



Estimating the value of worker training: a system reliability & LCOE perspective

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Motivation: Inflation Reduction Act (IRA)

To receive IRA tax credits, systems 1 MW_{ac} or larger must:

- pay local prevailing wages
- use 10-15% apprentice labor

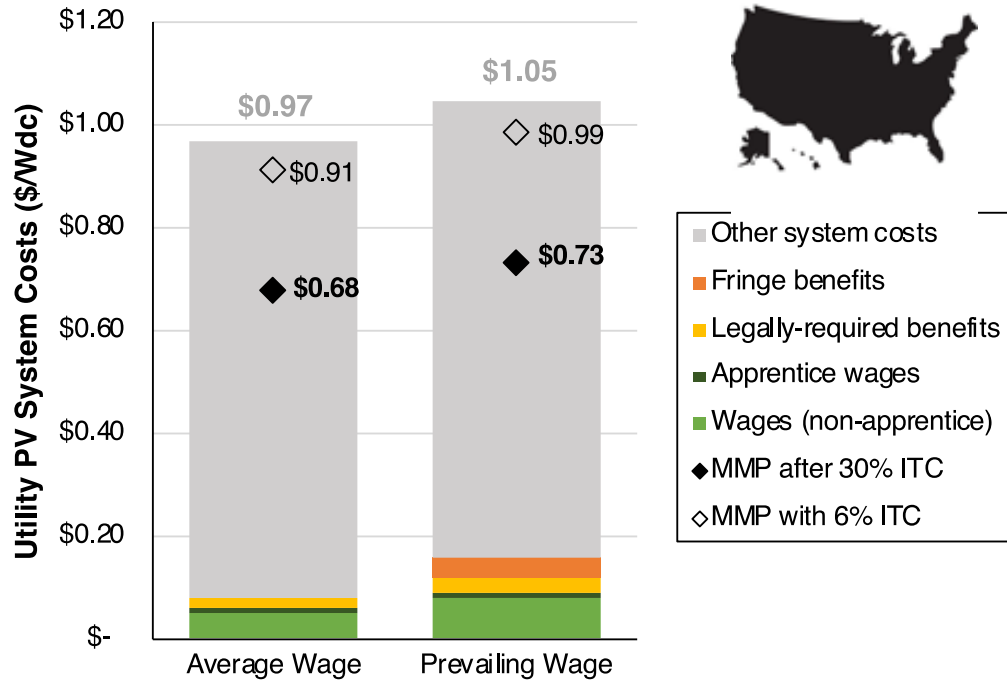
	ITC	PTC
Labor requirements met	30%	2.6 ¢/kWh
Requirements <u>not</u> met	6%	0.5 ¢/kWh

Projects may choose either:

- investment tax credit (ITC)
- production tax credit (PTC)

Installation cost comparisons

Utility system (>1MW_{ac})



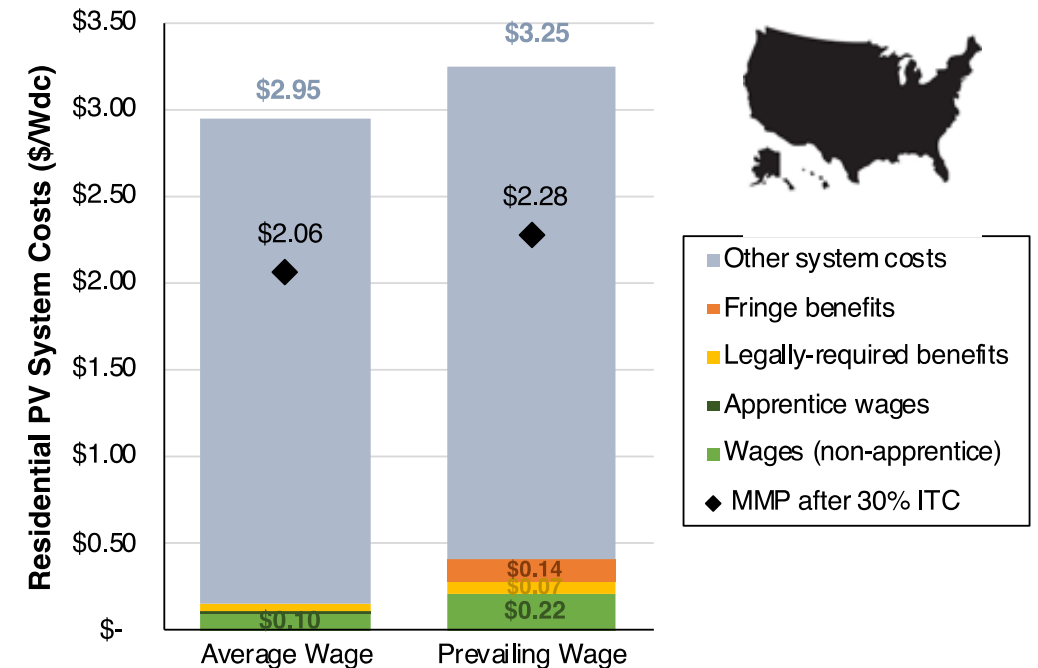
Compare average wage price with 6% ITC to prevailing wage price with 30% ITC:

