DuraMAT
Durable Module Materials Consortium

Updates to the Instant Online PV LCOE Calculator Tool

Brittany L. Smith
National Renewable Energy Laboratory

DuraMAT Webinar
August 9, 2021

Energy Materials Network
U.S. Department of Energy

NREL

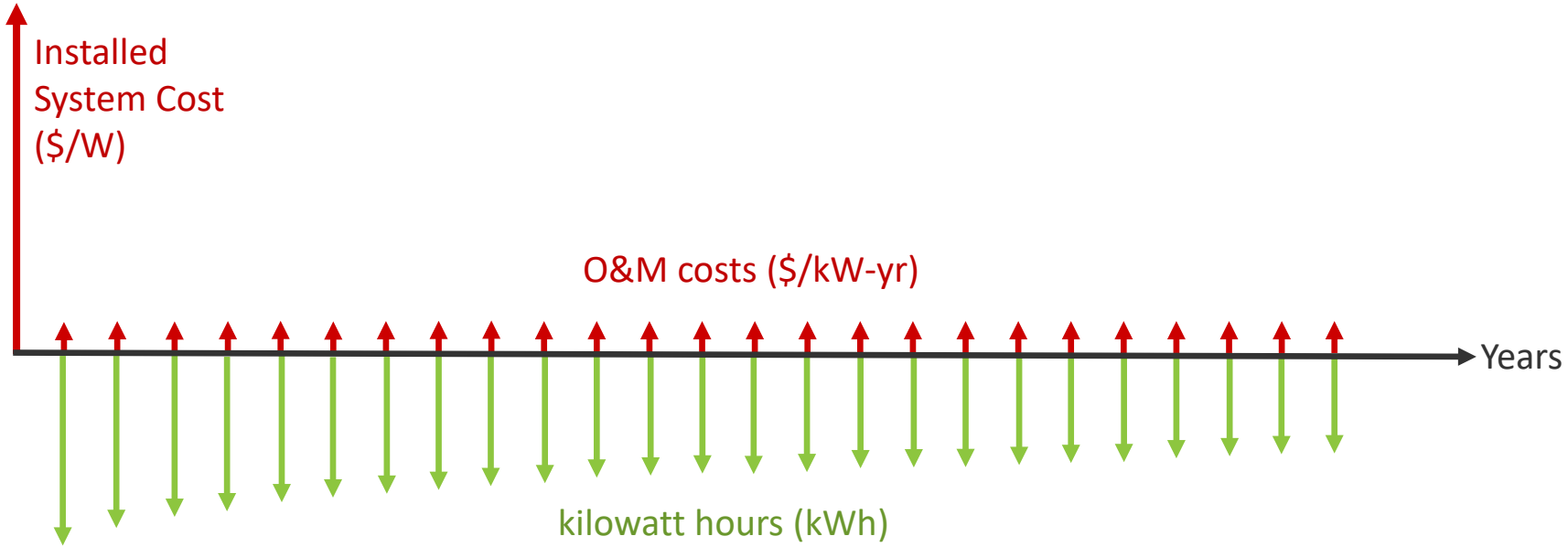
Sandia National Laboratories

BERKELEY LAB

SLAC NATIONAL ACCELERATOR LABORATORY

Levelized Cost of Energy

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



Simplified PV-LCOE Calculator

- PV technology-specific
- Editable preset fields targeted towards research applications
- Instant comparison of proposed changes to a baseline system

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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 introducing confounding factors

Simplified PV-LCOE Calculator

Calculator access:

- pvlcoe.nrel.gov
- nrel.github.io/PVLCOE/
- github.com/NREL/PVLCOE
- datahub.duramat.org/dataset/lcoe-calculator-tool

Previous Calculator Tutorials:

– duramat.org/assets/pdfs/duramat-webinar-sept2020.pdf
– nrel.gov/solar/solar-levelized-cost.html

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Calculator architects:

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Mike Deceglie
Sophie Andrews
Kelsey Horowitz

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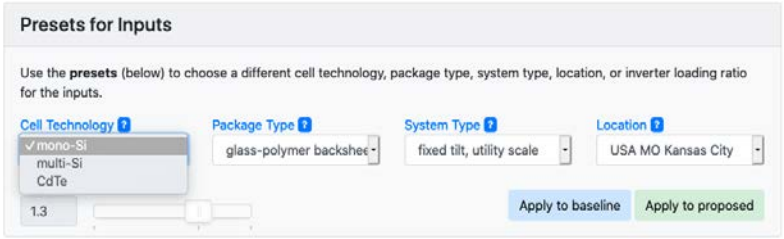
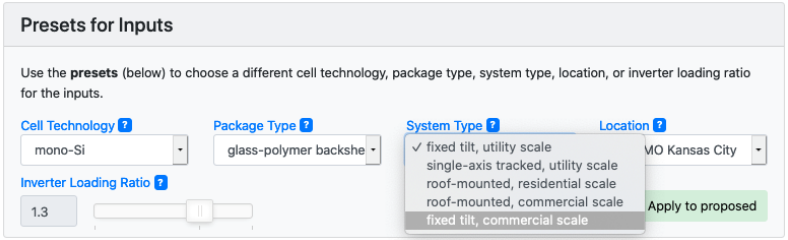
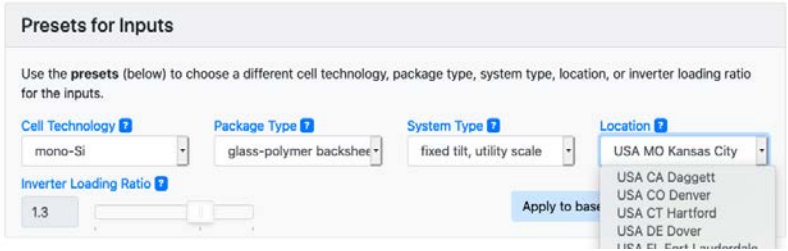
Example Use

Presets Menus







How much could this hypothetical backsheet cost?

