Quasar

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European stakeholder survey and first Co-Creation workshop

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1 Introduction and summary

1.1 Purpose of the document and executive summary

This report presents an analysis of the European stakeholder survey and the first Co-Creation workshop carried out as part of WP10 within the QUASAR project. The survey provides insights into perceptions of market development, social acceptance, as well as stakeholder views on the barriers and drivers for end-of-life (EOL) treatment of photovoltaic (PV) modules—specifically regarding repair, reuse, and recycling practices. The Co-Creation Workshop further explored these barriers in depth with engaged stakeholders from across Europe.

1.1.1 European stakeholder survey

The results of the **63 completed questionnaires** provide an initial insight into stakeholder perceptions and serve as a foundation for the Co-Creation workshops. These findings reflect the views of the participants and cannot be generalised to the broader population. The results show that participants expect **market demand for PV technology production in Europe to increase over the next 5 to 10 years**. The main obstacles to expanding production were identified as international competition and regulatory uncertainties. Additionally, **small-scale PV installations were generally perceived more positively than large-scale ones**. A key challenge to the social acceptance of large-scale installations is their perceived negative aesthetic impact on landscapes or neighbourhoods. With regard to end-of-life (EOL) PV modules, **participants consistently rated repair, reuse and recycling as more important than their perceived potential, particularly in the case of recycling, which was considered highly important.** Moreover, participants were asked to rank barriers and drivers related to EOL PV treatment

The main barriers to the treatment of EOL PV modules include:

- Module designs that are not recycling- or repair-friendly
- High costs associated with recycling, repair, and reuse
- Insufficient input streams of EOL PV modules for recycling

The main drivers for improving EOL treatment include:

- Rising prices for raw materials
- Growing demand for secondary raw materials
- Technological advancements
- Increasing regulatory pressure

1.1.2 First Co-Creation Workshop

On 6 May 2025, the first Co-Creation workshop of the QUASAR project brought together 42 participants in a hybrid format. Held at the bifa Umweltinstitut in Augsburg, the workshop enabled broad participation from consortium partners, Technical Advisory Group (TAG) members, and external stakeholder interested in the topic. The workshop aimed to facilitate networking among participants, share information about the project and survey results, and identify key barriers to the repair, reuse, and recycling of PV modules.

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First, the participants were given an overview of the project, including its objectives and the current status of the work packages. They then had time to get to know each other and share their views on their connection to EOL PV and the positive and negative aspects of EOL PV treatment, guided by a set of questions. After the exchange round, participants reflected on their conversations and wrote down their key takeaways, summarised as follows:

Surprising insights:

- The low market price of new PV modules poses a significant challenge to the economic viability of repair and recycling measures.
- Absence of scalable and profitable business models for EOL PV treatment.
- In some countries outside Europe, legislation mandates the take-back of PV modules
- Export of end of life modules from Europa may end as landfill and reduces recycling potential within Europe

Confirmed perceptions:

- Current waste volumes are considered insufficient to support a viable European recycling market, since many EOL modules do not enter formal recycling pathways. Therefore, a dedicated and coordinated collection infrastructure for EOL PV modules is required.
- The need to incorporate recyclability considerations into the module design process.
- Willingness to pay for recycling services remains limited.
- Interest in EOL PV technologies is growing worldwide, with an increasing availability of technical solutions, particularly in recycling.

After the exchange round, participants received a presentation summarising the results of the European stakeholder survey. Building on this input, the group work phase began, with participants divided into topic-specific groups focusing on barriers to recycling, reuse, and repair. Participants identified the main barriers and discussed possible solutions. The outcomes were the following:

Repair groups: One major obstacle is the **high cost of assessing module conditions and carrying out repairs**, which undermines economic viability. **Supply chain complexities and logistical challenges** were also identified as significant barriers to scaling up repair practices. Furthermore, the **lack of profitable business cases** was identified as a key issue. To address these issues, the group proposed financial incentives such as VAT reductions, tax benefits or CO_2-based incentives. Another prominent barrier is the **absence of standardised repair protocols**. To address this, participants recommended introducing certified testing procedures and establishing a second-life standard for repaired modules. However, they also acknowledged that such testing processes can be costly. One solution proposed was to develop differentiated testing

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approaches based on defect severity, which would reduce costs for minor issues while maintaining safety and quality standards.

Reuse groups: The groups noted that the **market** for reused modules **remains limited**, since second-use panels are perceived to be less reliable, while **new modules are more affordable due to their low cost.** This shifts **consumer preferences towards new products**, further reducing demand for repaired or refurbished modules. Possible solutions include promoting the donation of second-use panels to charities, encouraging charities to prioritise second-hand modules, offering subsidies for them, and developing certification or labelling schemes to guarantee their performance and ensure traceability. Another significant issue that emerged was **insurance reluctance**, with providers being reluctant to cover reused modules due to financial risks, market uncertainties, and limited track records. Participants suggested that establishing standards, certifications, and legislation could help to build trust and mitigate these concerns. Other barriers include the **absence of standardised protocols for assessing module condition and safety**, and a **shortage of skilled personnel** to carry out these assessments. To address these issues, the groups proposed conducting practical test runs within the QUASAR project to generate data that could inform updates to assessment guidelines and training materials.

Recycling groups: One of the most significant barriers identified by recycling groups is the **current low volume of EOL PV modules**. This makes recycling unprofitable and difficult to justify in terms of investment in dedicated, PV-specific recycling facilities. The groups emphasized the **need for stable input streams** to achieve economies of scale. To address these issues, participants suggested securing venture capital and public funding to support capacity growth, improving collection systems, enacting legal frameworks that make compliant EOL treatment more profitable than illegal disposal, and implementing standardized characterization protocols for modules prior to export outside the EU. Participants also highlighted that **high logistics and transport costs** further erode economic viability. They recommended establishing regional recycling hubs that leverage existing infrastructure and serve local end users. They also observed that **current electronic waste regulations (WEEE) do not adequately cover PV modules**, resulting in a **lack of regulatory pressure**. Targets can currently be met through glass recycling alone, providing no incentive to recover high-value materials. To address this issue, the groups recommended introducing material-specific recycling quotas for critical PV materials (Ag, Si, Cu, Pb and Sn), as well as revising existing legislation to introduce PV-specific requirements.

1.2 List of definitions acronyms and abbreviations

c-Si	Crystalline silicon
EOL	End-of-life
EU	European Union
PV	Photovoltaic
TAG	Technology Advisory Group
WP	Work package

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1.3 Structure

The structure of the report presents the findings of the European stakeholder survey and the first Co-Creation workshop conducted under task 10.4 of the QUASAR project. The first part presents the results of the European stakeholder survey (see Section 2), beginning with an overview of its objectives and methodology, followed by a description of the sample and results on market development, social acceptance, and the challenges and drivers related to repair, reuse, and recycling of PV modules. The second part focuses on the first Co-Creation workshop (see Section 3), including an overview of its purpose and setup, a description of the agenda and a summary of key outcomes.