- Prevailing wage ***premium*** would need to outweigh 24% of total system price
- Labor costs typically <15% of total system price

Installation cost comparisons

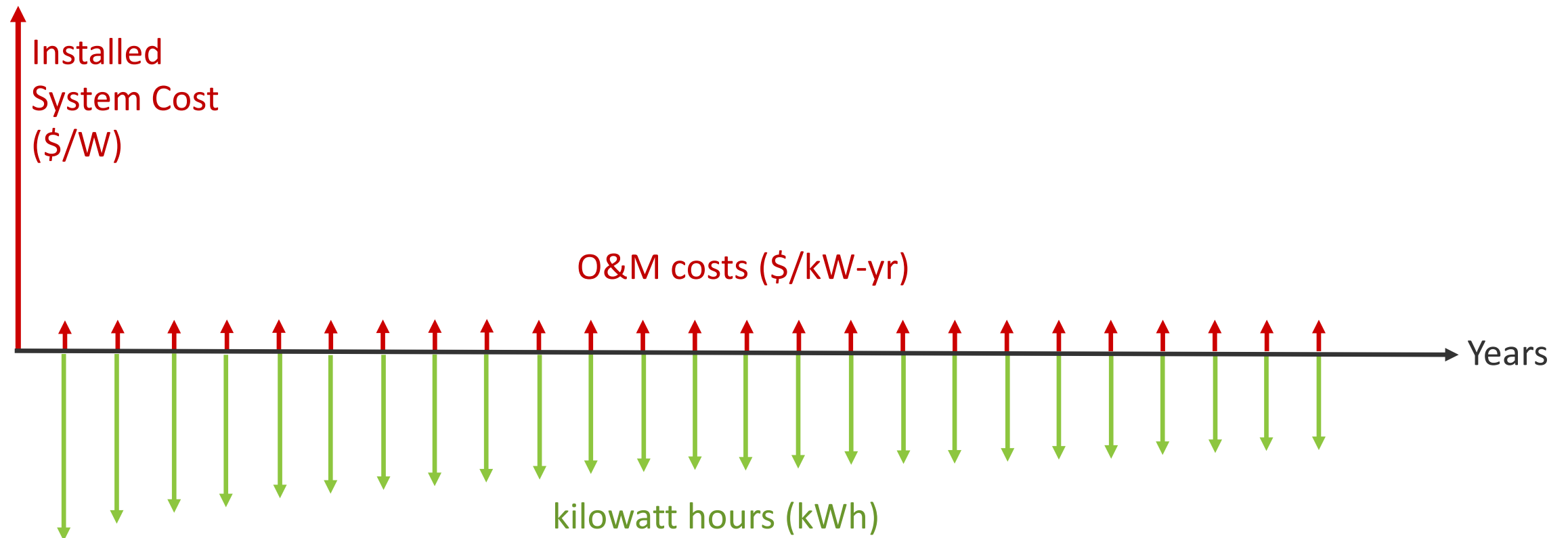
- 6% ITC penalty doesn't apply to smaller systems
- Will commercial systems be strategically sized less than 1MW_{ac} ?
 - Could there be ancillary benefits associated with higher labor expenses?

