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Characterisation data/report on full size reworked NICE modules using recovered components. Two stages: (i) after manufacturing, (ii) after degradation tests. (WP 4)

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CO	Confidential, only for members of the consortium (including the Commission Services)	x
EU-RES	Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)	
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Deliverable number:	D 4.2
Deliverable name:	Characterisation data/report on full size reworked NICE modules using recovered components. Two stages: (i) after manufacturing, (ii) after degradation tests.
Work package:	WP 4, Module Design for remanufacturing
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Abstract

This report summarises the work on reused module components in new modules, starting with the major results on the disassembly of old industrial size 60 cells NICE modules by Apollon Solar in addition to the report on Deliverable D4.1 from M12. The recovered module components with the highest reuse potential are the cover glass sheets and the copper connectors. One important aspect to underline is the fact that due to the nature of the NICE module technology major module components are not physically linked to each other over their entire surface area as it is the case in laminated/soldered standard modules.

The major result of this work is the demonstration of the reuse of old recovered glass sheets from old NICE modules in new laminated 60 cells modules that have been fabricated by Solitek. The obtained output power of above 250 W with 3 busbar multi-c Solar cells is comparable to the power obtained with new glasses, especially taking into account that the recovered glasses from old NICE modules did not have an Anti Reflective (AR) Coating.

Apollon Solar demonstrated the reuse of recovered copper interconnectors from old NICE modules by using them for new NICE mini-modules, showing through EL images that the cell fingers could be connected. A few reserves have to made on the industrial applicability of the reuse of these copper connectors due to their preparation prior to reuse in new modules and associated costs.

The second part of this deliverable Degradation tests on the modules could not be realized in this reporting period due to the late availability of modules and the long nature of these tests. Results will be reported in the coming regular progress report (Month 30).

Public introduction[1]

[1] All deliverables which are not public will contain an introduction that will be made public through the project Website

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1 INTRODUCTION

As shown in the report of Deliverable D4.1 Apollon Solar's NICE module technology allows for the disassembly of these modules into their components, which is mainly due to the fact that the components are not physically linked to each other over their entire surface area, as it is the case in laminated/soldered standard modules.

The objective of this deliverable is to demonstrate the reuse of some of the recovered module components from old discarded NICE modules in new modules, characterize these modules and subject them to environmental stress tests. The potential reuse of components of old modules as entire pieces presents an innovation compared to state-of-the-art module recycling that is destructive for most of the components and only allows them to be recovered recycling in form of a granule mix.

This work has been carried out by Apollon Solar and Solitek, with support from bifa and Ingesea.

2 RESULTS

2.1 Recovered module components after disassembly

After working on the optimization of the opening and disassembly process for NICE modules by Apollon Solar and INGESEA the recovered components with the highest identified reuse potential were the module glasses and the copper interconnectors.

In Glass/Glass modules and depending on their specific quality and component prices, the two glass sheets present the second highest cost source after the solar cells, amounting to 20% to 25% of the total module costs and depending on the module technology used. The copper wires with costs of around 2% of the total module costs present a smaller cost contribution, which is after cells, glass sheets, junction box and mechanical rear enforcement the 5th largest. This clearly shows an interest for reuse of these components, especially the glasses, provided that the recovery process is cheaper than new components and that the quality of the recovered components is acceptable and does not lead to module degradation when reused.

Recovered glasses from old NICE modules

Apollon Solar and INGESEA focussed on optimising the opening and disassembly process of old NICE modules with respect to process time and complete removal of the PIB (PolyIsoButhylene) edge seal and the PIB lines that are used to fix solar cells and copper connectors. The applied tools included a hot air gun and a thermo cutter to open and cut through the PIB edge seal (Figure 1), as well as an electronically vibrating scraper to mechanically remove PIB and Silicone from the glass surfaces (Figure 2). For a complete removal of the PIB traces a final cleaning step with a commercial liquid cleaning product was necessary.

