SAND2010-2441P

Levelized Cost Of Electricity
Sensitivity Assessment

PV Systems Integrator Workshop
Clarion Hotel, San Jose

Wednesday, March 31 – Thursday, April 1, 2010

Christopher P. Cameron
Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Levelized Cost of Energy

- **A Convenient Metric for Comparing Energy Costs Across Energy Sources**
  - **Captures Installed, Financing, and O&M Costs, and Reduction in Future Energy Output (Degradation)**
  - **Used by DOE to Evaluate Competiveness of Solar Relative to Conventional Energy Sources**
- **Other Metrics May Be More Important to Customer or Investor Decisions, e.g.**
  - **First Cost – a barrier to purchase**
  - **Return on Investment – 3rd Party-Owned Systems**

Sandia National Laboratories

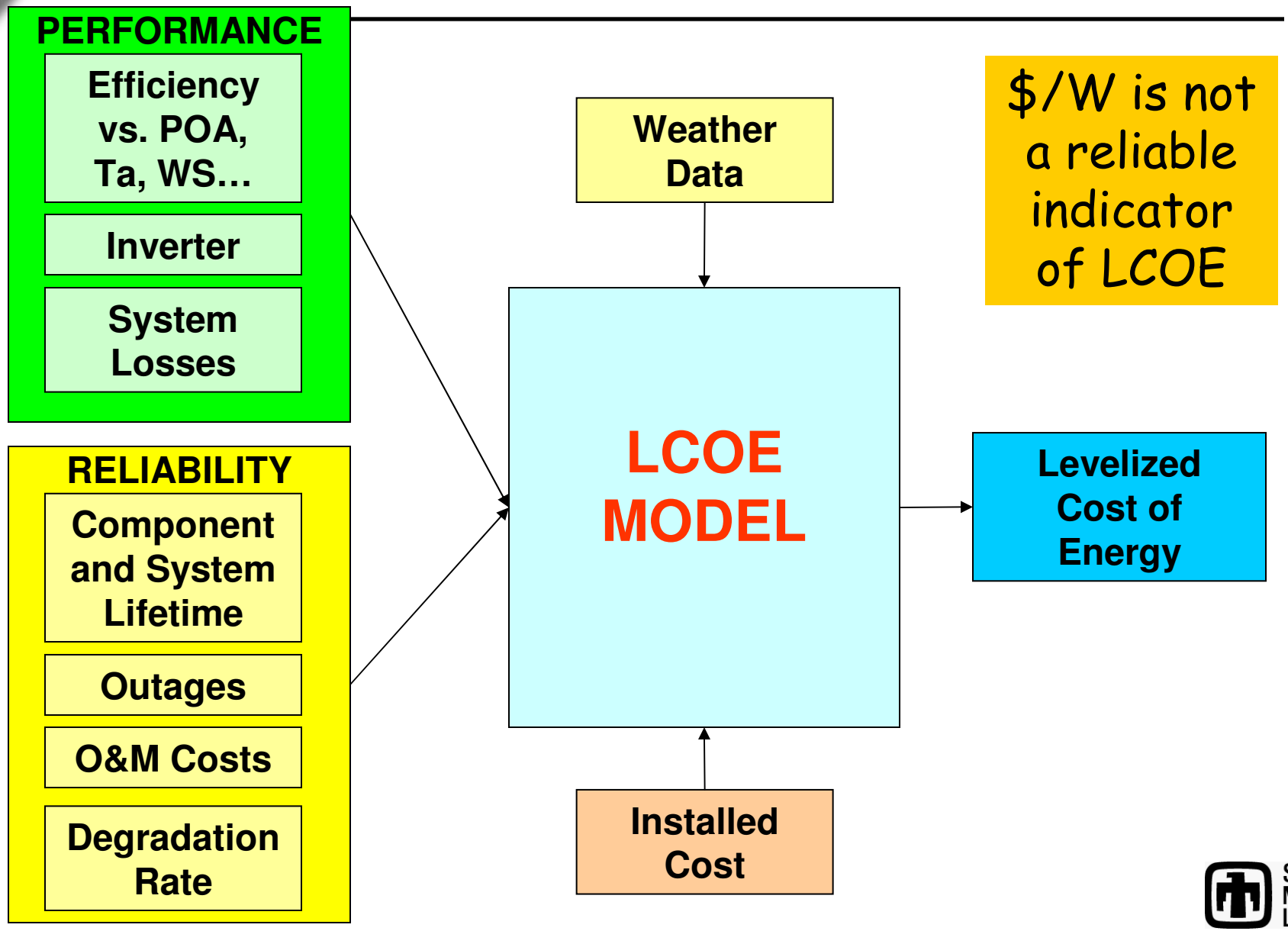
Levelized Cost of Energy

- Numerator includes *all* costs, C_n, by year
  - Includes first cost, financing, incentives, O&M
- Denominator includes energy production, Q_n, by year
  - Includes reduced energy production due to degradation
- d is discount rate
  - Future year costs and energy production have lower value/impact
- LCOE is calculated in real dollars

$$LCOE = \frac{\sum_{n=0}^{N} \frac{C_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}}$$

Sandia National Laboratories

LCOE Model



Sandia National Laboratories

Financial Assumptions

Type of Financing	Residential Mortgage	Commercial Loan
Inflation Rate (%)	2.5	2.5
Analysis Period (yrs)	30	30
Real Discount Rate (%)	5.5	5.5
Loan Term (yrs)	30	15
Loan Rate (%)	6	6
Loan (Debt) Fraction (%)	100	50
Federal Tax (%)	28	35
State Tax (%)	7	7
Property Tax (%)	0	0
Insurance (%)	0	0
Sales Tax (%)	0	0
Federal Depreciation Type	n/a	MACRS-Mid-Q
State Depreciation Type	n/a	
Incentives		
Federal Tax Credit (%)	30%	30%

