and Swisssolar.

The dismantled PV systems and components could in principle be reused and thus represent a potential for the circular economy and the expansion of renewable electricity production.

Figure 1 shows an example of how the overall economic and ecological costs and benefits of PV systems change over time and what effects early replacement or reuse can have. Depending on the assessment approach used - be it an economic or ecological cost-benefit analysis - and depending on the methodology chosen to quantify ecological expenditure (e.g. in the form of CO_2 equivalents or environmental impact points [EIP]), the results, in particular the height of the bars shown, can vary significantly.

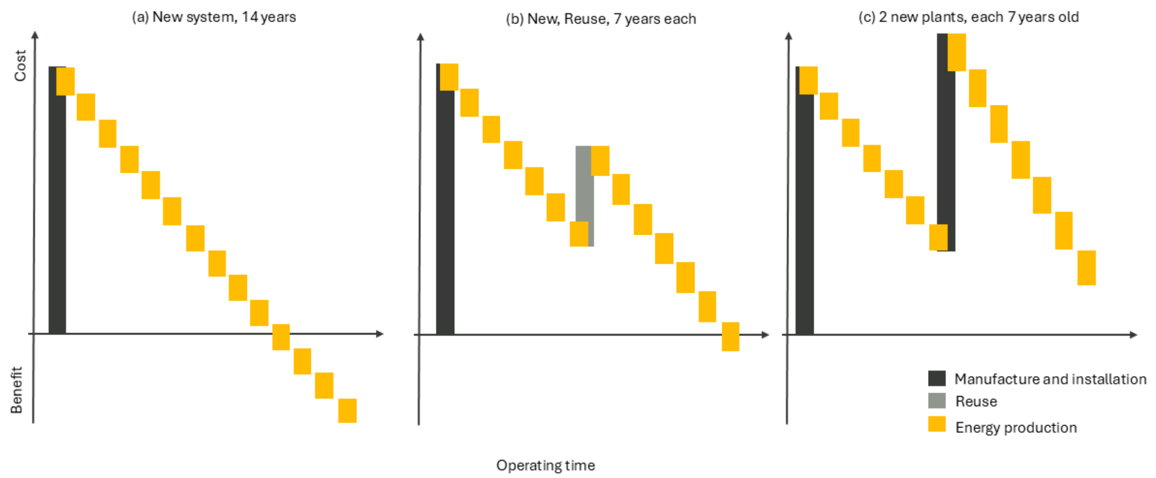

Figure1 : Development of the costs and benefits of manufacturing and utilising a PV system over several years of operation.

A sample calculation with figures from the price monitoring study by the Swiss Federal Office of Energy (SFOE) shows how high the economic potential of reuse could be.[2] The share of PV modules in the total costs of a system in 2023 was between 14% (systems 2-10kWp) and 36.9% (300-1000kWp). For the most common system size of 10-30kWp, the module costs are around 20%. If modules from reuse could be

[1] Frischknecht et al, "Methodology Guidelines on Life Cycle Assessment of Photovoltaic 2020."

[2] Bloch and Sauter, "Photovoltaikmarkt: Preisbeobachtungsstudie 2023."

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procured free of charge, the costs would be reduced accordingly by this proportion. Similar calculations can also be made for ecological considerations.

As part of the Swiss PV Circle project, the conditions under which the reuse of functional components or parts makes ecological or economic sense were analysed. The aim of these investigations was to identify sensible areas of application for the reuse of PV systems. For the study, PV systems were divided into three simplified components: PV modules, electronics, inverters and substructures. A new system refers to a system in which all components are new. A reused system refers to a system in which at least the PV modules have already been used before. However, reused systems can also utilise additional reused components. To analyse the effects of different degrees of reuse, various scenarios were developed and investigated in order to assess the economic and ecological implications of these approaches.

