High Efficient 3rd Generation Multi-Junction Solar Cells using Silicon Heterojunction and Perovskite Technology: Life Cycle Based Environmental Impacts

Matthias Stucki and René Itten
Zurich University of Applied Sciences, Institute of Natural Resource Sciences
Gruenental, 8820 Wädenswil, Switzerland
matthias.stucki@shanghai.unizh.ch

Introduction and Methods

In this study, the environmental impacts of monolithic silicon heterojunction organometallic perovskite tandem cells (SHJ-PSC) and single junction organometallic perovskite solar cells (PSC) were compared with the impacts of crystalline silicon based solar cells using a prospective life cycle assessment with a time horizon of 2025. This approach provides a result range depending on key parameters like efficiency, wafer thickness, kerf loss, lifetime, and degradation which are appropriate for the comparison of these different solar cell types with different maturity levels.

Table 1. Summary of different prospective scenarios with abbreviation, technology, parameters for cell and module efficiency, wafer thickness, kerf loss and description including references for parameter values [1-10]

<table>
<thead>
<tr>
<th>Abbr.</th>
<th>Technology</th>
<th>Efficiency in %</th>
<th>Thickness in micrometer</th>
<th>Water</th>
<th>Kerf</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mono-Si REF</td>
<td>Mono-crystalline, single-junction</td>
<td>16.5</td>
<td>15.1</td>
<td>295</td>
<td>145</td>
<td>Reference scenario for the current market average according to ITRPV [12]</td>
</tr>
<tr>
<td>Mono-Si ITRPV</td>
<td>Mono-crystalline, single-junction</td>
<td>26.0</td>
<td>23.8</td>
<td>140</td>
<td>60</td>
<td>Future scenario according to the ITRPV [9]</td>
</tr>
<tr>
<td>Poly-Si</td>
<td>Poly-crystalline, single-junction</td>
<td>16.0</td>
<td>14.7</td>
<td>295</td>
<td>145</td>
<td>Reference scenario for the current market average according to ITRPV [12]</td>
</tr>
<tr>
<td>Poly-Si ITRPV</td>
<td>Poly-crystalline, single-junction</td>
<td>20.0</td>
<td>18.3</td>
<td>150</td>
<td>60</td>
<td>Future scenario according to the ITRPV [9]</td>
</tr>
<tr>
<td>PSC</td>
<td>Perovskite single-junction</td>
<td>15.0</td>
<td>13.6</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Prospective scenario with low efficiency for perovskite single-junction cell [6]</td>
</tr>
<tr>
<td>PSC OPT</td>
<td>Perovskite single-junction</td>
<td>20.0</td>
<td>18.3</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Prospective scenario with high efficiency for perovskite single-junction cell [1.11]</td>
</tr>
<tr>
<td>SHJ-PSC</td>
<td>Monolithic two-terminal tandem cell using silicon heterojunction and perovskite tandem</td>
<td>26.0</td>
<td>23.8</td>
<td>140</td>
<td>60</td>
<td>Prospective scenario with low efficiency for monolithic two-terminal tandem cell using perovskite and silicon heterojunction tandem [9-10]</td>
</tr>
<tr>
<td>SHJ-PSC PESS</td>
<td>Monolithic two-terminal tandem cell using silicon heterojunction and perovskite tandem</td>
<td>30.0</td>
<td>27.5</td>
<td>130</td>
<td>60</td>
<td>Prospective scenario with low efficiency for monolithic two-terminal tandem cell using perovskite and silicon heterojunction tandem [11]</td>
</tr>
</tbody>
</table>

Prospective Scenarios and Results

The model approach applied uses process-based LCA data in combination with attributional allocation. The key parameters for wafer based crystalline silicon technologies are subject to prospective future scenarios based on expected trends. A similar modelling approach was applied in Louwen et al. [2], Frischnecht et al. [3] and Rufer & Braunischweig [4]. These key parameters were modelled based on future projections in the International Technology Roadmap for Photovoltaics (ITRPV) for mono-Si single-junction solar cells [5], Burschka et al. [6] and Yang et al. [7] for non-bifacial perovskite single-junction cells and Werner [8], Abrecht et al. [9], Bush et al. [10] and Almansouri et al. [11] for monolithic two-terminal SHJ-PSC tandem cells. The parameters for the different solar cell types have been summarised in Table 1. A relative decrease in efficiency of 8.5 % from cell to module was assumed for all solar cell types. This corresponds to the current market trend to mono-crystalline solar cells [12].

Figure 1. Contribution of the different components of the photovoltaic power plant to the life cycle greenhouse gas emissions per kWh of low voltage electricity produced, at inverter; depending on the lifetime related to mono-Si REF silicon with a given lifetime of 30 years; installation on a rooftop in Central Europe with an electricity yield of 919 kWh per kWp and year including average degradation of 10.5 % with a lifetime of 30 years; *optimistic lifetime of 30 years for PSC layer.

Discussion and Conclusion

- Key parameters for the environmental impacts are the module efficiency and lifetime of the modules as well as the degradation rate of the cell efficiency
- For GHG emissions and Energy Payback Time the deciding factor is the electricity demand during manufacturing (deposition process)
- The toxicity impacts of PSC solar cells are related to the use and emission of heavy metals (mainly Pb and Sn)
- Resource depletion is dominated by the use of indium for transparent conductive oxides (TCO) for SHJ and PSC solar cells, current mono-Si and poly-Si cells do not utilise indium containing TCOS and cause lower resource depletion
- 3rd generation solar cells using perovskites have the potential for improved performance compared to current photovoltaic technologies if the cells can be stabilised

References