

# An open-source framework for PV in the Circular Economy evaluation

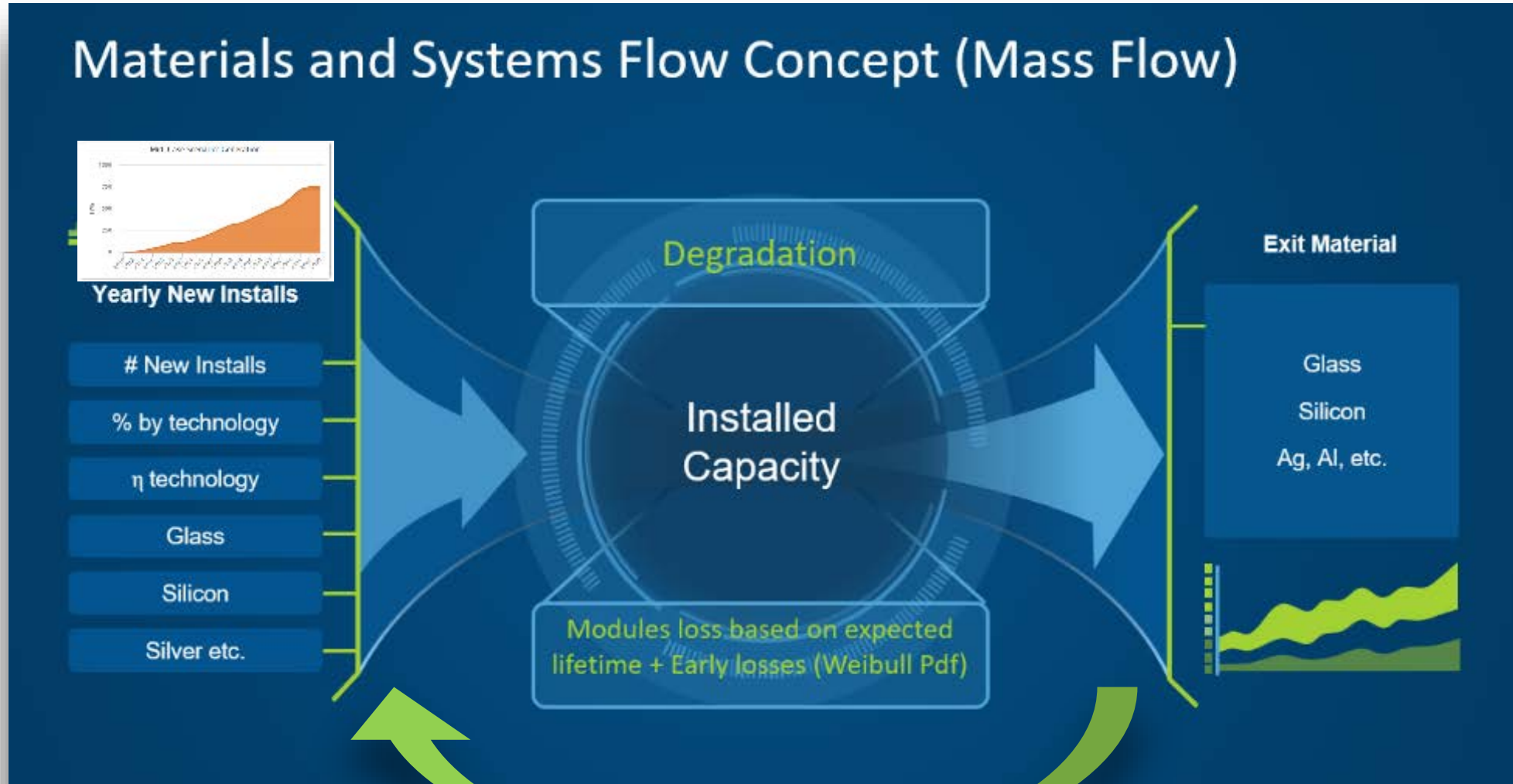
Silvana Ovaitt

5<sup>th</sup> Open Energy Modelling Workshop

‘Online Lightning Talk Mini-Workshop’