The calculations were always based on systems with the same nominal output. The effect of higher energy production of a new system with higher efficiency compared to a reused system with a limited installation area was therefore not taken into account, i.e. it was assumed that the areas available for the PV system do not restrict reuse. In addition, all calculations refer to rooftop systems.

2. Economic efficiency of reused systems

2.1 Initial situation

In order to consider the cost-effectiveness of reused systems, both the costs of refurbishing used components and the installation costs must be taken into account. If refurbished components can be procured more cheaply than comparable new components, it is possible, but not mandatory, that a reused system is economical. For a complete assessment, differences in service life, energy production and any differences in installation costs (safety precautions, labour, project planning) must also be taken into account. In the Swiss PV Circle project, the cost of refurbishing PV modules in particular was analysed in terms of cost-effectiveness, as it is to be expected that the installation costs of reused systems are comparable to new systems.

2.2 Reuse of modules: costs of reprocessing

The processing of used PV components includes disassembly, testing, provision and the associated transport and storage costs. While the costs for dismantling and provision can be estimated relatively reliably on the basis of standard industry experience, the testing of used components is a specific process whose costs must be calculated individually. The testing of PV modules is particularly relevant here, as defects in these components can have considerable consequences in terms of safety and costs.

Various technical methods exist for testing the safety, durability and production performance of PV modules. They were originally developed for the assessment of system damage (hail, fire), the commissioning of systems or for quality control during production. In principle, the methods provide a good indication of the condition of a module. As part of the Swiss PV Circle project, we have used them to create a guideline for the reuse of second-hand PV modules (see Deliverable 2.2).

A complete statement about the condition of a used PV module can only be made with the available methods if each module is tested individually. Interviews with potential customers as part of the Swiss PV Circle show that the acceptance of previously used modules by owners and/or customers is particularly high when

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individual module tests are carried out in a manner comparable to that of new modules. This is certainly also due to the fact that the reuse of components is more of a new topic and early failures can have significant cost consequences. A Swiss PV Circle workshop with international stakeholders shows that there is currently an international tendency for each individual module to be fully tested for reuse (see Deliverable 5.1).

Based on this initial situation, the Swiss PV Circle project focussed on determining the costs of individual module tests. Two pilot tests for testing used PV modules were supported and carried out in order to record and model the cost impact of testing. The first pilot was carried out in collaboration with Services Industriels de Genève (SIG)[3] and the municipality of Meyrin[4] , the second with the RE-WIN association[5] . In the first pilot, around 270 modules were tested with a mobile test system for PV modules from the Eastern Switzerland University of Applied Sciences (OST)[6] , and in the second pilot around 20 modules were tested with hand-held test devices from Solarenergie Küng GmbH[7] and with a prototype of a plug & play characteristic curve measuring device from Bern University of Applied Sciences (BFH) . [8]

The cost of testing the modules was between CHF 30-50 and CHF 50-90 per module, depending on the test method (Table 1). Renting a mobile test system is more cost-effective than using handheld test devices for batches of around 100 modules or more, as a higher throughput is achieved. These costs are applicable to the volume structure prevailing on the market today (small annual quantities, the modules are to be tested on a small number of systems as part of individual projects). The costs calculated take into account the rental of the devices and the personnel required for testing, but not other costs such as storage and transport, which were borne by the system owners.

If the demand for used modules were to increase and the volume structure were to change, an alternative production-based business model could be more financially effective. In this business model, a company makes specific investments in a test facility and operates it at high capacity in order to make the testing of PV modules as cost-effective as possible. The volume for such a business model would be available in principle. The volume of PV modules disposed of via SENS eRecycling was just under 50,000 in 2022, and the trend is still rising (see Deliverable 3.1). In such a business model, a company would have to independently procure the necessary quantity and quality of dismantled PV modules, test them in its own infrastructure, store them if necessary and market them.

