Life Cycle Analysis of an Adaptive Solar Facade

P. Jayathissa [☆a,**], M. Jansen[☆a], N. Heeren[b], S. Hellweg[b], A. Schlueter [a,*]

[a] *Architecture and Building Systems, Institute of Technology in Architecture, ETH Zurich, Switzerland*
[b] *Ecological System Design, Institute of Environmental Engineering, ETH Zurich, Switzerland*

Abstract

Text

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1. Introduction

Buildings are at the heart of society and currently account for 32% of global final energy consumption and 19% of energy related greenhouse gas emissions [1]

- In the last decades, building integrated photovoltaics (BIPV) have been adopted as part of the energy strategy towards 2050...

(advantages of BIPV, potential of BIPV)

- The current developments of light-weight efficient thin film technologies have brought new design possibilities for architects in BIPV design...

(Adaptive Building Envelopes, examples, Envelope is the barrier between the internal and external environment, Advantages, seamless coupling with solar tracking mechanics)

[☆] This document is a collaborative effort.

[*] Corresponding author
[**] Principal corresponding author
Email addresses: jayathissa@arch.ethz.ch (P. Jayathissa [☆]), heeren@ifu.baug.ethz.ch (N. Heeren), schlueter@arch.ethz.ch (A. Schlueter)

- One example of a multi functional facade that was recently released is the Adaptive Solar Facade.

- The aim of this paper is to analyse the life cycle emissions of an adaptive solar facade and provide comparisons with standard shading systems and static BIPV solutions.

2. Life cycle analysis methodology

- The analysis is performed according to ISO 14040, ISO 14044 and ISO 15804.
- The impact category, which will be evaluated, is the global warming potential (GWP). This is described as the emissions of $CO_2 - eq$ in kilograms divided by the functional unit.
- The functional unit used is twofold and based on the function of the adaptive building envelope. For the comparison with other shading systems facade area in m^2 is used, while comparison with other photovoltaic systems is done using electricity produced in kWh. According to the guidelines of the International Energy Agency (IEA), the calculation of kWh produced needs to be based for consistency on conversion efficiency η, performance ratio PR, irradiation I, lifetime LT and area A of the module. Equation 1 gives the exact formulation:

$$G = \frac{\mathrm{GWP}}{\mathrm{I} \cdot \eta \cdot \mathrm{PR} \cdot \mathrm{LT} \cdot \mathrm{A}} \tag{1}$$

- The LCI inventory was obtained through...
- The scope of the LCA comprises the embodied, operational and disposal global warming impact of the respective system. Figure 1 illustrates the system boundaries of the process flows. The supporting structures are also

included in the system boundaries. The reason for this is that technologies within the building envelope also change the design of the supporting structures. The supporting structure of solar panels is referred to as balance of systems (BOS).

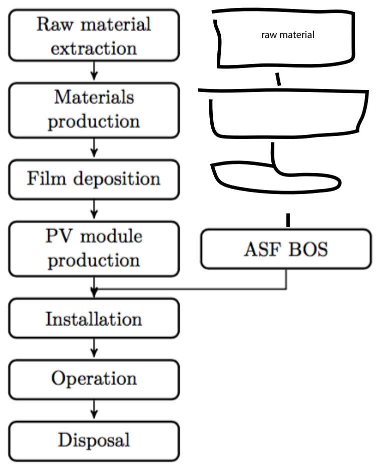

Figure 1: Thin-film incl. BOS system boundaries

- The cut-off approach is used for recycling and landfill. This means that recycling does not generate any credit for the product and resulting benefits are not taken into account. Furthermore the use of recycled products do not bear the burden of processes higher up the chain.

- The recipe midpoint (H) allocation method allows for an accurate evaluation of the GWP based on human impact factors.

- The adaptive solar facade uses CIGS thin film panels with an aluminum backing. This allows for a light-weight panel, needed for the flexible control of the system using silicone soft-robotic actuators.

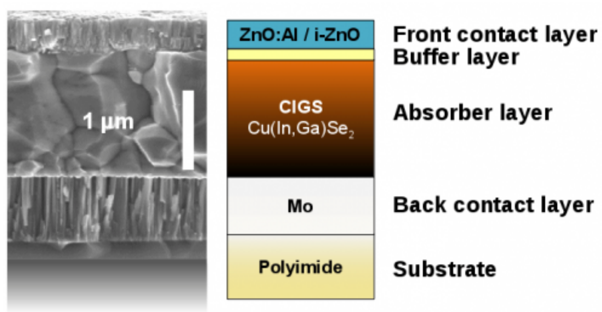

Figure 2: CIGS thin film structure

3. Environmental Performance of the Adaptive Solar Facade

- A breakdown of the embodied carbon emissions can be found in Figure 3... (brief discussion and design consideration)...

