Electronic Supplementary Material (ESI) for Energy & Environmental Science

Supplementary Information for "Deciphering Uncertainties in Energy & Environmental Analysis of Organic Photovoltaics"

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1. Process Data (Machinery)

Table 1. Slot die casting machine specifications

Conditions	
Speed	0.2-2.5 m min^{-1}
Web tension	80-90 N
Drying temperature	140 ^{o}C
Working corona treater power	1500 W
Working slot die power	1500 W
Working oven power	12000 W
Equipment	
Description	R2R printing and coating machine from Grafisk Maskinfabrik A/S comprising unwinder, corona treater, edge guide, rotary screen printer, flexo unit, coating roller, oven, cooling roller and winding station.
Maximum corona treater power	1500 W
Maximum slot die coater power	1500 W
Maximum oven power	12000 W
Material Inventory	
Front electrode layer	
PEDOT:PSS	39.34 g
Silver ink (18% Ag)	0.26 g
Active Layer	
P3HT	0.08 g
PCBM	0.07 g
Chlorobenzene	6.19 g
ELT layer	
$ZnO(OAc)_2$	3.71 g
KOH	1.86 g
MeOH	12.24 g
Acetone	24.50 g
MEA	0.37 g
Water	2.95 g
HTL layer	
PEDOT:PSS	26.23 g
Isopropanol	38.89 g
Back electrode layer	
Silver for interconnections	0.63 g

Table 2. Rotary screen printing specifications

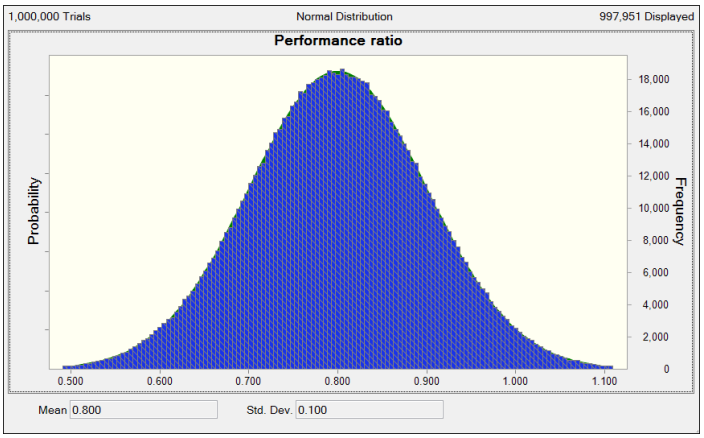
Conditions	
Speed	3m min^{-1}
Drying temperature	140^{o}C
Working RS printer power	200 W
Working oven power	12000 W
Equipment	
Description	R2R printing and coating machine from Grafisk Maskinfabrik A/S comprising unwinder, corona treater, edge guide, rotary screen printer, flexo unit, coating roller, oven, cooling roller and winding station.
Maximum RS printer power	1500 W
Maximum oven power	21000 W
Material inventory	
Front and back electrode layer	
Graphite full	4.59 g
Graphite interconnections	0.79 g

Table 3. Encapsulation specifications

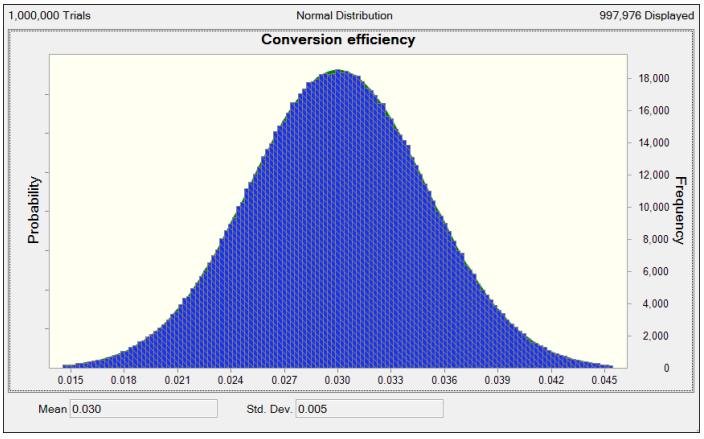
Conditions	
Speed	2 m min^{-1}
Working laminator power	1500 W
Equipment	
Description	Laminator comprising unwinder, edge guide and cutting table, laminator, laminate unwinder, longitudinal cutting knifes and rewinder.
Maximum power	1500 W
Material inventory	
Adhesive	20.24 g
PET encapsulation	61.65

