Swiss PV Circle

Work package 2 - Business model

Reuse guide for installation companies

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1. Initial situation

The reuse of PV modules and systems is neither systematically established nor widespread in Switzerland. Although there are local players who reuse dismantled, still functional PV modules and components locally to the best of their knowledge and belief, this remains the exception. In the coming years, however, significantly higher quantities of PV modules are expected to reach the end of their first life cycle and be suitable for reuse (see Deliverable 3.1).

With this in mind, the industry association Swissolar and the take-back system SENS eRecycling have decided to promote reuse in Switzerland as part of the Swiss PV Circle project. In order to establish a standardised approach within the industry, these guidelines have been developed, which are specifically aimed at installation companies. It is intended to raise awareness of the issue of reuse and provide the relevant stakeholders with practical recommendations for dealing with reusable PV modules.

The guidelines are organised chronologically and describe the procedure for reusing PV modules (see Figure 1). Firstly, the key aspects of an economic assessment of the reuse potential are explained (section 2.1), followed by a technical assessment (section 2.2). The test and dismantling procedures on site are then described (section 2.3). The final step focuses on further testing, including cleaning, inspection and repair (section 2.4). This structured approach is intended to support installation companies in considering the reuse of PV modules and, ideally, establishing them as a valid alternative to recycling.

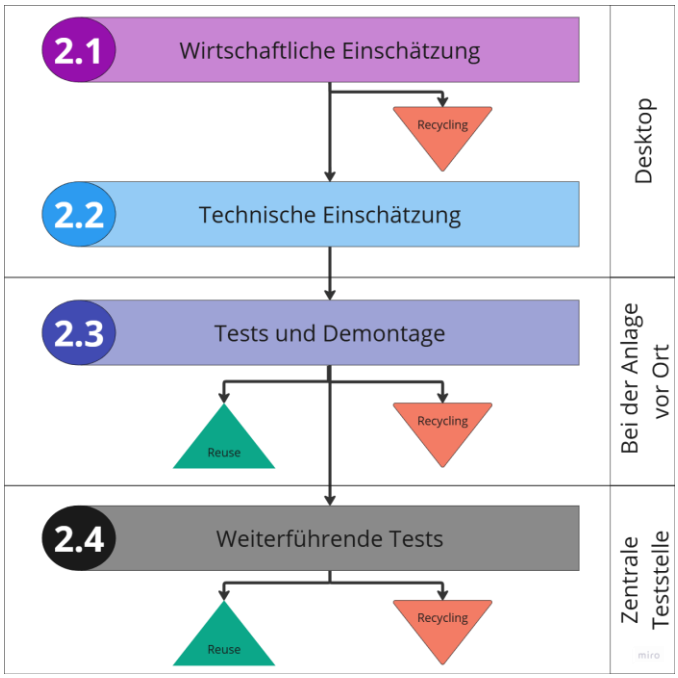

Figure 1: Procedure for reusing PV modules.

2. Procedure Reuse

When installation companies are confronted with PV modules that are potentially suitable for reuse, various economic, technical and procedural questions arise, which we would like to address here. A detailed decision tree (Figure 2) helps to provide a quick overview of these questions.

