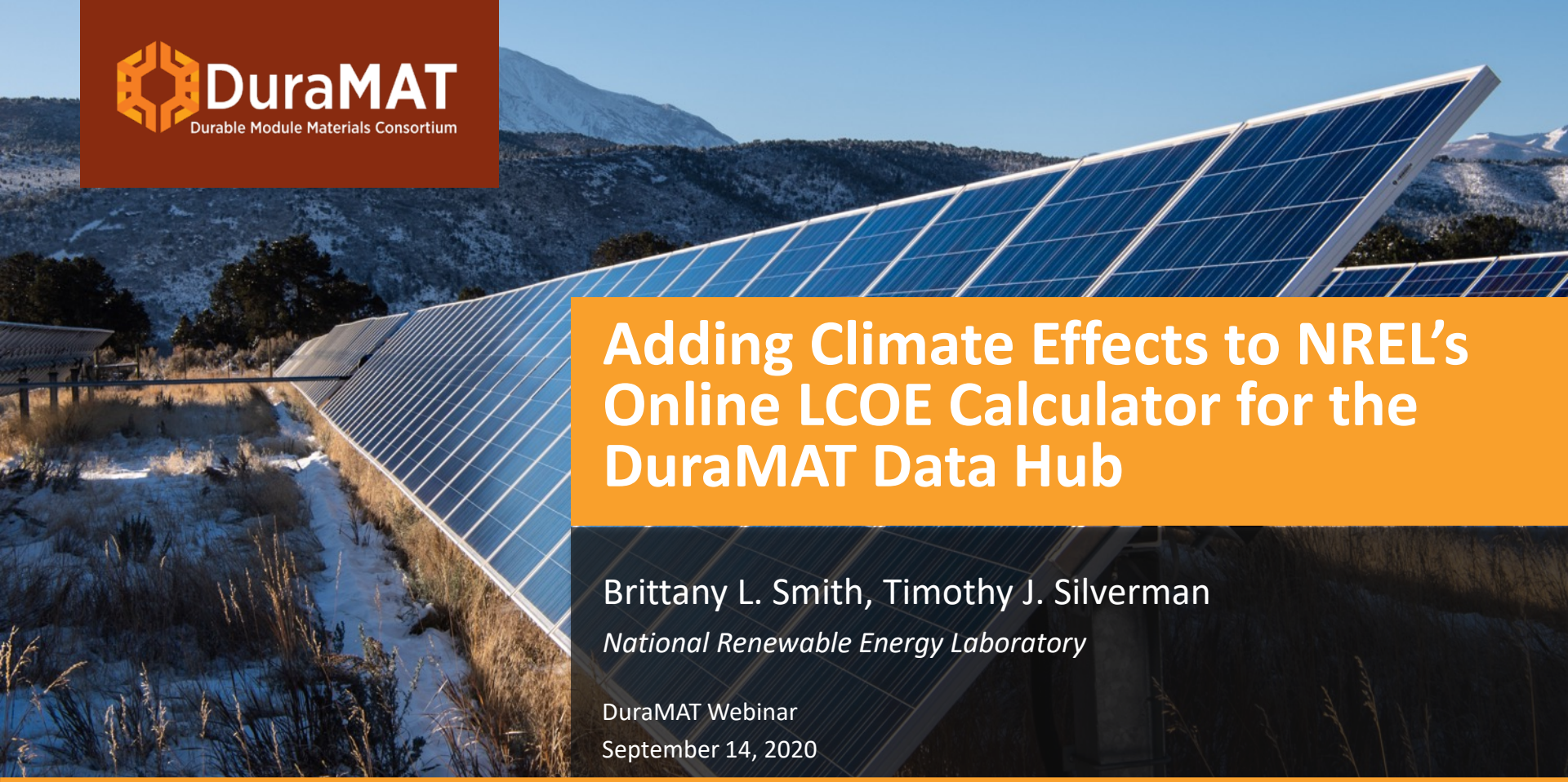


DuraMAT
Durable Module Materials Consortium

Adding Climate Effects to NREL's Online LCOE Calculator for the DuraMAT Data Hub

Brittany L. Smith, Timothy J. Silverman
National Renewable Energy Laboratory

DuraMAT Webinar
September 14, 2020

Energy Materials Network
U.S. Department of Energy

NREL

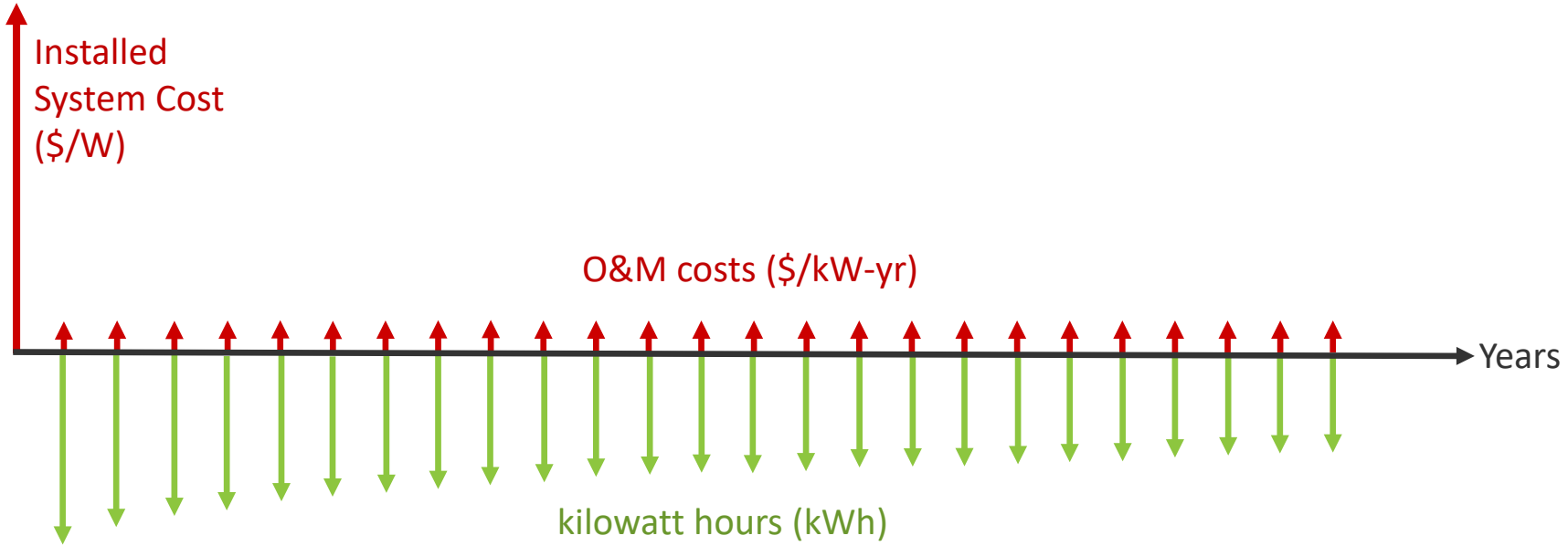
Sandia National Laboratories

BERKELEY LAB

SLAC NATIONAL ACCELERATOR LABORATORY

Levelized Cost of Energy

$$\text{LCOE (\$/kWh)} = \frac{\text{Total Costs over Service Life (\$)}}{\text{Total Energy Produced over Service Life (kWh)}}$$



LCOE Calculation Option: SAM

System Advisor Model (SAM): https://sam.nrel.gov/

+ Different financial models
+ Detailed options for module and system designs
+ Can model solar + storage
– Learning curve
– Difficult to quickly evaluate research directions without potentially introducing confounding factors