Table1 : Overview of the test costs for PV modules collected in the Swiss PV Circle project

Quantity structure	Kind	CHF / tested module[1]	Rp / Wp[2]
Small quantities Individual projects	Manual with handheld testers	50-90	22 - 40
	Rental of mobile test system per use (from 100 modules / lot)	30-50	13 - 22
Continuous volume flow	Mobile test facility on site	45 (at 1,000 M/y)[3] 39 (at 3,000 M/y)	17 - 20

[3] "https://ww2.sig-ge.ch/."
[4] "https://meyrin.ch/fr."
[5] "https://re-win.ch/."
[6] "https://www.ost.ch/en/research-and-consulting-services/technology/renewable-energies-and-environmental-engineering/spf-institute-for-solar-technology/testing/mobile-pv-test-laboratory."
[7] "https://www.solarenergie-kueng.ch/."
[8] Jäggi and Bucher, "Plug & Play-Kennlinienmessgerät für Photovoltaik-Module."

Dedicated test infrastructure	Test Centre Switzerland (fixed installation) (from 5,000 modules / year)	43 (at 3,000 M/y) 28 (at 10,000 M/y) 25 (at 30,000 M/y)	11 - 19

[1]excluding modules that do not pass the tests.

[2]with an average of 250 Wp / module and 90% of the modules passing the tests.

[3]M/J: Modules / year

Full cost calculations by Swiss PV Circle show that this business model becomes more cost-effective from a test volume of 3,000-5,000 modules per year despite additional costs (space, administration, transport, storage, amortisation, interest, etc.) and test costs in the range of CHF 25-45, depending on the annual volume, can be achieved.

The test costs per module are similar regardless of the size and efficiency of the module, as each module must always be tested individually. If the test costs are calculated in relation to the nominal output, the costs for older modules with a smaller surface area and lower efficiency are much higher than for newer modules. With test costs per module of CHF 50, an older module with a nominal output of 250 Wp would have test costs of around CHF 0.2/Wp, while a newer module with a nominal output of 350 Wp would have test costs of around CHF 0.14/Wp. These costs are slightly lower to similar to the market prices of conventional new modules (as of January 2025), but do not take into account potential costs in planning and project planning or the substructure (old mounting systems, additional surface area) or the potentially limited service life.

Enquiries from the market during the project period suggest that at the moment it is mainly systems with modules with an output of less than 250 Wp that are being dismantled. Assuming that modules must all be tested individually for reuse, the test costs calculated in the project show that the reuse of such modules in the current quantity structure is hardly economically attractive compared to new modules. This is particularly true when risk premiums and margins are not taken into account. Modules with a higher output (>350Wp), which are available in large quantities in the same design, such as in an industrial plant, are economically more interesting.

In a changed market situation with higher new module prices and increasing availability of reusable modules (see Deliverable 3), reuse could become more financially attractive.

2.3 Reuse of modules: influence of test methods

The individual module tests currently used for reuse are cost-intensive, require a great deal of effort and only scale to a limited extent with increasing quantities. If the requirements for the tests to be carried out could be reduced and reliable and robust information on the condition of PV modules and systems could still be collected, this would have a significant impact on the economic efficiency of module reuse.

In an optimistic scenario with current volume structures and individual module tests, a cost reduction of around 20% compared to new modules is possible. Taking into account the cost shares of PV modules in the total system costs, this would result in reductions of 3% for systems with 10-30 kWp and 7% for systems with 300-1,000 kWp output (calculated on the basis of SwissEnergy, 2024). Taking into account the risks and potential additional costs (system maintenance), these savings are rather small. With alternative test methods, which could, for example, enable savings of 80% compared to new modules, the total costs of systems would be reduced by 11-29%.

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The pilot test carried out in collaboration with SIG shows the limits of the technical test methods used. In the trial, a total of 273 modules with an age of 20 years were tested for suitability for reuse. Here, 49 (18%) were excluded from reuse due to visible defects with a simple visual inspection (detachment of backsheets, oxidation, defective cables, plugs or diodes, glass breakage, etc.). Only 8 further modules (3%) were excluded from reuse due to failure to pass the technical tests.