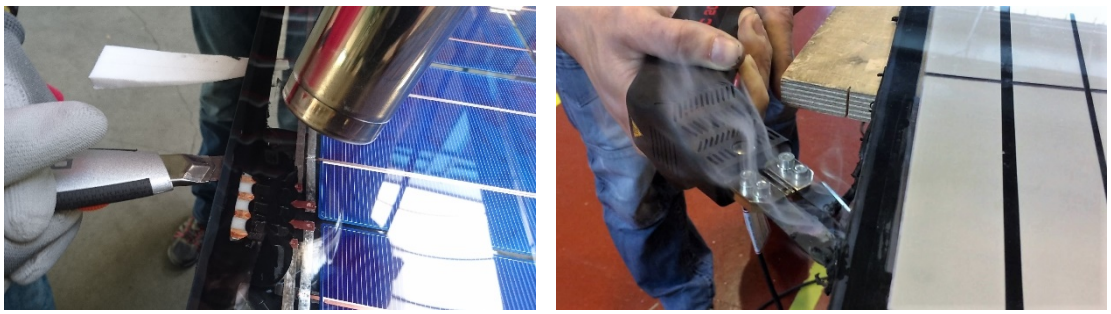

Figure 1: Opening of NICE module by hot air gun + cutter (left) or thermocutter (right)

Figure 2: Removal of PIB/Silicone from glass edge with vibrating scraper.

Figure 3 shows one of the recovered glass sheets from an old NICE module with a more detailed view in Figure 4 at one of the glass edges (on top of a paper sheet) to demonstrate that from a visual point of view the glass edge has been sufficiently cleaned, although a few small PIB dots remain visible.

Figure 3: Recovered glass from an old 60 cells NICE module for reuse.

Figure 4: Detailed view on an edge of one of the recovered glasses from old NICE modules for reuse.

Recovered copper connectors from old NICE modules

The same tools as described above for the PIB edge seal opening and removal have been used to detach the copper interconnectors on old NICE module from the rear glass. A set of recovered copper connectors can be seen in Figure 5, distinguishing between copper connectors for cell to cell interconnection and soldered copper connectors to module bus wires for connection to the first and last cells in a string. The bus wires in old NICE modules were made from tinned copper.

