# Analysis of the Global Warming Potential of Scalable Perovskite-Silicon Tandem Solar Cells

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Keywords: perovskite-silicon tandem solar cells, global warming potential (GWP), life cycle assessment (LCA).
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The present work addresses the environmental impact of the fabrication of scalable perovskite-silicon tandem solar cells (Pero-Si). Thus, the global warming potential (GWP) for the production and use phase of a roof-mounted Pero-Si system has been performed and compared to that of a polycrystalline silicon heterojunction solar cell (HJT) [1]. Additionally, preliminary assessment of the GWP for the end-of-life phase of Pero-Si systems was performed.

A cradle-to-gate analysis with functional unit 1 $m^2$ mounted panel for specific dry and hot desert climate conditions as well as solar input of 1925 kWh/$m^2$/a [2], 1 kilowatt peak (kWp) and 1 kilowatt hour (kWh) of alternating current (AC) electricity generated by the Pero-Si tandem PV system was done in accordance with the framework presented in the ISO standards 14040-4/14044 [3, 4] and the recommendations of the IEA PVPS Task 12 'Methodology Guidelines for LCA on PV' [4]. Here, Umberto 11 software, the Ecoinvent 3.8 database and the Environmental Footprint 3.0 impact assessment method were used.

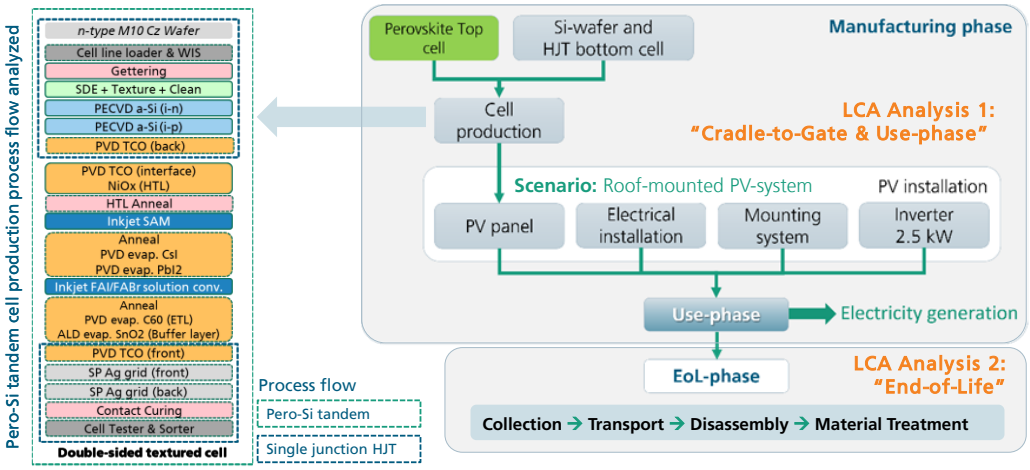
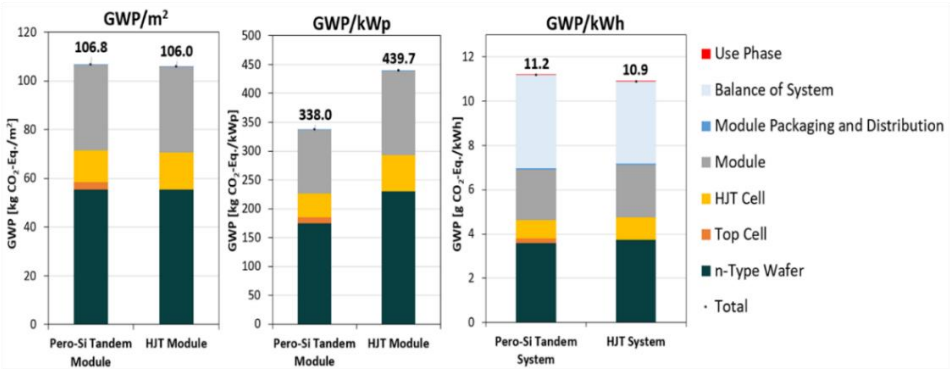



**Figure 1**. Left: Fabrication process flow of a Pero-Si tandem solar cell and of a hetero junction solar cell (HJT); Right: system boundaries for the life cycle assessment of the Pero-Si tandem solar cell for fabrication and use phase (top) as well as for end of life (bottom).