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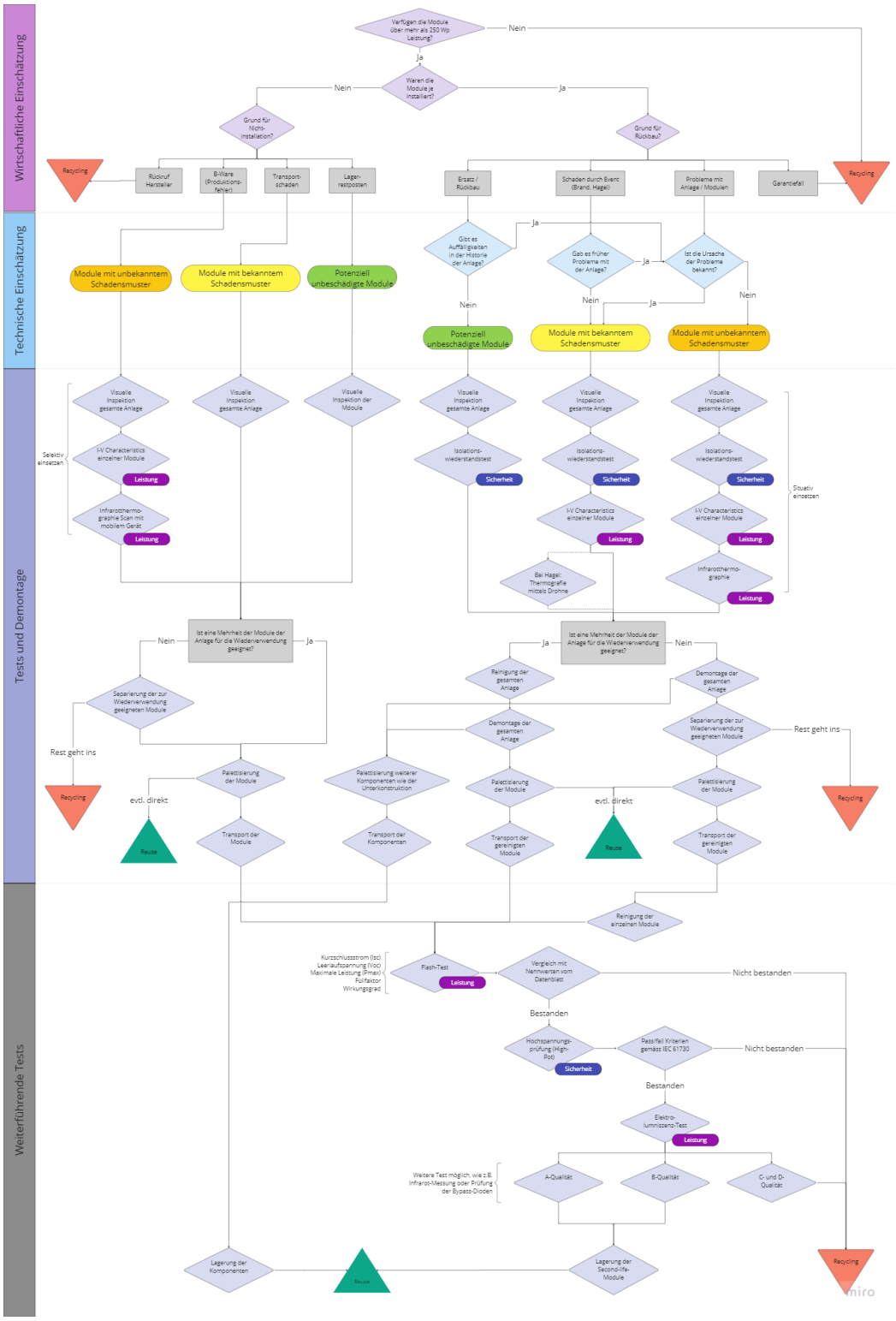

Figure 2: Reuse decision tree.

2.1 Economic assessment

Before dismantling, the economic potential of reusing PV modules or the entire PV system should first be assessed. This assessment is crucial to ensure the profitability of reuse. The key question is whether used photovoltaic modules will find buyers on the market. This depends to a large extent on their remaining rated output and their utilisation history, and in particular on why they are being offered for reuse. As the general

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profitability analyses (see Deliverable 2.1) show, the reuse of other components (substructure, cables, electrical installation, weighting) can also have an important impact on the profitability of a project.

Ideally, the new installation location is already known before dismantling. This makes planning easier, as the number of modules required, the reuse of other components such as the substructure and the price sensitivity of the future owners can be taken into account when selecting the appropriate test procedure.

As a guideline, we recommend only considering modules with a rated output of more than 250Wp for reuse (see Figure 2). Modules with this power are usually not older than 15 years. Other European reuse actors have similar criteria in terms of power and age.

It is also essential for the economic evaluation to know why a module is available for reuse in the first place. There are various reasons for this. Roughly speaking, modules can be divided into two categories: modules that have never been installed and modules that have already been installed but uninstalled prematurely (see Figure 2).

- Modules that have never been installed may come from leftover stock, may have been damaged during transport, may have been declared as B goods with slight production faults or may have been recalled by the manufacturer.
- Modules that have already been installed may, for example, have been dismantled due to a system extension or system replacement (re-powering), partially damaged by external influences such as hail or fire, dismantled as a warranty case or have other problems that have led to premature dismantling.