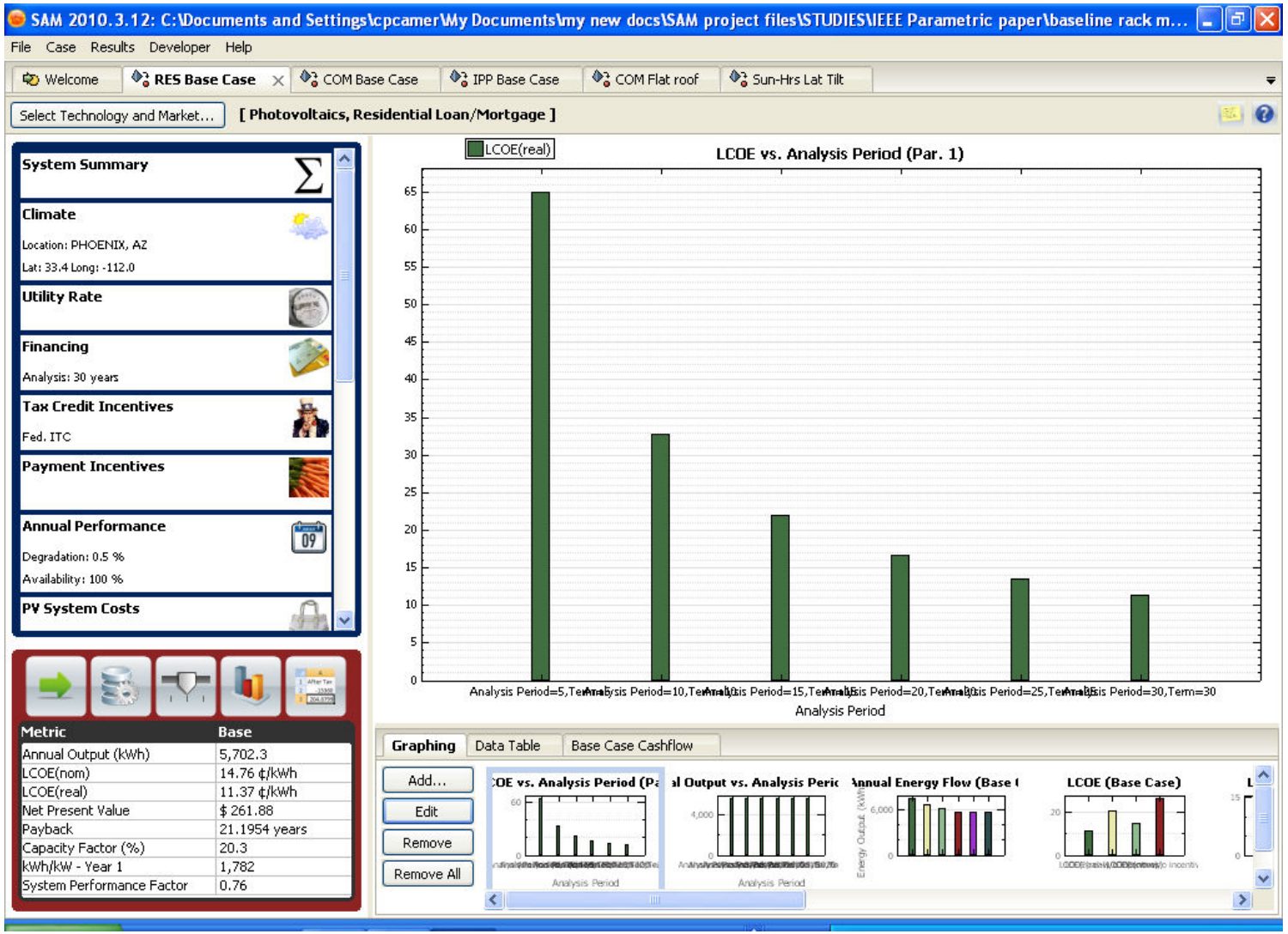
Sandia National Laboratories

Reference Systems - Phoenix

Rack Mount	Res	Com
Array Power (Wdc)	3,200	500,000
System Derate Factor	90.0%	90.0%
System Degradation	0.50%	0.50%
Tilt	20.00	33.40
Inverter Efficiency	94.2%	94.8%
Yield kWh/kW- yr 1	1782	1816
System Perf Factor	0.76	0.76
COSTS		
Module $/Wdc	$4.84	$4.35
Inverter $/Wac	$0.71	$0.64
Total Installed Cost $/Wdc	$7.96	$6.59
Inverter Replace/Rebuild (%)	100%	50%
Inverter Life (Yrs)	10	10
Routine O&M ($/yr)	$127	$8,237
Routine O&M (% of 1st cost)	0.50%	0.25%