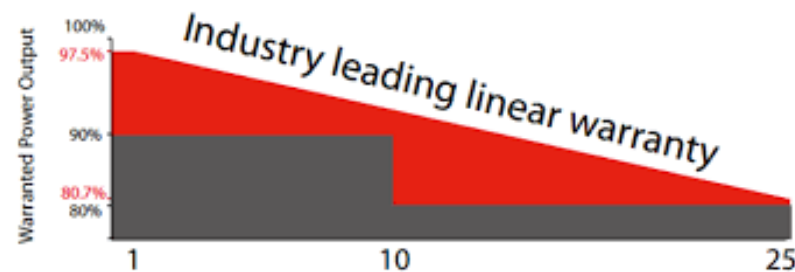
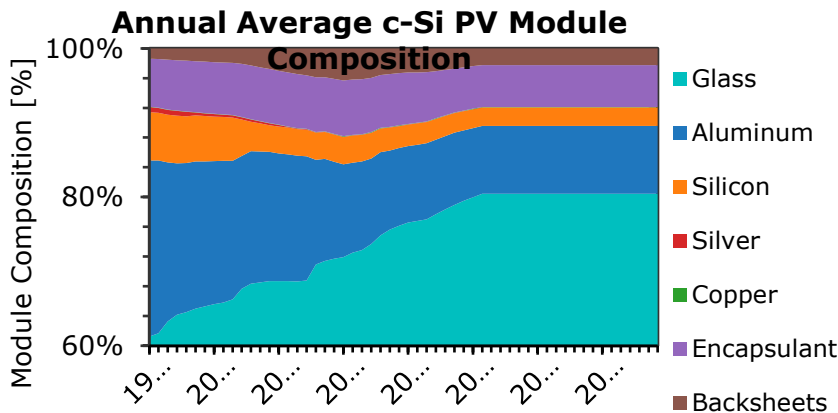
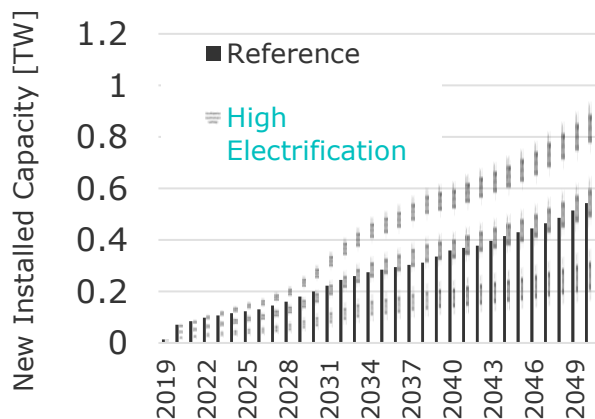
16/Feb/22

**openmod** open energy  
modelling initiative

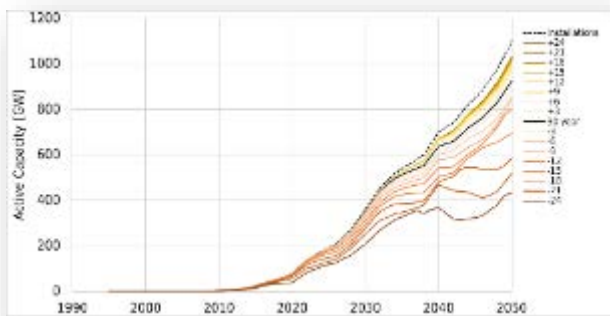


# Features material flow tracking for waste, virgin needs, and installed capacity

Bringing PV and Sustainability communities together, Interdisciplinary

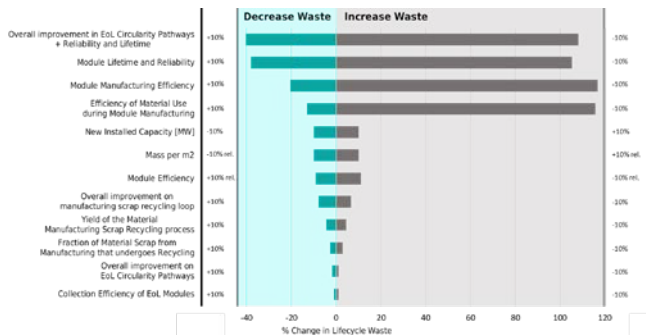


Able to use ANY deployment forecast (county, US, other countries, world, or by specific technology)



Accurate Installed Capacity Calculated with degradation, and bifaciality corrections

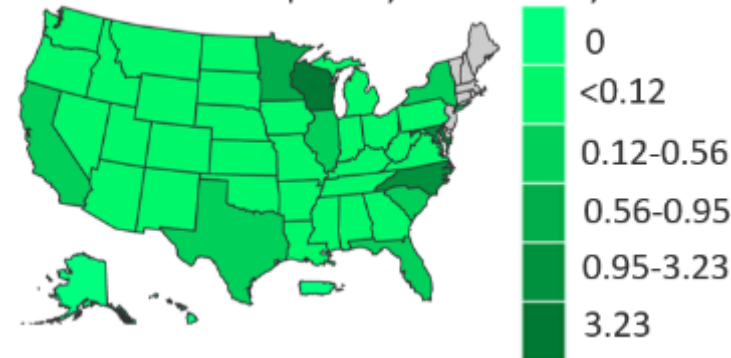
Historic and projected baselines  
Virgin Material Needs consider MFG Efficiencies, all as open-data!