1.4 Relationship with other documents

As part of Work Package 10, insights from a Europe-wide stakeholder survey and the first Co-Creation Workshop have been combined to provide a comprehensive understanding of social acceptance, as well as the opportunities as well as challenges related to the repair, reuse, and recycling of end-of-life (EOL) PV modules. Both activities are part of a broader design thinking process aimed at developing practical, stakeholder-informed solutions for the treatment of EOL PV modules. The process comprises five phases:

- **Phase 1 – Empathize:** The online questionnaire was used to gather insights into stakeholder perspectives related to EOL PV.
- **Phase 2 – Define:** The first Co-Creation Workshop focused on identifying key barriers regarding EOL PV practices raised by stakeholders.
- **Phase 3 – Ideation**: In the second Co-Creation Workshop, stakeholders will collaboratively develop potential approaches and ideas to address the defined barriers.
- **Phase 4 – Prototype:** The third Co-Creation Workshop will initiate the development of practical solution concepts for EOL PV treatment.
- **Phase 5 – Test:** In the final stage, selected solutions will be tested and evaluated for feasibility and stakeholder acceptance.

This report therefore gives insights on the stakeholder survey results (Empathize phase) and first Co-Creation workshop (Define phase). The findings will serve as a foundation for the second and third Co-Creation Workshops planned under work package 11.4 and will directly contribute to shaping the project's ongoing stakeholder dialogue and final recommendations.

2 European Stakeholder Survey

2.1 Overview and methodology

Between 18 September 2024 and 13 March 2025, the QUASAR stakeholder survey was conducted online via the SoSci Survey platform. The survey was designed as a quantitative questionnaire to gather broad input on stakeholder perspectives related to PV market development, the social acceptance of PV as a renewable energy source, and the end-of-life (EOL) treatment of PV modules, with a focus on repair, reuse, and recycling

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Although the initial target was to collect at least 150 responses, only 63 complete responses were received. Despite this lower number, extensive outreach was undertaken to reach relevant stakeholders. The survey was promoted via the QUASAR website, bifa's newsletter and social media channels (see Figure 1), as well as at various presentations and events, including Sustainable Solar Europe 2024, a conference in Oslo and EU PVSEC 2024. Additional awareness-raising and promotion were carried out through the partner networks of the QUASAR consortium and via printed flyers.

Nevertheless, the results offer valuable insights and guidance for future discussions and developments within the project. The outputs were also used to prepare the first Co-Creation workshop. However, readers should bear in mind the number of responses when interpreting the results. The data are not representative and cannot be generalised to the entire European PV sector. This limitation would persist even with a higher response rate (e.g. 150), given the sector's diversity and fragmentation, which make full representativeness in such stakeholder surveys inherently difficult to achieve.

FIGURE 1: SOCIAL MEDIA POST

2.2 Sample

The sample consisted of 63 European participants from Norway (21), Germany (15), Spain (14), France (4), Ireland (3), Netherlands (2), Italy (2), United Kingdom (1), and Lithuania (1). Participants were asked to indicate their affiliation or relation to PV through a multiple-choice question (n=81). Most respondents identified as researchers (22), followed by PV module owners (11), PV system operators (8), and industry consultants (6).

To assess their level of familiarity with the PV industry, participants had to rate their knowledge on a scale from 1 (not familiar) to 10 (very well familiar). The results revealed a wide

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range of familiarity levels, with an average rating of 6.08. Almost half of the participants (47.5%) rated their familiarity as 7 or higher, indicating they are familiar or very familiar with the PV sector, while 28.6% rated their familiarity as 4 or lower, suggesting little or no familiarity.

2.3 Results

2.3.1 Market development of PV technology in Europe

Participants assessed the **current and future market demand for PV technology production in Europe** (see Figure 2). Perceptions of the current market are mixed, with a significant proportion viewing it as stagnant (32.2%), while a smaller proportion perceive it as growing (23.7%) or strongly growing (6.8%). A notable percentage sees it as declining (23.7%) or strongly declining (13.6%). However, expectations become increasingly optimistic over time. For the next five years, 54.4% of respondents anticipate growth or strong growth, compared to only 19.3% who expect a decline or strong decline. Over a ten-year horizon, optimism strengthens further, with nearly 60% predicting market growth or strong growth, despite a persistent minority (23.1%) expecting decline or strong decline. **These results suggest growing confidence in future demand for PV technology in Europe over the next five to ten years.**

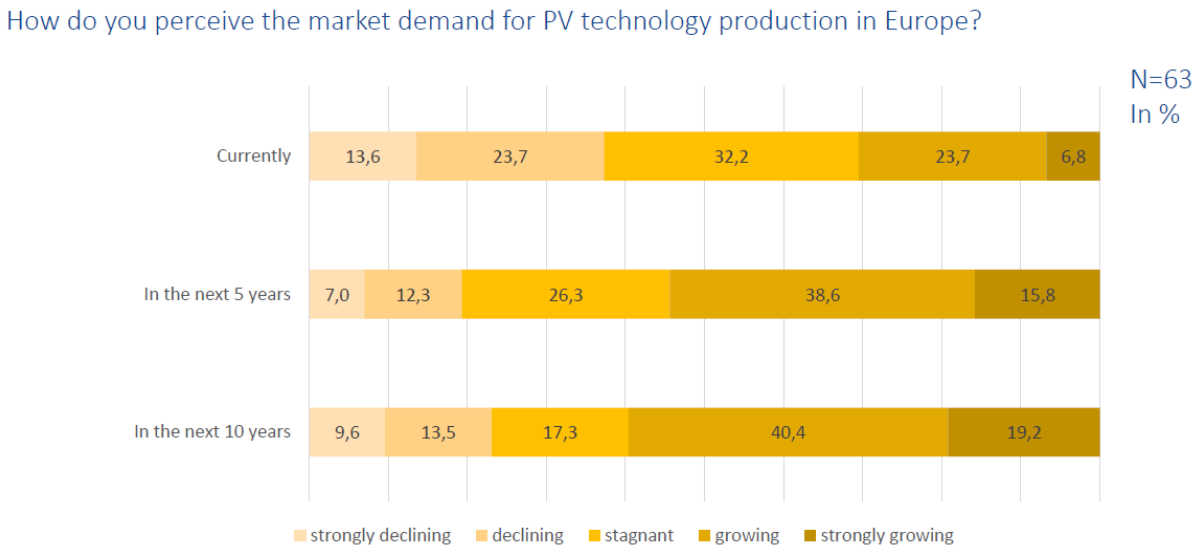

FIGURE 2: PERCEPTION MARKET DEMAND FOR PV TECHNOLOGY IN EUROPE

Participants were asked to rank the **potential drivers for PV technology production in Europe** according to their perceived significance (see Table 1). The ranking was determined by the average position that participants assigned to each factor. A lower ranking suggests a higher perceived importance, and vice versa. Only factors that were considered important by the respondents were included in the ranking. This is why n varies depending on how many participants included the driver in their ranking.