Sandia National Laboratories

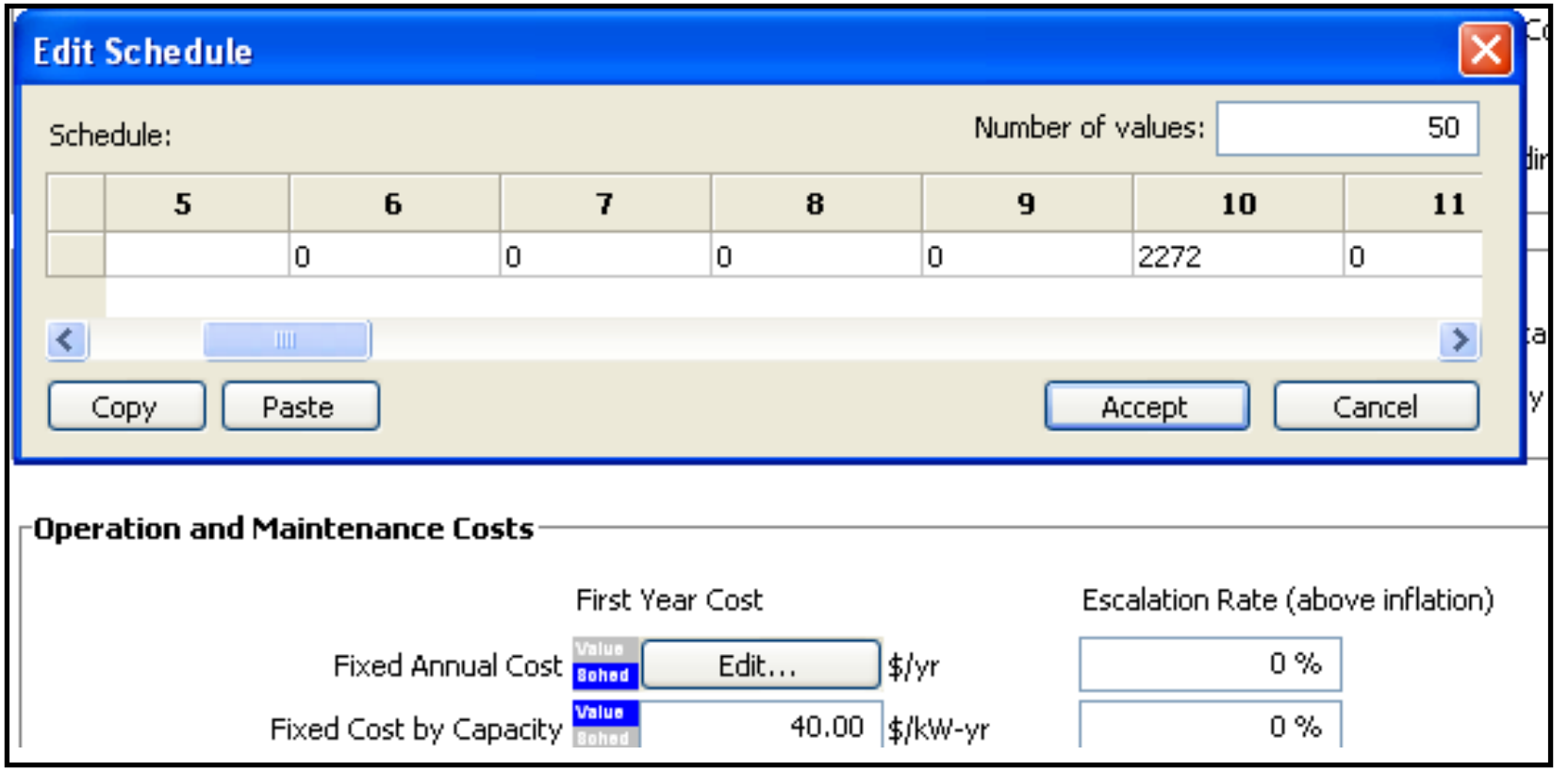
Analysis Performed with Solar Advisor Model
A Decision Support Tool