Simplified PV-Specific Calculator

http://pvlcoe.nrel.gov/

- Available online since 2018

https://github.com/NREL/PVLCOE

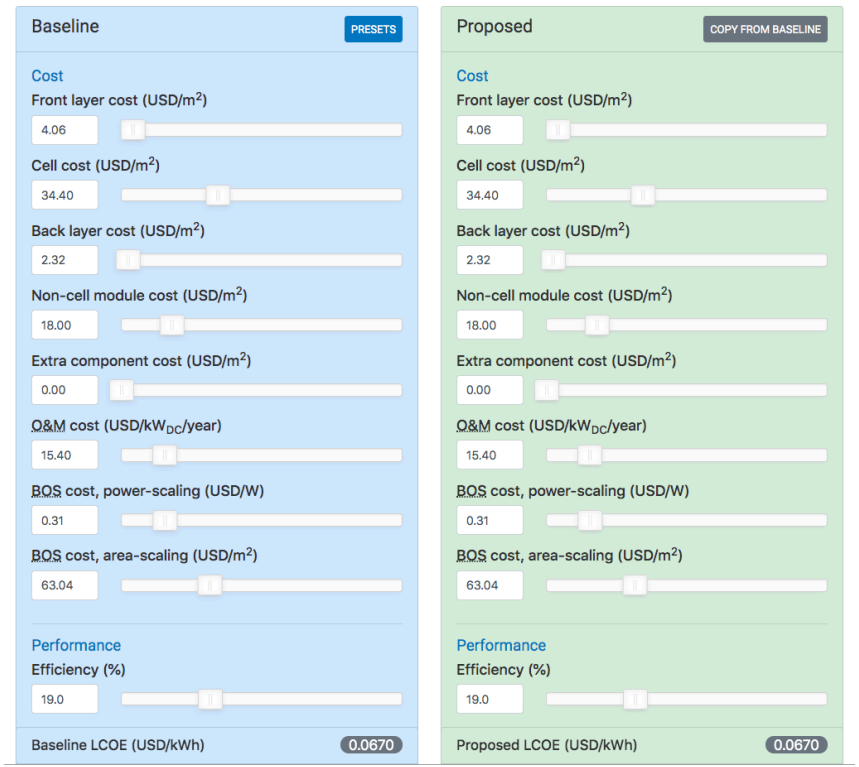
- Source code on GitHub since July 2020

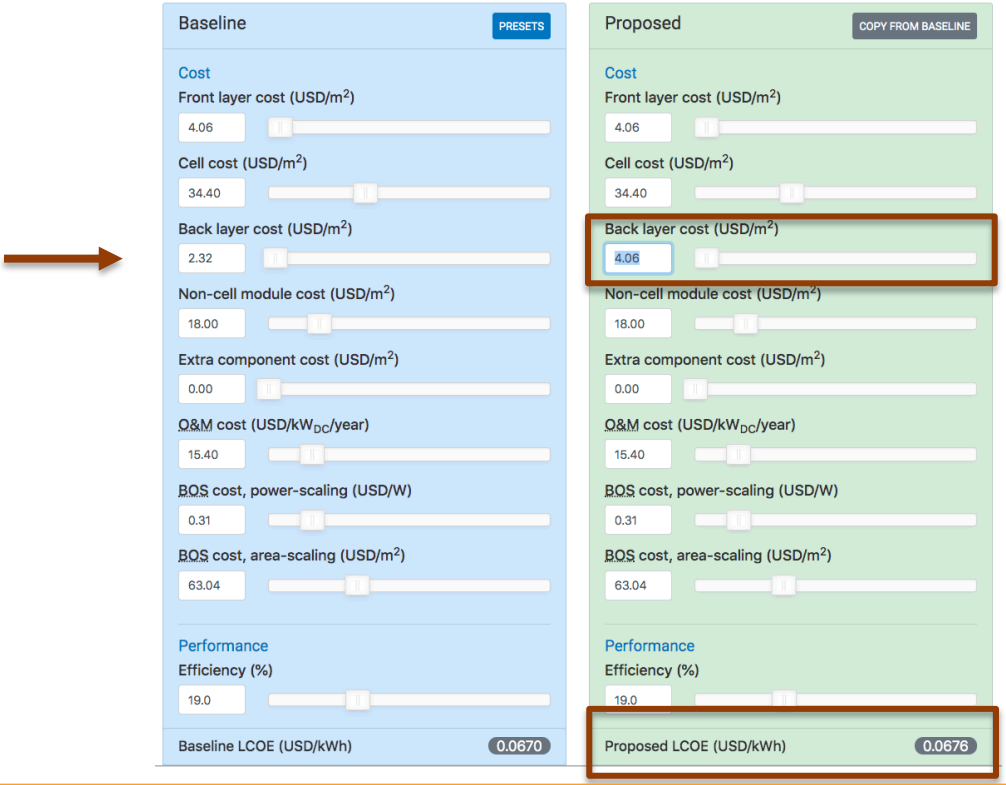