The results indicate a relatively close ranking, with no single driver standing out as significantly more important than the others. However, government policies (average rank: 2.66) and cost-effectiveness (3.04) are ranked the highest, suggesting these factors are perceived as

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the most influential. Conversely, social acceptance for PV (6.56) was ranked the lowest, indicating it is considered less critical to market growth in the immediate term. Furthermore, participants were given the opportunity to suggest other drivers not listed in the survey. Additional factors mentioned include:

- Electrification of industrial and transport demand
- Development of batteries
- Rules about sharing spare energy with neighbours
- Scale and availability of component suppliers

TABLE 1: POTENTIAL DRIVERS OF THE MARKET FOR PV TECHNOLOGY PRODUCTION IN EUROPE

Ranking	Potential drivers	n
2,66	Government policies	61
3,04	Cost-effectiveness	56
3,88	Incentives	58
4,33	Growing demand for energy independence	57
4,44	Technological advancements improving solar module efficiency	57
5,67	Increasing awareness and concern about climate change	51
6,18	Growing demand for resilience against power outages	51
6,44	Technological advancements for PV recycling	55
6,56	Social acceptance for PV as renewable energy	52

A range of **challenges** currently hinder the growth of PV technology production in Europe. Participants were asked to rank these challenges according to their perceived importance (see Table 2). The most significant challenge identified was competition from international PV markets (average rank: 1.93), followed by policy and regulatory uncertainty (2.91) and supply chain constraints (3.29). In open responses, participants emphasized the issue of international competition, particularly highlighting China. One participant mentioned that European producers struggle to compete with manufacturers that operate under less stringent regulations and have lower production costs.

TABLE 2: POTENTIAL CHALLENGES OF THE MARKET FOR PV TECHNOLOGY PRODUCTION IN EUROPE

Ranking	Potential challenges	n
1,93	Competition from international PV markets	56
2,91	Policy and regulatory uncertainty	57
3,29	Supply chain constraints	52
3,55	Material shortages	55
3,81	Competition from conventional energy sources	52
4,66	Public resistance or “Not In My Backyard”-opposition	47

2.3.2 Social acceptance of PV as a renewable energy

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The survey also explored public perceptions of the **social acceptance of PV technology as a renewable energy source**. Participants rated the public attitude, on a scale from 1 (very negative attitude) to 10 (very positive attitude), toward **small-scale and large-scale PV installations** in their region (see Figure 3). The results reveal a clear preference for small-scale PV installations, which received a consistently high average rating of **8.2**, indicating broad public support. In contrast, large-scale PV installations were viewed more cautiously, with an average rating of **5.4**.

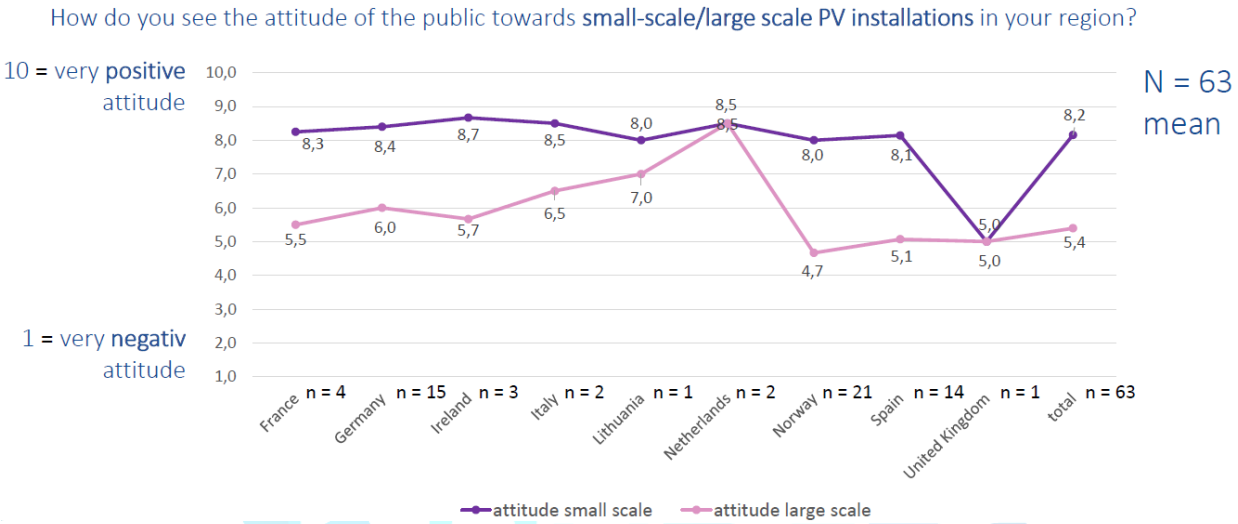

FIGURE 3: PERCEIVED SOCIAL ACCEPTANCE OF SMALL-SCALE/LARGE-SCALE PV INSTALLATIONS

Moreover, participants ranked several **factors contributing to the social acceptance of large-scale PV installations** in their region, according to their perceived importance (see Table 3). These findings suggest that the public's acceptance of large-scale PV installations is mostly influenced by how they are perceived in terms of financial and environmental impact.

TABLE 3: CONTRIBUTORS TO SOCIAL ACCEPTANCE OF LARGE-SCALE PV INSTALLATIONS

Ranking	Contributors	n
3,16	Economic benefits	58
3,35	Environmental benefits	57
3,44	Cost-effectiveness compared to traditional energy sources	55
3,64	Government incentives and policies support	56
3,64	Positive public perception	56
4,54	Awareness campaigns	50
4,89	Job creation	53

Among the listed factors that **challenge the social acceptance of large-scale PV installations** (see Table 4), the perceived negative aesthetic impact was given the highest priority by the participants (average rank: 1.86). In their open text responses, participants highlighted additional challenges, including concerns about biodiversity and the perception that PV

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installations compete with agricultural use. They also mentioned a lack of tangible benefits for nearby residents affected by the developments.