These figures show the importance of subjecting modules to a preliminary visual inspection before a technical inspection in order to reduce the costs of a technical inspection. They also show that modules from systems that were operated without any significant problems in their first life and have no visible defects can largely be used in a second life. No guarantee can be given for the duration of a second life, even with individual module tests. Technical test procedures can detect isolated defects, but it must be questioned whether a cost-intensive test of each individual module is expedient or whether tests of entire systems or strings would be more expedient. String- and plant-based measurements including historical production data and module tests of individual modules, coupled with the safety verification for the commissioning of a reused plant, could therefore in principle be sufficient to obtain sufficient information for the technical assessment of reusability. Individual module tests could be reduced to a selection of a few modules (problematic strings, random selection).

2.4 Reuse of entire systems

If other system components can be reused, the potential cost savings increase. Ideally, an existing system including all components can be relocated to a new area without any testing costs. In this case, only labour and safety costs are incurred, which in total account for between 28% (300-1000 kWp) and 37% (2-10 kWp) of the total system costs.[9] In such a scenario, a maximum of 60-70% of the system costs could therefore be saved.

If an increased amount of labour is assumed or certain components have to be replaced, the cost advantage is quickly reduced. From a financial perspective, the reuse of inverters and electronic components appears more attractive than that of mounting systems, although the latter may be easier to implement in practice. A mounting system contributes around 10-15% to the system costs, while inverters and electronics together contribute around 15-27%.[10]

2.5 Influence of the one-off payment

With a one-off payment (EIV), PV system operators receive a one-off investment contribution. One-off payments for PV systems are granted on the basis of various influencing variables, including the angle of inclination and system output, and on the basis of average costs.

As potential cost savings from reuse are not included in this cost calculation and the remuneration is calculated on a flat-rate basis, the one-off remuneration with a high proportion of reuse can have a higher impact in percentage terms. A plant that can be realised with a cost saving of 30% compared to a new plant before taking the EIV into account thanks to reuse has a price advantage of 40% compared to a new plant after taking the EIV into account (Table 2). These calculations assume that a system with the same output is

[9] Bloch and Sauter, "Photovoltaic market: Price observation study 2023."

[10] Bloch and Sauter.

built at the same location, although a system with reused modules requires more space (optimisation of self-consumption, i.e. in the context of a home).

If a reused system with lower output is compared with a new system with higher output (utilisation of the existing area, lower output of reused modules), this effect does not occur or only occurs to a limited extent, depending on the assumptions.

Table2 : Influence of the EIV on the total costs of PV systems with and without EIV

Attachment[1]	***Investment costs ex. EIV*** [2] *CHF*	***EIV***[3] *CHF*	***Investment costs incl. EIV*** *CHF*	***Specific net costs,*** ***CHF/kWp***
20 kWp New	45'000	8'000 (18%)	37'000	1'850
20 kWp, Re-Use+[4]	30'000	8'000 (26%)	22'000	1'110
20 kWp, Re-Use-[5]	40'500	8'000 (20%)	32'500	1'625
15 kWp, Re-Use+[4]	24'000	6'000 (25%)	18'000	1'200
15 kWp, Re-Use-[5]	33'000	6'000 (18%)	27'000	1'800

[1]Assumption: same location, system with the same output, with reused modules, but higher space requirement
[2]According to SwissEnergy, 2024, 20kWp (CHF 45,000) and 15kWp (CHF 36,500), calculated according to 2023 formulas.
[3]According to the EIV tariff calculator from Pronovo[11]
[4]Optimistic calculation example, 30% cost reduction compared to new installation
[5]Realistic calculation example, 10% cost reduction compared to new installation

3. Ecology of reused systems

3.1 Initial situation

The following scenarios were analysed in order to investigate the possibilities and limits of reuse for the sustainability of PV systems:

- **Comparison of reuse with new system:** The installation of a new system at the reuse site is also an option.
- **Reuse on areas without restrictions on service life:** The service life of the system is not limited by the place of application (i.e. it can be assumed that a new system will have a service life of 25-30 years).
- **Reuse on surfaces with a limited service life:** The operating time of the system is limited due to the installation location (e.g. new replacement building, roof renovation or extension planned, heavy soiling).
- **Re-use on areas that do not permit new planting:** A new plant is out of the question at the second use site or it cannot be guaranteed that a new plant would be created.

All calculations were carried out both for CO_2emissions and for environmental impact points (EIPs). UBP combine a variety of environmental impacts according to the ecological scarcity method.[12] In the case of UBP, technology metals such as copper and gold contained in electronics have a higher weighting.

[11] "https://pronovo.ch/de/services/tarifrechner/."
[12] FOEN, "Eco-factors Switzerland 2021 according to the ecological scarcity method."

The use of ecological credits in life cycle assessments in the energy sector is no longer recommended, as very different results are generated with different assumptions and values.[13] Accordingly, the cost-benefit analysis was analysed with the following question: From what lifespan does a reused system produce energy that causes lower emissions than a new PV system, taking into account the emissions from provision? The detailed assumptions for the calculations can be found in Appendix 1.

3.2 Influence of the testing of photovoltaic modules

In the economic evaluation, the testing of PV modules has a significant impact, while it is comparatively insignificant from an ecological perspective. The test processes have a low water consumption for cleaning the modules as well as the energy requirement for operating the test facilities and equipment, which can, however, be used several times. In addition, the transport of the modules to stationary test facilities or the use of mobile test equipment on site must be taken into account. Studies carried out by Mija Fossard from the School of Economics and Engineering of the Canton of Vaud (HEIG-VD) as part of the REMCO project[14] show that the ecological costs of testing measured in UBP and CO_2emissions are negligible when testing on site. Testing PV modules therefore always makes ecological sense, even if they are only reused for a short time.

3.3 Reuse on land without restrictions (scenario 1a)

In the case of reuse on land without restrictions, the effect of the degree of reuse is fully visible. Reusing an entire plant is already more environmentally friendly than building a new plant from a second lifetime of approx. 4 (CO_2) and 2.5 (UBP) years (Figure 2).

If only the modules are reused and new components are otherwise used, a second service life of 10-13 (CO_2) and 12.5-13.5 (UBP) years is required. This depends on the area required by the modules for the same nominal output and the corresponding amount of substructure. If additional components are reused, the required operating time is shorter, as the energy produced must be distributed over fewer emissions. The factors are described in scenario 2.