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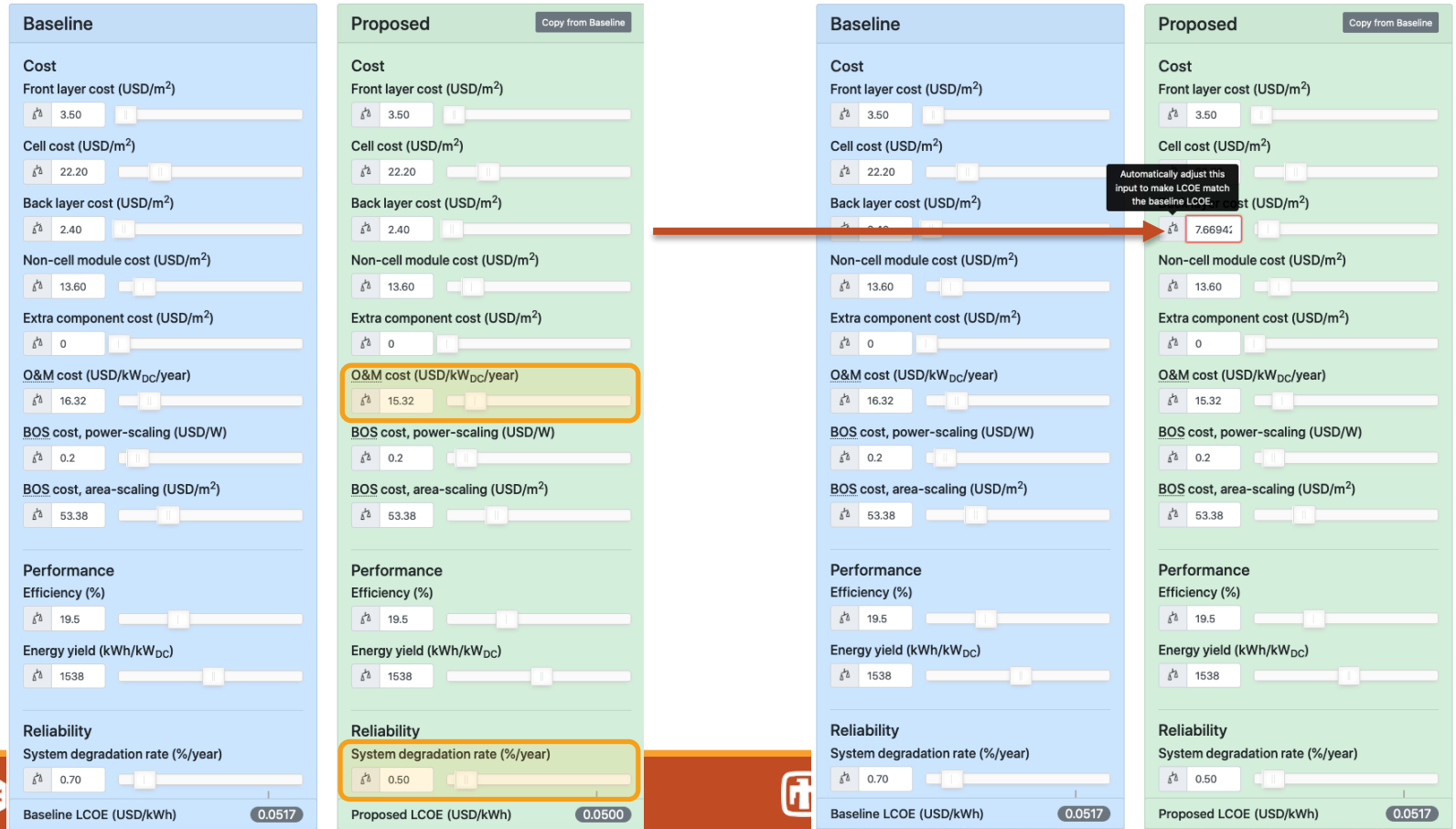
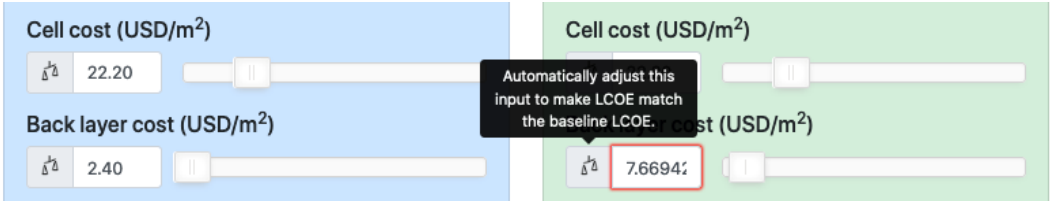