Framework that allows easy scenarios comparison Sensitivity Analysis

Service Life definitions (project lifetime, degradation, and improved failures and reliability approach)

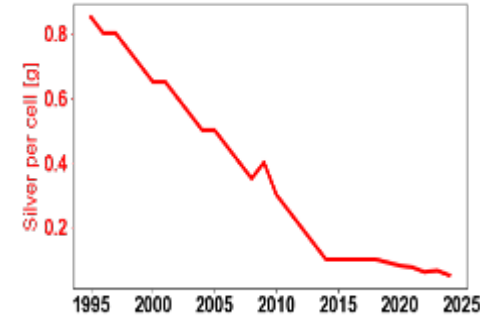
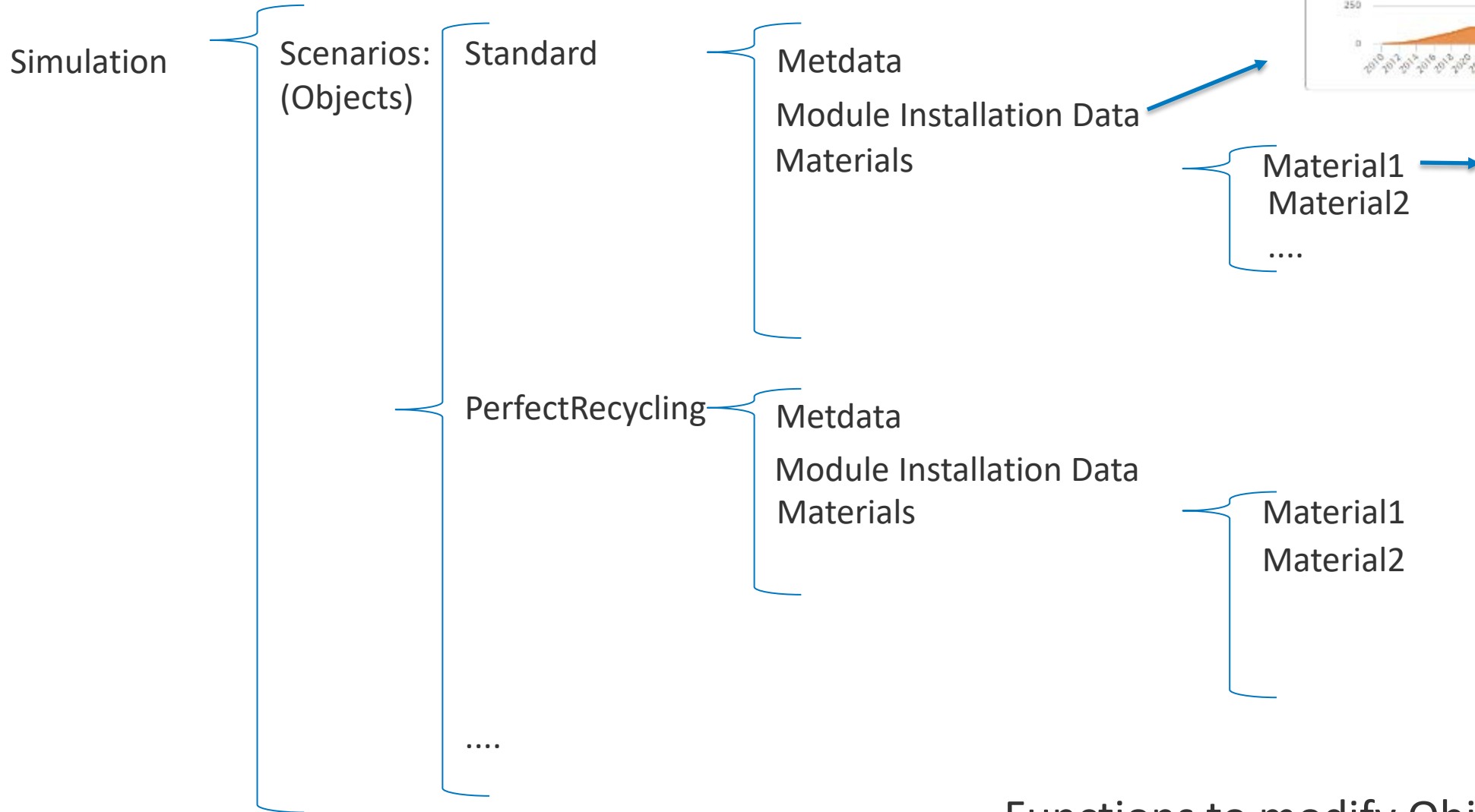
Landfill % occupied by PV Waste By Mass