https://www.nrel.gov/analysis/solar-levelized-cost.html

- Tutorial on calculator use, online 9/15/20

Simplified PV-Specific Calculator

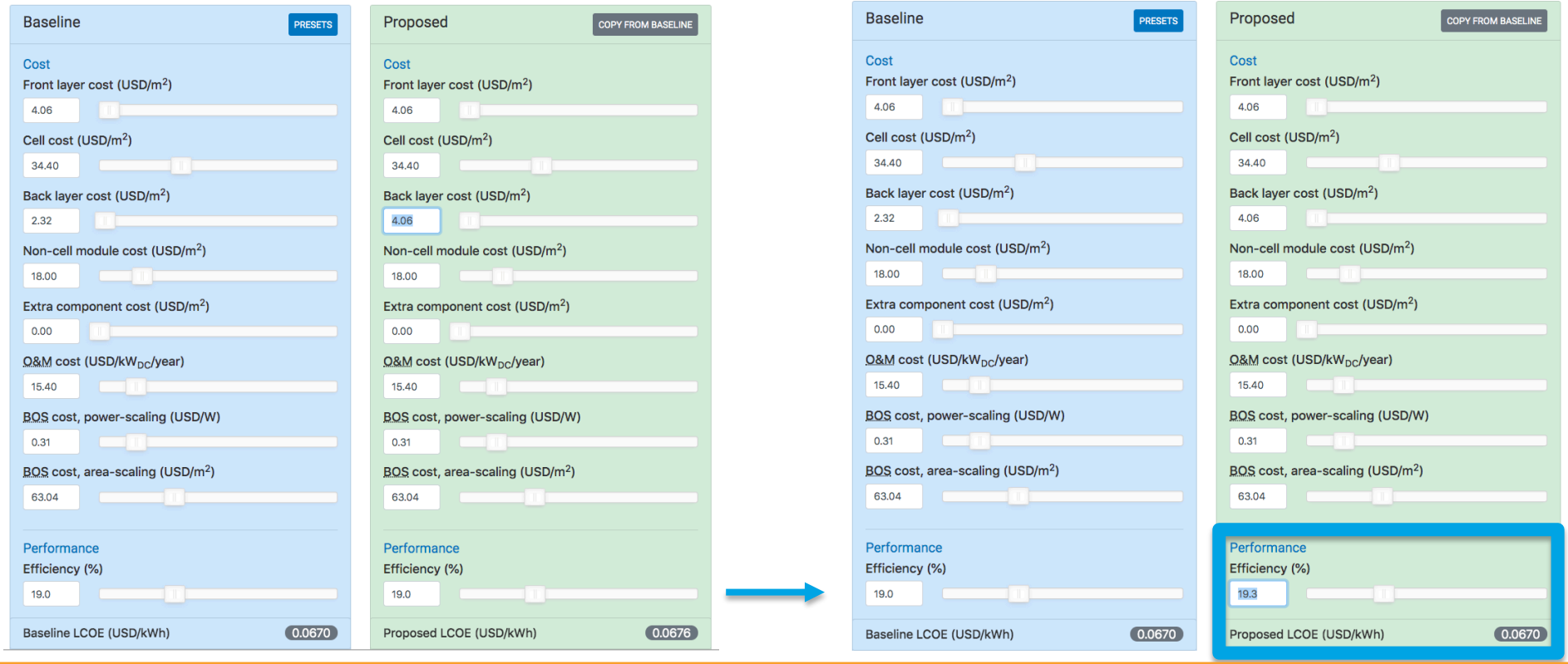
If you make a module bifacial....



