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

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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]

Abbre-viation	Technology	Efficiency in %		Thickness in micrometer		Description
		Cell	Module	Wafer	Kerf	
Mono-Si REF	Mono-crystalline silicon, single-junction	16.5	15.1	295	145	Reference scenario for the current market average according to IEA PVPS [12]
Mono-Si ITRPV	Mono-crystalline silicon, single-junction	26.0	23.8	140	60	Future scenario according to the ITRPV [5]
Poly-Si REF	Poly-crystalline silicon, single-junction	16.0	14.7	295	145	Reference scenario for the current market average according to IEA PVPS [12]
Poly-Si ITRPV	Poly-crystalline silicon, single-junction	20.0	18.3	150	60	Future scenario according to the ITRPV [5]
PSC PESS	Perovskite single-junction	15.0	13.8	n.a.	n.a.	Pessimistic scenario with low efficiency for pervovskite single-junction cell [6]
PSC OPT	Perovskite single-junction	20.0	18.3	n.a.	n.a.	Optimistic scenario with high efficiency for perovskite single-junction cell [7,11,15]
SHJ-PSC PESS	Monolithic two terminal tandem cell using perovskite and silicon heterojunction tandem	26.0	23.8	295	145	Pessimistic scenario with low efficiency for monolithic two terminal tandem cell using perovskite and silicon heterojunction tandem cell [8–10]
SHJ-PSC OPT	Monolithic two terminal tandem cell using perovskite and silicon heterojunction tandem	30.0	27.5	120	60	Optimistic scenario with low efficiency for monolithic two terminal tandem cell using perovskite and silicon heterojunction tandem cell [11,16]

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], Frischknecht et al. [3] and Rufer & Braunschweig [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], Albrecht 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 cell to module efficiency ratio for mono-Si solar cells [12].