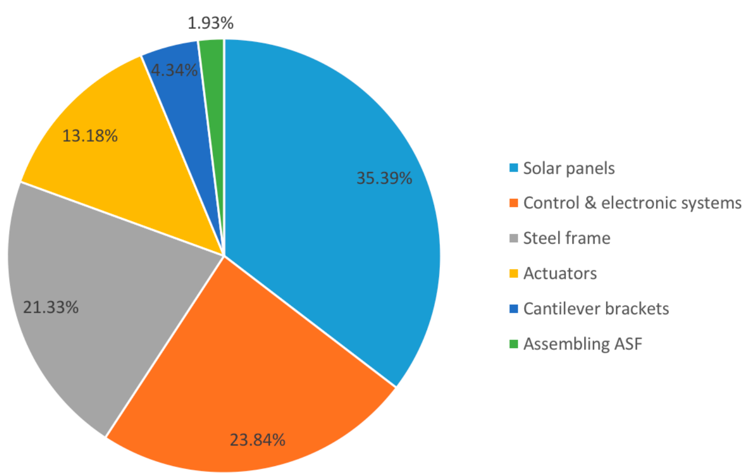

Figure 3: Breakdown of the embodied carbon emissions, it can be seen that xxxx has the greatest GWP contribution

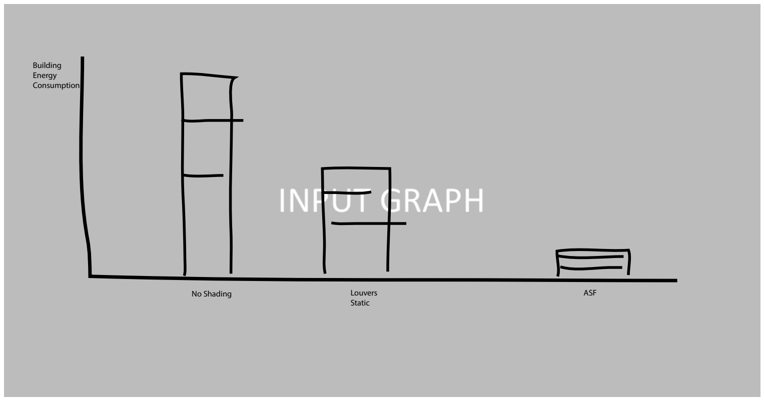

Figure 4: Breakdown of the opperational carbon emissions, we can see a added savings of xxx compared to a static louvered shading system

- The results of the analysis can be summarized in Figure 5...

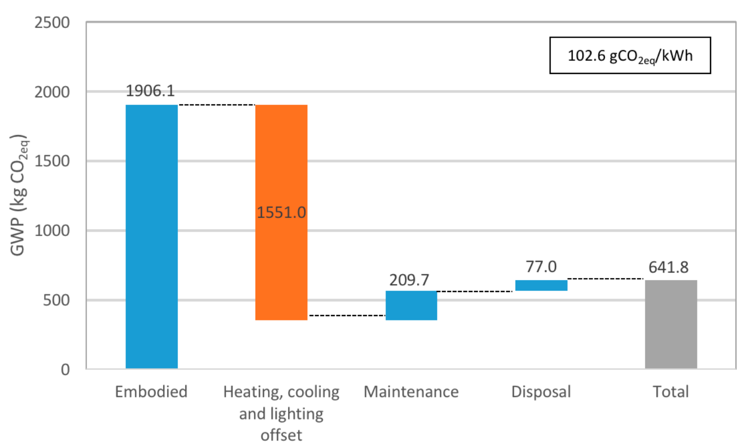

Figure 5: Waterfall diagram of GWP of the ASF. The far left column details the embodied carbon emissions. The second bar details the emission reduction of the building through the smart shading algorithms of the ASF. The third column shows an increase of emissions through maintenance. The fourth column shows an increase in emissions in the disposal. This leaves us with a final emissions value. When we apply this value to Equation 1 we obtain an emission factor per kwH of 173.8gCO2/kWh.