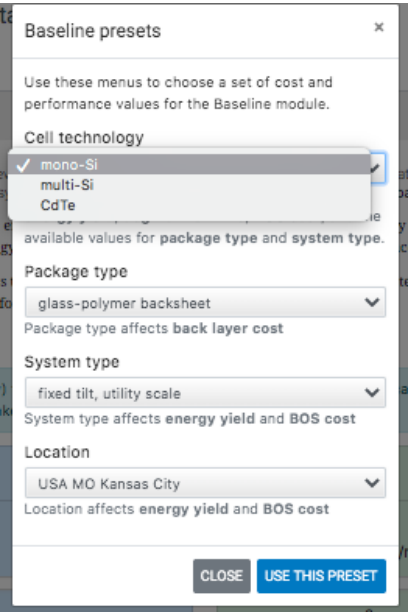


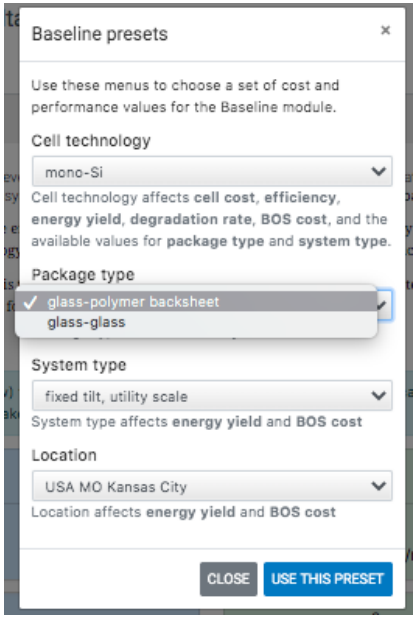
Simplified PV-Specific Calculator

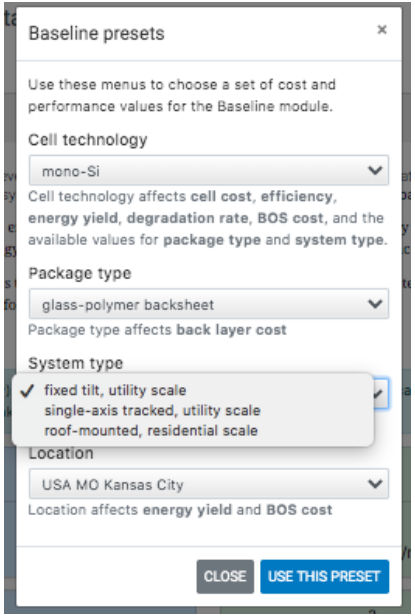
How efficient should it be to break even?