Residential system ($\ll 1\text{MW}_{ac}$)



Levelized Cost of Energy (LCOE)

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

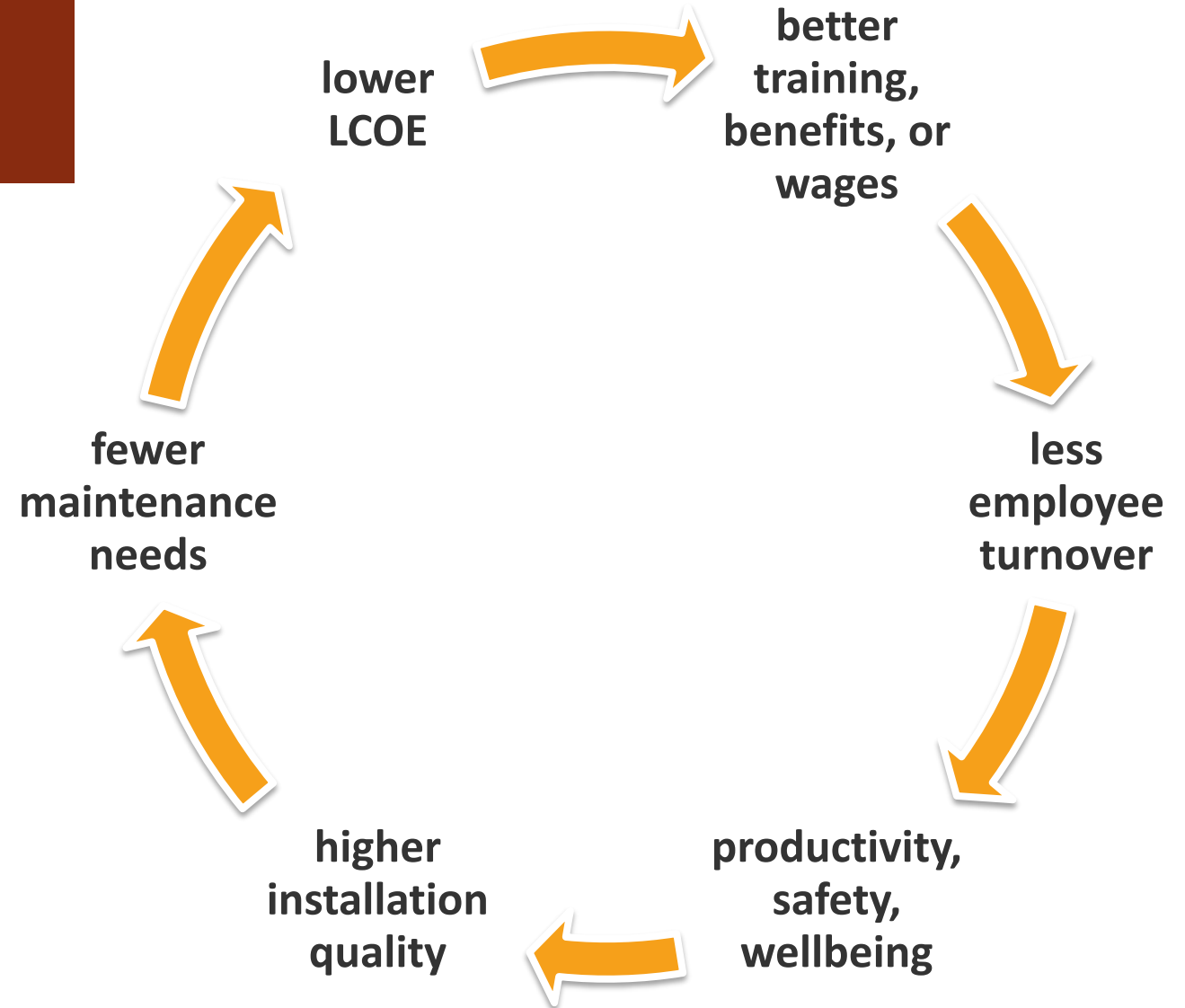


Potential LCOE effects



Potential LCOE effects

Higher productivity could offset higher labor expenses



Approach:

comparing equivalent LCOEs

How much **additional energy generation** would offset **higher labor expenses**?

What **reduction in maintenance costs** would offset **higher install labor expenses**?

- **Higher Labor Expenses**
- + ...improved energy yield?
- + ...lower degradation rate?
- + ...longer system life?
- + ...lower maintenance costs?

Step 1: Select from a set of system options

Presets for Inputs

Use the **presets** (below) to choose a different cell technology, package type, system type, location, or inverter loading ratio for the inputs.

