

Modeling of Solar PV Technology Breakeven Prices and Sensitivity

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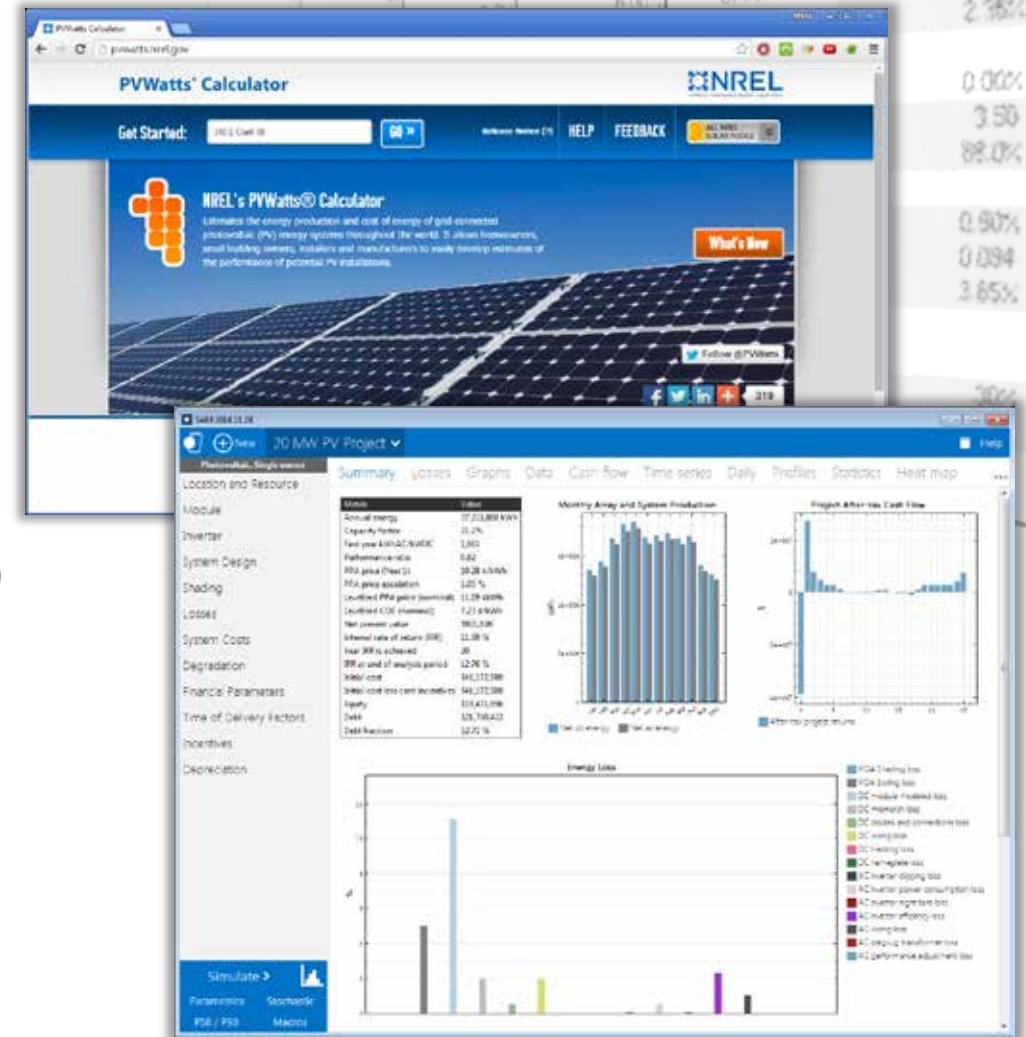
MARMET Workshop