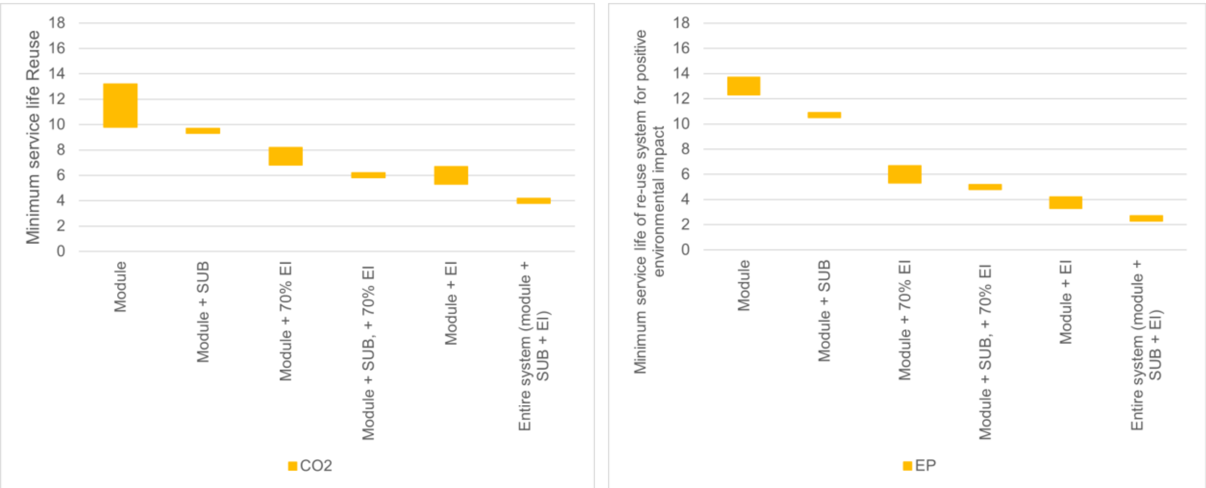

Figure 2 : Operating time of a reused PV system, from which reuse is more environmentally friendly than a new system. Calculated on the left on the basis of CO_2 emissions, on the right on the basis of environmental impact points (EP). Module: Reuse of the PV

[13] Frischknecht et al, "Methodology Guidelines on Life Cycle Assessment of Photovoltaic 2020."

[14] "https://www.hes-so.ch/en/research-innovation/research-projects/detail-projet-recherche/remco-reemploi-des-materiaux-de-construction-etat-des-lieux-sur-les-defis-logistiques."

modules, SUB: Reuse of the substructure, EI: Reuse of the electrical installation incl. inverter, 70% EI: Reuse of 70% of the electrical installation incl. inverter. Components not mentioned are assumed to be newly constructed.

3.4 Reuse on areas with a limited service life (scenario 1b)

If the service life of a PV system is limited from the outset, a new PV system cannot utilise its advantage of a long service life. At such a location, the new PV system is also associated with higher emissions and environmental pollution, as the ecological costs of constructing the system are independent of its service life. This means that reuse pays off earlier. If a new PV system with a planned service life of only 15 instead of 30 years is planned, it has around twice the emissions per kWh produced (same ecological costs in construction, half the energy production leads to 96g instead of 48g CO_2/kWh). The necessary operating time shown in Figure 2 for scenario 1a would therefore be halved in such a case.

3.5 Reuse on areas that do not permit new planting (scenario 2)

It is possible that in future there will be more areas where the installation of a new system is not permitted, desired or possible. This may apply to the following areas, for example:

- Areas where the construction of a PV system is required by law and a new system is financially unattractive (shady, temporary, etc.).
- Areas where the building owner pursues a forward-looking approach to reducing grey emissions or prefers reuse in principle.
- Areas belonging to owners who do not have the necessary capital to build a new facility.

Scenario 2 is the only scenario that results in an additional expansion of PV capacity. The ecological cost of reusing a PV system must be in proportion to the benefit of the additional electricity production and the remaining operating time, even on such areas. It is therefore compared with the usual emission values for PV electricity.

If a PV system is completely relocated, only the transport costs need to be taken into account. These are balanced out after a second service life of less than one year, even in the case of reuse as a result of export to Africa or Eastern Europe (Table 3). It should be noted that the effects of a lack of recycling infrastructure are not taken into account in these analyses.

Table3 : Second lifetime of a completely relocated plant required to equalise transport emissions (use of reference values in the Annex).

Destination	***Transport distance***	***transport kg CO2/kWp****	***Transport kUBP/kWp****	***CO2 equalisation***	***Equalisation UBP***
Switzerland	150km lorry	3	5	3 weeks	2 weeks
East DE, South IT, CZ, SK, HU	1'000km lorry	18	34	4.5 months	3 months
SP, UA	2'000km lorry	36	68	9 months	6 months
East Africa, GH	9'000km ship, 1'000km lorry	24	50	6 months	4 months

* Including substructure, electronics and inverter. Around 100kg material / kWp for modules with an output of 250Wp.