Updates to the Calculator in 2021

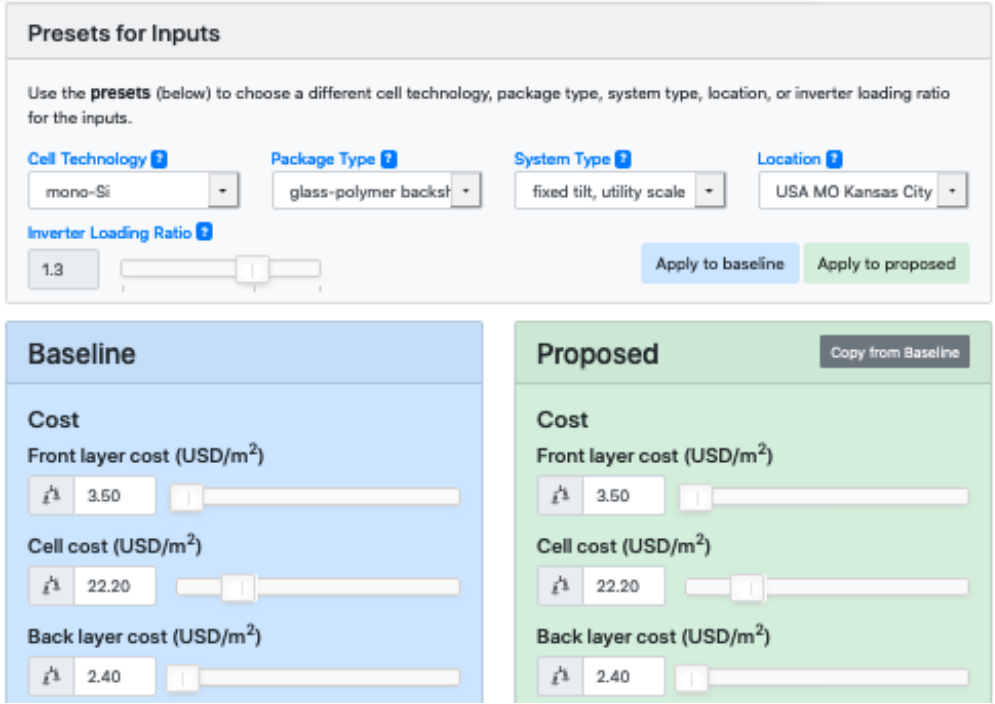
Updated Calculator Features

- Breakeven buttons



Updated Calculator Features

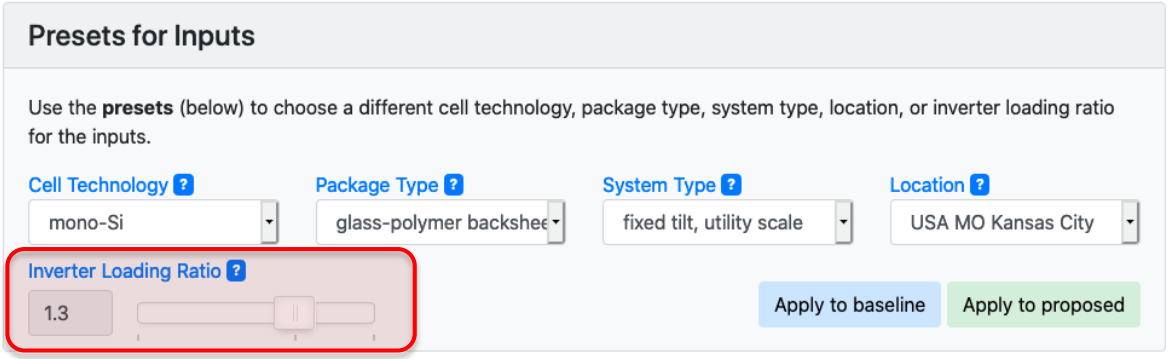
- Breakeven buttons
- Reconfigured preset menu



Updated Calculator Features

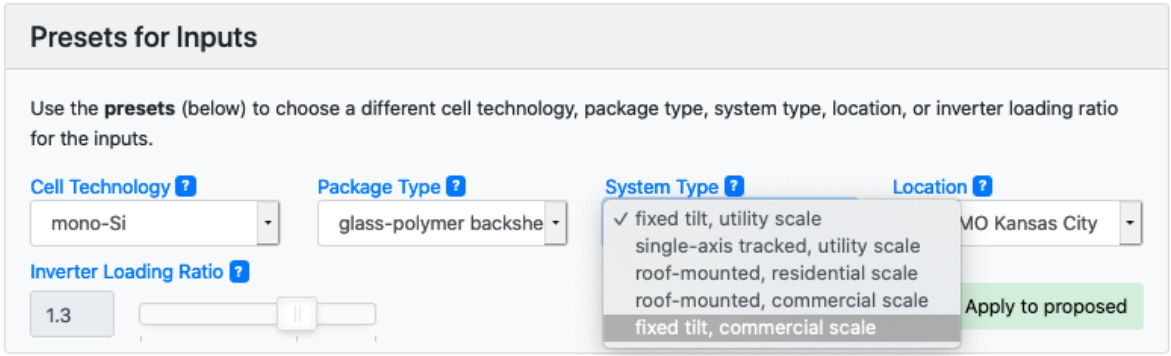
- Breakeven buttons
- Reconfigured preset menu
- Inverter Loading Ratio

Inverter Loading Ratio affects both BOS costs and energy yield



Updated Calculator Features

- Breakeven buttons
- Reconfigured preset menu
- Inverter Loading Ratio
- Commercial system types



Degradation Rate Relationship

Exponential Relationship:

$$e_n = e_{yield}(1-r)^{(n-1)}$$

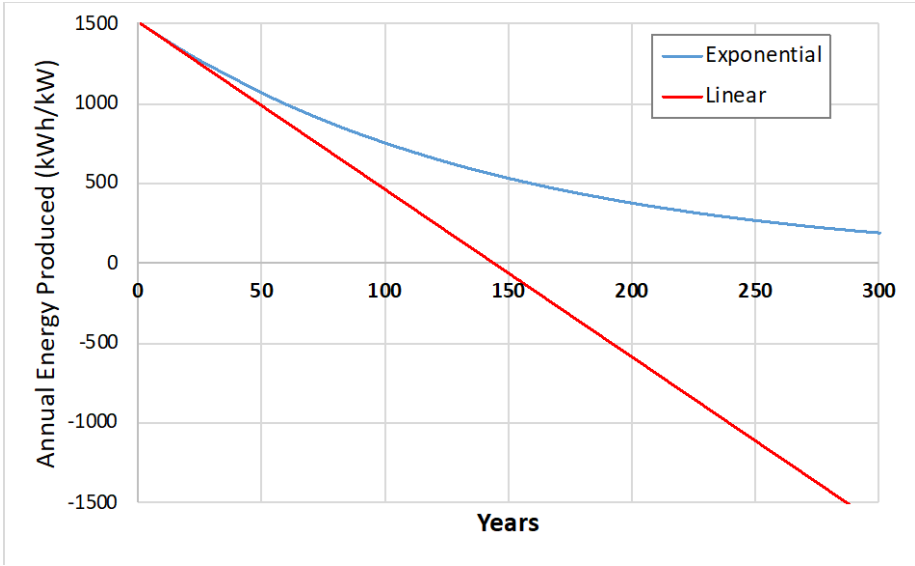
Linear Relationship:

$$e_n = e_{yield}[1-r(n-1)]$$

r is the degradation rate
n is the year of operation
e is the energy produced

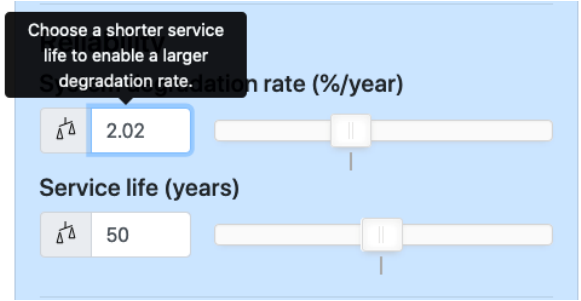
For a system with:

- 0.7% degradation rate
- 1500 kWh/kW first year energy yield



Limits on Numerical Ranges

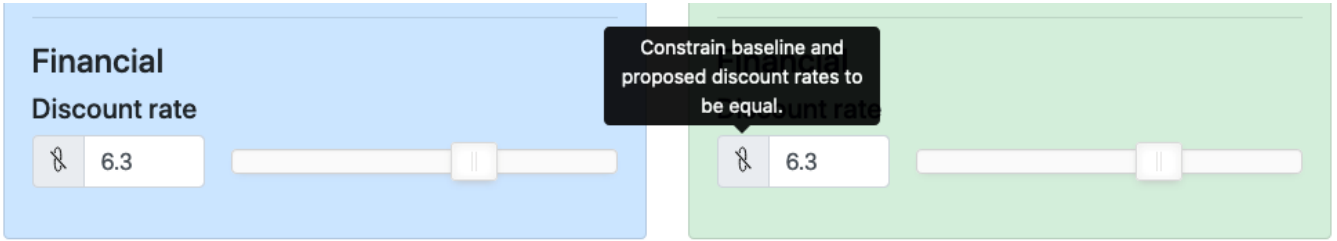
Restricted service life range & added dead zone to slider to keep energy non-negative and prevent continuous costs on a PV system that does not generate energy.



Physically-motivated limits on:

- efficiency (0-100%)
- energy yield > 0
- degradation rate > 0%

Discount Rate Comparison



- Sync / unsync discount rates (instead of breakeven button)

Updated Default Preset Values

Updated from 2017 data:

- System costs
- O&M costs
- Module-level costs
- Module efficiency values

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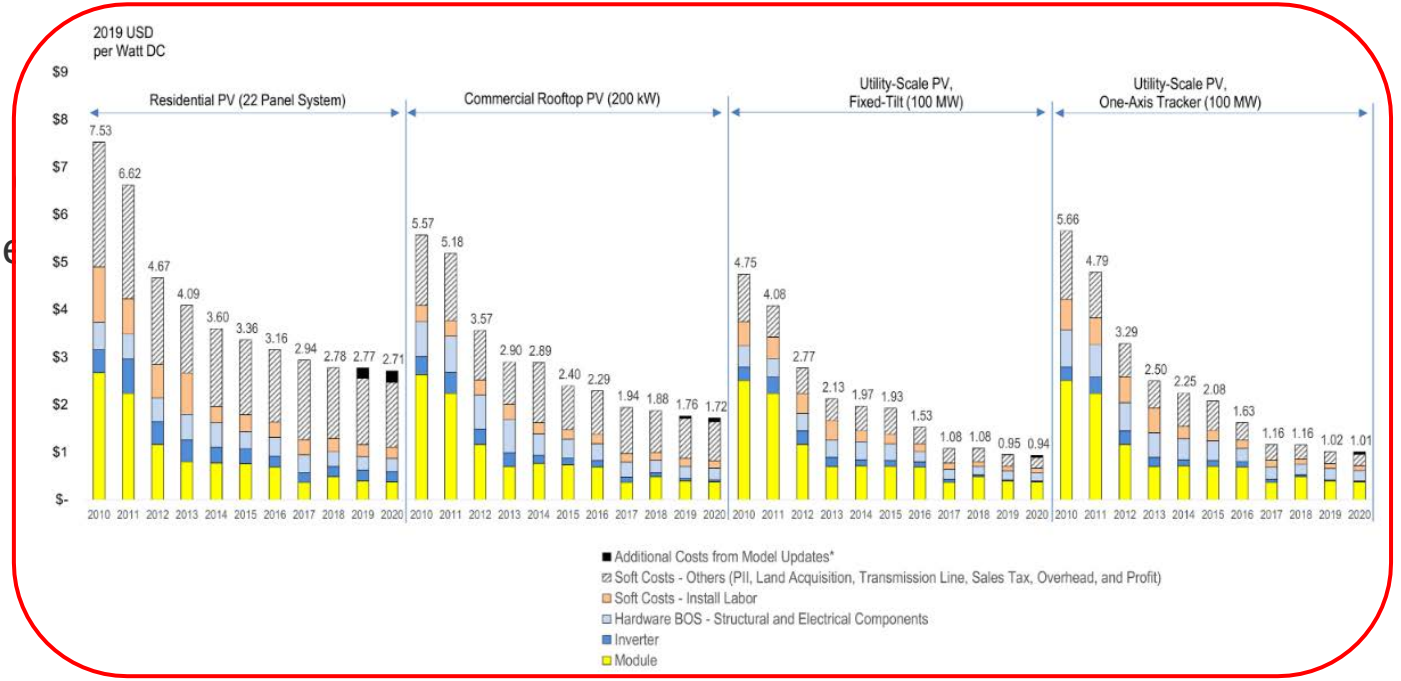
Q1 2020 US PV System Cost Benchmark - nrel.gov/docs/fy21osti/77324.pdf



Also removed BOS cost dependence on location

Updated Default Preset Values

Updated from 2017 data:

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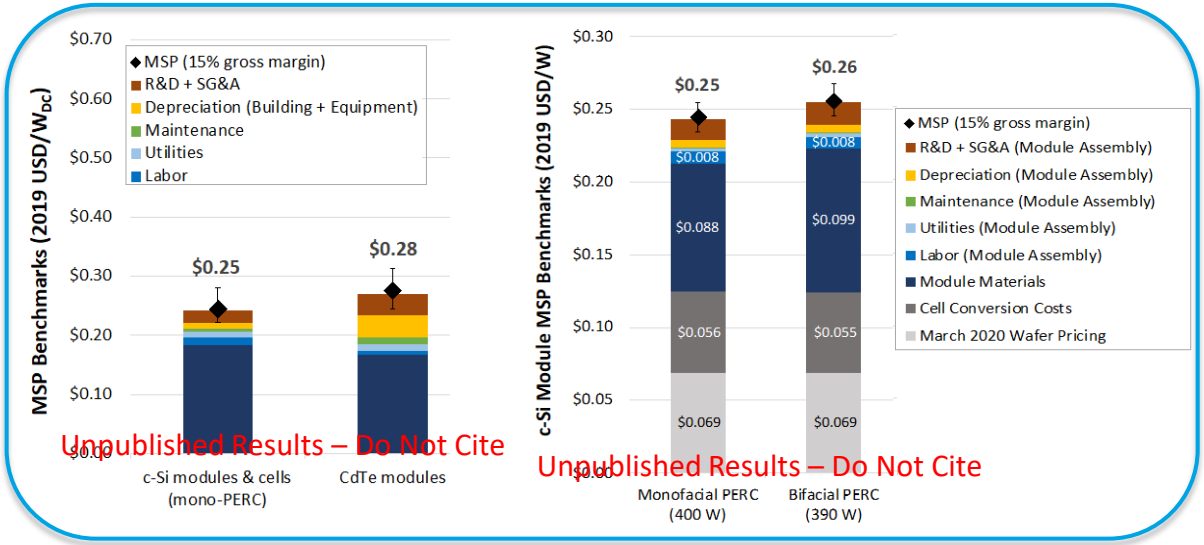
- Module-level costs
- Module efficiency values

2020 Module Cost Benchmark Report, Forthcoming



Energy Yield Values called directly from SAM

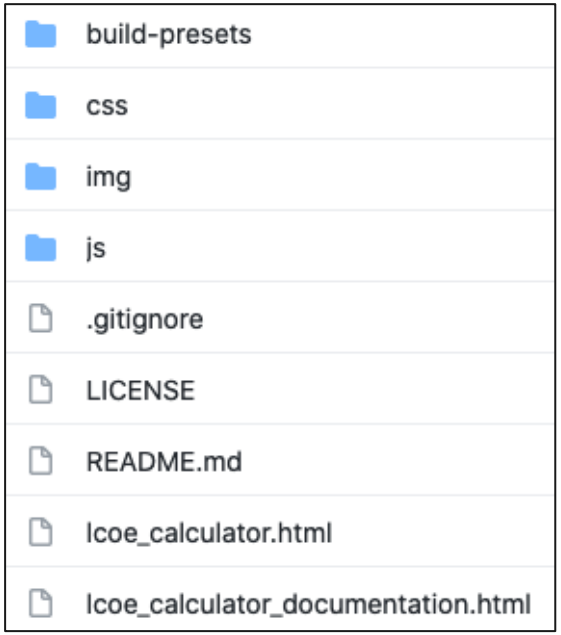
Previously, the calculator relied on a table of energy yield values built manually from SAM using the “Detailed PV Model”

Now, PySAM package is used by calculator to call SAM directly. Relies on:

- PVWatts model
- NSRDB weather data

Customize a Local Version of the Calculator

GitHub Repository Structure



github.com/NREL/PVLCOE

GitHub Repository Structure

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- js
- .gitignore
- LICENSE
- README.md
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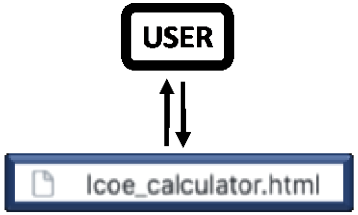
- lcoe_calculator_documentation.html



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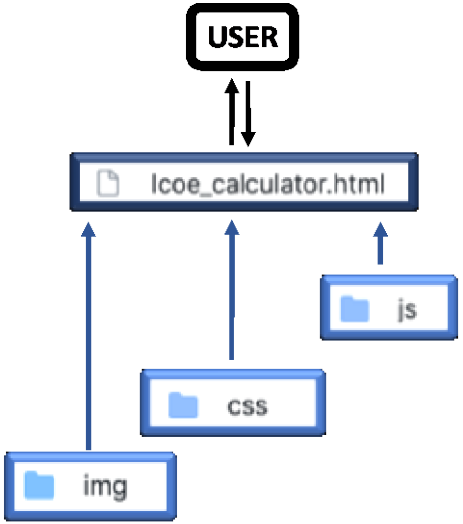

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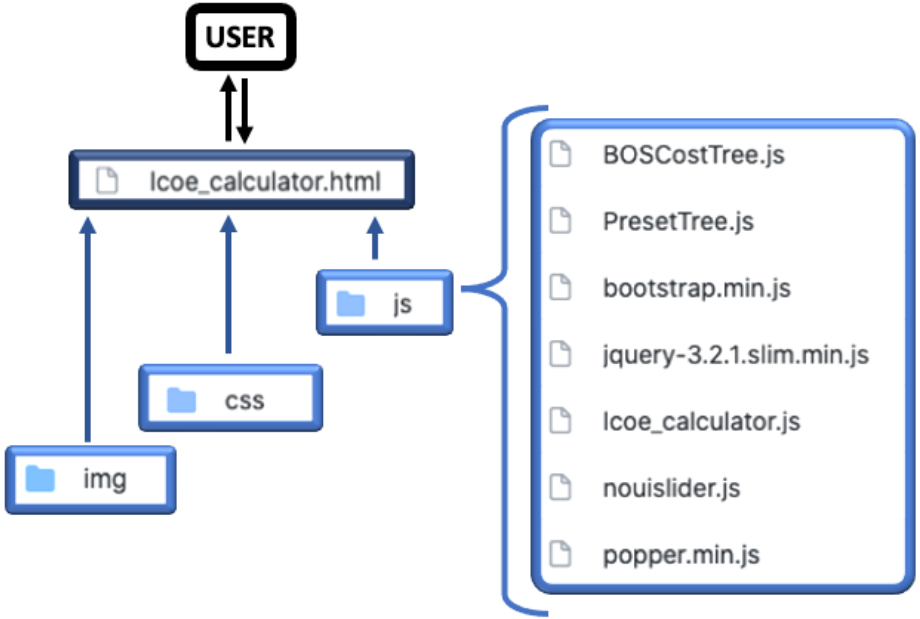