3/30/15



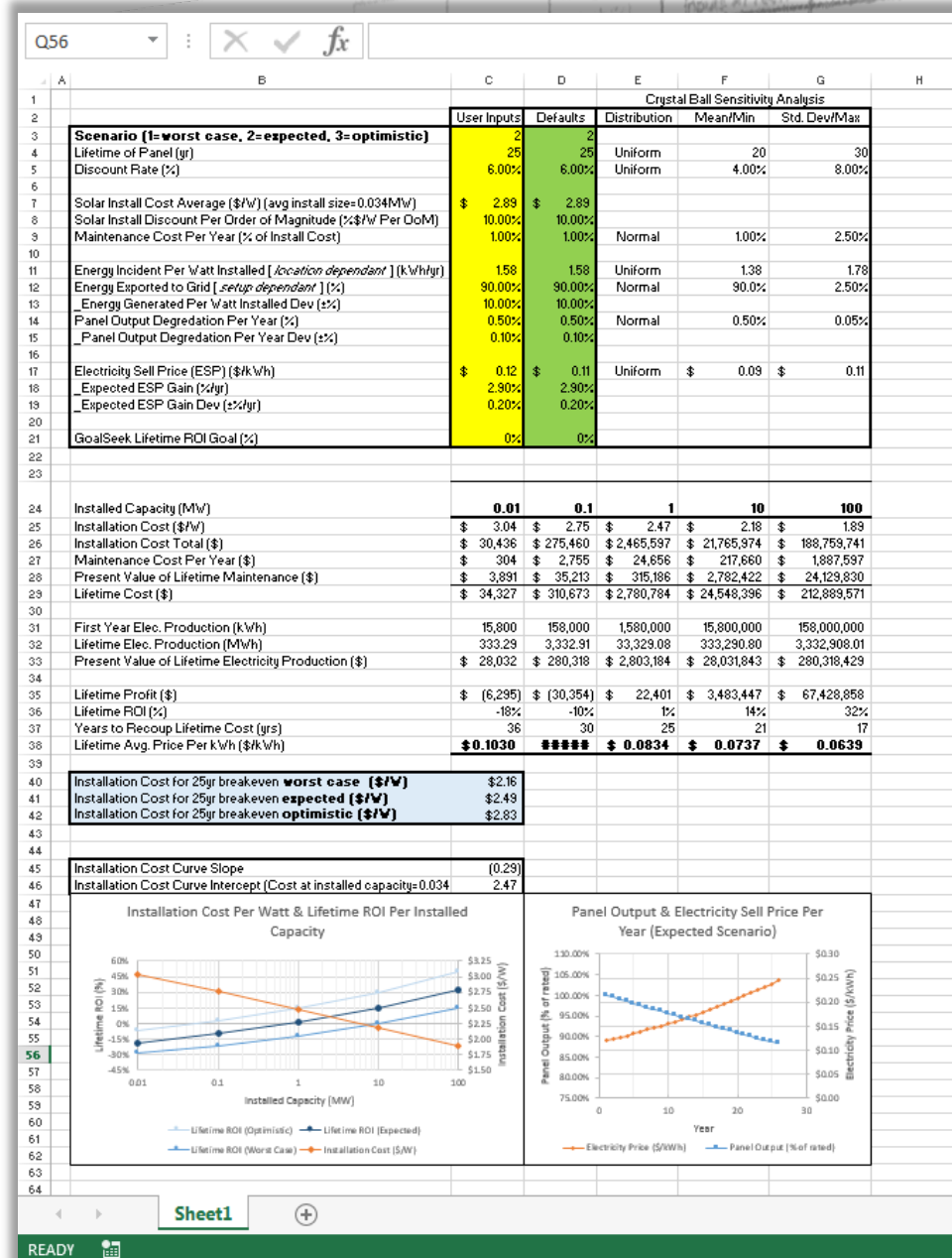
Motivation

- § Alternative calculators built for different purposes
 - NREL PVWatts
 - NREL System Advisor Model (SAM)
- § Unable to investigate sensitivity of various assumptions
- § Challenging to estimate economic value of improvements given uncertainty



Approach

- § Built in Excel to allow easy access to anyone wishing to evaluate potential installation
- § Discounted cash flow model
- § Users only change assumptions in yellow
- § Sensitivity studies can be performed with risk analysis software
- § NREL outputs could be used as input



Input

Model Parameters	Input	Default	Change due to tech (%)	Inputs W/ Tech
Scenario (1=Worst-case, 2=Expected, 3=Best-case)	2	2	n/a	2
System Lifetime (yr)	25	25	0.0%	25
Discount Rate (%)	6.00%	6.00%	0.0%	6.00%
Inflation Rate (%)	2.36%	2.36%	n/a	2.36%
_Inflation Rate Deviation (±%)	1.00%	1.00%	n/a	1.00%
Annual O&M Cost (% of Install Cost)	0.75%	0.75%	-25.0%	0.56%
Avg. Daily Peak-Sun Hours [<i>location dependent</i>] (hr/day)	5.00	3.50	0.0%	5.00
DC to AC Derating [<i>setup dependent</i>] (%)	86.00%	86.00%	5.0%	90.30%
_DC to AC Derating Deviation (±%)	5.00%	5.00%	n/a	5.00%
Panel Degradation Per Year (%)	0.50%	0.50%	0.0%	0.50%
Electricity Price (\$/kWh)	\$ 0.110	\$ 0.110	n/a	\$ 0.110
Annual Electricity Price Gain (%/yr)	3.65%	3.65%	n/a	3.65%
_Annual Electricity Price Gain Deviation (±%/yr)	0.55%	0.55%	n/a	0.55%
Depreciation (1=True, 0=False)	0	1	no	0
Depreciable Basis (% of Est. Installation Cost)	40%	40%	0.0%	40%
Effective Corporate Tax Rate (%)	30%	30%	0.0%	30%



Modeling DPP

- § Differential power processing (DPP) provides additional production
 - Allows all panels to track the maximum power point and only processes the current difference between adjacent units
- § DPP facilitates reduction in maintenance cost
 - Distributed nature of DPP allows for quick identification of faulty or impaired equipment



Model

- § Discounted cash flow (DCF) model uses inputs to calculate revenues and expenses for each year
- § Each cash flow is then discounted to the present
- § Breakeven installation price is equal to the installation expense today equal to all future cash flows discounted to present

The background image shows a complex spreadsheet with multiple columns and rows of data. The columns are labeled 'Input', 'Default', 'Change due to tech', 'Inputs w/ Tech', 'Distribution', and 'Breakeven'. The rows contain various numerical values, percentages, and text labels like 'Uniform' and 'Normal'. The spreadsheet is tilted and partially obscured by the text on the slide.