If new components are used for the construction of reused systems, these must also be offset by an additional operating time or electricity production. The use of new electronics and inverters increases the required operating time by 5.5 (CO2) or 9 years (UBP). In comparison, the use of a new substructure requires only 2 additional years of operation.

4. Conclusion

The economic viability of reusing PV systems under the current market conditions, particularly due to the low prices of new modules, is only possible under very narrow conditions (as of January 2025). Modules with a very short service life and correspondingly high efficiency or the relocation of complete systems are of interest for reuse. Calculations must be made on a case-by-case basis, taking into account the expected revenue (electricity price, self-consumption share) and any additional costs of reuse (space requirements, planning costs). In terms of system costs, reuse would be particularly worthwhile for large systems (300-1,000 kWp), where the modules account for a larger proportion of the total costs. At the same time, however, in Europe it is large systems in particular that are often dismantled before the end of their technical life, as higher yields can be achieved here through re-powering with more efficient modules. [15]

Due to the costs involved in testing used PV modules, it makes sense to reduce the number of tests carried out as far as possible and to avoid individual module tests wherever possible. In this way, used PV modules can be competitively priced, even compared to favourable alternatives such as stock leftovers. The number of tests can be reduced in particular if additional identical PV modules can be purchased and stored at low cost to compensate for any premature failures.

The reuse of PV systems does not always make sense from a sustainability perspective either. However, the requirements for ecological reuse are far less restrictive than from an economic perspective. Priority should be given to the reuse of PV systems in which as many components as possible are reused. Where possible, preference should be given to locations where the operation of a new PV system for the entire expected service life cannot be prioritised, or locations where new PV systems are not an option (additional capacity expansion). However, even at normal sites with an expected operating life of 30 years (scenario 1b), the use of a reused PV system makes sense under certain conditions. At best, a case-by-case assessment should be carried out.

Swiss PV Circle's calculations show that the location of a reused PV system hardly plays a role and that export makes ecological sense despite the long transport distances. However, it should be noted that export is not always legally permissible (see Deliverable 5.2). Exports can also cause significant social costs, as there are no established recycling systems for PV modules and electronics in all countries, meaning that recycling is carried out in precarious circumstances.[16] Exports should therefore only be made to countries with functioning take-back systems for PV modules and electronics.

Reuse makes particular sense from both an ecological and economic point of view for PV systems that are as complete as possible (reuse of modules, substructure, inverter and electronics). While identical PV modules can be installed at different locations, the substructure and inverters such as the electronics are heavily customised to the roof and the characteristics of the system (e.g. location of fuse box, alignment of

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[15] Ariolli, Oviedo Hernandez, and van der Heide, "Re-Use of PV Modules and Circular Business Models."

[16] Agyeman et al, "Toward a Circular Economy in Ghana's Renewable Energy Sector"; Cimadomo, "Advancing a Circular Economy for Solar Photovoltaics Exported for Reuse - Analysing the Institutional Feasibility of International Extended Producer Responsibility for EU-West Africa Transboundary Movements."

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modules, system capacity). In reality, there are therefore strict limits to the reuse of these components. In order to promote the reuse of these components, details of these components should be recorded in detail so that their suitability can be checked in individual cases (see Deliverable 1.1 and 1.2).

The suitability of a system for reuse depends on many factors and information. The form "Documentation requirements for a transfer of PV systems for reuse" developed as part of the Swiss PV Circle project is intended to allow all useful information to be collected in a central document and made available to interested parties (see Deliverable 2.3). This document is also intended to include details of the substructure and inverters.