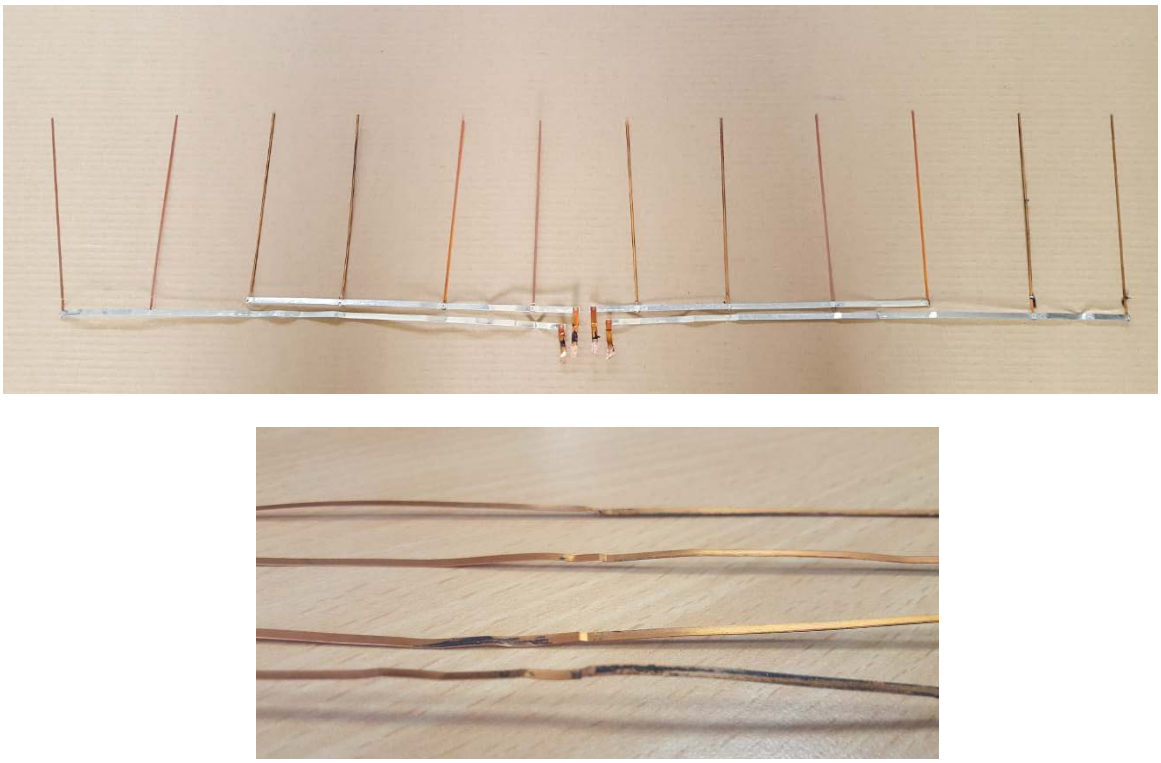

Figure 5: Recovered copper connectors from old NICE modules.

Top: Set of connectors to the first cells in a module string, consisting of pure copper wires to contact the cells that are soldered to tinned copper buswires.
Bottom: Set of recovered pure copper connectors for the cell to cell string interconnection.

As can be seen from Figure 5, the recovered copper wires are more or less deformed, deviating from a straight line and in some cases covered with black residues from the PIB fixation lines. These two points present challenges for the reuse of these copper connectors in new NICE modules, for which they need to be perfectly straightened, stress free and free of insulating material that might cause an increased contact resistance.

2.2 Reuse of recovered components in new PV modules

In absence of an industrial NICE module manufacturing line Apollon Solar has set up a basic tool set together at a university laboratory on a subcontracting basis to be a able to

manufacture NICE mini modules, featuring major aspects of the NICE technology (absence of soldering and EVA) that allowed to validate important elements of deliverable D4.2. However, the lack of precision due to the absence of automated tools for the positioning of cells, copper connectors and the establishing of the underpressure, the absence of neutral gas inside the module and the use of non-tempered glasses does not make these modules fit for degradation tests.

It was not possible to integrate the recovered full-size glasses from old NICE modules into new NICE mini-modules, due to the fact that these glasses are fully tempered and cannot be cut to smaller dimension. However, NICE minimodules were manufactured reusing recovered copper interconnectors from old NICE modules.

Glass Reuse

In order to demonstrate the reuse of the recovered glasses it was decided that Solitek fabricated standard laminated glass/backsheet modules from 3 busbar multi-c solar cells with these recovered lasses. The recovered NICE module glass sheets could be re-used only for glass/backsheet module production, but not for glass/glass type solar module. The reason is a mismatch of dimensions with the standard glass sheets used by Solitek. Technically different sizes of front and back glass sheets could be still laminated, but visually the module would not look correct and would have issues with mounting it into the PV system. The photos in the following Figures 6 to 8 show the different manufacturing steps, demonstrating that the recovered glasses could be handled like new glasses in the industrial PV module manufacturing environment at Solitek.