Output

§ For a given set of assumptions, model immediately provides

- Lifetime profit (+ or -)
- Lifetime ROI (return on investment)
- Number of working years required to recuperate costs
- Avg. price per kWh
- Install cost (\$/W) required to breakeven in best, worst, and expected scenarios*

*independent of installation size

Change due to	Inputs W/Tech	Distribution	Capacity of interest
20	25	Uniform	4.00%
0.00%	25	Uniform	2.95%
0.00%	25	Normal	0.00%
0.00%	25	Uniform	3.50
0.00%	25	Normal	88.0%
0.00%	25	Normal	0.90%
0.00%	25	Uniform	0.034
0.00%	25	Normal	3.65%
0.00%	25	Uniform	30%
0.00%	25	Uniform	30%

Capacity of interest	Capacity of interest	Capacity of interest	Capacity of interest
2.54	0.25	0.25	0.25
853,038	2.64	653,038	0.25
4,949	3.72	80,345	0.25
740,244	60,259	740,244	0.25
350,413	720,157	350,413	0.25
9,357	350,413	9,357	0.25
770,234	9,856	770,234	0.25
170,234	608,746	170,234	0.25
29,990	808,746	29,990	0.25
4.7	80,583	4.7	0.25
24	12.3%	24	0.25
0.0805	0.0746	0.0805	0.25