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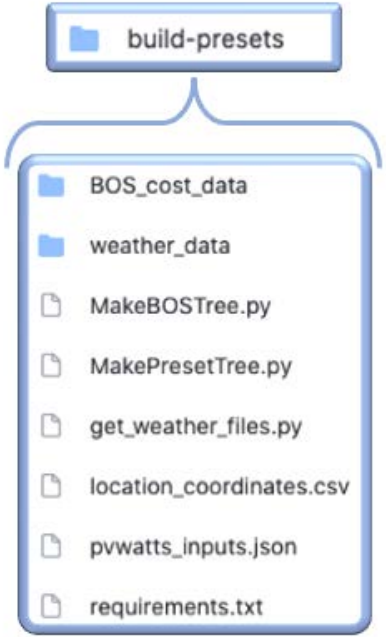

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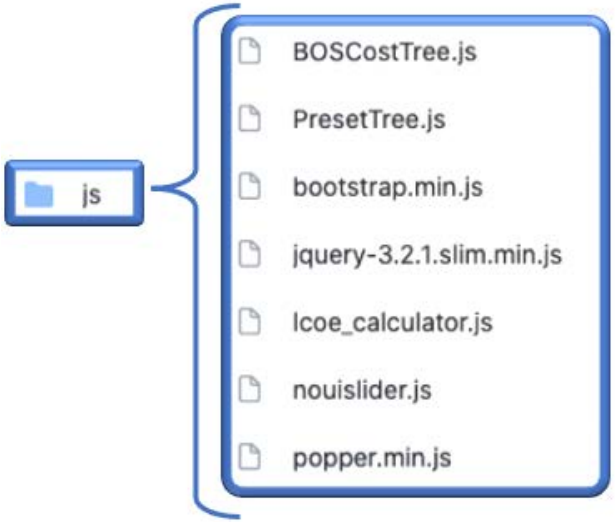

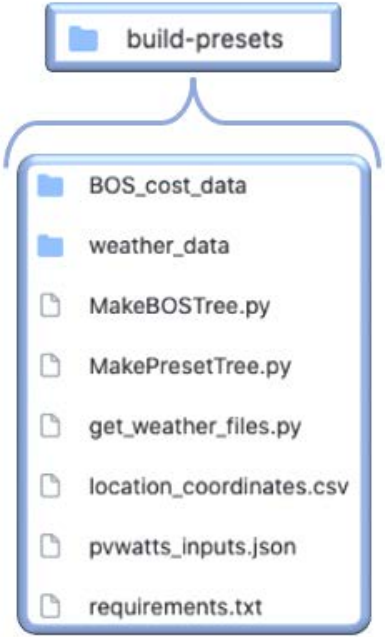

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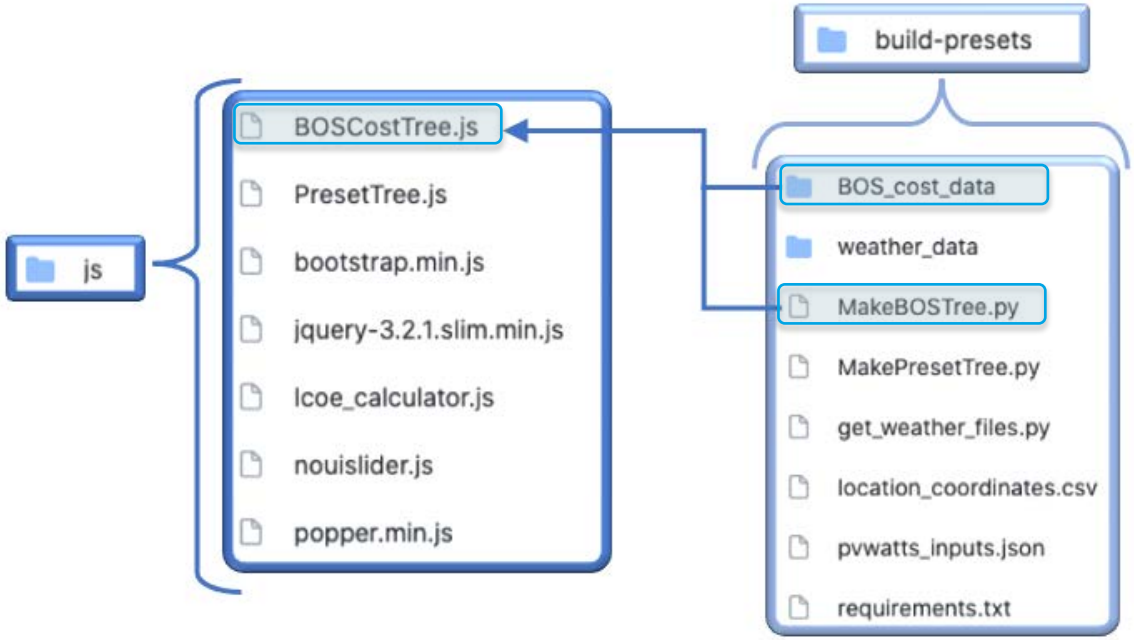

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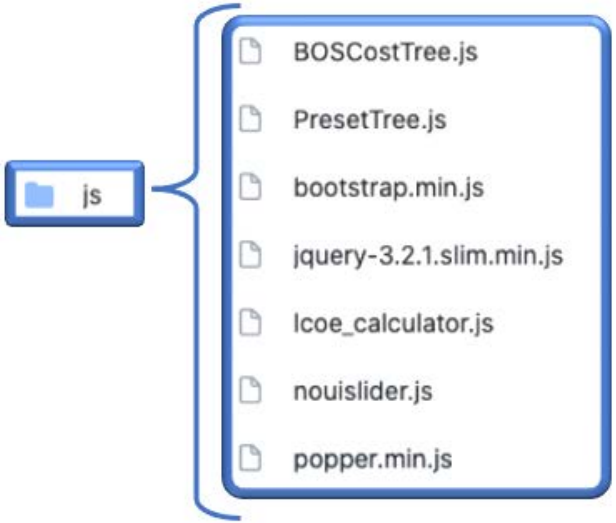