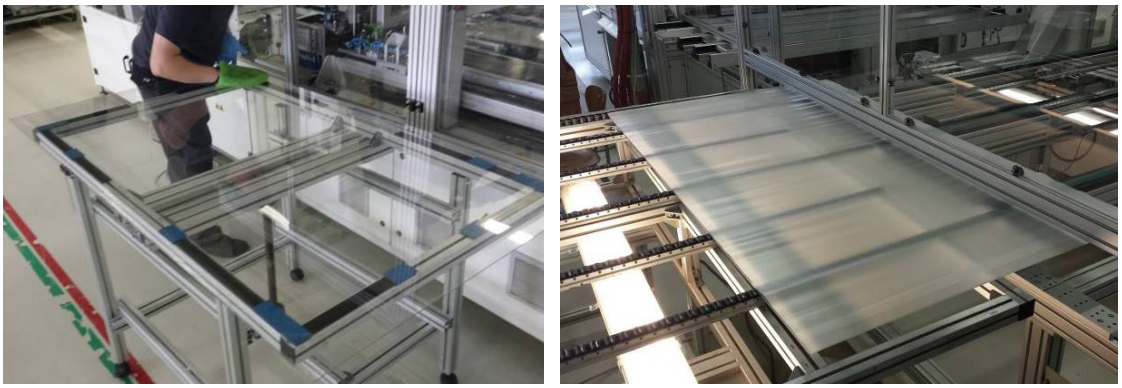

Figure 6: Manufacturing of Glass/Backsheet modules using recovered front glass from old Apollon Solar NICE modules: Step 1 - manual glass cleaning (left) and Step 2 – laying of the front EVA sheet (right).

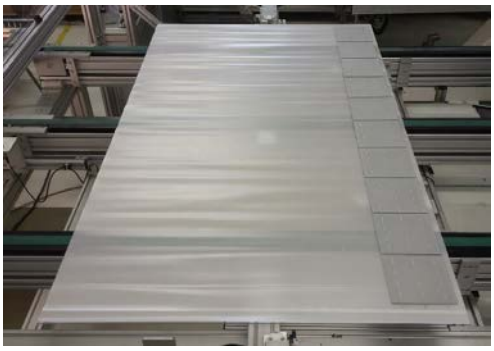


Figure 7: Manufacturing of Glass/Backsheet modules using recovered front glass from old Apollon Solar NICE modules: Step 3 – Solar cell stringing and placing on front EVA/Glass (left) and Step 4 – interconnection and laying of 2nd EVA layer and backsheet (right).


Figure 8: Manufacturing of Glass/Backsheet modules using recovered front glass from old Apollon Solar NICE modules: Step 5 – Entering the laminator (left) and Step 6 – J-Box assembly + IV Testing (right).

One of the finalized modules with a reused front glass from an old NICE module is shown in Figure 9. The IV data of the two modules with reused front glasses are summarized in Table 1.

Figure 9: Finalised glass/backsheet modules with reused front glass sheets from old NICE modules.

Module ID	Isc [A]	Imp [A]	Voc [V]	Vmp [V]	Pmp [W]
ECOSOLAR old glass #1	8.87	8.29	38.26	30.27	250.88
ECOSOLAR old glass #2	8.92	8.33	38.35	30.30	252.53

Table 1: IV data from 2 Glass/Backsheet EcoSolar modules by Solitek, having 2 reused front glasses from old NICE modules of Apollon Solar.

Taking into account that the reused glasses from old NICE modules date back to a time when no ARC coatings were used, the power output of these modules with 3BB multi-c cells of just above 250 W is in the expectable range. This indicates that the reuse of these recycled glasses did not affect the PV performance. Only some optical defects at the glass edge (mainly residues of PIB material) are visible, indicating that a better cleaning procedure is needed after glass sheet recovery.

Damp Heat/Thermo-Cycling of these EcoSolar modules will be performed during the next reporting period. These tests usually take a few months and the results will be presented in the next periodic report in M30.

Apollon Solar has launched a new generation, fully automated NICE module production line in 05/2017 with a system integrator partner. This line will become operational for the final semester of the project for the manufacturing of full size NICE modules, allowing Apollon Solar to manufacture full industrial size modules incorporating recovered glasses from old NICE modules.

Copper connector reuse

Apollon Solar worked on reusing copper connectors that have been recovered from old NICE modules in new nice mini-modules, the recovered copper connectors have been shown in Figure 5 above.

A small number of 1-cell NICE mini modules have been made, trying to reuse these recovered copper interconnectors. The challenge was to manually place front and rear copper wires at an identical position with respect to the cell before applying the underpressure. Any misalignment would otherwise lead to cell cracks as happened in the NICE mini module shown in Figure 10, where a crack started at the upper left corner due to a misalignment between the upper and lower copper interconnector occurred, as a result of the combination of less precise manual pick and place operation and the not fully straightened copper. On the right side however, both, upper and lower copper connectors are correctly super positioned with respect to the cell, so that electrical contact could be established and no cell crack occurred. The cell used was a busbar free bifacial cell and the copper connectors were the ones with buswires soldered to them as depicted on the upper photo in Figure 5 to have external connectors already attached that are lead throhg the PIB edge seal. The cell crack had a negative impact on the IV performance of the cell reducing the module Fill Factor to 64%.