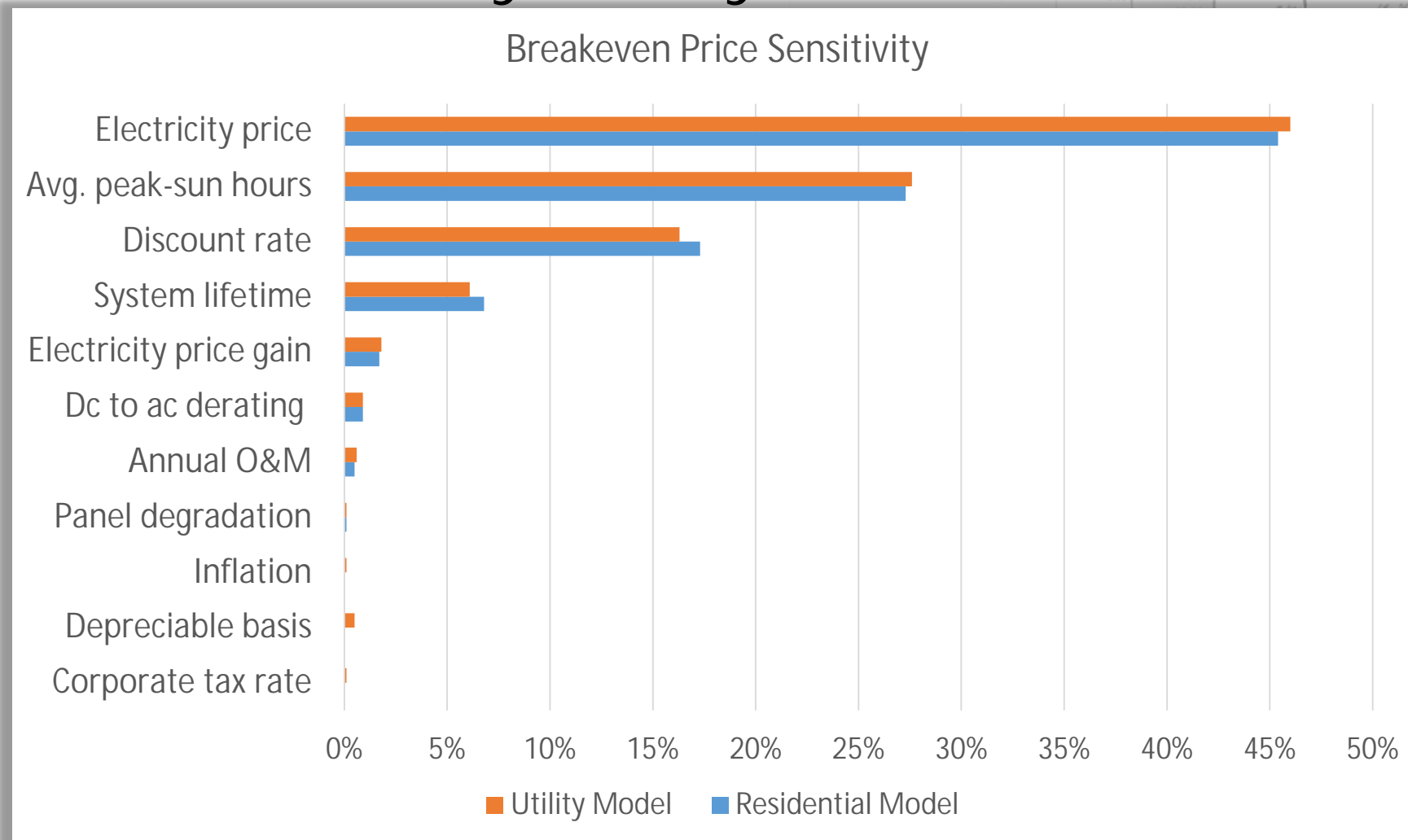


Monte Carlo Analysis

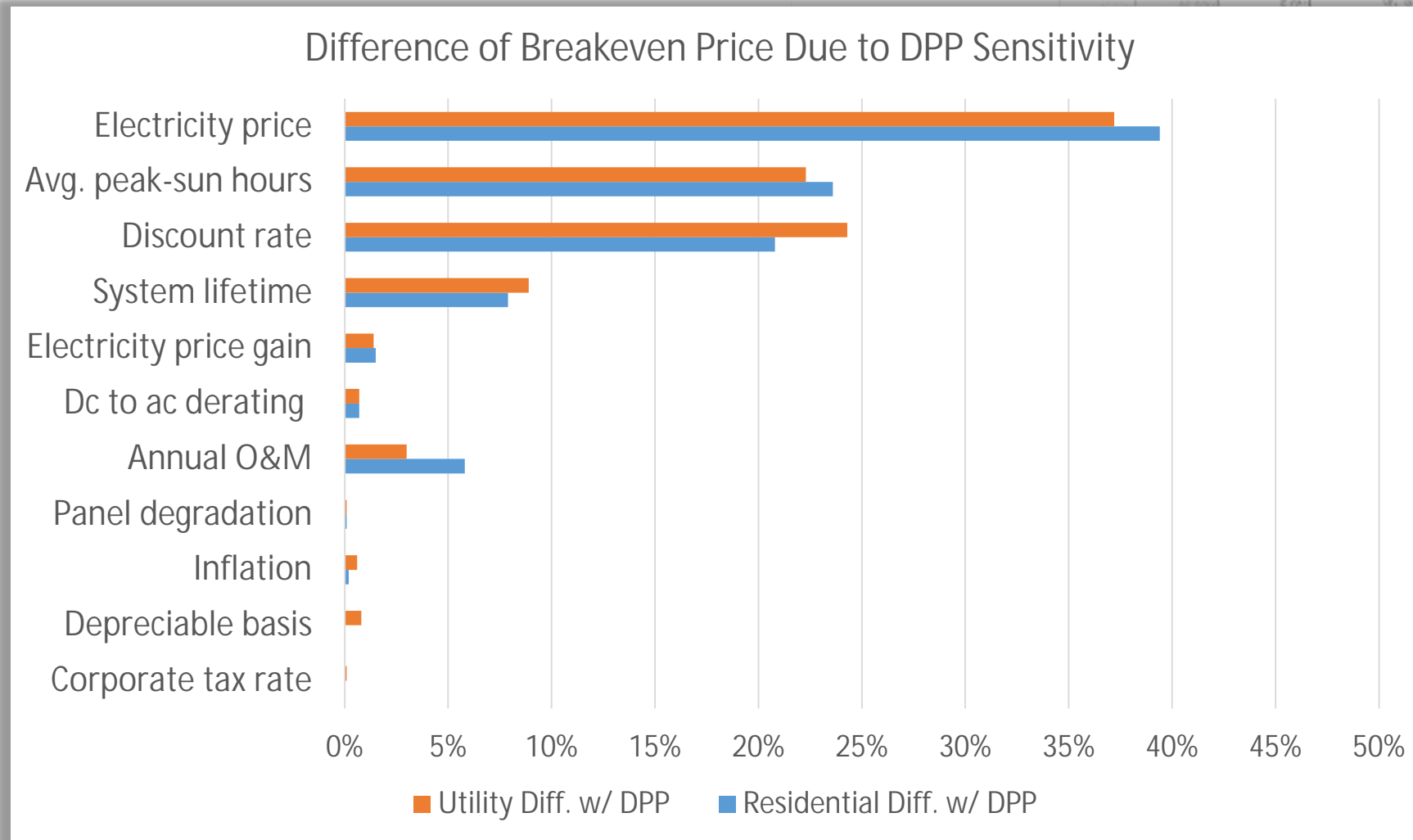
§ Input *distributions* contribute to output *distribution*

Model Parameters	Residential			Utility		
	Distribution	Mean/Min	Std. Dev/Max	Distribution	Mean/Min	Std. Dev/Max
System Lifetime (yr)	Uniform	20	30	Uniform	20	30
Discount Rate (%)	Uniform	4.00%	8.00%	Uniform	4.00%	8.00%
Inflation Rate (%)	Normal	2.36%	1.04%	Normal	2.36%	1.04%
_Inflation Rate Deviation (±%)		1%			1%	
Annual O&M Cost (% of Install Cost)	Uniform	0.00%	0.50%	Uniform	0.35%	0.85%
Avg. Daily Peak-Sun Hours [<i>location dependent</i>] (hr/day)	Uniform	3.50	6.00	Uniform	3.50	6.00
Overall DC to AC Derating [<i>setup dependent</i>] (%)	Normal	86.0%	2.50%	Normal	86.0%	2.50%
_Energy Exported to Grid Deviation (±%)		5%			5%	
Panel Degradation Per Year (%)	Normal	0.50%	0.10%	Normal	0.50%	0.10%
Electricity Price (\$/kWh)	Uniform	\$ 0.094	\$ 0.185	Uniform	\$ 0.094	\$ 0.185
Annual Electricity Price Gain (%/yr)	Normal	3.65%	0.38%	Normal	3.65%	0.38%
_Annual Electricity Price Gain Deviation (±%/yr)		0.55%			0.55%	
Depreciation (1=True, 0=False)		0			1	
Depreciable Basis (% of Est. Installation Cost)	Uniform	30%	50%	Uniform	30%	50%
Effective Corporate Tax Rate (%)	Uniform	30%	40%	Uniform	30%	40%