Based on these reasons, different conclusions can be drawn regarding the reuse potential as well as the necessary test procedure and the associated costs. For example, reuse is not recommended for modules that have been recalled by the manufacturer or in the case of warranty claims. Such modules no longer fulfil the manufacturer's quality or safety requirements.

2.2 Technical assessment

A technical assessment should be carried out before dismantling. It is advisable to analyse the performance and/or monitoring data of the system from this period. This raises two questions (see Figure 2):

- Does the system history show any anomalies? These can be, for example, longer phases with reduced or missing power, but also individual outlier strings. It is important to check the performance loss rate (PLR) over time, where deviations between the actual and expected power loss observed over a longer period of time may indicate previously unknown technical or operational problems. The inverter data can also be used to identify previously unknown insulation problems.
- Did the system previously have problems or events that have already been identified and, if necessary, rectified? Such historical events can have an influence on the suitability for reuse, depending on the type and rectification. Events such as storm damage due to hail, above-average partial shading caused by vegetation, heavy soiling or other problems can play a role here. Fault and maintenance logs can help to determine the problems and events (see Deliverable 2.3)

At the end of the technical assessment, the modules of a system can be divided into the following categories (see Figure 2):

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1. potentially undamaged
2. with a known damage pattern
3. with an unknown damage pattern

These findings influence the subsequent test procedures. The technical assessment is easier for modules that have never been installed. Remaining stock items can generally be regarded as potentially undamaged. Modules with transport damage have a known damage pattern, while modules with minor production defects (B-goods) may have an unknown damage pattern.

2.3 Test and disassembly procedures

Before dismantling the PV system, the next step should be to carry out on-site clarifications. The documentation template from the Swiss PV Circle project can be used for this (see Deliverable 2.3). The principle here is to reduce the scope of testing to the necessary minimum, while at the same time ensuring the safety and quality of the modules. The scope of testing therefore differs depending on the classification of the modules - potentially undamaged, with a known damage pattern or with an unknown damage pattern - and therefore also in terms of the time and costs involved (see Figure 2). It is also recommended that the scope and type of tests carried out be adapted to the needs of the next owner.

Potentially undamaged modules

In the case of potentially undamaged modules, a visual inspection of the modules and the remaining system components is recommended. If necessary, additional insulation resistance tests at system or string level may be worthwhile (IEC 61730-2:2023, IEC 62446-1:2016). For PV systems with a rated power of up to 10kWp, the insulation resistance must be measured with the test voltage specified in Table 1. The result is satisfactory if each circuit has an insulation resistance that is not less than the corresponding value in Table 1.[1] For systems with a rated power of more than 10kWp, the same test can be carried out at string level and evaluated using the same target values . The insulation resistance test must be carried out by qualified personnel in accordance with the applicable standards.

Table 1: Minimum values for insulation resistance test

Maximum system voltage (calculated according to IEC 62548) V	Test voltage V	Minimum insulation resistance MW
<120	250	0.5
120 to 500	500	1
500 to 1,000	1'000	1
1,000 to 1,500	1'500	1

If the visual inspection and the insulation resistance test provide positive results for potentially undamaged modules, direct reuse can be considered without the need for further tests (see section 2.4). This is particularly

[1] Tsanakas et al, "Toward Reuse-Ready PV"; van der Heide et al, "Re-Use of PV Modules: Progress in Standardisation and Learnings from a Real Case Study."

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the case for modules that are dismantled in the course of a system expansion or system replacement (re-powering) and do not exhibit any unknown damage according to the technical assessments. Optionally, it may be useful to subject individual modules to further tests on a random basis.

Modules with a known damage pattern

The test procedure for modules with a known damage pattern also starts with a visual inspection and an insulation resistance test. In addition, the current-voltage characteristics of individual modules or strings should be tested with a portable measuring device (IEC 61829:2015) and compared with the original data sheet values (IEC 60891:2021), insofar as these make it possible to identify the expected damage pattern.

If the damage pattern is hail damage, it is advisable to carry out infrared thermography, for example with a drone (IEC TS 62446-3:2017), to identify hotspots that make modules unsuitable for reuse. Certainly unsuitable are modules with hotspot(s) where the temperature difference between the hotspot and the neighbouring areas of the module is more than 40°C[2] . It is also advisable to test all modules with a known damage pattern individually in further tests (see section 2.4).