Cell Technology ? **Package Type** ? **System Type** ? **Location** ?

mono-Si ▼ glass-polymer backshee ▼ fixed tilt, utility scale ▼ USA MO Kansas City ▼

Inverter Loading Ratio ?

1.3

APPLY TO BASELINE **APPLY TO PROPOSED**

Step 2: Default input values pre-populate (additional fields visible on website)

Baseline	Proposed COPY FROM BASELINE
Cost	Cost
Front layer cost (USD/m ²)	Front layer cost (USD/m ²)
<input type="text" value="3.50"/> <input type="range"/>	<input type="text" value="3.50"/> <input type="range"/>
Cell cost (USD/m ²)	Cell cost (USD/m ²)
<input type="text" value="22.20"/> <input type="range"/>	<input type="text" value="33.30"/> <input type="range"/>
Back layer cost (USD/m ²)	Back layer cost (USD/m ²)
<input type="text" value="2.40"/> <input type="range"/>	<input type="text" value="2.40"/> <input type="range"/>
Baseline LCOE (USD/kWh) 0.0517	Proposed LCOE (USD/kWh) 0.0553

Step 3: Results generated include LCOE (module price & system cost also)

Estimating training costs

If each worker receives 1 week (40 hours) of training each year at full pay, and we distribute this expense across the projects they install per year:

	Utility	Commercial	Residential
Projects per year	5	20	80
% increase labor costs per project	1.9%	1.9%	1.9%

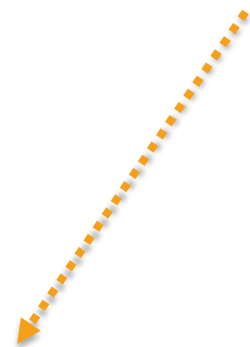
- PVLCOE calculator includes labor in “area-scaling BOS costs” per m²
- Estimate using NREL annual system cost benchmark reports:
 - labor hours per m²
 - hourly wage & legally-required benefits

Step 1: Select system type from top menu

Step 2: Propose increased install labor cost

Baseline	Proposed COPY FROM BASELINE
Cost	Cost
Front layer cost (USD/m ²)	Front layer cost (USD/m ²)
3.50	3.50
Cell cost (USD/m ²)	Cell cost (USD/m ²)
22.20	22.20
Back layer cost (USD/m ²)	Back layer cost (USD/m ²)
2.40	2.40
Non-cell module cost (USD/m ²)	Non-cell module cost (USD/m ²)
13.60	13.60
Extra component cost (USD/m ²)	Extra component cost (USD/m ²)
0	0
O&M cost (USD/kW _{DC} /year)	O&M cost (USD/kW _{DC} /year)
17.46	17.46
BOS cost, power-scaling (USD/W)	BOS cost, power-scaling (USD/W)
0.2	0.2
BOS cost, area-scaling (USD/m ²)	BOS cost, area-scaling (USD/m ²)
66.67	66.88
Baseline LCOE (USD/kWh) 0.0489	Proposed LCOE (USD/kWh) 0.0490

Increase labor costs by 1.9%
(not total BOS costs)