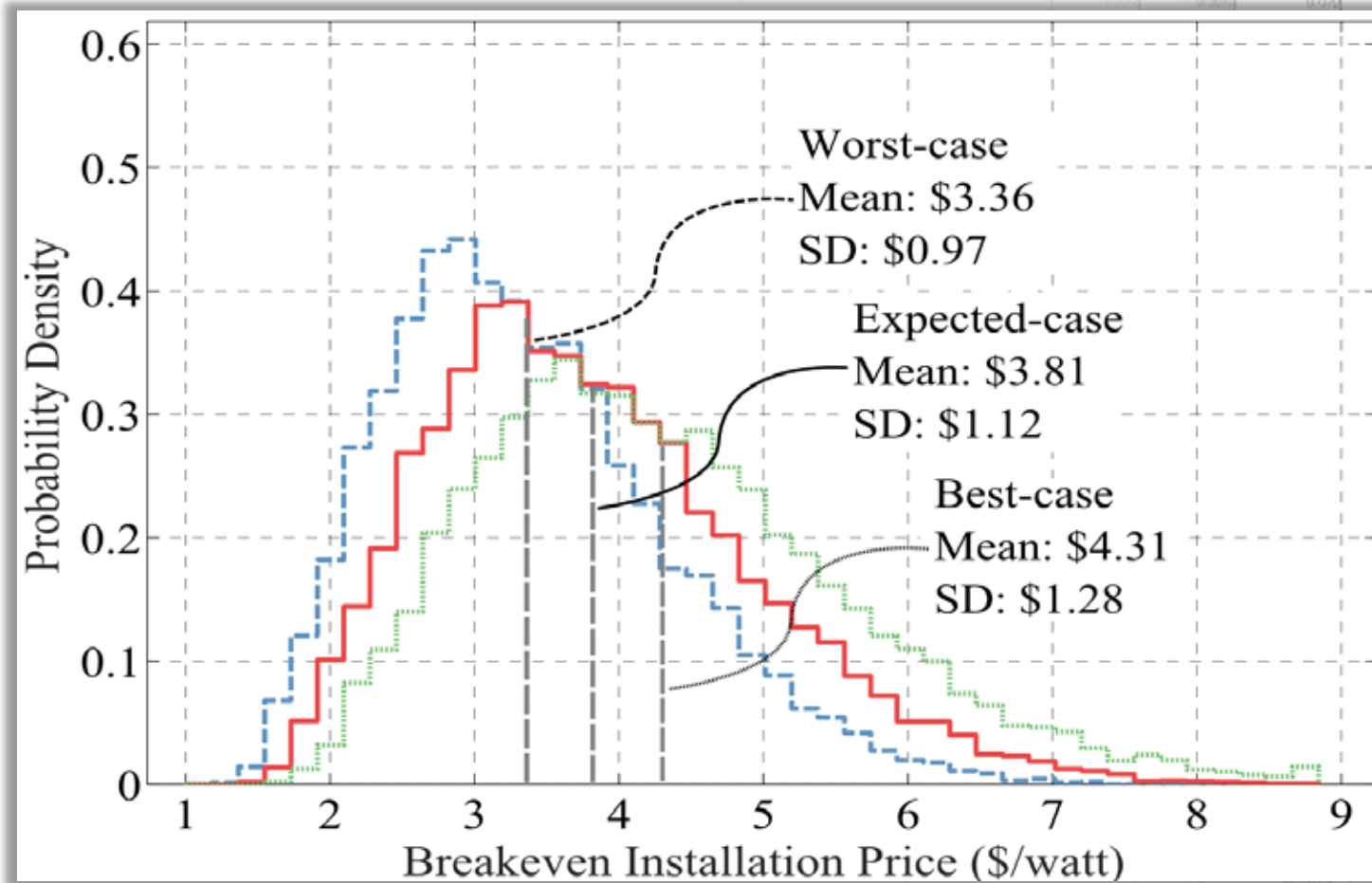
Model Sensitivity Analysis



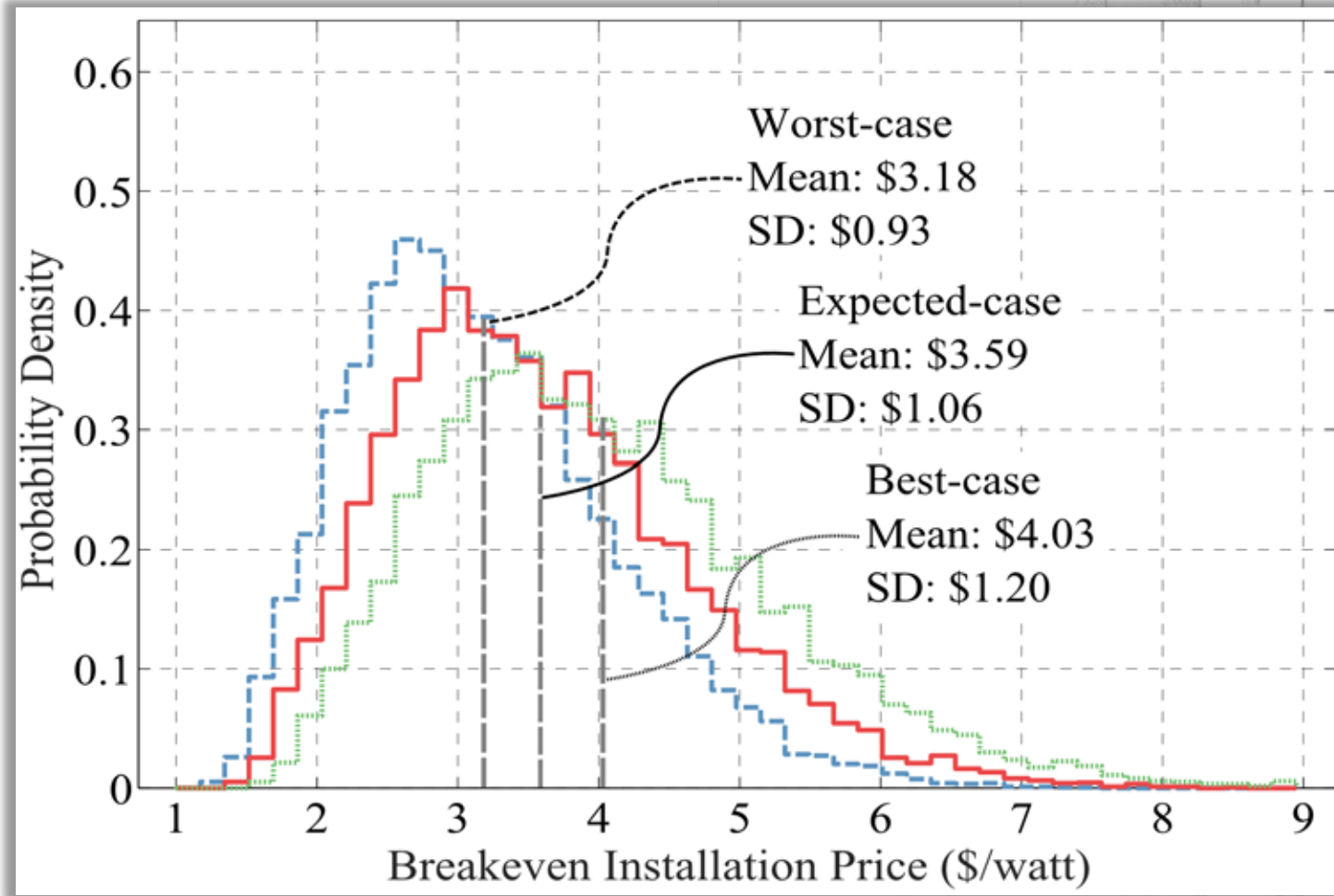