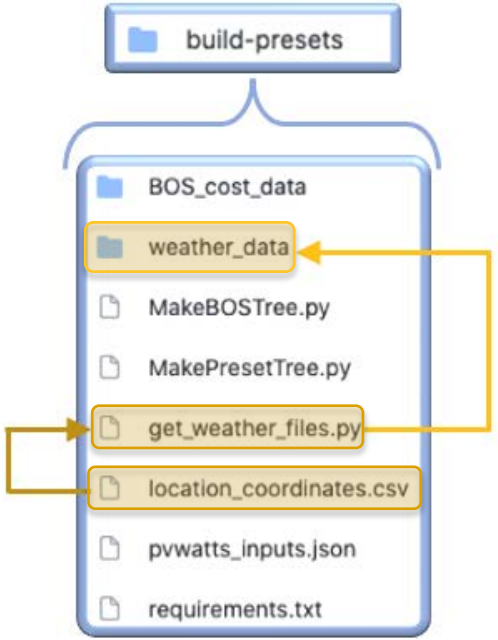

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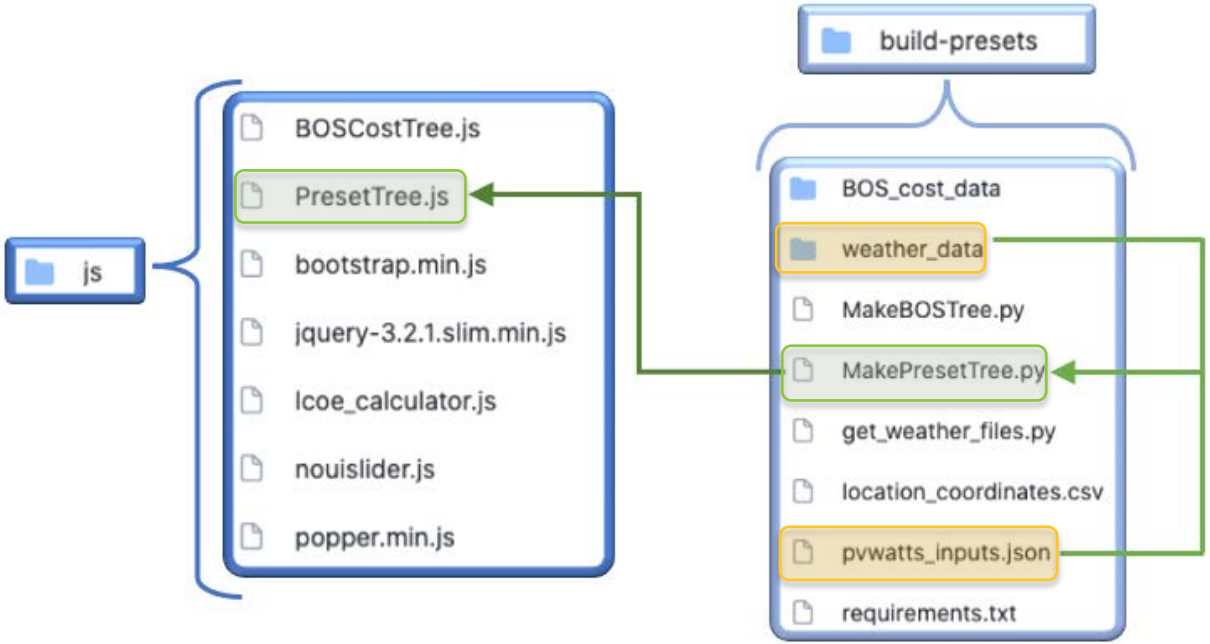

github.com/NREL/PVLCOE

Editing Your Local Version

If you want...

More locations to choose from:

- add coordinates to “location_coordinates.csv”

Changes to energy yield or SAM settings:

- Edit PVWatts inputs in “pvwatts_inputs.json”
- Edit SAM settings within “MakePresetTree.py”

All this is documented in more detail in the repository README file

Changes to cell technologies, package types, system types, non-BOS costs, efficiencies, or degradation rates:

- Add menu items or edit values in “MakePresetTree.py”

Changes to BOS costs:

- Edit contents of the /BOS_cost_data/ folder within the /build-presets/ folder

Citation

If you use results from this calculator in a publication or proposal, please cite:

SJ Andrews, BL Smith, MG Deceglie, KA Horowitz, and TJ Silverman. “NREL Comparative PV LCOE Calculator.” Version 2.0.1, August 2021

Note: We recommend including the URL for a specific commit if citing results from an unreleased version.

Thank You

www.duramat.org

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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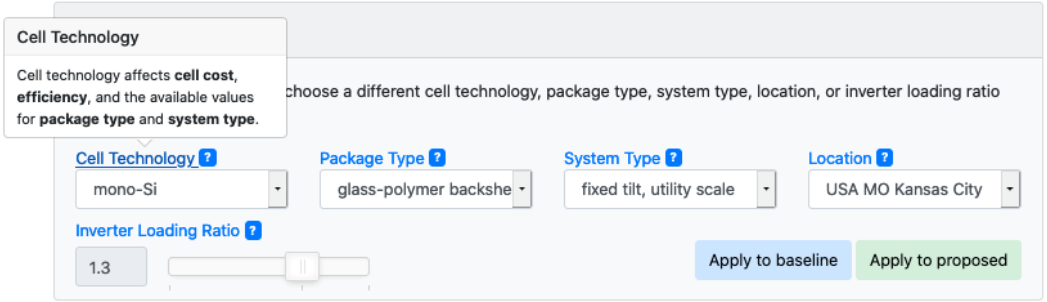
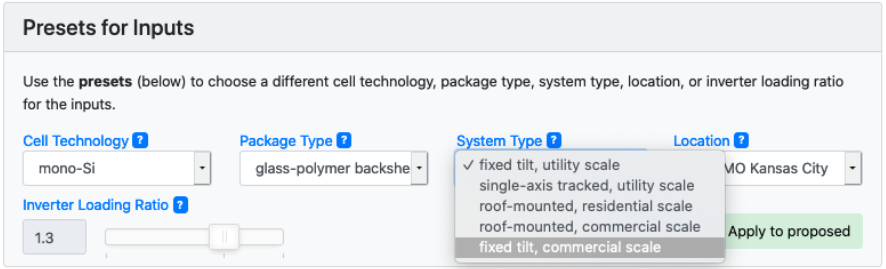
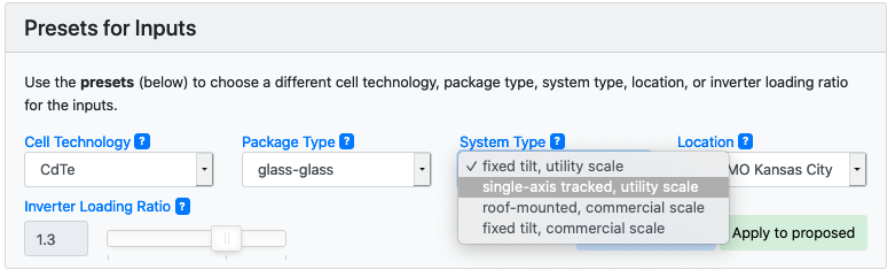
Backup Slides