TABLE 4: CHALLENGES TO SOCIAL ACCEPTANCE OF LARGE-SCALE PV INSTALLATIONS

Ranking	Challenges	n
1,86	Perceived negative aesthetic impact on landscapes or neighbourhoods	57
2,91	Lack of understanding or misinformation about solar energy technology	55
3,14	Opposition from “Not In My Backyard” -sentiments	51
3,14	Negative emotional impact due to a change in a familiar location	50
3,61	Limited public participation or engagement in decision-making processes	51
4,81	Fear of potential health risks or safety hazards	37

Furthermore, participants ranked a number of **strategies that could help strengthen public acceptance of large-scale PV projects**. The narrow range of rankings suggests that social acceptance is likely to be best supported by a combination of measures rather than by a single dominant strategy. Open comments reinforced this, proposing additional ideas such as developing joint business cases with agricultural stakeholders, offering direct benefits to nearby residents, and strengthening the role of the European PV industry to underline regional economic value.

TABLE 5: STRATEGIES TO ENHANCE SOCIAL ACCEPTANCE OF LARGE-SCALE PV INSTALLATIONS

Ranking	Strategies	n
2,07	Provision of financial incentives or energy price advantages (compared to fossil energy sources)	56
2,37	Discussions with residents and stakeholders to address concerns	52
2,53	Public education about the benefits and capabilities of PV technology	55
2,66	Incorporation of community preferences and feedback into PV installation projects	56

2.3.3 Repair: potential, importance, barriers and drivers

Further, **repair practices** were examined. Survey participants assessed the **potential of PV module repair practices** within the European PV industry over the next five years, as well as the **importance of further developing these practices**. The results are illustrated as box plots showing the distribution of responses (see Figure 4: Potential and importance of repair practicesFigure 4). Each box represents the middle 50% of responses, while the whiskers indicate the full range—from 1 (minimum) to 10 (maximum).

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The perceived **potential of PV repair practices** received a moderate average rating of **5.7**, with responses covering the full range from 1.0 to 10.0. The middle 50% of responses (the interquartile range) fell between 4.0 and 8.0. Together, these wide ranges suggest a diverse set of views and some uncertainty regarding the potential of PV repair practices within the next five years. In contrast, the **importance** of further developing and improving repair practices was rated much higher, with a **mean value of 7.8,** and responses mostly concentrated between 4.0 and 10.0, with a few outliers at 1, 2, and 3. The interquartile range was narrower (between 7.0 and 9.5), indicating broad agreement on the strategic importance of developing repair practices further in the European PV sector.

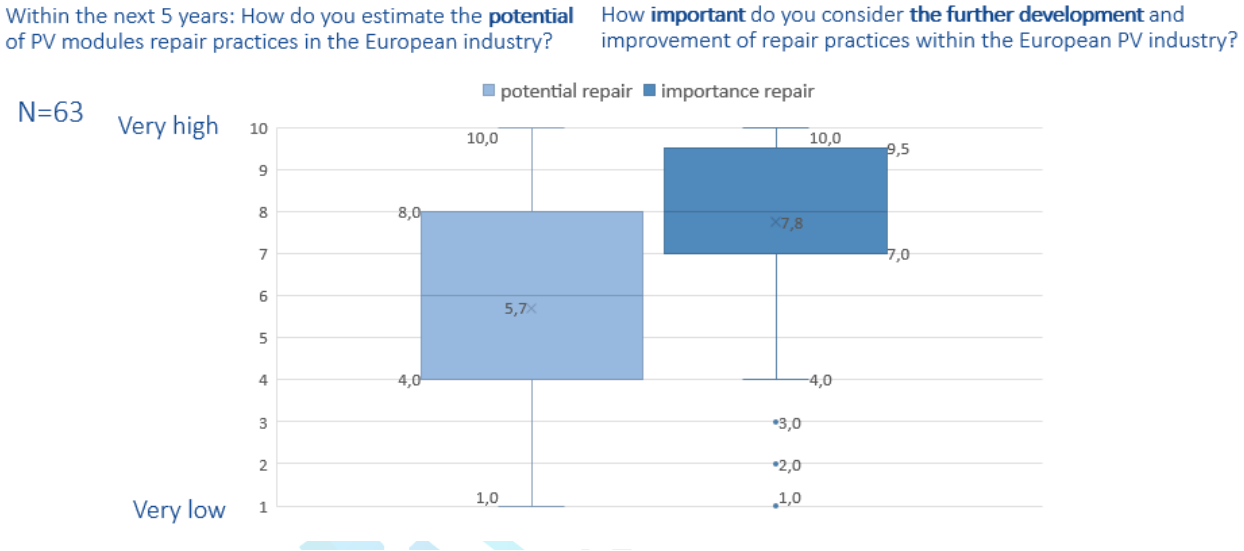

FIGURE 4: POTENTIAL AND IMPORTANCE OF REPAIR PRACTICES

Participants ranked several **potential barriers** that may hinder the adoption of repair practices for PV modules (see Table 6). The most prominent concern was the high cost of assessing module condition and carrying out repairs, with an average ranking of 2.08. This was followed by non-repair-friendly product design (2.86). Additional barriers mentioned in open responses included the lack of economically viable repair volumes, safety and warranty concerns, and the absence of a clear regulatory or policy framework supporting repair.

TABLE 6: POTENTIAL BARRIERS TO ADOPT REPAIR PRACTICES FOR PV MODULES

Ranking	Barriers	n
2,08	High costs to assess module condition and perform repairs	53
2,86	Non-repair-friendly design	51
4,11	Limited availability of repair facilities	47
4,14	Consumer attitudes favouring new products over repaired or refurbished ones.	51
4,35	Lack of standardized repair protocols	48
4,60	Supply chain complexities and logistical challenges	48
4,62	Limited availability of skilled technicians	45

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Building on the identified barriers, participants also ranked key **drivers that could support the uptake of PV module repair practices** in Europe (see Table 7). Taken together, the results imply that a combination of economic, technological, and environmental drivers will be necessary to create momentum for repair-oriented solutions in the European PV sector. In open responses, participants also pointed to education as an enabling factor.

TABLE 7: POTENTIAL DRIVERS TO ADOPT REPAIR PRACTICES FOR PV MODULES

Ranking	Drivers	n
2,62	Growing prices for raw materials	52
2,89	Technological advancements enabling more efficient and cost-effective repair processes	54
3,35	Increasing awareness of the environmental impact of electronic waste (e-waste)	57
3,38	Regulatory pressure to minimize landfilling	52
3,78	Environmental sustainability goals	46
4,31	Collaboration and partnerships across the PV industry	49

2.3.4 Reuse: potential, importance, barriers and drivers

As with repair practices (see Section 2.3.3), participants were asked to evaluate both the potential for implementing EOL PV reuse practices in the European industry over the next five years and the importance of further developing such practices. As can be seen in Figure 5, the results show a similar pattern to that of repair practices. The perceived **potential of reuse practices** received a moderate average rating of **6.1**, but responses varied widely, ranging from 2 to 10. In contrast, the **importance of developing reuse practices** was rated considerably higher, with an average of **7.9**. Responses were more concentrated, with 50% falling between 7.0 and 9.5, and only a few low outliers (as low as 2.0 or 3.0). This distribution reflects a stronger consensus that reuse is a strategically important topic for the European PV sector, even if its potential is considered more limited or uncertain within the next five years.

