Material Implications for Large-Scale Adoption of Photovoltaic Technologies
GHG emission reduction
Renewable Energy Scenarios
Environmental and Resource Implications of Renewable Energy
Considering

• Life Cycle impacts of over 1,000 environmental exchanges.
• Materials efficiency improvements.
• Conversion efficiency improvements.
• Blue map scenario.
• Around 30 electricity generation technologies.
• For mineral constraints: top 20 PV technologies.
Materials Requirements for CIGS

Normalized Environmental Impacts of Electricity from Ground Mounted CIGS and CdTe PV systems in 2010
US Southwest Insolation = 2400 kWh/m²/year

- Metal Depletion: 246.23%
- Total Land Occupation: 208.25%
- Carcinogens: 76.14%
- Global Warming: 78.12%
- Water Depletion: 31.89%
- Fossil Depletion: 28.96%
- Non-carcinogens: 12.07%
- Respiratory Effects: 12.18%
- Non-combustion: 12.23%
- Photochemical Oxidation: 10.75%
- Eutrophication: 1%
- Ecotoxicity: 10%
Environmental Impacts of electricity from ground mounted thin film PV in 2010 and 2030

US Southwest insolation = 2400 kWh/m²/year
PV material requirements under Blue map scenario as a percentage of 2010 reserve base

The graph shows the projected increase in mineral reserve base requirements for various PV materials from 2010 to 2050. The materials include CIGS, CdTe, CdSe, GaAs, InP, ZnTe, ZnSe, PbSe, PbS, Ag2S, Bi2S3, ZnO, CuO, Cu2S, CZTS, Zn3P2, Cu2O, CdS, WSe2, Ga, Te, Se, and Bi.

The x-axis represents the years from 2020 to 2050, while the y-axis indicates the percentage increase in mineral reserve base requirements from 2010 levels.
What about Balance of System (BoS)?

- Steel for frames, transformer and IMC conduit: 28.75%
- Inverter: 8.63%
- Steel manufacturing: 7.00%
- Flat glass: 2.37%
- Copper wire drawing: 1.90%
- CdTe: 0.53%
- Solder, Sn95.5Ag3.9Cu0.6: 0.89%
- Semiconductor machinery manufacturing: 0.80%
- Other: 1.39%
- Copper for transformer & wiring: 47.74%
Conclusion

• Material consumption can be a significant constraint for large-scale adoption of renewable energy technologies.

• Some technologies pose higher risks than others.

• Ga, Te, Se, and In are recognized as key potential limiting factors for large-scale PV deployment.

• Materials used for BoS are not negligible.
Acknowledgement

• My students working on the project
  – Jeremie Hakian
  – Joeseph Bergesen