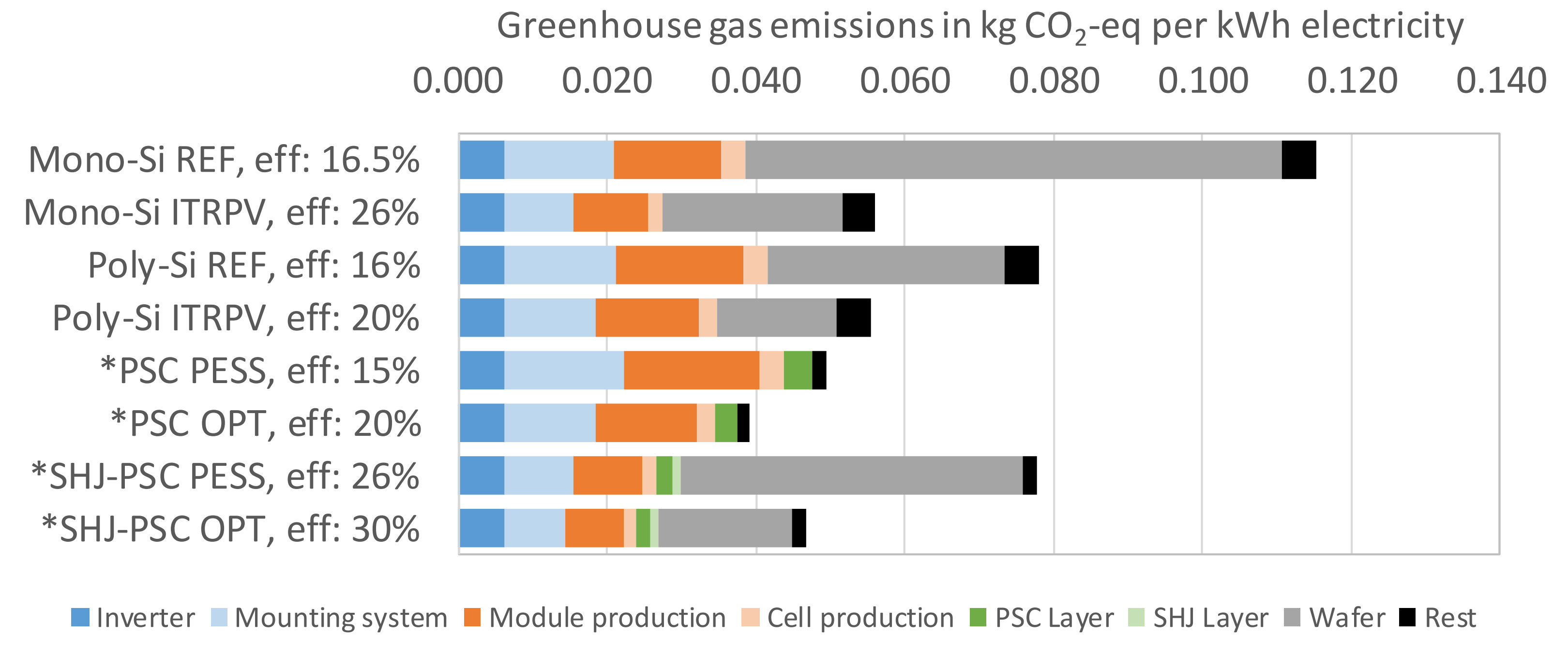

Figure 1. Contribution of the different components of the photovoltaic power plant to the life cycle greenhouse gas emissions per kWh of low voltage electricity produced, at inverter; with installation on a rooftop in Central Europe with an electricity yield of 919 kWh per kWp and year including average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

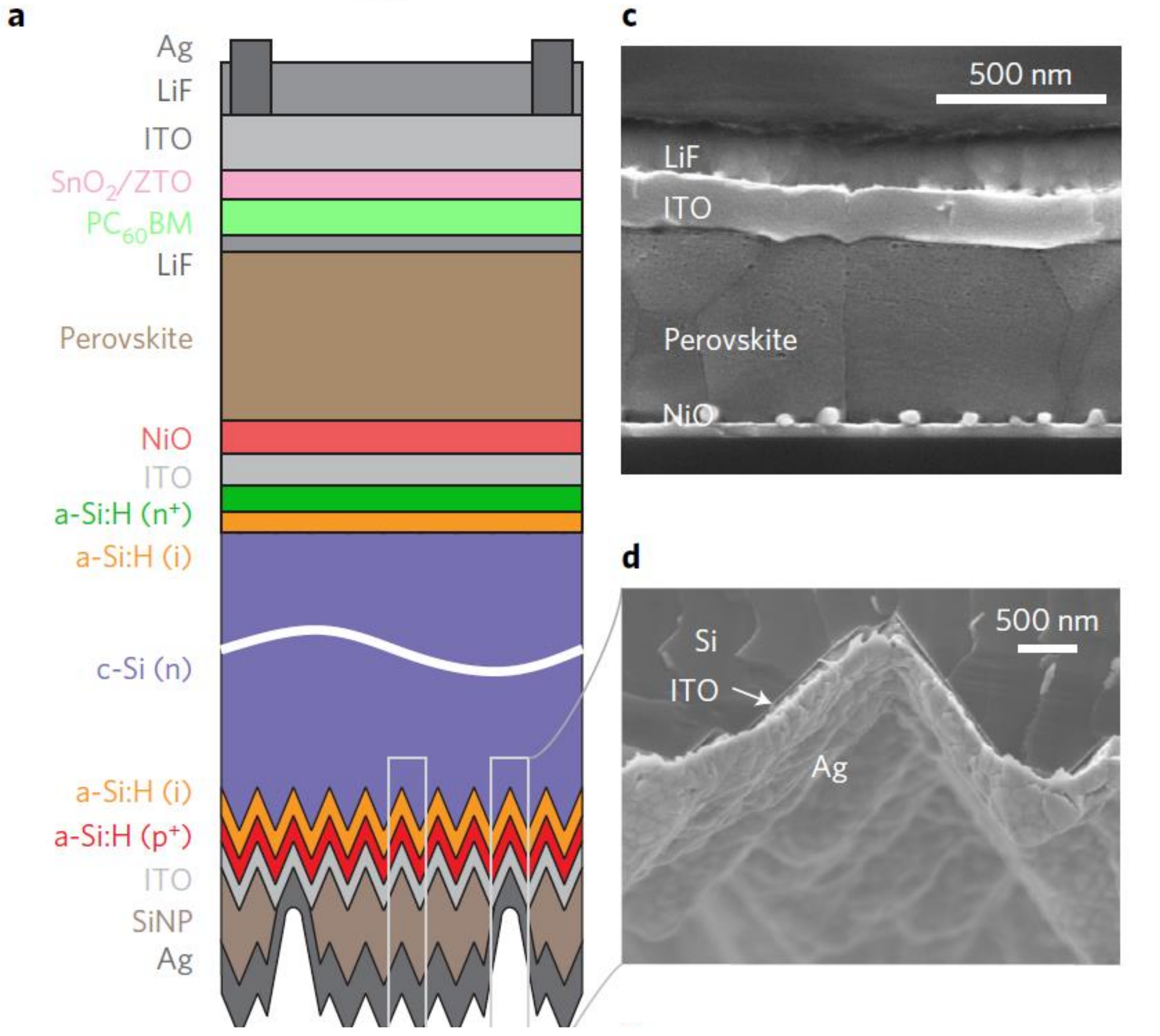

Figure 3. Schematic representation of the silicon heterojunction perovskite tandem cell (Bush et al. [10])