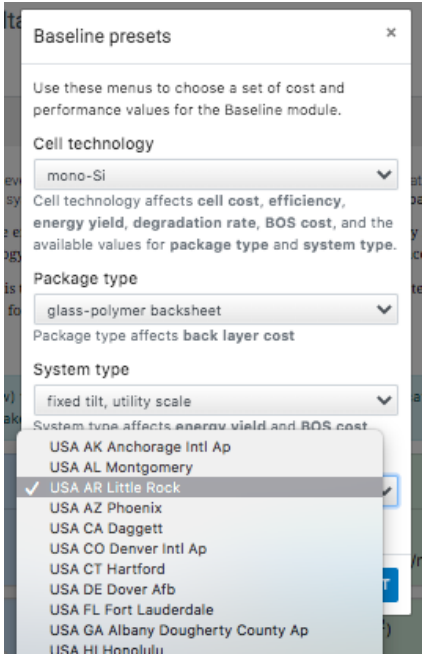


System Options

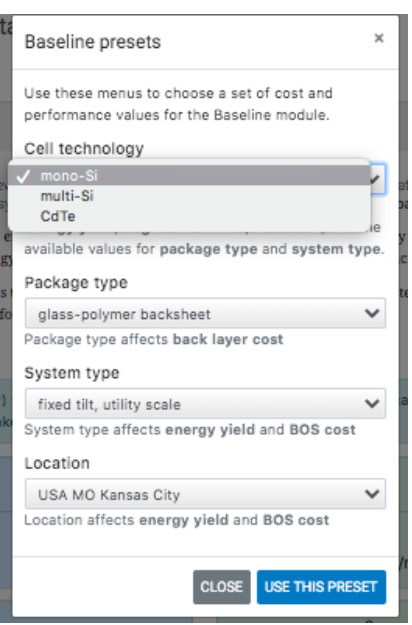


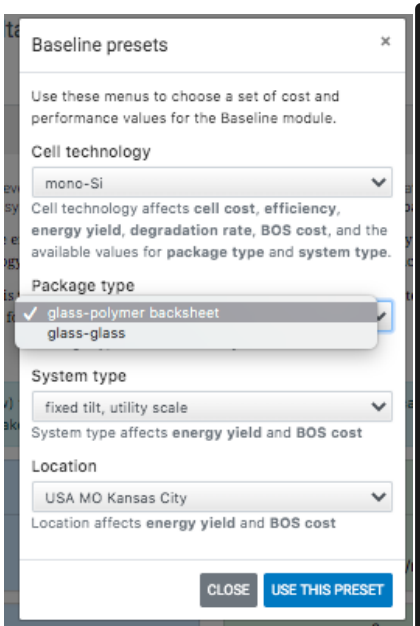


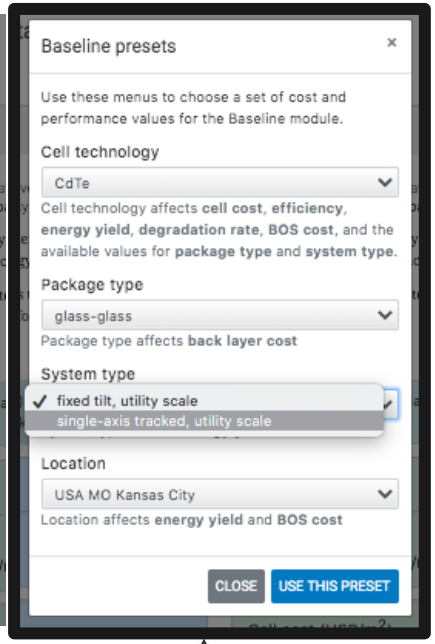


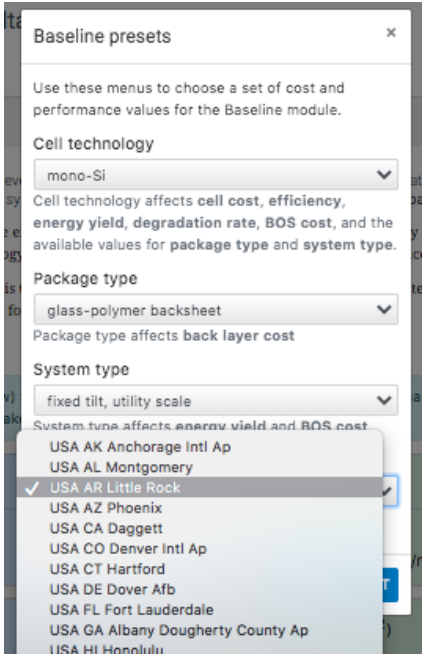


System Options









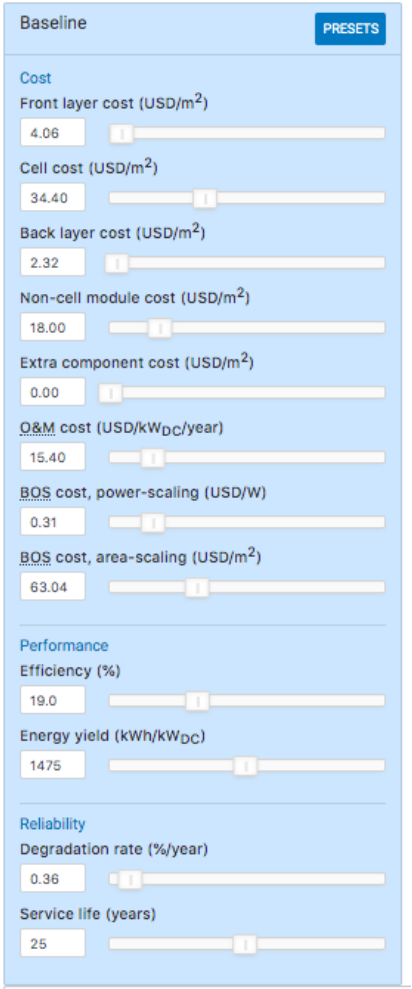
Certain selections limit which other options are available

Preset Default Values

Default values pre-populate based on your drop-down selections, but values can be adjusted.

Currently,

- Cell technology affects:
  - **cell cost**
  - **efficiency**
  - **energy yield**
  - **degradation rate**
  - **BOS cost**
  - available options for **package type** and **system type**
- Package type affects: **back layer cost**
- System type affects: **energy yield** and **BOS cost**
- Location affects: **energy yield** and **BOS cost**