Model Sensitivity Analysis



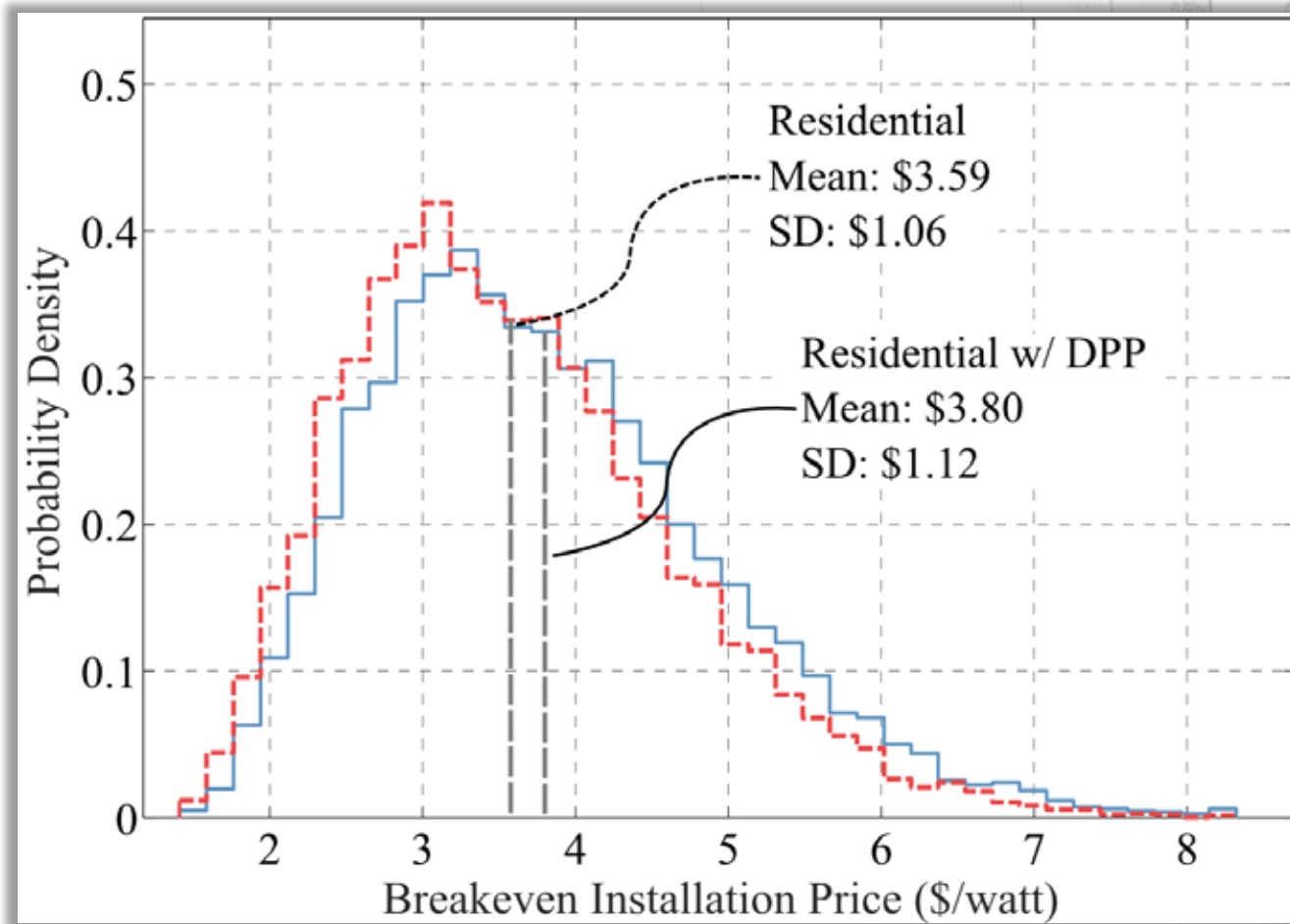
Model Breakeven