Step 3: Compare results

Baseline

Cost

Front layer cost (USD/m²)
3.50

Cell cost (USD/m²)
22.20

Back layer cost (USD/m²)
2.40

Non-cell module cost (USD/m²)
13.60

Extra component cost (USD/m²)
0

O&M cost (USD/kW_{DC}/year)
17.46

BOS cost, power-scaling (USD/W)
0.2

BOS cost, area-scaling (USD/m²)
66.67

Baseline LCOE (USD/kWh) 0.0489

Proposed COPY FROM BASELINE

Cost

Front layer cost (USD/m²)
3.50

Cell cost (USD/m²)
22.20

Back layer cost (USD/m²)
2.40

Non-cell module cost (USD/m²)
13.60

Extra component cost (USD/m²)
0

O&M cost (USD/kW_{DC}/year)
17.46

BOS cost, power-scaling (USD/W)
0.2

BOS cost, area-scaling (USD/m²)
66.88

Proposed LCOE (USD/kWh) 0.0490

Proposed COPY FROM BASELINE

Cost

Front layer cost (USD/m²)
3.50

Cell cost (USD/m²)
22.20

Back layer cost (USD/m²)
2.40

Non-cell module cost (USD/m²)
13.60

Extra component cost (USD/m²)
0

O&M cost (USD/kW_{DC}/year)
17.3733

BOS cost, power-scaling (USD/W)
0.2

BOS cost, area-scaling (USD/m²)
66.88

Proposed LCOE (USD/kWh) 0.0489

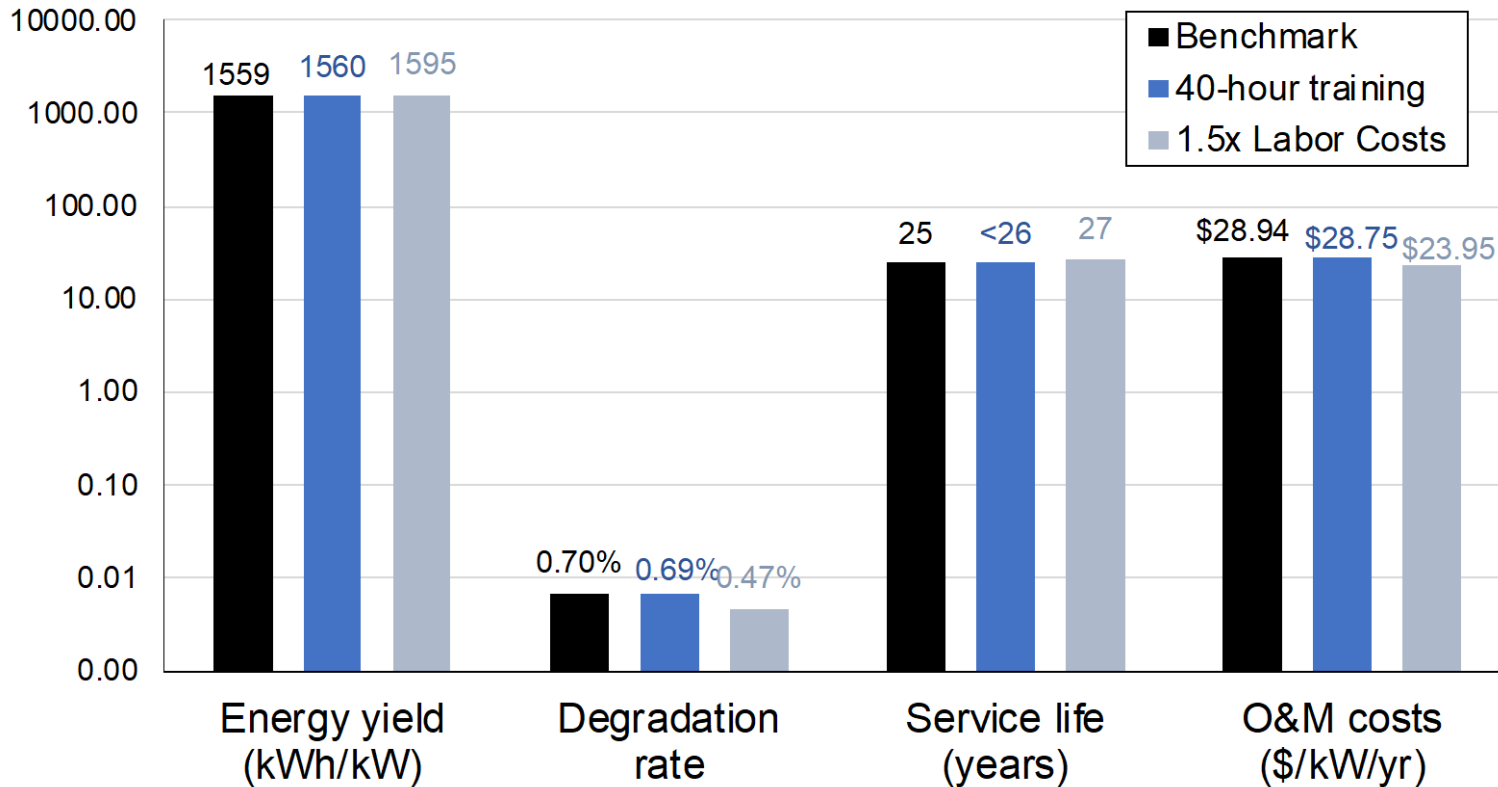
Automatically adjust this input to make LCOE match the baseline LCOE.