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Currently,

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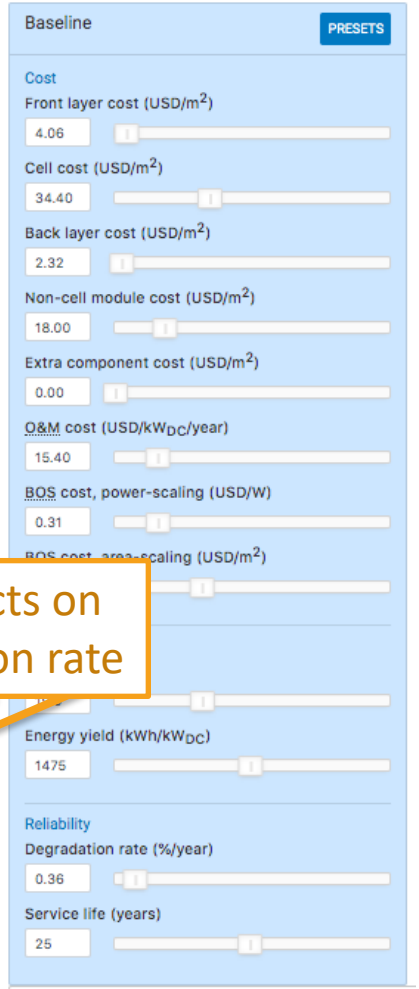
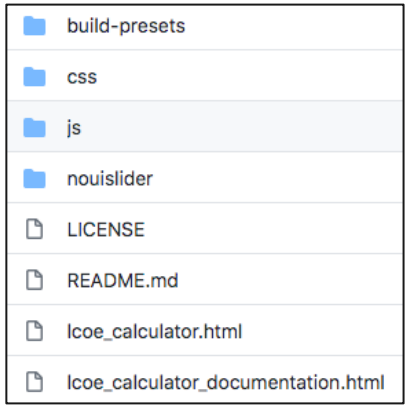
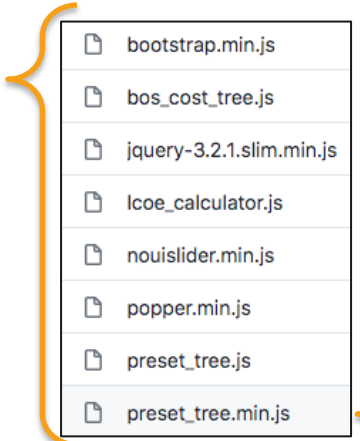


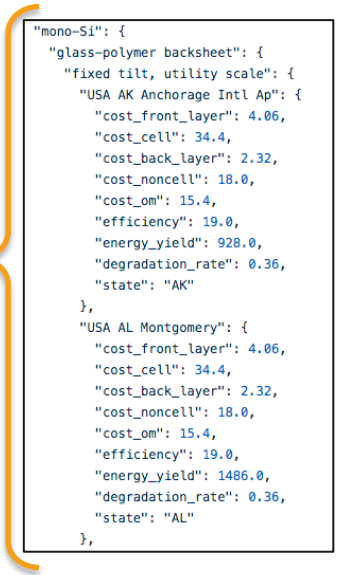
Add effects on degradation rate

Where to Update Default Values

Here's how the GitHub repository is organized:

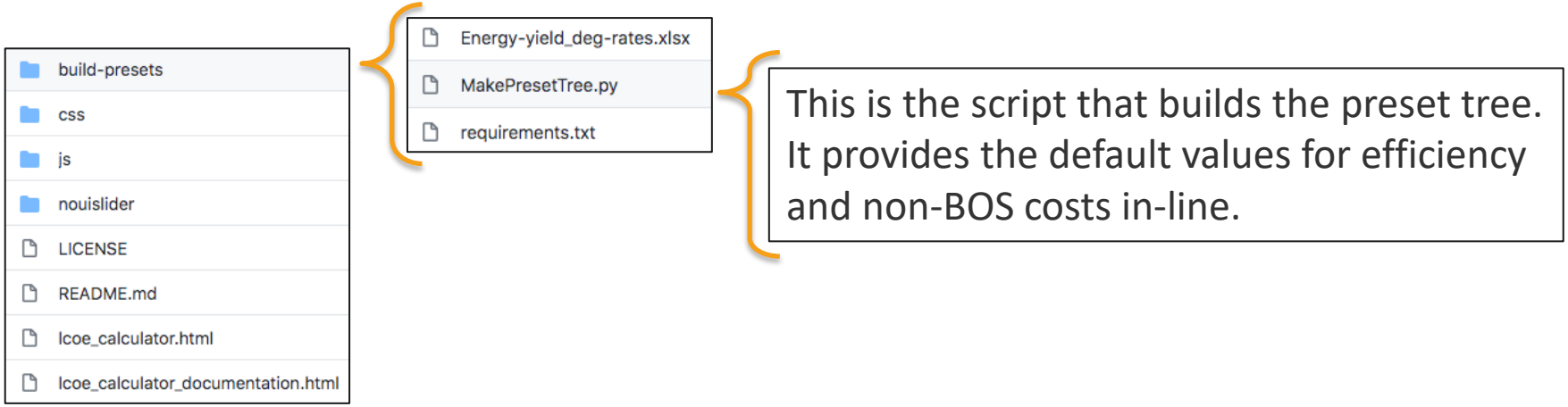






Most default values are called from the preset tree, which looks basically like this →
(except BOS costs, which are called from the bos_cost_tree)