- As input parameters of production processes are stochastic, a Monte Carlo simulation is used to include this stochastic behavior in the results, as shown in Figure 6...

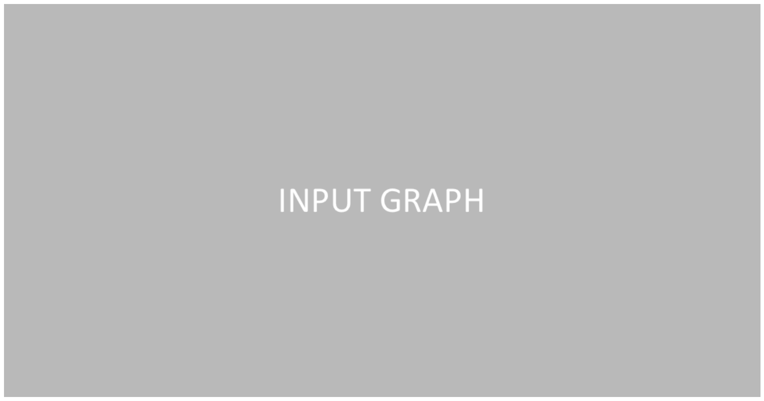

Figure 6: Monte carlo simulation based on input uncertainties

4. Comparison to other technologies

- The adaptive solar facade was compared with standard facade shading systems and other static BIPV solutions...

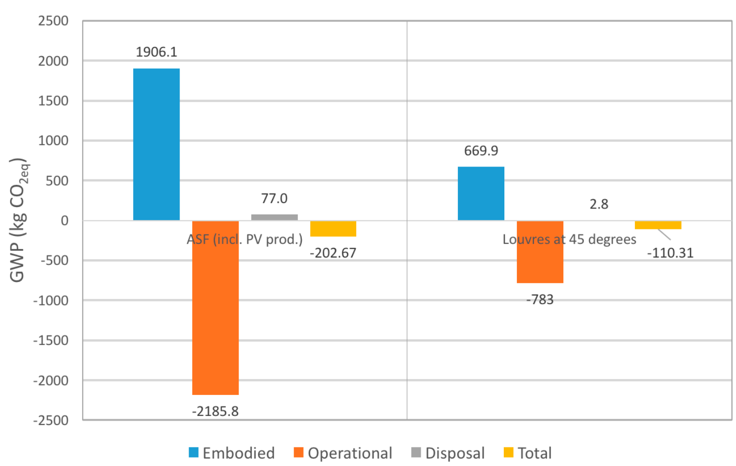

Figure 7: The comparison of the ASF with a static louvered shading system

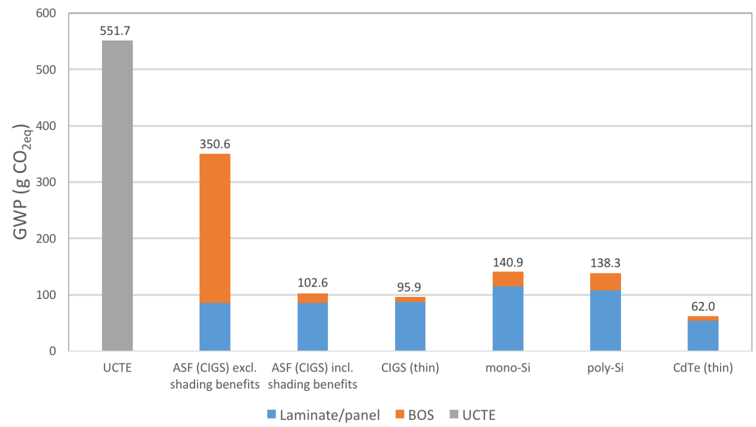

Figure 8: BIPV comparison of thin-film and BOS

5. Discussion

- Other advantages of the ASF that are not clear in the LCA analysis, such as daylighting and user centered control

6. Conclusion

- xxx% of Embodied emissions of the photovoltaic BOS can be offset through smart shading
- This multi functionality brings about new advantages/disadvantages for solar as it has a reduced/increased the emissions per kWh by xxx%
- Higher embodied CO2 compared to a classic photovltaic retrofit. However reduction can be made through x y and z
- Results are highly sensitive to x y and z

7. Acknowledgments

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References

[1] Fifth assessment report, mitigation of cliamte change, Intergovernmental Panel on Climate Change 674–738.