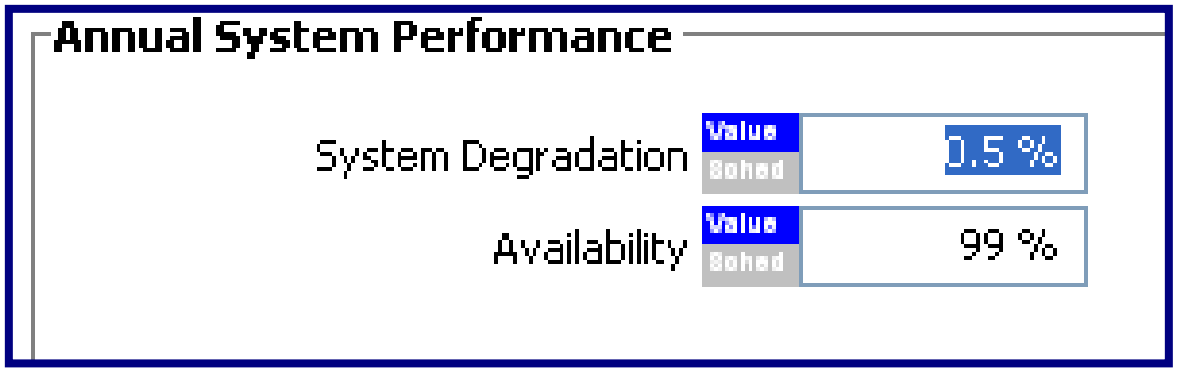


Free: www.nrel.gov/analysis/sam/

Sandia National Laboratories

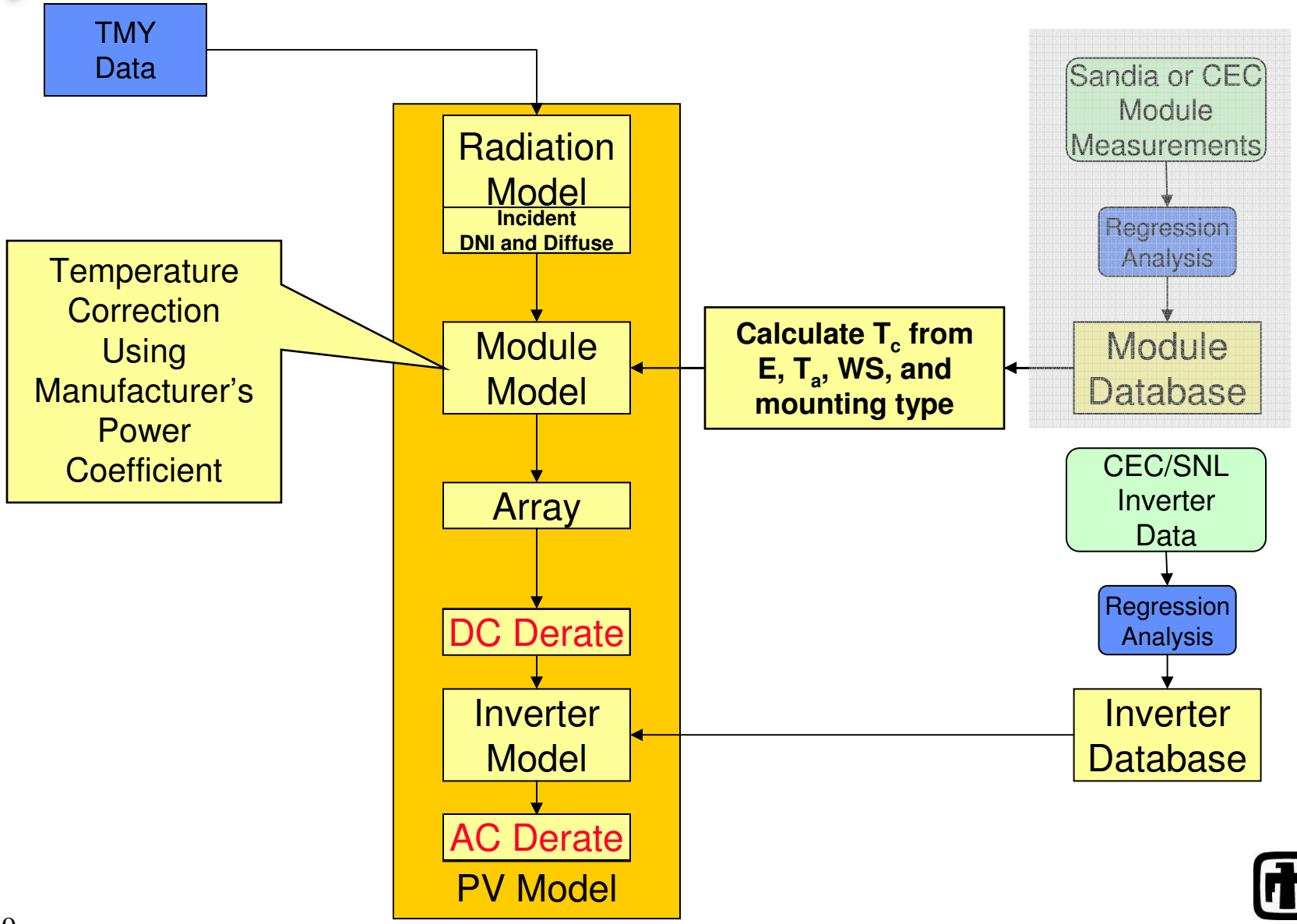
O&M Inputs in SAM





Sandia National Laboratories

Solar Advisor Model Includes
PVWatts, CEC-5 Parameter Model, Sandia PV Array Performance Model



Sandia National Laboratories

Levelized Cost of Energy for Reference Systems

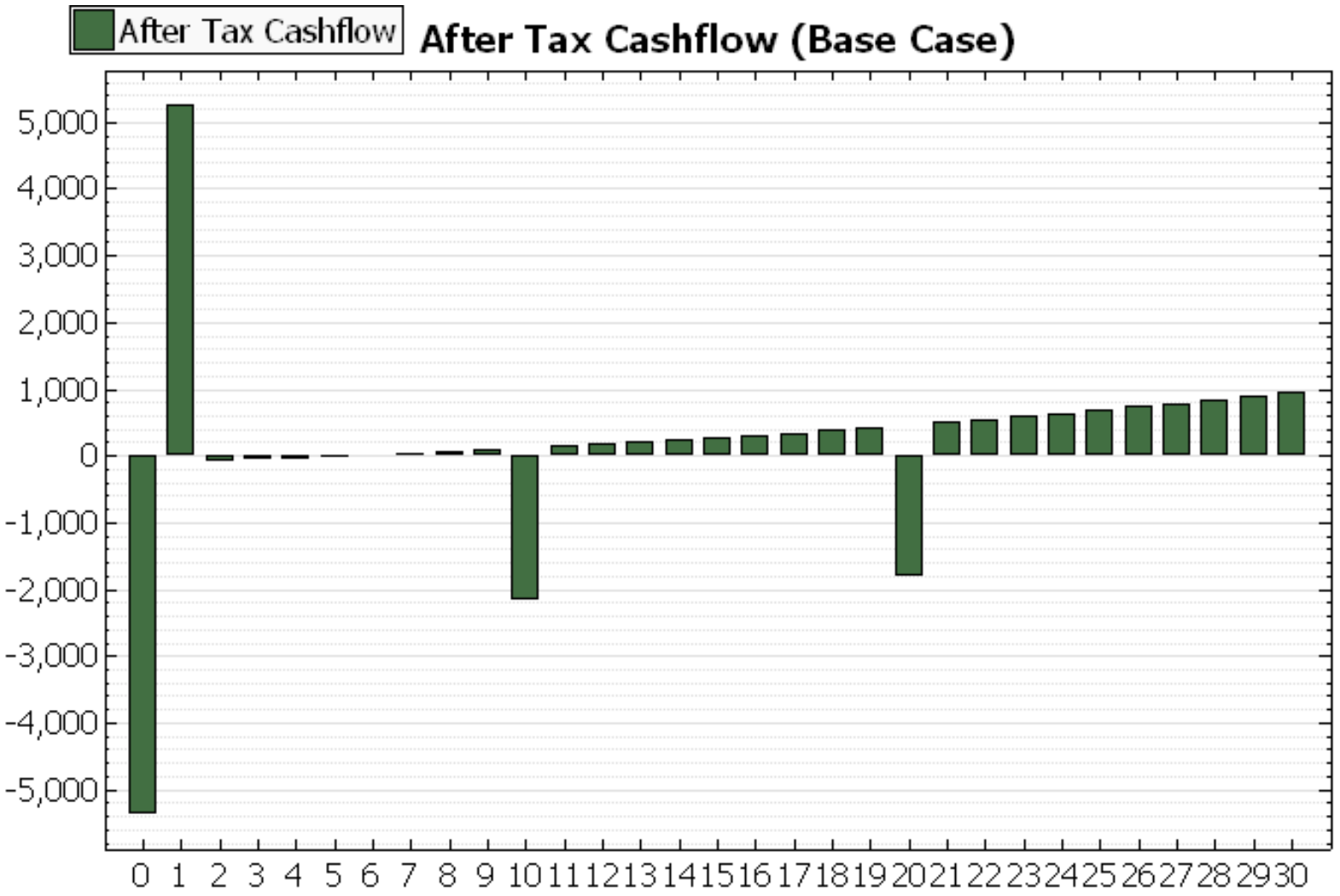
LCOE (¢/kWh)	Res	Comm
Total	**15.6**	**7.9**
First Cost Contribution	**11.4**	**6.9**
Total O&M Contribution	**4.2**	**1.1**
Routine O&M Contribution	2.3	0.6
Inverter O&M Contribution	1.9	0.5