Flexible Spatial and Temporal analysis NREL | 3

# Structure

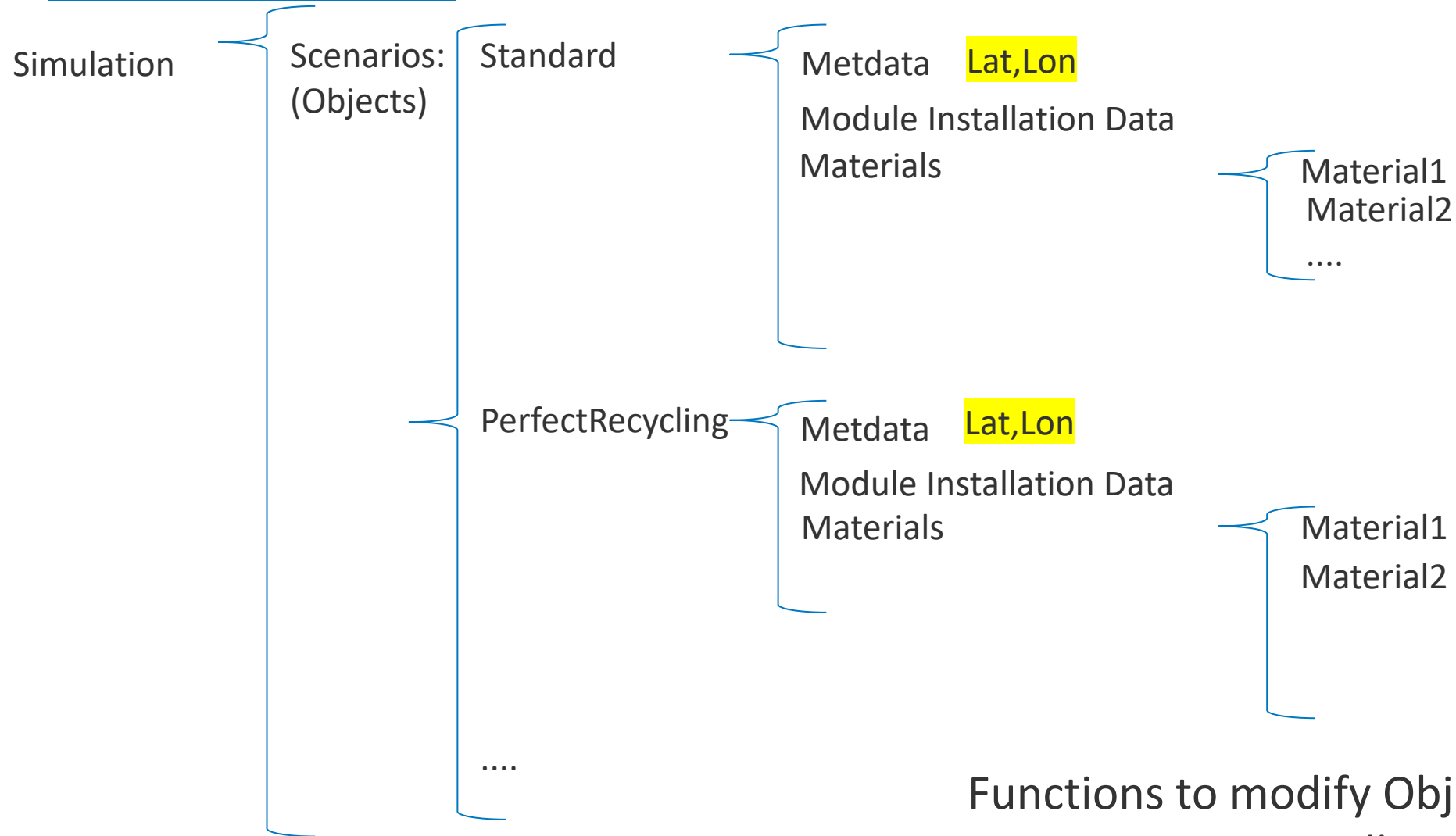
Python Class structure to enable keeping track of PV Modules & Materials



Functions to modify Objects (modify parameters, run, collect results, etc). NREL | 4

# Structure

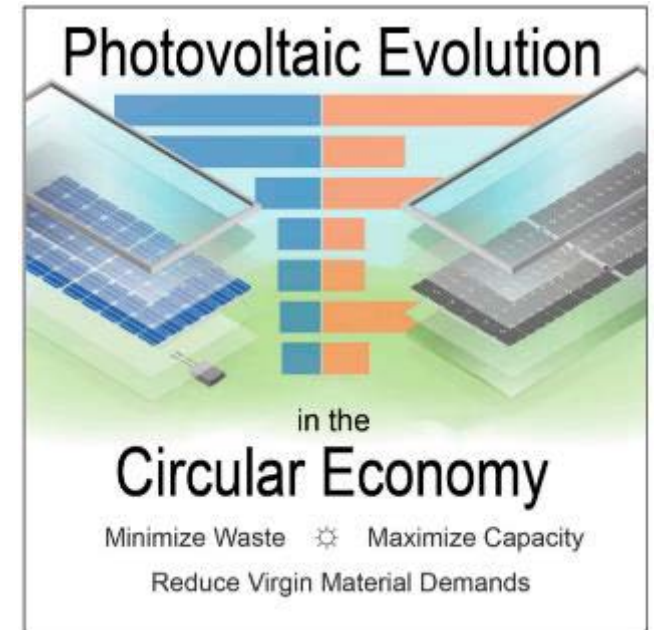
Python Class structure to enable keeping track of PV Modules & Materials



Functions to modify Objects (modify parameters, run, collect results, etc).