Prices (Utility)



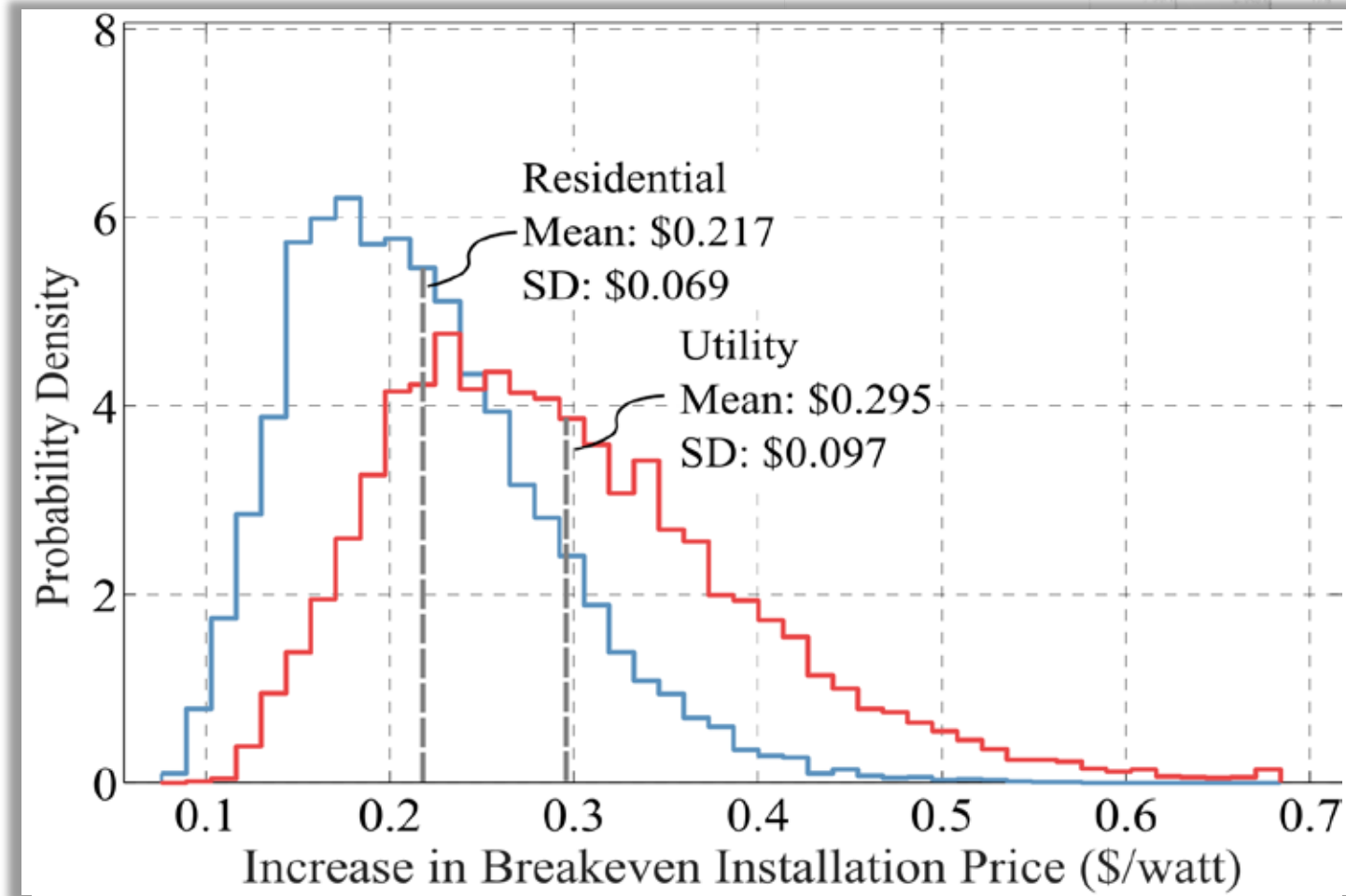
Model Breakeven Prices (Residential)