Scales with First-Cost and Energy Yield

Scales with O&M Cost and Energy Yield

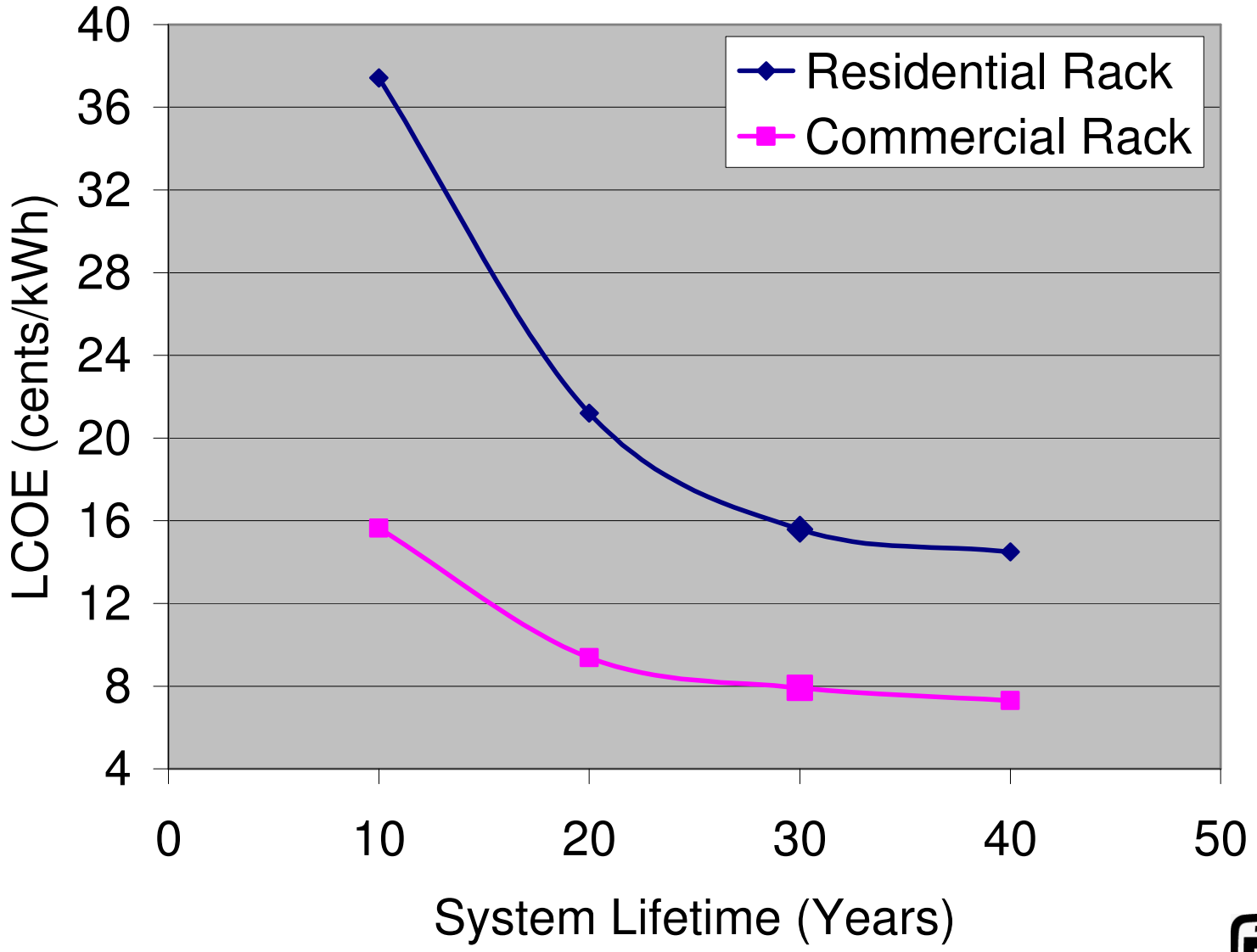
Sandia National Laboratories

Cash Flow with 12¢/kWh Utility Rate with 2% Escalation (above inflation)