The GWP assessment for the production and use phase of Pero-Si tandem solar cell system indicate that the environmental impact of the perovskite top-cell of the tandem solar cell accounts only ca. 2% of the GWP for the production of the entire tandem solar cell. Furthermore, it has been shown that the GWP per kWp for a Pero-Si tandem solar cell is lower as compared to that of a Silicon Heterojunction single junction (HJT) cell, due to the higher efficiency of the Pero-Si tandem solar cell. Additionally, it has been indicated that a lower GWP per kWh for Pero-Si system as compared to a HJT system may be anticipated only if the Pero-Si tandem solar cell exhibits comparable lifetime and degradation rate. Thus, a sensitivity analysis revealed that a difference in lifetime larger than 5 years (i.e., 25 years for Pero-Si vs. 30 years for HJT) as well as a difference in the degradation rate larger than 0.2 percent points (i.e., 0.9% for Pero-Si vs. 0.7% for HJT) lead to a higher GWP per kWh of the Pero-Si tandem system as compared to the HJT system.

(a)




(b)

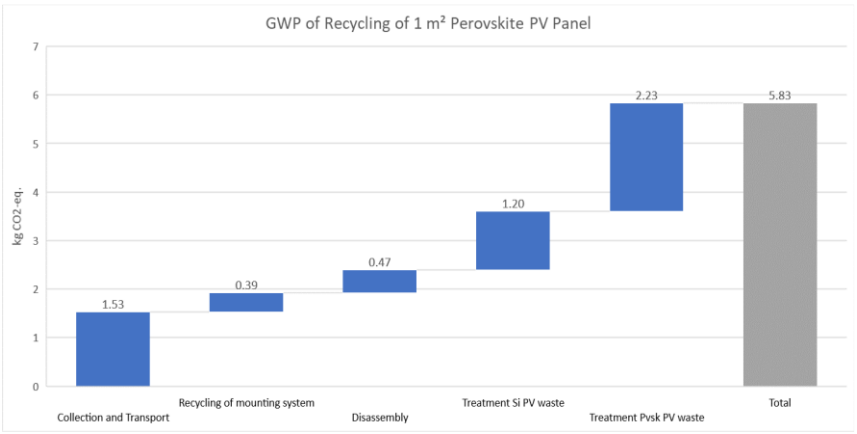



**Figure 2.** (a) Comparative analysis of the GWP share of the different components of the Pero-Si tandem solar cell system vs. HJT system for three different functional units. For GWP/kWh analysis (right graph) different lifetimes and degradation rates have been taken: for the HJT- based system a system lifetime of 30 years and an annual degradation rate of 0.7%/a was assumed and for the Pero-Si tandem-based system a 5 year lower system lifetime of 25 years and a 0.2%/a higher degradation rate of 0,9%/a; (b) GWP assessment for the recycling of 1 $m^2$ Pero-Si tandem system.

Additionally, a comparative GWP assessment of the end-of-life phase of Pero-Si tandem solar cells and HJT cells based on a cut-off approach was performed, i.e., the contribution of the use of recycled materials as secondary resource was not considered. The disassembly and treatment of the frame and of the HJT cell as was modelled based on literature available data [6], whereas the treatment of the perovskite top cell in the Pero-Si tandem module was modelled based on primary data generated at Fraunhofer IWKS. The assessment pointed out to a GWP of 5.83 kg $CO_2$-eq. for 1 $m^2$ of Pero-Si module, which agrees well with the literature (5.9 kg $CO_2$-eq. / $m^2$)

**Acknowledgements**
This work was supported by the Fraunhofer Lighthouse project (MaNiTU) - https://manitu.fraunhofer.de/.

**References**

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