# Open Software

- BSD 3-Clause License; Copyrighted to Alliance for Sustainable Energy, LLC
- Contributors License Agreement
- Readthedocs Documentation
- Version control
- Zenodo DOI
  - Ovaitt, Silvana, Heather Mirletz, and Acadia Hegedus. (2021). NREL/PV\_ICE: Release version 2 (v0.2.0). Zenodo. <https://doi.org/10.5281/zenodo.5196342>
- Pip installable
- Issue trackers
- Peer Reviewed Software
  - Ovaitt, S.\*, Mirletz, S.\*, Seetharaman, S., Barnes, T. PV in the Circular Economy, a dynamic framework analyzing technology evolution and reliability impacts. iScience; 2022. <https://doi.org/10.1016/j.isci.2021.103488>



**PAPER COVER IMAGE FROM:** Ovaitt, S.\*, Mirletz, S.\*, Seetharaman, S., Barnes, T. PV in the Circular Economy, a dynamic framework analyzing technology evolution and reliability impacts. iScience; 2022. <https://doi.org/10.1016/j.isci.2021.103488>

# Open Data

## Dynamic baselines of historic and projected c-Si PV data are provided

- Baselines incorporate and harmonize aspects of PV technology and market trends, ex:
  - Silicon vs. Thin Film
  - Monocrystalline vs Multicrystalline
  - Glass-backsheet vs Glass-Glass
- Previous waste projections used out of date material and module properties, so we updated

### Baseline Creation Data/Plots:

Harmonizing added capacity

Market share of Monocrystalline vs Multi-crystalline Si

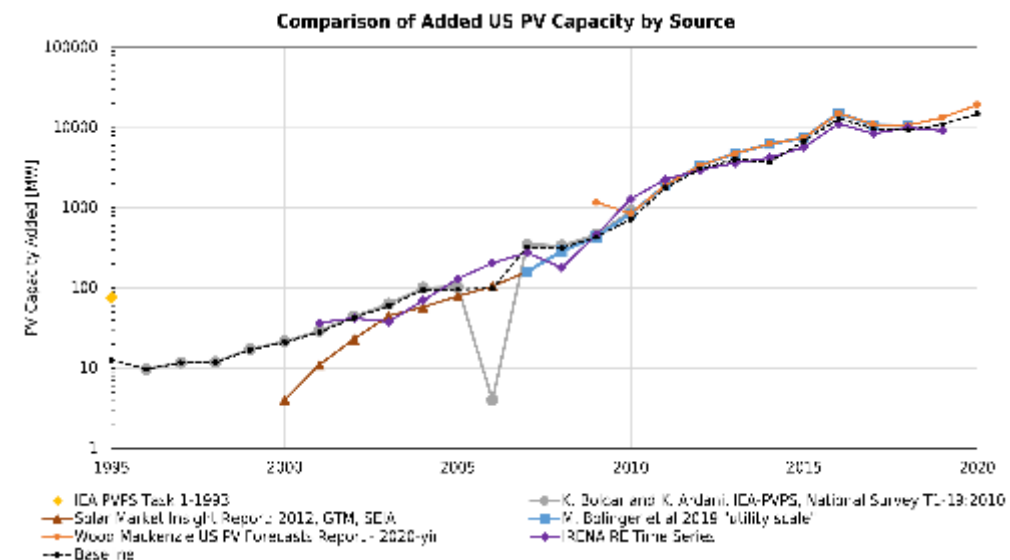
Annual Average Module Efficiency

Annual Average Module Material Composition

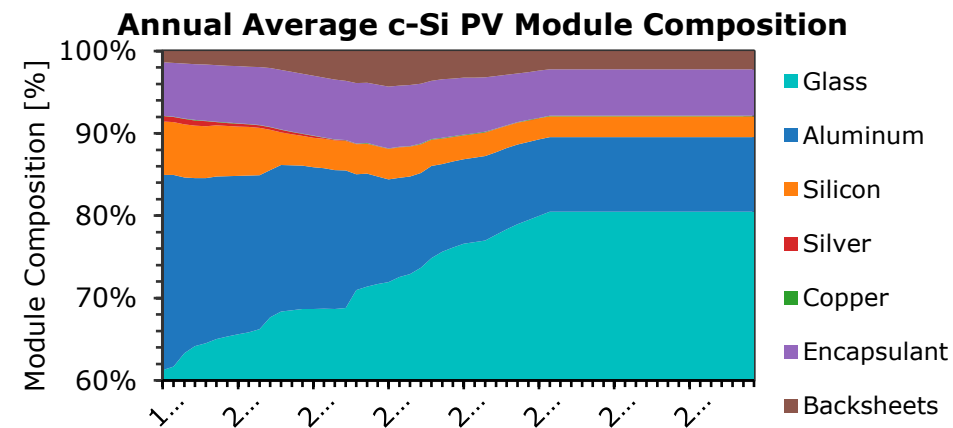
Comparison of Mass-Power factor to prior literature