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Appendix

Appendix 1: Assumptions for the ecological calculations

- Reused components do not carry any residual emissions from the first utilisation phase (cut-off approach). The recycling of the PV system is already taken into account in the first utilisation phase based on the data used.
- The dismantling of a system is independent of the reuse of components. Reuse therefore always extends the total service life of the components by the duration of their second life. Without reuse, the components would have been recycled after the first utilisation phase.
- The life cycle assessment data in the construction sector was used for all CO2 and UBP factors. [17]
- An average service life of 15 years was assumed for inverters, with a corresponding proportionate replacement inverter in the event of a longer operating period.[18] For all other components, the service life is unlimited or corresponds to the expected service life of a new system (30 years).
- The break-even emission values used were 48g CO_2/kWh and 151 UBP/kWh for average energy from new PV systems, as long as the new system reaches its full service life of 30 years.
- All calculations were carried out on the basis of a mono-Si rooftop system with an average energy production of 1,000 kWh/installed kWp output per year.
- The effect of additional electronics and substructure requirements for reused modules with lower efficiency and higher space requirements was taken into account.

[17] "https://www.kbob.admin.ch/en/ecobalance-data-in-the-building-area."
[18] Tschümperlin et al, "Life Cycle Assessment of Low Power Solar Inverters (2.5 to 20 kW)."

Literature

Agyeman, Eric, David A. Quansah, Augustine Ntiamoah, Lena D. Mensah, and Emmanuel W. Ramde. "Toward a Circular Economy in Ghana's Renewable Energy Sector: A Quantitative Assessment of Waste from Solar Photovoltaic Modules in Ghana." *International Journal of Green Energy*, March 3, 2025, 1-20. https://doi.org/10.1080/15435075.2025.2469136.

Ariolli, Daniela, Guillermo Oviedo Hernandez, and Arvid van der Heide. "Re-Use of PV Modules and Circular Business Models." Trust-PV, August 2023. https://trust-pv.eu/reports/repair-re-use-and-in-source-recycling-of-pv-modules-and-bos-components/.

BAFU. “Ökofaktoren Schweiz 2021 gemäss der Methode der ökologischen Knappheit.” Bundesamt für Umwelt (BAFU), 2021.

Bloch, Lionel, and Yannick Sauter. “Photovoltaikmarkt: Preisbeobachtungsstudie 2023.” EnergieSchweiz, Bundesamt für Energie, June 13, 2024.

Cimadomo, Simone. "Advancing a Circular Economy for Solar Photovoltaics Exported for Reuse - Analysing the Institutional Feasibility of International Extended Producer Responsibility for EU-West Africa Transboundary Movements." Lund: Master thesis - IIIEE, Lund University, 2024.

Frischknecht, R, P Stolz, G Heath, M Raugei, P Sinha, and M de Wild-Scholten. "Methodology Guidelines on Life Cycle Assessment of Photovoltaic 2020." International Energy Agency, April 2020. https://iea-pvps.org/wp-content/uploads/2020/07/IEA_Task12_LCA_Guidelines.pdf.

"https://meyrin.ch/fr," n.d.

"https://pronovo.ch/de/services/tarifrechner/," n.d.

"https://re-win.ch/," n.d.

"https://ww2.sig-ge.ch/," n.d.

"https://www.hes-so.ch/en/recherche-innovation/research-projects/detail-projet-recherche/remco-reemploi-des-materiaux-de-construction-etat-des-lieux-sur-les-defis-logistiques," n.d.

"https://www.kbob.admin.ch/en/oekobilanzdaten-im-baubereich," n.d.

"https://www.ost.ch/en/research-and-consulting-services/technology/renewable-energies-and-environmental-engineering/spf-institute-for-solar-technology/testing/mobile-pv-test-laboratory," n.d.

"https://www.solarenergie-kueng.ch/," n.d.

Jäggi, Adrian, and Christof Bucher. “Plug & Play-Kennlinienmessgerät für Photovoltaik-Module,” 2025.

Tschümperlin, Laura, Philippe Stolz, Franziska Wyss, and Rolf Frischknecht. "Life Cycle Assessment of Low Power Solar Inverters (2.5 to 20 kW)." Swiss Federal Office of Energy SFOE, October 3, 2016.

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