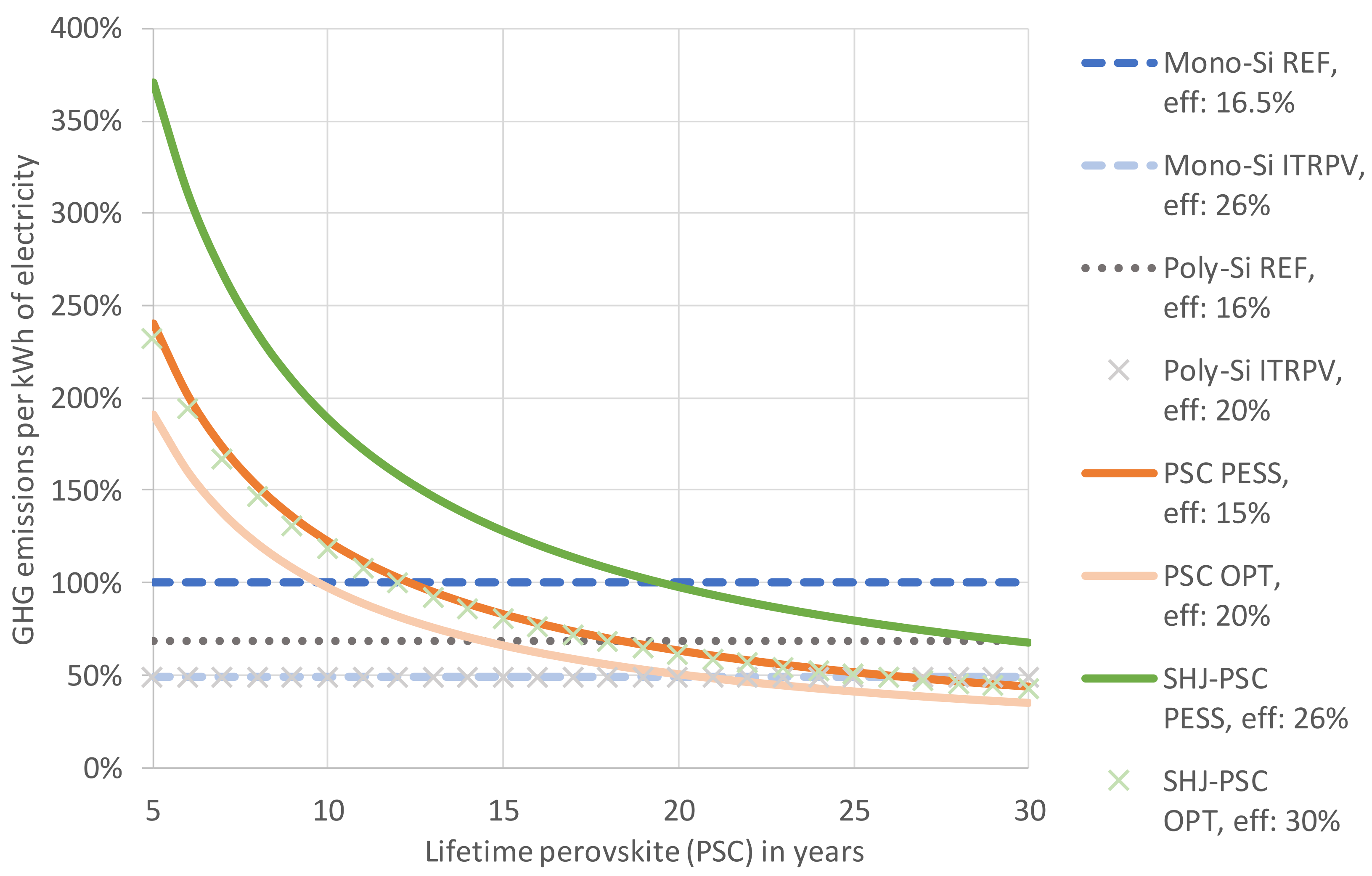

Figure 3. Life cycle greenhouse gas emissions per kWh of low voltage level electricity produced, at inverter, depending on the lifetime relative to mono-Si-REF silicon with a given lifetime of 30 years; installation on a rooftop in Central Europe with an electricity yield of 919 kWh per kWp and year including average degradation of 0.7 % per year; lifetime variable for PSC and SHJ-PSC tandem.

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

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