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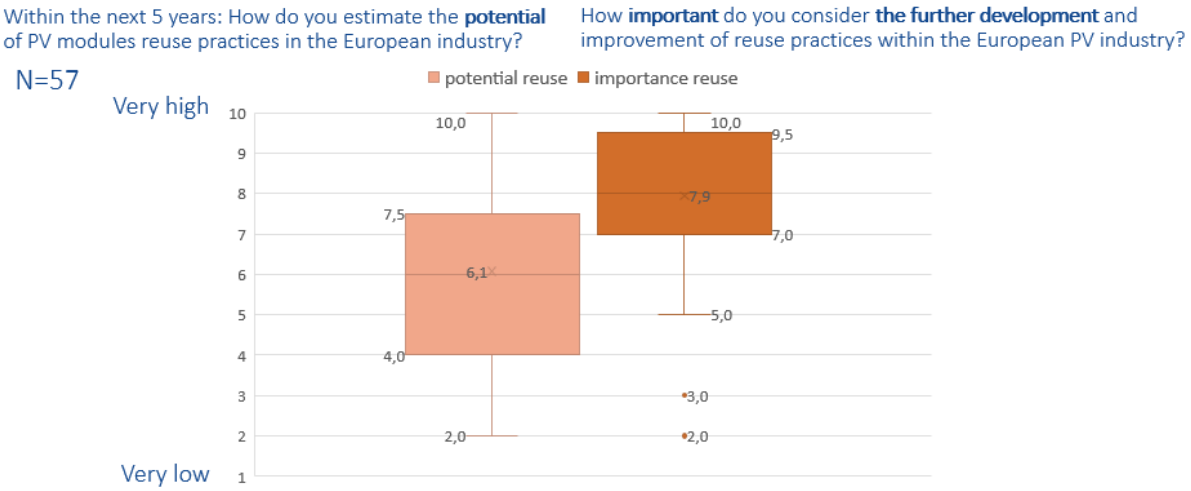

FIGURE 5: POTENTIAL AND IMPORTANCE OF REUSE PRACTICES

Participants also ranked the **potential barriers** that may hinder the broader adoption of **reuse practices for PV modules in Europe** (see Table 8). The low cost of new modules was rated as the most significant barrier (average rank: 1.88), which could reduce the incentive to invest in reuse solutions. This was followed, with a certain degree of ranking disparity, by the non-reuse-friendly design of existing modules (3.42) and consumer preferences for new over reused products (4.04). One open response additionally mentioned reluctance from insurance providers as a further challenge.

TABLE 8: POTENTIAL BARRIERS TO ADOPT REUSE PRACTICES FOR PV MODULES

Ranking	Barriers	n
1,88	Low costs for new modules	50
3,42	Non-repair-friendly design	50
4,04	Consumer attitudes favouring new products over repaired or refurbished ones	45
4,30	Lack of standardized protocols to assess module condition and safety	50
4,56	Limited availability of repair facilities	43
5,11	Incompatible racking and mounting designs for different PV module technologies	44
5,16	Supply chain complexities and logistical challenges	44
5,51	Limited availability of skilled technicians to assess module condition and safety	43

Next, the participants ranked factors that could encourage the uptake of reuse practices for PV modules in Europe (see Table 9). The top three factors were: technological advancements that make reuse more efficient and cost-effective (average rank: 2.77), closely followed by rising demand for secondary raw materials (2.92), and broader environmental sustainability goals

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(3.05). Additional comments pointed to cost savings and job creation as further motivators, particularly given Europe's limited PV manufacturing capacity.

TABLE 9: POTENTIAL DRIVERS TO ADOPT REUSE PRACTICES FOR PV MODULES

Ranking	Drivers	n
2,77	Technological advancements enabling more efficient and cost-effective reuse processes	48
2,92	Growing demand for secondary raw materials	48
3,05	Environmental sustainability goals	41
3,06	Regulatory pressure to minimize landfilling	47
3,37	Increasing awareness of the environmental impact of electronic waste (e-waste)	52
4,45	Collaboration and partnerships across the PV industry	44

2.3.5 Recycle: potential, importance, barriers and drivers

Furthermore, participants assessed the potential and importance of PV module recycling practices, as they did for repair (see Section 2.3.3) and reuse practices (see Section 2.3.4). As shown in Figure 6, the **perceived potential of recycling practices** is broadly comparable to that of reuse and repair. With an **average rating of 7.3**, individual scores ranging from 2.0 to 10.0, and an interquartile range of 6.0 to 9.0, the results point to a slightly more optimistic outlook. However, the **importance of further developing recycling practices** received a notably higher rating. With an average rating of **9.2**, it surpasses the perceived importance of both reuse and repair. Responses were tightly clustered, with 50% falling between 8.5 and 10.0, reflecting a strong consensus on the strategic urgency of advancing recycling within the European PV sector.