Virgin Material Yield/Efficiency

Manufacturing Yield/Efficiency



PLOT EXAMPLES FROM: Ovaite, S.\*, Mirlitz, S.\*, Seetharaman, S., Barnes, T. PV in the Circular Economy, a dynamic framework analyzing technology evolution and reliability impacts. iScience; 2022. <https://doi.org/10.1016/j.isci.2021.103488>

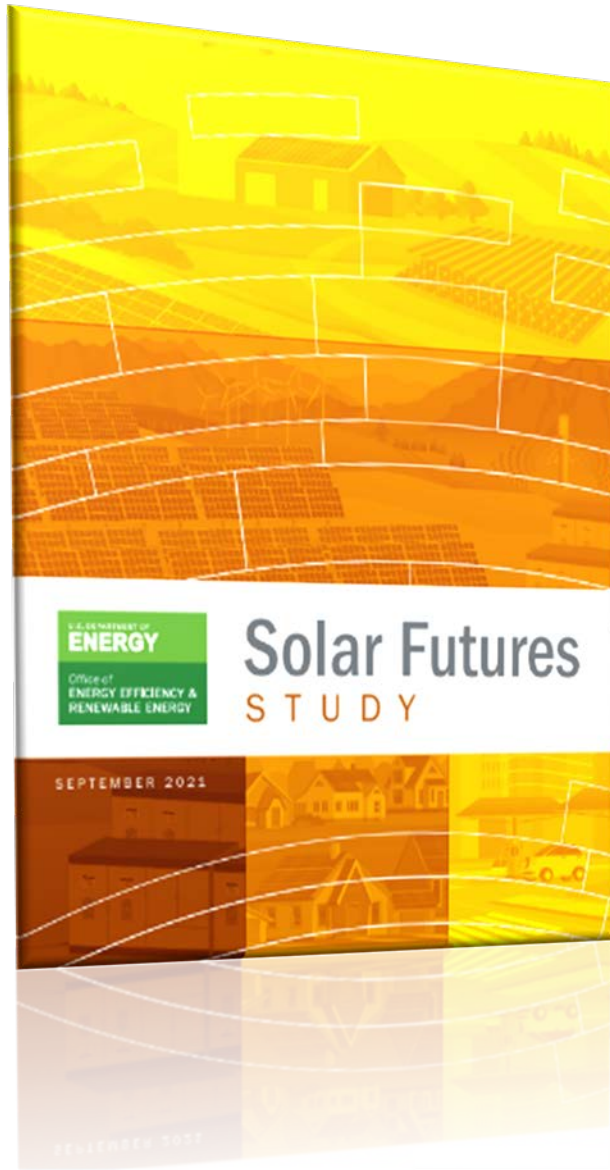


Baseline creation documented on Github Jupyter Journals, and on [1] Ovaite, S.\*, Mirlitz, S.\*, Seetharaman, S., Barnes, T. PV in the Circular Economy, a dynamic framework analyzing technology evolution and reliability impacts. iScience; 2022. <https://doi.org/10.1016/j.isci.2021.103488>

(Or explore/download them from [https://openei.org/wiki/PV\\_ICE](https://openei.org/wiki/PV_ICE))



# Open Science



- Journals for reproducing publication results  
[https://github.com/NREL/PV\\_ICE/tree/main/docs/tutorials](https://github.com/NREL/PV_ICE/tree/main/docs/tutorials)
- Solar Futures
  - U.S. Department of Energy. Solar Futures Study. September 2021. <https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf>
  - Heath, Garvin, Ravikumar, D., Ovaitt, S. Walston, L., Curtis, T., Millstein, D., Mirletz, H., Hartmann, H., McCall, J. Environmental and Circular Economy Implications of Solar Energy in Decarbonized U.S. Grid. 2022 Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-80818. <https://www.nrel.gov/docs/fy22osti/80818.pdf>.
- Photovoltaic Specialists Conference
  - Ovaitt, S., Mirletz, H., Hegedus, A., Gaulding, A. Barnes, T. PV Evolution in the light of Circular Economy. 48<sup>th</sup> IEEE PVSC Conference, June 2021. <https://doi.org/10.1109/PVSC43889.2021.9518683> or <https://www.nrel.gov/docs/fy21osti/78989.pdf>
- MRS Presentation / NREL Poster with Agent-Based Model data
  - Hegedus, A, Ovaitt, S, Walzberg, J., Mirletz, H, Barnes, T. Evaluating material circular efficacy of waste-management scenarios using PV ICE (PV in the Circular Economy Tool). Poster presented at the 2021 SULI Internship Poster Session at NREL. <https://www.nrel.gov/docs/fy21osti/80715.pdf>