Expected Breakeven Prices (Residential + DPP)



Difference in Breakeven Price due to DPP



Discussion

§ Installation price per watt show positive ROI

Percentile	Residential (\$/W)		Utility (\$/W)	
	10 th	90 th	10 th	90 th
Worst-case	\$2.09	\$4.47	\$2.21	\$4.70
Expected	\$2.34	\$5.04	\$2.49	\$5.35
Best-case	\$2.62	\$5.67	\$2.80	\$6.06

§ Estimate that DPP can increase installed value per watt

Percentile	Residential (\$/W)		Utility (\$/W)	
	10 th	90 th	10 th	90 th
Worst-case	\$0.125	\$0.281	\$0.170	\$0.389
Expected	\$0.138	\$0.310	\$0.185	\$0.425
Best-case	\$0.151	\$0.342	\$0.202	\$0.465



Discussion (cont.)

- § Weighted national residential system costs \$3.48 per watt in Q4 2014
 - Model shows 48.9% can breakeven
- § Weighted national utility system costs less than \$2.00 per watt
 - Model shows 98.0% can breakeven

The background image shows a complex spreadsheet with multiple columns and rows of data. The top section includes columns for 'Input W/Tech', 'Distribution', and 'Breakeven %'. The bottom section includes columns for 'Capacity of Interest' and 'Difference'. The data points are numerical values, some in percentages and some in dollar amounts.



Conclusion

- § Model best suited for modeling at smaller level
- § Many more case studies can be run
- § Different technologies/parameter changes can be evaluated
 - Automated PV wash systems
- § Plan to make available online for anyone to use

Input WI Tech	Distribution	merit
2	Uniform	20
25	Uniform	4.00%
2.98%	Uniform	2.98%
0.00%	Normal	0.00%
1.00%	Uniform	3.50
0.75%	Uniform	88.0%
3.00	Normal	0.90%
86.00%	Normal	0.034
5.00%	Normal	3.65%
5.00%	Normal	
0.50%	Normal	
0.70	Uniform	
3.05%	Normal	
0.85%	Normal	
40%	Uniform	
30%	Uniform	

Capacity of Interest	Capacity of Interest WI Tech	Capacity of Interest Difference
100	0.25	0.25
1.09	2.64	2.64
147,698	859,098	653,038
147,698	4,949	80,345
22,392,252	740,244	60,259
27,742,023	350,413	720,157
85,765,250	9,357	350,413
2,679,521	770,234	9,856
356,093,617	-	608,746
-	170,254	-
98,053,617	29,390	808,746
36,351,584	4.7%	89,583
49.5%	24	12.3%
0.0576	0.0805	0.0746



Questions

Input	Default	Change due to tech (%)	Inputs w/ Tech	Distribution	Value
20	20	n/a	20	Uniform	20
4.00%	4.00%	0.0%	4.00%	Uniform	4.00%
2.95%	2.95%	0.0%	2.95%	Normal	2.95%
1.00%	1.00%	n/a	1.00%	Uniform	0.00%
0.75%	0.75%	-25.0%	0.56%	Uniform	3.50
3.00	3.00	0.0%	3.00	Uniform	88.0%
86.00%	86.00%	5.0%	91.30%	Normal	0.90%
5.00%	5.00%	n/a	5.00%	Normal	0.034
0.50%	0.50%	0.0%	0.50%	Normal	3.65%
0.70	0.70	n/a	0.70	Uniform	
3.05%	3.05%	n/a	3.05%	Normal	
0.55%	0.55%	n/a	0.55%	Normal	
40%	40%	0.0%	40%	Uniform	30%
30%	30%	0.0%	30%	Uniform	30%

Capacity of Interest	Capacity of Interest w/ Tech	Capacity of Interest Difference
0.25	0.25	0.25
2.64	2.64	-
653,038	653,038	-
4,949	3,712	(1,237)
80,345	60,259	(20,086)
740,244	720,157	(20,086)
350,413	350,413	-
9,357	9,356	-
770,234	608,746	-
-	-	-
170,254	808,746	-
29,390	89,583	-
4.7%	12.3%	-
0.0805	0.0746	-