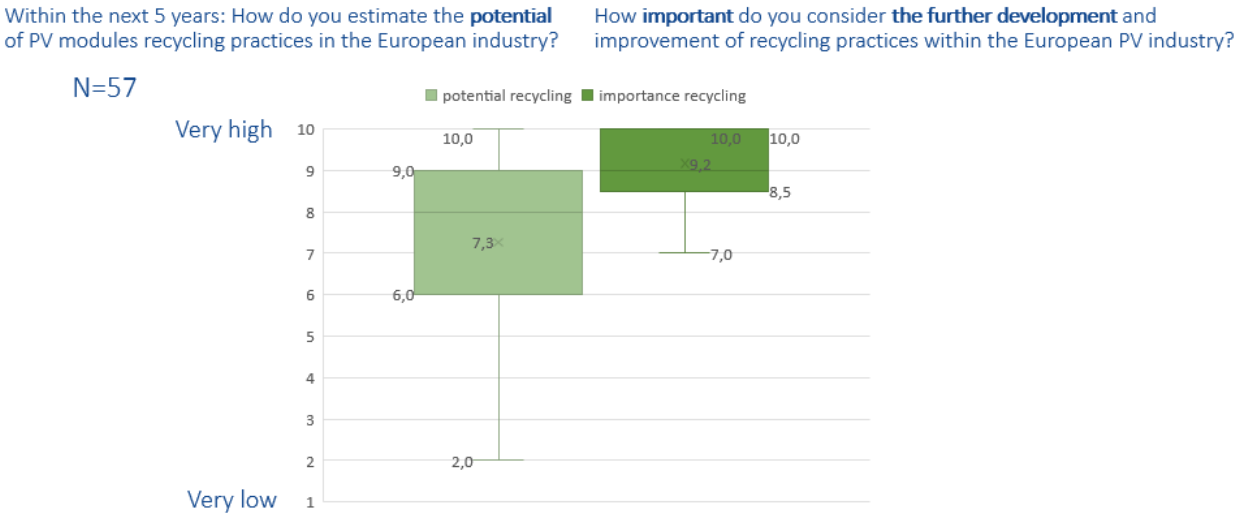

FIGURE 6: POTENTIAL AND IMPORTANCE OF RECYCLE PRACTICES

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Moreover, participants were asked to rank potential **barriers to adopting recycling practices for PV modules in Europe** (see Table 10). The most pressing issue was the currently low volume of end-of-life (EOL) PV modules, which makes it difficult to justify investments in dedicated, PV-specific recycling infrastructure (average rank: 2.65). This was followed by non-recycling-friendly module designs (3.04) and the limited effectiveness of current commercial recycling technologies for c-Si in recovering high-value materials (3.22). Additional comments emphasized high capital expenditure and overall recycling costs as further barriers.

TABLE 10: POTENTIAL BARRIERS TO ADOPT RECYCLE PRACTICES FOR PV MODULES

Ranking	Barriers	n
2,65	Input streams of EOL PV-modules are currently relatively low, making it challenging to justify investment in dedicated recycling facilities customized for PV	48
3,04	Non-recycling-friendly module design	47
3,22	Current commercial recycling technologies for c-Si modules fail to recover high-value materials	45
3,83	Module bill of materials varies by module type, manufacturer, and vintage	47
4,02	High energy consumption and/or chemical use for recycling processes	44
4,75	Lack of standardized recycling protocols	44
5,09	Supply chain complexities and logistical challenges	45

Participants also prioritized the **potential drivers for the adoption of recycling practices for PV modules in Europe** (see Table 11). At the top was the opportunity to recover near-critical materials such as aluminium, copper, and silicon (average rank: 3.74). Close behind were regulatory pressure from the Waste Electrical and Electronic Equipment (WEEE) Directive (3.77) and the growing demand for secondary raw materials (3.91). In open comments, participants also pointed to regulatory incentives targeting the recovery of critical and strategic raw materials as a potential lever for change.

TABLE 11: POTENTIAL DRIVERS TO ADOPT RECYCLE PRACTICES FOR PV MODULES

Ranking	Drivers	n
3,74	Recovery of near-critical materials, such as aluminium, copper, and silicon	50
3,77	Regulatory pressure from WEEE directive	47
3,91	Growing demand for secondary raw materials	45
3,96	Technological advancements enabling more efficient and cost-effective recycling processes	50
4,63	Regulatory pressure from Green Deal	43
4,74	Regulatory pressure to minimise landfilling	42

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5,06	Increasing awareness of the environmental impact of electronic waste (e-waste)	47
5,57	Environmental sustainability goals	37
6,73	Collaboration and partnerships across the PV industry	37

3 First Co-Creation Workshop

3.1 Overview

On Tuesday, 6 May 2025, the first of three Co-Creation workshops was conducted at the bifa Umweltinstitut in Augsburg. The workshop was organised and moderated by the bifa project team It was scheduled to take place immediately before the Intersolar fair in Munich, following consultations with members of the consortium and Technology Advisory Group (TAG). This timing was chosen due to Augsburg's proximity to Munich (approximately 60 km), allowing attendees to combine the workshop with travel to Intersolar. The workshop was deliberately scheduled to coincide with the TAG meeting held that same afternoon. This enabled TAG members, who are key stakeholders for the workshop and project, to contribute to the workshop and take their fresh insights directly into the subsequent TAG meeting.

To ensure broad accessibility, the workshop was held in a hybrid format. Participants who were unable to travel to Augsburg had the opportunity to join remotely. Zoom was used as a video conferencing tool, while GroupMap supported the interactive and collaborative parts of the workshop. A total of 42 people took part in the workshop. Of these, 23 attended in person at bifa and 19 joined online. Participants included nine members of the Technology Advisory Group, six external workshop participants, primarily from academic institutions, and members of the project consortium. The agenda was as follows:

From 8:45	Get together
9:00	Welcome + presentation of the Quasar project
9:15	Presentation of Quasar work tasks
10:00	Exchanging views on EOL PV treatment
10:25	Break
10:40	Presentation of Quasar survey results
10:55	Group work: Interactive session
11:45	Plenary discussion of the group work results
12:00	Farewell and end of the workshop

3.2 Workshop description and outcomes

3.2.1 Introduction: presentation of the project and work tasks

The workshop began with an introduction by Roksana Rotter (bifa), who welcomed the participants, explained the objectives of the workshop and presented the agenda. This was

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followed by an insightful presentation by the project leader, Martin Bellmann (Sintef), who gave a general overview of the project.

Following the project overview, representatives from the consortium provided a series of brief presentations, so-called "4-minute pitches", to introduce the objectives and current status of their respective work packages. These gave participants a concise yet comprehensive insight into the project's structure and ongoing activities, setting the scene for the workshop's interactive sessions. The pitches were presented in the following order:

WP 1	From EOL-PV-modules to secondary raw materials – logistics, treatment, quality, quantity and routes (Lead: SINTEF)
WP 2-3	Product Circularity/Waste Stream Information/EOL Management/ Digitalisation (Lead: EEU)
WP 4	Industrial Pilot-A: High throughput and highly integrated PV modules recycling line based on controlled pyrolysis and mild chemistry (Lead: ROSI)
WP 5-6-7	Industrial Pilot-B: Emerging delamination and disintegration technologies for EOL-PV modules & recyclability of next generation PV technology (Lead: LUX)
WP 8	Products: from technological value to the market (Lead: SINTEF)
WP 9	Design & Methods for improved Circularity (Lead: SOL)
WP 10-11-12	Process assessment: TEA, LCA, social acceptance, circular economy – initial assessment (Lead: BIFA)
WP 13	Communication, dissemination, outreach activities (Lead: SEC)

3.2.2 Exchange round

The next agenda item was an interactive **exchange round**, designed to foster personal connection to the topic and share their initial perspectives. This helped to create a common ground and build trust for the collaborative work to follow. Attendees were invited to discuss a set of guiding questions in small groups of three to four people. For online participants, breakout rooms were created to ensure a similarly intimate and engaging discussion format. The guiding questions were:

- **This is my connection to EOL PV treatment:**
  What brings me here? What is my role or interest in this topic?
- **Good news regarding EOL:**
  What is something positive I've seen related to PV end-of-life, such as a promising trend, project, or idea?
- **Bad news regarding EOL:**
  What is a challenge, barrier, or frustration I've encountered in the context of EOL PV treatment?