Preset Constraints







Make-Preset-Tree.py

```
This code uses the PySAM wrapper for the SAM GUI to generate energy yield and create a new preset tree.
It loops through every combination of cell technology, package type, system type, inverter loading ratio
and location to determine the energy yield with those settings.

Note: this script runs PySAM 3300 times (for each preset combination) and takes ~30 mins to finish running.
"""
import pandas as pd
import json
import PySAM.Pvwattsv7 as pvwatts
import glob
import PySAM.ResourceTools as tools
import PySAM.PySSC as pssc
from pathlib import Path  # for platform independent paths

# to avoid rounding issues, the lat and lon returned by pysam are in this file
# locations maps a lat/lon pair to the string name of the location
locations = {}
df = pd.read_csv('location_coordinates.csv')
for index, row in df.iterrows():
    locations[row['ID']] = 'USA ' + \
        row['State'] + ' ' + row['Place']

# 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', 'roof-mounted, commercial scale', 'fixed t
    'multi-Si': ('fixed tilt, utility scale', 'single-axis tracked, utility scale', 'roof-mounted, commercial scale', 'fixed tilt, commercial scale'),
    'CdTe': ('fixed tilt, utility scale', 'single-axis tracked, utility scale', 'roof-mounted, commercial scale', 'fixed tilt, commercial scale')
}


# Preset values for module parameters: costs are in USD per square meter, efficiency reported as a percentage
module_details = {
    'cost_front_layer': 3.5,
    'cost_cell': {'mono-Si': 22.2, 'multi-Si': 19.4, 'CdTe': 21.3},
    'cost_back_layer': {'glass-polymer backsheet': 2.4, 'glass-glass': 3},
    'cost_noncell': 13.6,
    'efficiency': {'mono-Si': 19.5, 'multi-Si': 17.5, 'CdTe': 18.0},
}


# Preset values for operation & maintenance costs, reported in USD/kW(DC) per year
cost_om = {
    'fixed tilt, utility scale': 16.32,
    'single-axis tracked, utility scale': 17.46,
    'roof-mounted, residential scale': 28.94
```

To keep energy non-negative, degradation rate and service life must satisfy the inequality:

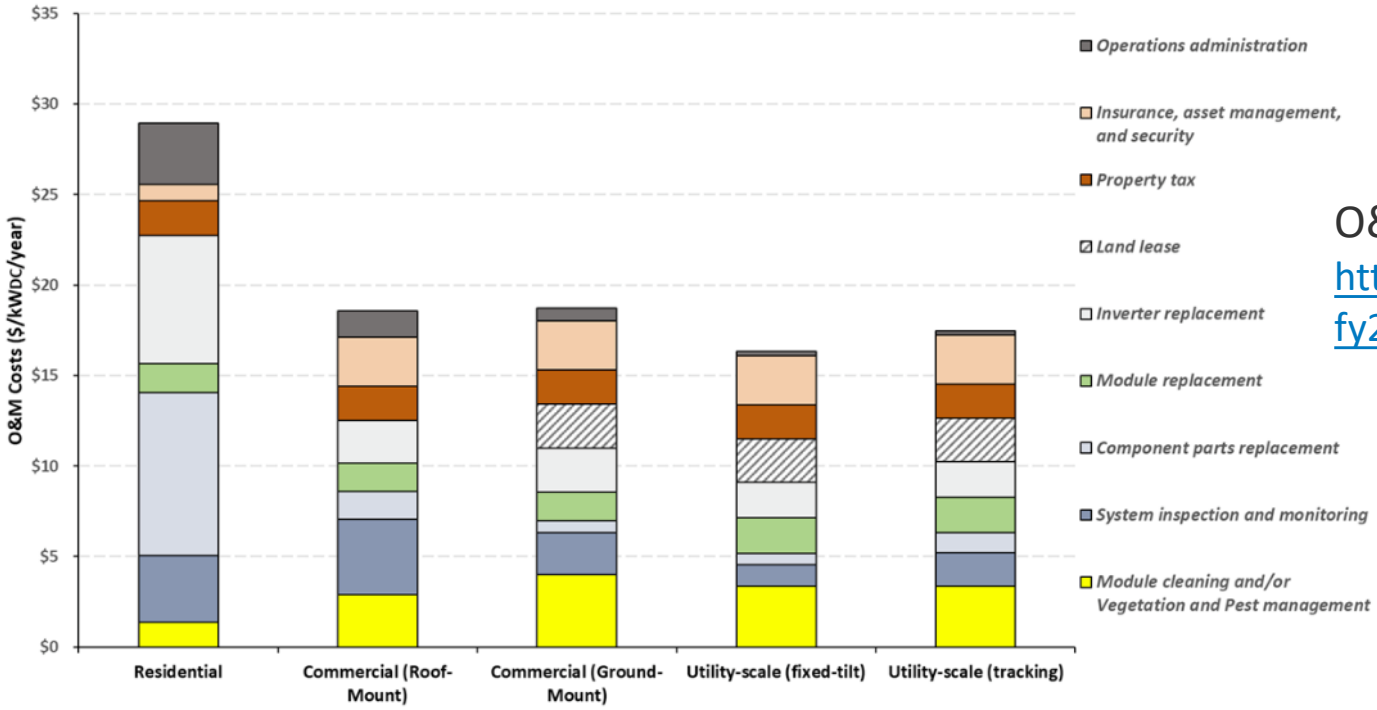
$$(n - 0.5) / Rd < 1$$

Where:

n is service life

Rd is degradation rate

O&M Costs



O&M cost tool
https://www.nrel.gov/docs/fy20osti/74840.pdf

Curve-fitting: BOS Cost as a Function of Efficiency