How to Update Default Values



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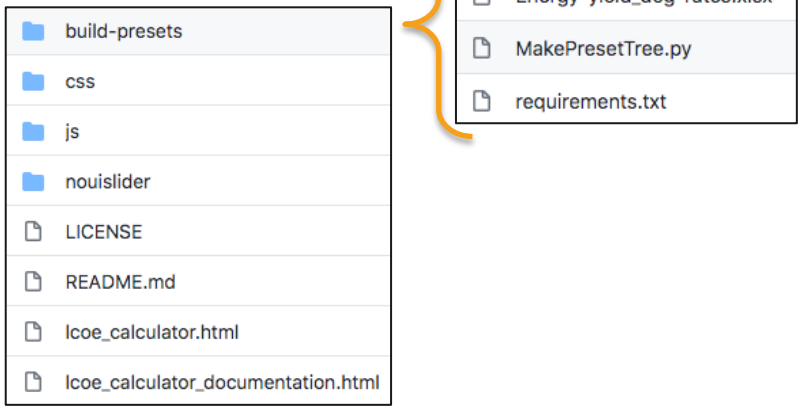
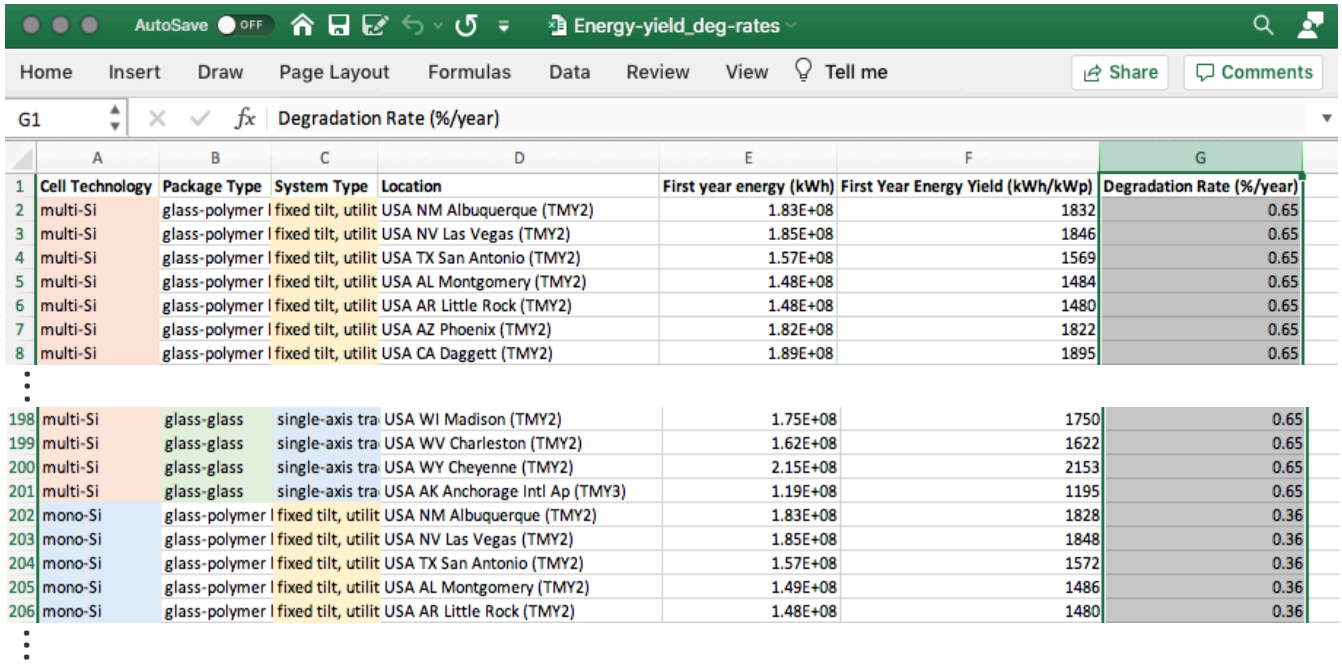


This provides the default values for energy yield and degradation rates (previously, only energy yield)

How to Update Default Values



	A	B	C	D	E	F	G
1	Cell Technology	Package Type	System Type	Location	First year energy (kWh)	First Year Energy Yield (kWh/kWp)	Degradation Rate (%/year)
2	multi-Si	glass-polymer l	fixed tilt, utilit	USA NM Albuquerque (TMY2)	1.83E+08	1832	0.65
3	multi-Si	glass-polymer l	fixed tilt, utilit	USA NV Las Vegas (TMY2)	1.85E+08	1846	0.65
4	multi-Si	glass-polymer l	fixed tilt, utilit	USA TX San Antonio (TMY2)	1.57E+08	1569	0.65
5	multi-Si	glass-polymer l	fixed tilt, utilit	USA AL Montgomery (TMY2)	1.48E+08	1484	0.65
6	multi-Si	glass-polymer l	fixed tilt, utilit	USA AR Little Rock (TMY2)	1.48E+08	1480	0.65
7	multi-Si	glass-polymer l	fixed tilt, utilit	USA AZ Phoenix (TMY2)	1.82E+08	1822	0.65
8	multi-Si	glass-polymer l	fixed tilt, utilit	USA CA Daggett (TMY2)	1.89E+08	1895	0.65
⋮							
198	multi-Si	glass-glass	single-axis tra	USA WI Madison (TMY2)	1.75E+08	1750	0.65
199	multi-Si	glass-glass	single-axis tra	USA WV Charleston (TMY2)	1.62E+08	1622	0.65
200	multi-Si	glass-glass	single-axis tra	USA WY Cheyenne (TMY2)	2.15E+08	2153	0.65
201	multi-Si	glass-glass	single-axis tra	USA AK Anchorage Intl Ap (TMY3)	1.19E+08	1195	0.65
202	mono-Si	glass-polymer l	fixed tilt, utilit	USA NM Albuquerque (TMY2)	1.83E+08	1828	0.36
203	mono-Si	glass-polymer l	fixed tilt, utilit	USA NV Las Vegas (TMY2)	1.85E+08	1848	0.36
204	mono-Si	glass-polymer l	fixed tilt, utilit	USA TX San Antonio (TMY2)	1.57E+08	1572	0.36
205	mono-Si	glass-polymer l	fixed tilt, utilit	USA AL Montgomery (TMY2)	1.49E+08	1486	0.36
206	mono-Si	glass-polymer l	fixed tilt, utilit	USA AR Little Rock (TMY2)	1.48E+08	1480	0.36
⋮							

If updating values for an entire package type or system type, paste & drag might be easiest.