After the exchange round, participants were asked to reflect individually on their discussion and write down their insights in response to the following questions: What are your insights after the first round of exchanges?

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- What surprised you?
- Where do you see yourself confirmed?

Participants on site wrote their reflections on cards and placed them on a shared wall. These inputs were made available for everyone to read during the following break. Online participants used the GroupMap tool to share their reflections in the same way, ensuring the full integration of contributions from both in-person and virtual participants. Table 12 provides an overview of the reflections from both the on-site and online groups.

TABLE 12: REFLECTIONS EXCHANGE ROUND

What surprised you?	Where do you see yourself confirmed?
On site	
• Cost and revenue of decommissioning not part of business plans yet • Buying a brand new PV panel is cheaper than repairing one • Price of new modules are so low that it is difficult to compete with repaired / recycled modules • Lack of clear profitable business case, without correct regulation • A great network for the implementation of a supply chain to repair PV-modules • Potential economic value of EOL PV modules is not (yet) included in the business plan • Outside Europe: Legislation for take back PV modules occurs • I was surprised at the different factors affecting the reuse rate of EOL PV modules • Repair & Reuse less important compared to recycling (might be a chance until industrial recycling technologies are operating) • Unencapsulated modules are assigned a lower fire protection class • Scalable processes that "grow" with business development • Risk capital for industrializing process → risk taking → political framework • Changing Waste to new Products	• PV Recycling Technologies are in place. Waste volumes are missing at the moment • PV marked is still young, meaning the willingness to pay for recycling is low • Price of new modules are a huge limitation for the EOL PV-treatment • increasing attention to EOL business and R&D • ↑ increasing PV waste volumes and importance ↑ Increasing engagement of industrial actors • Growing interest in recycling PV in other regions of the world • Europe has a mandatory system to collect PV-modules • For Recycling technologies economic benefit is very important • Pushing EU- independency from far east countries regarding raw materials • Availability of technical solutions increasing (for recycling processes)
Online	
• Export of end of life modules from Europa may end as landfill and reduces recycling potential within Europe • In WP 9, if we are replacing EVA with other materials, then is that feasible? Will it not produce waste? What are the challenges while recycling this material?	• Need (requirement) for inclusion of recyclability in module design process • PV module recycling is a challenge task, both in terms of technology and maybe market • EOL solutions are needed world-wide.

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○ Comment: what is the substituent? ○ Comment: different encapsulant material are already on the market: EVA, POE, TPO etc • No standard recycling processes for the large quantities of PV waste that will soon be generated. ○ Comment: what means no standard? ○ Comment: Sophisticated and, above all, economical processes (fast) for recovering materials beyond aluminium frames and glass • Cost of inspection of EOL panels compared to production of new panels are relatively high.	• Low volumes of EOL PV and still some challenges • Modules do not reach the European recycling market ○ Comment: Europe need some collection company for EOL PV modules • Cost of repairing or reusing modules instead of use new modules • Difficult to reintegrate Silicon into new PV production • Nice that there are many people who pursue the same goals • Whole PV waste volume low compared to other waste streams • Still early, volumes still low - there is time to develop recycling

3.2.3 Presentation of the survey results and group work

The next part of the workshop focused on presenting the results of the **European stakeholder survey**. Roksana Rotter (bifa) provided an overview of the main findings (see Section 2), sharing insights into stakeholder perspectives on the development of the PV market, social acceptance, and the barriers and drivers of PV recycling, repair, and reuse practices. These insights formed the basis for the subsequent group work session.

The final part of the workshop involved **group work** intended to further the discussion and pinpoint the most significant barriers for EOL PV treatment in Europe. Participants were assigned to topic-specific groups: Repair, Reuse, or Recycling. On site, participants were divided into four groups (two focused on Recycling), each with around five people. Online, participants completed the same task in similarly sized breakout rooms, using the collaborative working tool GroupMap. The group work was conducted in two steps:

In the **first step,** the groups reviewed a pre-defined list of barriers (repair, reuse, or recycle practices) from the survey (see Table 6, Table 8, and Table 10). Then they discussed whether they agreed with the current order, rearranging items as necessary and adding any missing barriers to the list and placing them in the appropriate position.

In the **second step**, each group selected at least two barriers to explore in more depth using a structured worksheet. For each selected barrier, they were asked to assess the following:

- **Barrier**: e.g. non-repair-friendly design
- **Urgency**: How urgent should this be addressed? (High / Medium / Low)
- **Why is it a barrier?** What makes it difficult to overcome?

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- **Ideas for solution:** What could help to remove or reduce this barrier? How could the project specifically contribute to solving it?
- **Who should act?** Which stakeholders or actors should take action? What role could the QUASAR project play?

The results of the ranking are presented in the following Tables (13-19).

TABLE 13: OUTCOMES GROUP WORK - REPAIR (GROUP 1)

Step 1	
Ranking	Barriers
1	High costs to assess module condition and perform repairs
2	Supply chain complexities and logistical challenges
3	Lack of profitable business case
4	Consumer attitudes favouring new products over repaired or refurbished ones.
5	Lack of standards (testing and certification)
6	Lack of standardized repair protocols
7	Non-repair-friendly design
8	Limited availability of skilled technicians
9	Limited availability of repair facilities
Step 2	
Barrier	Lack of profitable business case (3)
Urgency	H
Why is it a barrier?	$
Ideas for solution	• VAT Discount • Tax discount • CO2 incentives
Who should act?	• EU commision • Member states

TABLE 14: OUTCOMES GROUP WORK - REPAIR (GROUP 2)

Step 1	
Ranking	Barriers
1	High costs to assess module condition and perform repairs
2	Lack of standardized repair protocols
3	Non-repair-friendly design
4	Consumer attitudes favouring new products over repaired or refurbished ones.
5	Limited availability of repair facilities
6	Supply chain complexities and logistical challenges

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7	Limited availability of skilled technicians	
Step 2		
Barrier	protocol and standards	testing will lead to costs
Urgency	high	• high: repair will help energy transition ... • even cleaner than recycling option • faster
Why is it a barrier?	warranty	• capacity to identify the error • how serious is the error?
Ideas for solution	• certified testing • second life standard	distinction in type of error: • e.g. external (junction box) • e.g. internal failure (glas, backsheet)
Who should act?	• standard committees • PV industry as a whole	• e.g. PV Cycle Industry Guidelines • producer responsibility organizations PROs • some entity that understands testing procedures