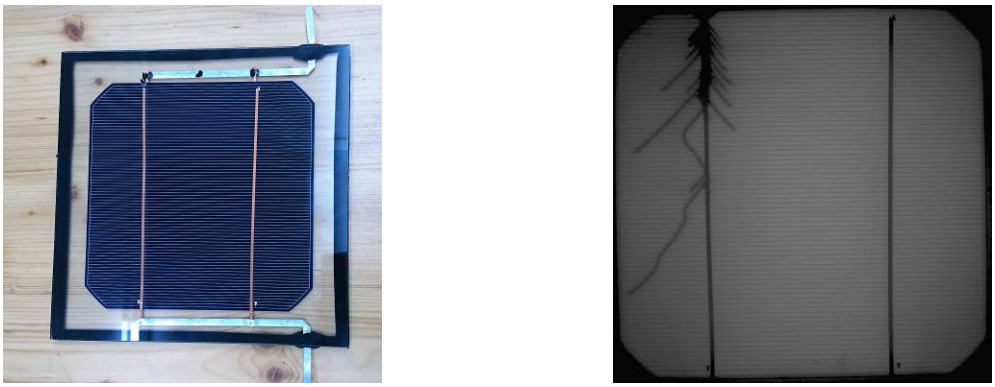

Figure 10: One-cell NICE mini module with integrated recovered Cu-connectors from old NICE modules. Visual image on the left and EL Image on the right.

In conclusion, the technical feasibility of copper connector reuse has been shown with the reserve of requiring high alignement precision between the front and rear connector, that is obtained with an automated industrial pick and place system. In addition, the recovered copper connectors would require a new automated elongation and straightening to avoid potential deviations from the initial positions, as well as a more efficient cleaning procedure to remove all PIB traces. The industrial application of reused copper connectors from old NICE modules is less straight forward than the reuse of glasses and requires also a more thorough economical analysis, which does not question the recycling value of the recovered copper connectors from a pure material point of view in other fields than Photovoltaics.

3 FURTHER PERSPECTIVES

In preparation of Milestone 6 (Month 34) “Eco Solar Demonstrator Modules” additional industrial size 60 cells modules will be manufactured, integrating reused glasses from old NICE modules. The progress on this work will be reported in the next WP 4 interim progress report at Month 30.

- Apollon Solar plans to manufacture new industrial size, 60 cells NICE modules incorporating reused glasses from old NICE modules, as soon as the new industrial NICE line will be fully operational by Month 34. In the meantime, the cleaning process of glasses will be optimized.

- Solitek will continue with accelerated testing of the already fabricated modules with reused glasses (Damp heat and thermo-cycling) and will produce a new series of modules with reused glasses for outdoor testing.

- With the diagnostic tools of AIMEN becoming available, results from photoelasticity and transmission spectral analysis of recovered glasses will be correlated with the performance of the obtained modules.

- The preparation and positioning of copper connectors for reuse will be tested with the tools of the new industrial NICE line by Apollon Solar to verify if this can help to overcome the problems encountered with the manual fabrication of the NICE mini modules.

4 CONCLUSION

- The reuse of PV module glasses recovered from old NICE modules could be demonstrated on an industrial scale. The resulting modules showed an expectable performance in terms of STC power, indicating that the reuse did not affect the initial module performance, only a few traces of PIB were visible at the glass edge which only had a visual impact. This result is considered to be a novelty, showing a high innovation potential in terms of resource efficiency towards a circular economy in PV.

- The technical feasibility of reuse of recovered copper connectors in new modules has been demonstrated. However, to be fully compatible on an industrial scale additional processing steps for the conditioning of the copper wires would be required. This does not affect the reuse or recycling of the these recovered copper wires in other industries.