If updating values by location, creating a dictionary and then combining the INDEX and MATCH functions might be best.

...then, run MakePresetTree.py

Climate Effects on Degradation Rate

Jordan, Dirk C., et al. "Compendium of photovoltaic degradation rates." *Progress in Photovoltaics: Research and Applications* 24.7 (2016): 978-989

- 4 climate categories, but differences between degradation rates are not statistically significant
- Module and system degradation rates are each present in the data and are not analyzed separately when comparing climate categories

Deceglie, Michael G., et al. "Fleet-scale energy-yield degradation analysis applied to hundreds of residential and nonresidential photovoltaic systems." *IEEE Journal of Photovoltaics* 9.2 (2019): 476-482

- Shows statistically significant dependence of degradation rate on average temperature

Adding New System Options

edit MakePresetTree.py

```python

# %% Define feasible system configurations
cell_technologies = ['mono-Si', 'multi-Si', 'CdTe']

package_types = {
    'mono-Si': ('glass-polymer backsheet', 'glass-glass'),
    'multi-Si': ('glass-polymer backsheet', 'glass-glass'),
    'CdTe': ('glass-glass', )
}

system_types = {
    'mono-Si': ('fixed tilt, utility scale', 'single-axis tracked, utility scale', 'roof-mounted, residential scale'),
    'multi-Si': ('fixed tilt, utility scale', 'single-axis tracked, utility scale'),
    'CdTe': ('fixed tilt, utility scale', 'single-axis tracked, utility scale')
}


# %% Preset values for module parameters: costs are in USD per square meter, efficiency reported as a percentage
module_details = {
    'cost_front_layer': 4.06,
    'cost_cell': {'mono-Si': 34.4, 'multi-Si': 31.45, 'CdTe': 30},
    'cost_back_layer': {'glass-polymer backsheet': 2.32, 'glass-glass': 3},
    'cost_noncell': 18.,
    'efficiency': {'mono-Si': 19.0, 'multi-Si': 17.0, 'CdTe': 16.0},
}
```

```python

# %% Define feasible system configurations
cell_technologies = ['mono-Si', 'multi-Si', 'CdTe', 'perovskite']

package_types = {
    'mono-Si': ('glass-polymer backsheet', 'glass-glass'),
    'multi-Si': ('glass-polymer backsheet', 'glass-glass'),
    'CdTe': ('glass-glass', ),
    'perovskite': ('glass-glass','polymer-polymer')
}

system_types = {
    'mono-Si': ('fixed tilt, utility scale', 'single-axis tracked, utility scale', 'roof-mounted, residential scale'),
    'multi-Si': ('fixed tilt, utility scale', 'single-axis tracked, utility scale'),
    'CdTe': ('fixed tilt, utility scale', 'single-axis tracked, utility scale'),
    'perovskite': ('fixed tilt, utility scale', 'single-axis tracked, utility scale', 'roof-mounted, residential scale')
}


# %% Preset values for module parameters: costs are in USD per square meter, efficiency reported as a percentage
module_details = {
    'cost_front_layer': {'glass-polymer backsheet': 4.06, 'glass-glass': 4.06, 'polymer-polymer': 20},
    'cost_cell': {'mono-Si': 34.4, 'multi-Si': 31.45, 'CdTe': 30, 'perovskite': 20},
    'cost_back_layer': {'glass-polymer backsheet': 2.32, 'glass-glass': 3, 'polymer-polymer': 2.32},
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```

Adding New System Options

edit MakePresetTree.py

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    'cost_back_layer': {'glass-polymer backsheet': 2.32, 'glass-glass': 3, 'polymer-polymer': 2.32},
    'cost_noncell': 18.,
    'efficiency': {'mono-Si': 19.0, 'multi-Si': 17.0, 'CdTe': 16.0, 'perovskite': 16.0},
}
```

And append
Energy-yield_deg-rates.xlsx

601	CdTe	glass-glass	single-axis tra	USA AK Anchorage Intl Ap (TMY3)	1.22E+08	1220	0.4
602	perovskite	glass-glass	single-axis tracked, utility scale				
603	perovskite	glass-glass	fixed tilt, utilit	USA CO Denver Intl Ap (TMY3)			
604	perovskite	glass-glass	roof-mounted,	USA CO Denver Intl Ap (TMY3)			
605	perovskite	polymer-polym	single-axis tra	USA CO Denver Intl Ap (TMY3)			
606	perovskite	polymer-polym	fixed tilt, utilit	USA CO Denver Intl Ap (TMY3)			
607	perovskite	polymer-polym	roof-mounted,	USA CO Denver Intl Ap (TMY3)			
608							

Future Updates to the Calculator

- Complete update of cost and efficiency data (still 2018 data) once NREL's 2020 PV System Benchmark is out
- Improve "value of efficiency" handling
- Potentially, statistically significant degradation rate updates from PV Fleets data, based on:
  - Climate zones
  - Racking types

Thank You

www.duramat.org