Find break-even points (equivalent LCOE) for:

- Energy yield
- Degradation rate
- O&M costs
- Service life

Residential Systems

Residential rooftop system: 14.82 ¢/kWh



% change	40-hour training	1.5x Labor Costs
Energy yield	0.1%	2.3%
Degradation rate	-1.4%	-32.9%
Service life	0.4%	8.0%
O&M costs	-0.7%	-17.2%

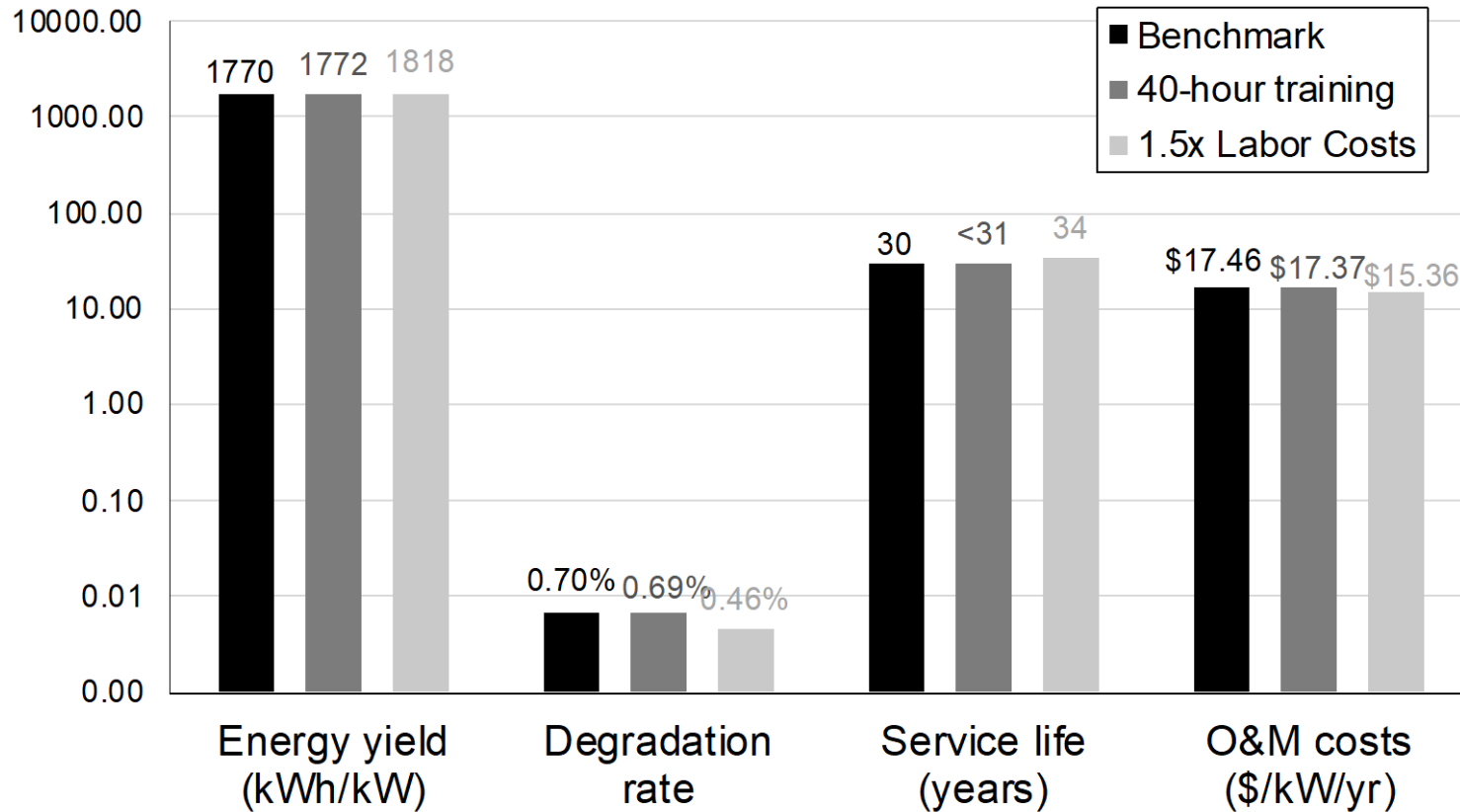
Modest changes for:

- Energy yield
- Service life
- O&M costs

Degradation rate is challenging, but could play a role when effects are combined

Utility Systems

Utility 1-axis tracker system: 4.67 ¢/kWh



	40-hour training	1.5x Labor Costs
% change		
Energy yield	0.1%	2.7%
Degradation rate	-1.4%	-34.3%
Service life	0.3%	13.3%
O&M costs	-0.5%	-12.0%

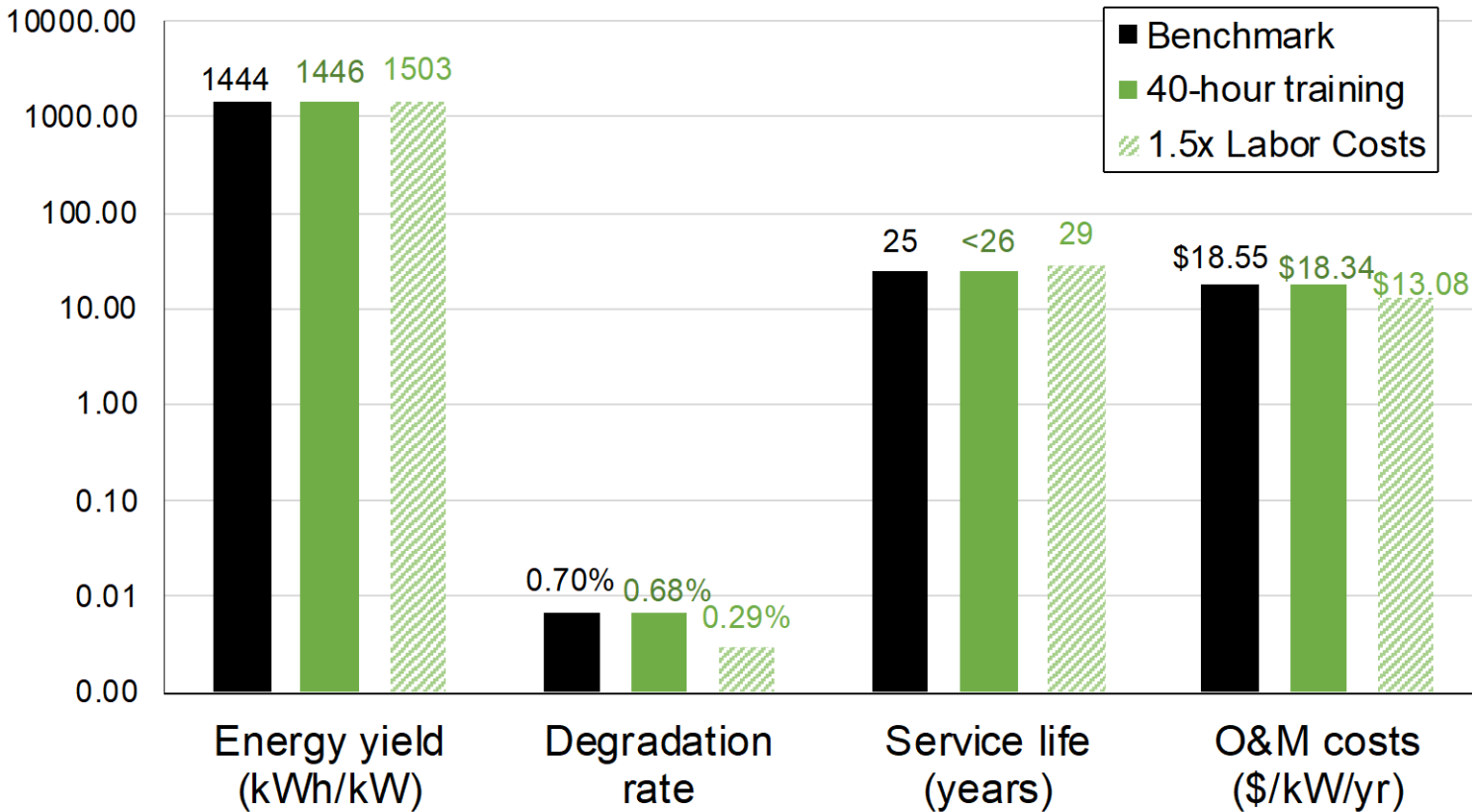
Modest changes for:

- Energy yield
- Service life
- O&M costs

Degradation rate is challenging, but could play a role when effects are combined

Commercial Flat-Roof Systems

Commercial rooftop system: 9.96 ¢/kWh



	40-hour training	1.5x Labor Costs
% change		
Energy yield	0.1%	4.1%
Degradation rate	-2.9%	-58.6%
Service life	0.4%	16.0%
O&M costs	-1.1%	-29.5%

- Modest change for energy yield, service life
- Degradation rate and O&M costs are challenging, but could play a role when effects are combined

Similarly, if O&M labor costs increase \$1-\$2 per kW/yr, service life needs to increase by 1 year to achieve same LCOE

Detailed Cost Analysis Model (DCAM): dcam.opennei.org

- Free, public, user-friendly online tool
- Enables bottom-up modeling of PV costs:
 - Manufacturing of ingots, wafers, cells
 - Assembly of modules
 - Installation of PV systems
- Leverages NREL component and system cost benchmark research
- Can be used to analyze cost impacts of technology or installation choices

Detailed Cost Analysis Model (DCAM): dcam.openei.org

Utility + PV / Q1-2022 Utility PV Benchmark

Public Updated: January 23 2023

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Inputs

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Output

INPUTS

System Description [+ add note](#)

Year	2022	
Project Location	United States	
Axis Type	One-Axis	
Project Size	5	MWDC
System VDC	1500	VDC
Transmission Line	<input checked="" type="checkbox"/> 2.7	miles
Nominal to Real USD Factor	0.952	

Modules [+ add note](#)

Module Efficiency	20.3	%
Module Width	40.32	inches
Module Length	76.68	inches
Module Power	405	W
Module Weight	47.84	lbs
Module Price	0.33	\$/W

OUTPUT

Utility-PV MSP Results (\$/Wdc)

MSP - Minimum Sustainable Price

Project Size (MWDC)	5
Axis Type	One-Axis
EPC/Developer Net Profit	0.0893
Contingency	0.0292
Developer Overhead	0.111
Transmission Line	0
Permitting Fee	0.0419
Interconnection Fee	0.0217
Sales Tax	0.0419
EPC Overhead	0.0898
Installation Labor & Equipment	0.133
Electrical BOS	0.143
Structural BOS	0.151
Inverter	0.0397
Module	0.314
Total Utility + PV System Cost	1.21

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www.duramat.org

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Background Slides

Simplified PV-LCOE Calculator: pvlcoe.nrel.gov

- PV technology-specific
- Editable preset fields, targeting research applications
- Instant comparison of proposed changes to a baseline system
- Distinct from:

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

- + Different financial models
- + Detailed options for module and system designs
- + Can model solar + storage

- May be more challenging for new users to navigate
- Difficult to quickly evaluate research directions without introducing confounding factors

Presets for Inputs

Use the **presets** (below) to choose a different cell technology, package type, system type, location, or inverter loading ratio for the inputs.

Cell Technology Package Type System Type Location

Inverter Loading Ratio

Baseline

Cost

Front layer cost (USD/m²)

Cell cost (USD/m²)

Back layer cost (USD/m²)

Non-cell module cost (USD/m²)

Extra component cost (USD/m²)

O&M cost (USD/kW_{DC}/year)

BOS cost, power-scaling (USD/W)

BOS cost, area-scaling (USD/m²)

Performance

Efficiency (%)

Energy yield (kWh/kW_{DC})

Reliability

System degradation rate (%/year)

Service life (years)

Financial

Discount rate

Proposed

Cost

Front layer cost (USD/m²)

Cell cost (USD/m²)

Back layer cost (USD/m²)

Non-cell module cost (USD/m²)

Extra component cost (USD/m²)

O&M cost (USD/kW_{DC}/year)

BOS cost, power-scaling (USD/W)

BOS cost, area-scaling (USD/m²)

Performance

Efficiency (%)

Energy yield (kWh/kW_{DC})

Reliability

System degradation rate (%/year)

Service life (years)

Financial

Discount rate

Results

LCOE result

Baseline LCOE (USD/kWh) **0.0517**

Proposed LCOE (USD/kWh) **0.0517**

Additional results

Baseline

Module price (USD/W) **0.25**

Total installed system cost (USD/W) **0.72**

Proposed

Module price (USD/W) **0.25**

Total installed system cost (USD/W) **0.72**