TABLE 15: OUTCOMES GROUP WORK - REUSE (GROUP 1)

Step 1		
Ranking	Barriers	
1	Low costs for new modules → Consumer attitudes favouring new products over repaired or refurbished ones	
2	Insurance reluctance	
3	Lack of standardized protocols to assess module condition and safety	
4	Incompatible racking and mounting designs for different PV module technologies + electrical mismatch	
5	Limited availability of repair facilities + repair procedures	
6	Limited availability of skilled technicians to assess module condition and safety	
7	Supply chain complexities and logistical challenges & dismantling know-how	
8	Non-repair-friendly design	
Step 2		
Barrier	Insurance reluctance	Lack of skilled technicians
Urgency	H	H
Why is it a barrier?	• No insurance for reused modules Financial risk • Limited market • Uncertainty	Unskilled workers damage the module

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Ideas for solution	• Standards • Certifications • Legislations	• Practical test run with QUASAR • Update the guidelines based on the results
Who should act?	IEC members + stakeholders + insurance & producers	QUASAR partner, e.g. Scatec

TABLE 16: OUTCOMES GROUP WORK - REUSE (GROUP 2)

Step 1	
Ranking	Barriers
1	Low-acceptance of second-hand/-life "things"
2	Missing label for second life PV modules
3	No big market
4	To find a market with/or clients
5	Low costs for new modules
6	Non-repair-friendly design
7	Consumer attitudes favouring new products over repaired or refurbished ones
8	Lack of standardized protocols to assess module condition and safety
9	Limited availability of repair facilities
10	Incompatible racking and mounting designs for different PV module technologies
11	Supply chain complexities and logistical challenges
12	Limited availability of skilled technicians to assess module condition and safety
Step 2	
Barrier	market
Urgency	Very!
Why is it a barrier?	• Used panels "less trustworthy" (no warranty?) • New panels too cheap
Ideas for solution	• Second-use panels could be donated (charities, etc)? Or the other way: charities should prioritize buying second-hand • Subsidies for second-hand models (e.g., Solitek pays 1EUR for recycling on sale, but this doesn't seem to show up again when 2LS buys it) • certifications/labels (trackability of tests at different times, performance guarantees,…)
Who should act?	• Gov: mandate labelling (eco-design directive?) • Quasar can be a showcase ("success story" where we've shown successful/ economical re-use?)

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TABLE 17: OUTCOMES GROUP WORK - RECYCLE (GROUP 1)

Step 1		
Ranking	Barriers	
1	Input streams of EOL PV-modules are currently relatively low, making it challenging to justify investment in dedicated recycling facilities customized for PV	
2	Non-recycling-friendly module design	
3	Current commercial recycling technologies for c-Si modules fail to recover high-value materials	
4	Module bill of materials varies by module type, manufacturer, and vintage	
5	High energy consumption and/or chemical use for recycling processes	
6	Lack of standardized recycling protocols	
7	Supply chain complexities and logistical challenges	
Step 2		
Barrier	Logistics/ transport costs	Economy of scale, stable input stream needed
Urgency	H	M Structures already established, room for more improvement
Why is it a barrier?	Costs!	Investment + operational finanzial risk
Ideas for solution	Regional recycling hubs, utilizing existing recycling structures, regional downstream users	• Venture capital • Public funding supporting growth process
Who should act?	• Municipalities involvement • Authorities • Circular economy stakeholders • Public funding	• Successful „lighthouse projects“ • „bankability“ • venture capital (VC)

TABLE 18: OUTCOMES GROUP WORK - RECYCLE (GROUP 2)

Step 1	
Ranking	Barriers
1	Input streams of EOL PV-modules are currently relatively low, making it challenging to justify investment in dedicated recycling facilities customized for PV
2	Current commercial recycling technologies for c-Si modules fail to recover high-value materials
3	Non-recycling-friendly module design
4	• Elevated CAPEX investment to implement recycling of high-value material

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	• High cost of recycling
5	Lack of regulatory pressure to recover high value materials
6	Module bill of materials varies by module type, manufacturer, and vintage
7	High energy consumption and/or chemical use for recycling processes
8	Lack of standardized recycling protocols
9	Supply chain complexities and logistical challenges

Step 2		
Barrier	Input streams too low	Lack of regulatory pressure
Urgency	High	High
Why is it a barrier?	• Economy of scale • Justify investments • Weak business case	Current recycling quotas give no incentive to recycle high-value materials like Ag and Si
Ideas for solution	• Make legal EOL treatment more profitable than illegal ones • Improvement of collection	Material-specific recycling quotas for: • Ag • Si • Cu • Pb and Sn?
Who should act?	• Regulation agencies • Waste management stakeholders	Regulation agencies

TABLE 19: OUTCOMES GROUP WORK - RECYCLE (GROUP 3)

Step 1	
Ranking	Barriers
1	The regulations for electronic waste do not fit PV
2	Input streams of EOL PV-modules are currently relatively low, making it challenging to justify investment in dedicated recycling facilities customized for PV
3	Non-recycling-friendly module design
4	Current commercial recycling technologies for c-Si modules fail to recover high-value materials
5	Module bill of materials varies by module type, manufacturer, and vintage
6	High energy consumption and/or chemical use for recycling processes
7	Lack of standardized recycling protocols
8	Supply chain complexities and logistical challenges

Step 2		
Barrier	The regulations for electronic waste (WEEE) do not fit PV	Low volume
Urgency	High	Medium

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Why is it a barrier?	• Unfair competition because glass recyclers meet the quota through glass alone - silver and Si do not have to be recycled (according to law) • 80% recovery rate for PV modules is too low (only glass recycling is sufficient)	• Recycling is not economically profitable • Export of WEEE • PV waste is transported out of EU (second life marked)
Ideas for solution	• Regulations on which materials should be recovered • material specific recycling quote • Revision of exciting laws	Standard characterisation of modules before export out of EU for the second hand market
Who should act?	EUC	Awareness oft he issue

4 Outlook

The findings from this survey and the first Co-Creation Workshop will form the basis of Task 11.4 and lay the groundwork for the next stage of stakeholder engagement. The second Co-Creation Workshop is planned for approximately six months' time and will correspond to Phase 3 “Ideation” (see Section 1.4) of the design thinking process. During this session, stakeholders will come together to build on the barriers and insights identified in the first Co-Creation workshop and collaboratively develop and prioritise innovative ideas for EOL PV treatment.

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