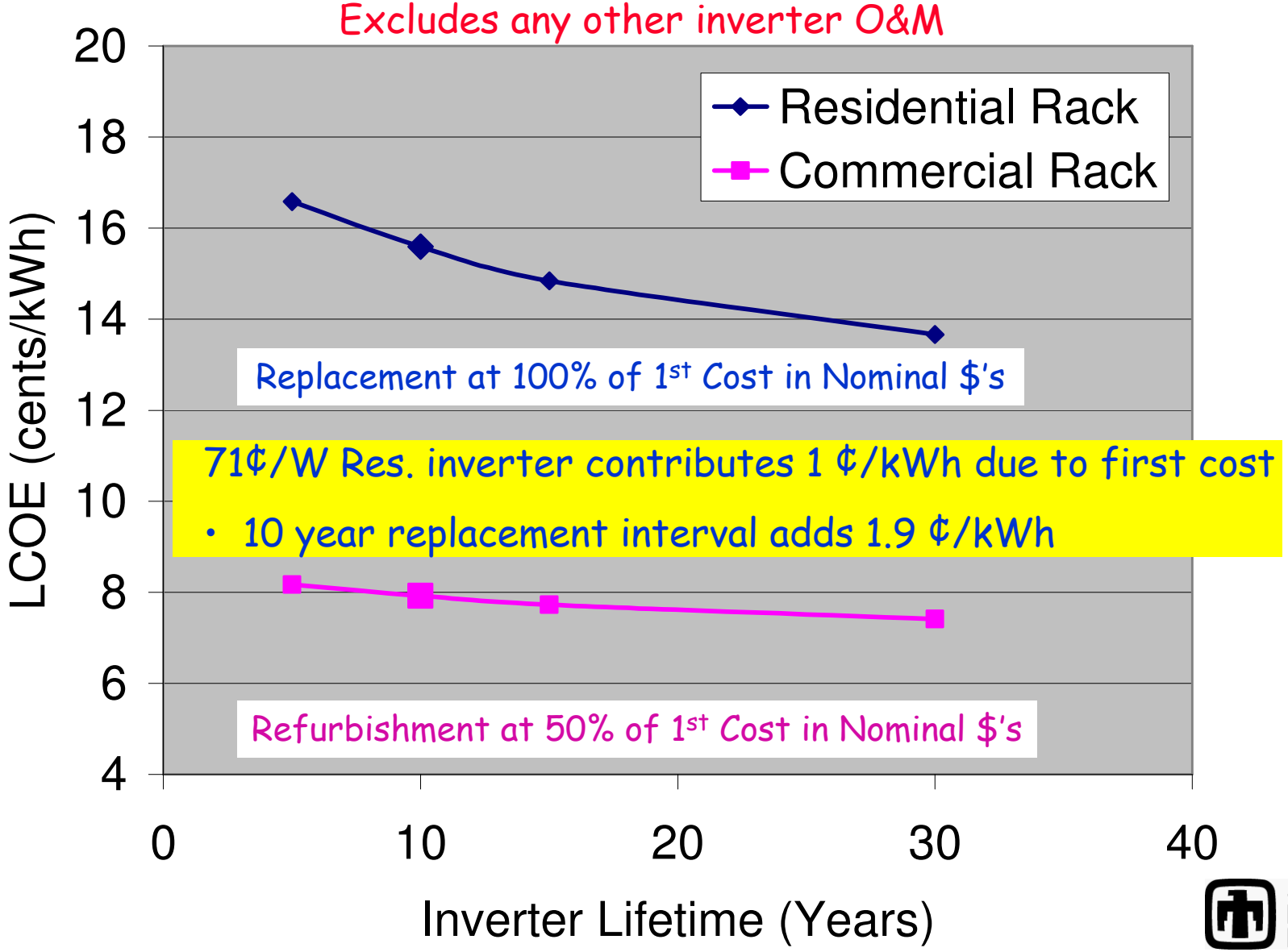
Sandia National Laboratories

Effect of System Lifetime on LCOE



Sandia National Laboratories

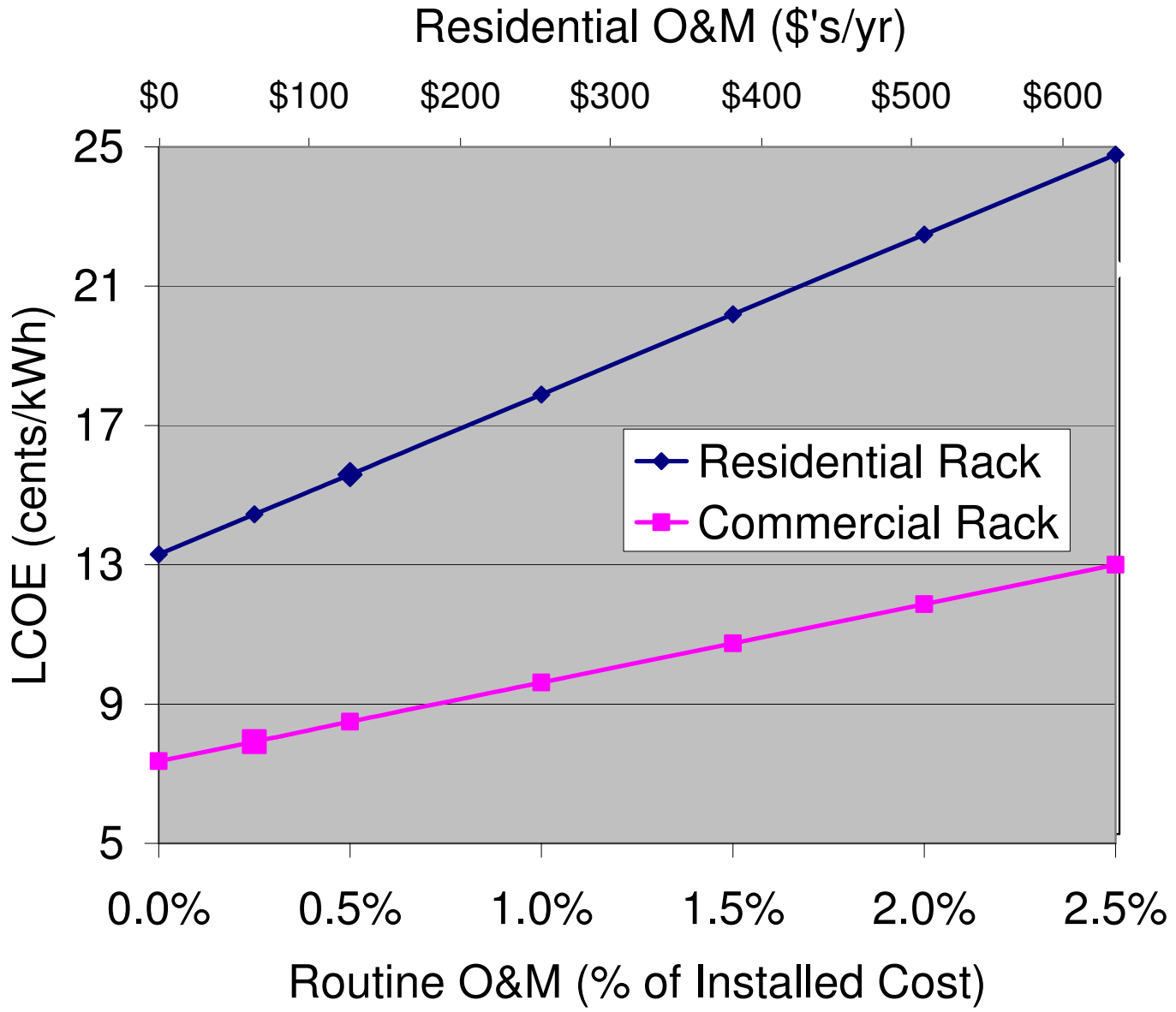
Effect of Inverter Lifetime on LCOE



Sandia National Laboratories

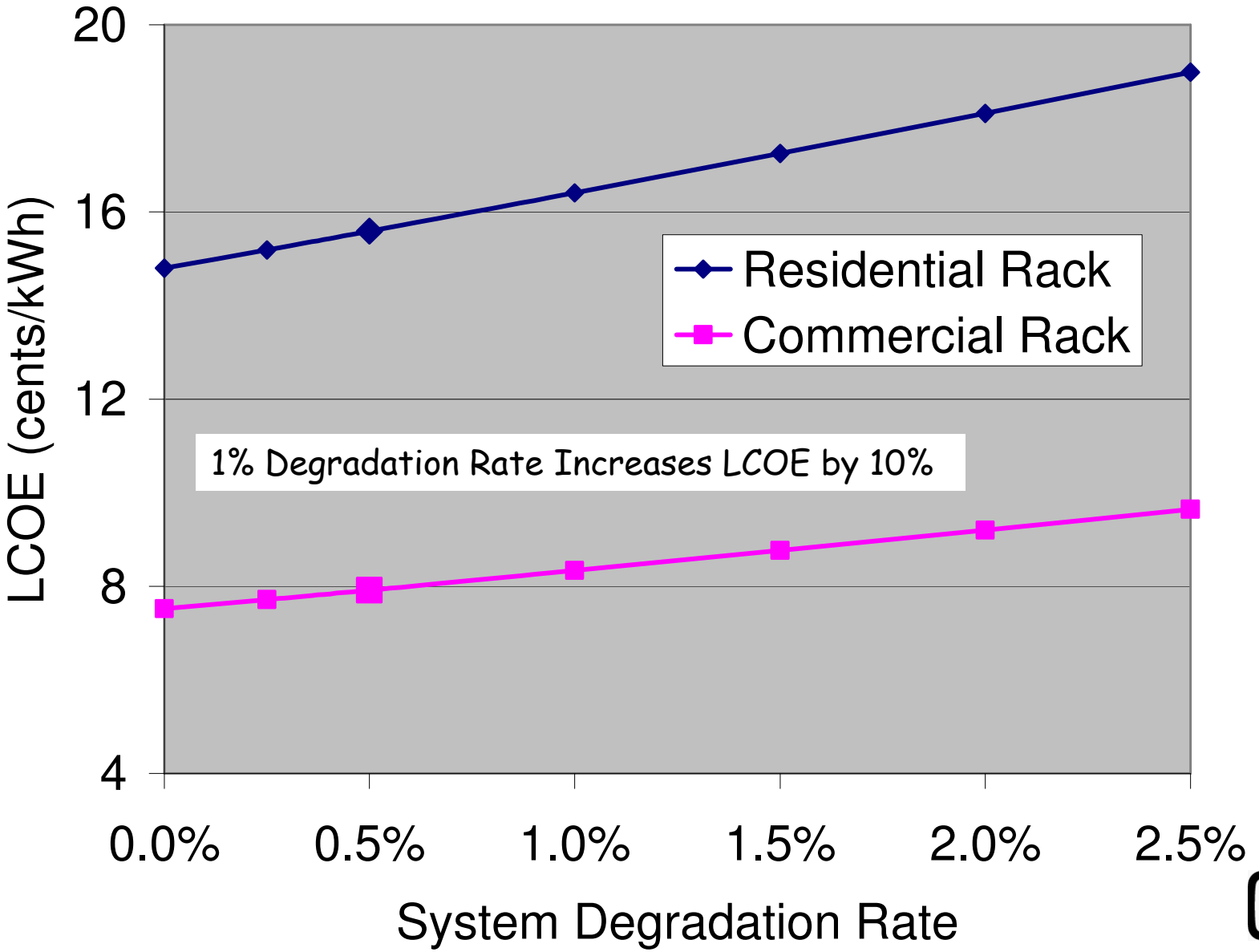
Effect of Routine* O&M on LCOE

*Other Than Inverter Replacement/Refurbishment



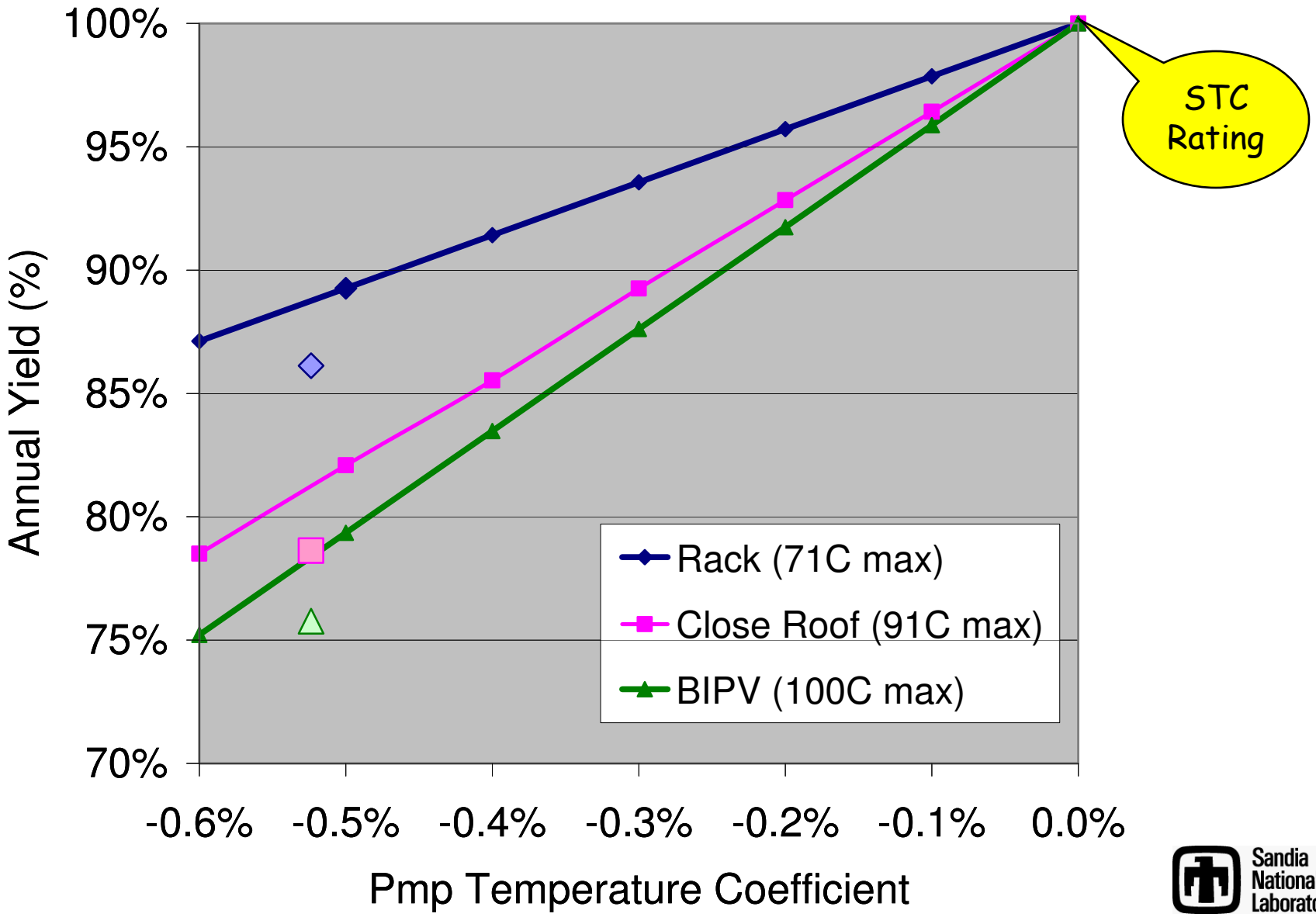
Sandia National Laboratories

Effect of System Degradation Rate



Sandia National Laboratories

Mounting Configuration Affects Cell Temperature and Performance



Sandia National Laboratories

What Values Should We Be Using for Model Inputs Low, High, Most Likely?

Residential (~ 4 kW)

- System
  - Installed Cost ($/W)
  - O&M ($/yr)
  - Derate Factor
- Modules ($/Wp)
- Inverter
  - First Cost ($/Wp)
  - Lifetime (Yrs)
  - Replacement Cost
    - % of First Cost for Inverter
    - $'s for Labor…

Commercial (500kW)

- System
  - Installed Cost ($/W)
  - O&M ($/yr)
  - Monitoring Cost ($/yr)
  - Derate Factor
- Modules ($/Wp)
- Inverter
  - First Cost ($/Wp)
  - Lifetime (Yrs)
  - Replacement Cost
    - % of First Cost for Inverter
    - $'s for Labor…

What, If Any, Routine Maintenance Do You Perform? Inspection? Cleaning? Other?

Sandia National Laboratories