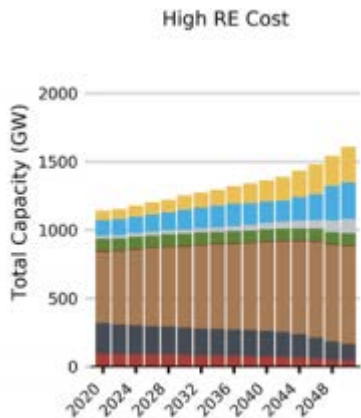
# Open Science



## PV ICE's Integrated NREL Circular Approach



NEW INSTALLS



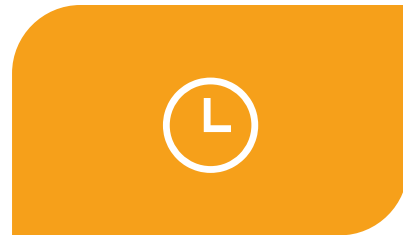
ReEDS



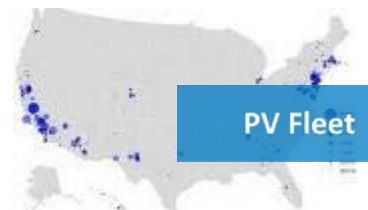
MANUFACTURING



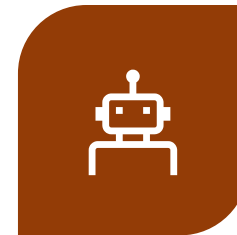
MFI



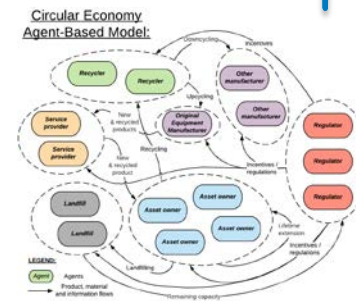
INSTALLED CAPACITY AND  
EXTENDED USEFUL LIFE



PV Fleet



EOL  
MODES



Walzberg's Agent-  
Based Model



CIRCULAR  
PATHWAYS

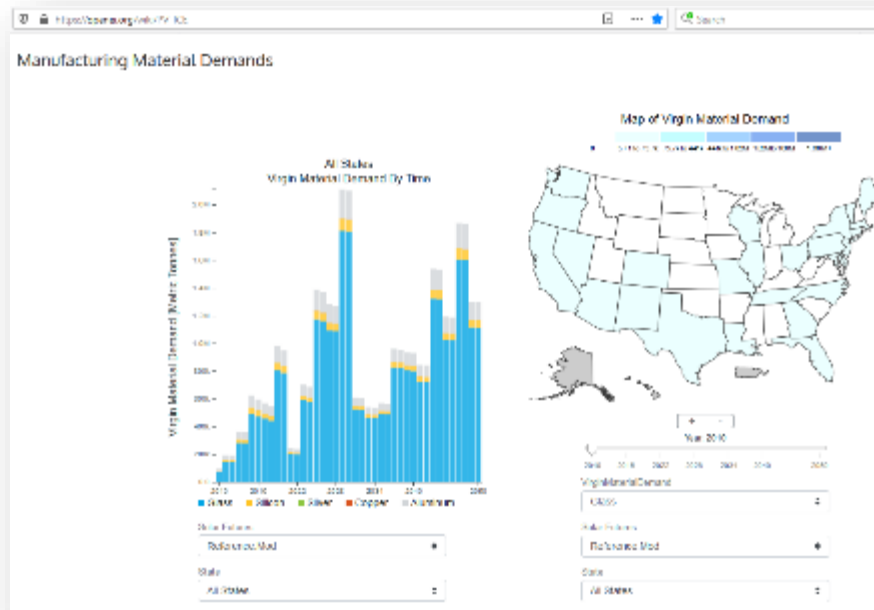


CELAVI Landfill  
calculation approach

# Accessibility

## Open EI Webpages

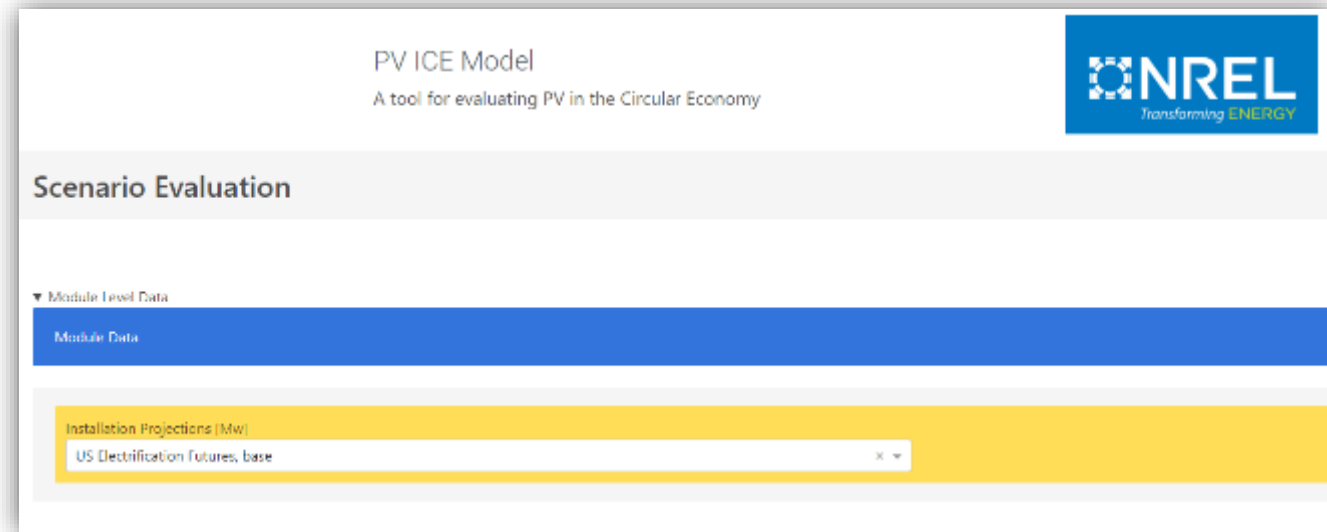
Dynamically explore the baselines and data generated from PV ICE analyses