Modules with unknown damage pattern

For modules with an unknown damage pattern, a more comprehensive technical assessment is recommended. In addition to the visual inspection, the insulation resistance test and the testing of the current-voltage characteristic of individual modules, this also includes an infrared thermography examination of individual modules using a portable device (IEC TS 62446-3:2017). Modules with an unknown damage pattern should always be tested individually in further tests (see chapter 2.4).

The various test procedures must be applied depending on the situation and individual circumstances. The situational application of these tests is based on the previously conducted economic and technical assessment as well as the visual inspection on site. If the entire system or a large proportion of the modules are suitable for reuse, it may make financial sense to clean the modules on site before dismantling. This depends on whether cleaning is possible and efficient in the installed state and on the cleaning capacity of the organisation carrying out the reuse. The fewer modules that are suitable for reuse, the less useful on-site cleaning is. Modules that cannot be reused and are sent for recycling should be clearly labelled so that they can be easily separated from the reusable modules. The decommissioning of a system should be reported to Pronovo (see Deliverable 2.3).

The reusable modules should then be carefully stacked with the glass surface facing upwards, ideally on special pallets that protrude beyond the edges of the modules, for further transport. If EURO pallets are used, it is advisable to stack the modules crosswise so that the modules rest on the frame. No more than 30 modules per pallet should be stacked on top of each other and secured with lashing straps. Ideally, protective stacking aids made of cardboard, plastic or similar materials should be used, especially to protect the corners. Other system components such as substructures, cables, fastenings, ballast and similar should also be considered for reuse and palletised accordingly. The more components that are reused, the greater the economic and ecological benefit in the second utilisation phase (see Deliverable 2.1).

[2] van der Heide et al, "Re-Use of PV Modules: Progress in Standardisation and Learnings from a Real Case Study."

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The process is similar for modules that have never been installed (see Figure 2). A visual inspection is recommended in all cases; further tests can be carried out depending on the situation. As there are usually no other system components in such cases, only the modules are usually considered for reuse.

2.4 Further tests

In order to systematically analyse the safety, durability and performance of the reusable modules, it is advisable to test all modules individually. This also ensures that there is a test protocol for each module, which can be given to the new owner as a guarantee of the functionality of the modules, which in turn increases the probability of sale. However, in order to ensure the cost-effectiveness of reuse, it may also be that further tests for all modules are too extensive. Sampling tests can be particularly useful for system expansions or system replacement (re-powering), where all modules are potentially undamaged and should still be of the same quality, and can significantly reduce the time and costs involved.

A flash test to determine the short-circuit current, open-circuit voltage, maximum power, fill factor and efficiency is suitable as a first advanced test. The values can be compared with the nominal values from the product data sheet or - even better - with the results of the initial flash tests during production in order to recycle modules that are unsuitable for reuse. Modules should be considered unsuitable for reuse if their performance deviates by more than 20% from the expected nominal performance or by more than 10% from the average performance within the test group[3]. Modules whose I-V curves show significant deviations from the nominal curve, for example in the form of steps or steep drops in gradient, should also be excluded.

To ensure the safety of the modules, a high-voltage test (high pot) should also be carried out (IEC 61730-2). This allows the continuity of the earthing and the resistance between all four frame parts to be measured, as well as the insulation resistance. The pass/fail result shows whether a module is still safe to be reused as a second-hand module.

An electroluminescence test should be performed to visualise inactive areas as well as microcracks in the cells that are invisible to the human eye. Typically, the affected areas of a cell are categorised into three severity levels: non-critical if less than 1% of the cell is affected, critical if 1-20% of the cell is affected, and very critical if more than 20% of the cell is affected. Modules in which one or more cells with a severity level of very critical are present or in which more than eight cells are classified as critical fall into categories D or C and are sent for recycling. Modules with fewer than eight cells with a severity level of "critical" are assigned to category B, while modules with a severity level of non-critical or no complaints correspond to category A (categorisation according to the Swiss PV Circle pilot). Allocation to the categories can be defined more strictly or less strictly depending on the future location of the modules.

[3] van der Heide et al.

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