[https://openei.org/wiki/PV\\_ICE](https://openei.org/wiki/PV_ICE)  
[https://openei.org/wiki/PVSC\\_PVICE](https://openei.org/wiki/PVSC_PVICE)

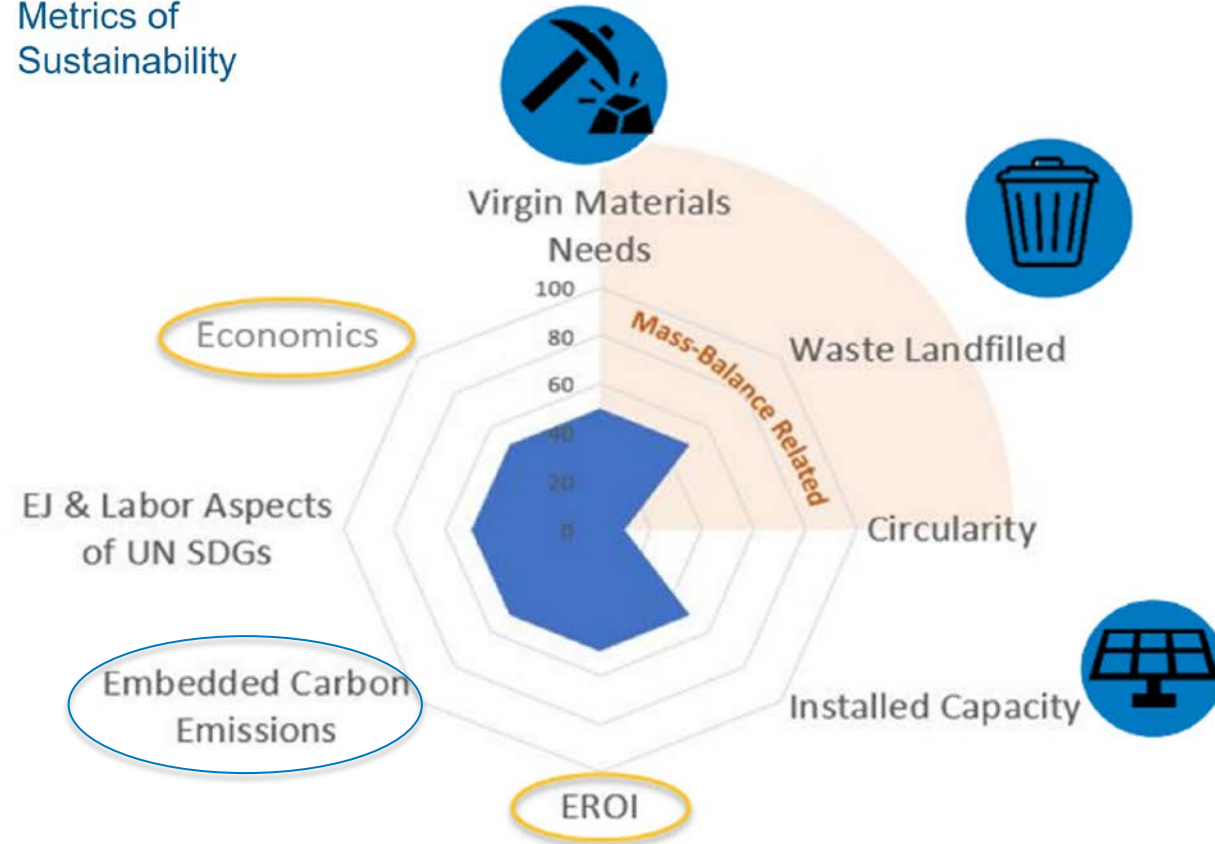
## Visual Interface

In the Works 😊



# Future Work

Metrics of Sustainability



# Thank you

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[www.nrel.gov](http://www.nrel.gov)

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[https://github.com/NREL/PV\\_ICE](https://github.com/NREL/PV_ICE)

NREL/PR-5K00-82146

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