2. Probability distributions for assumptions

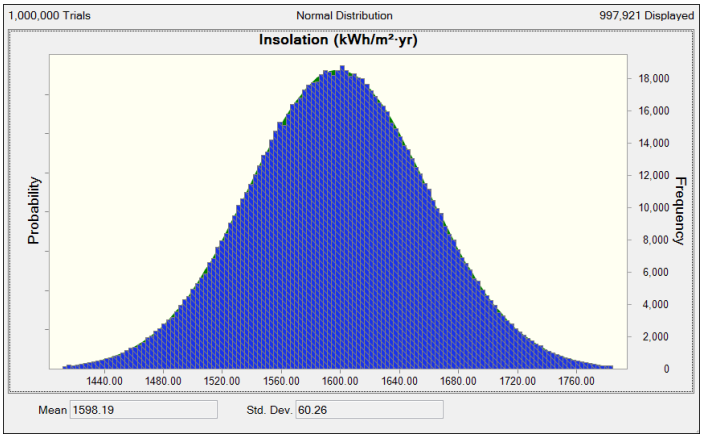
Performance ratio



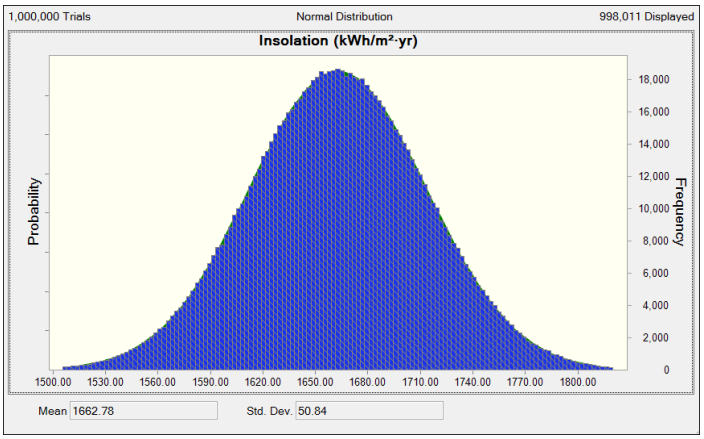
Conversion efficiency



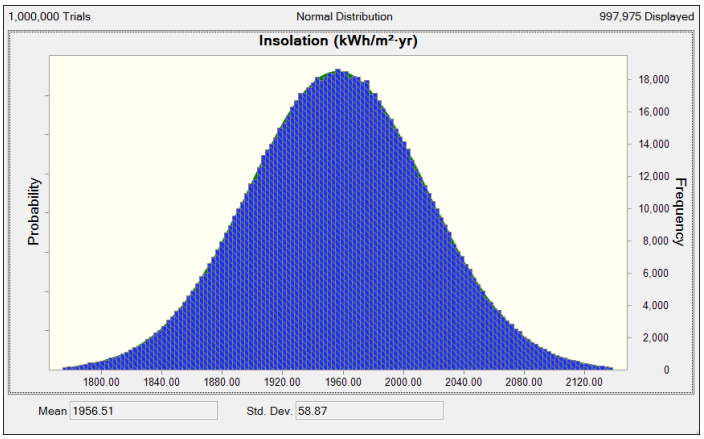
Solar insolation for Chicago



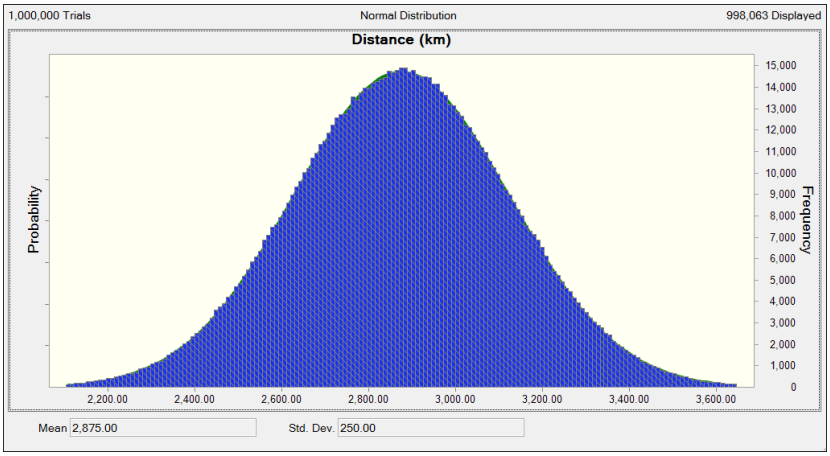
Solar insolation for NYC



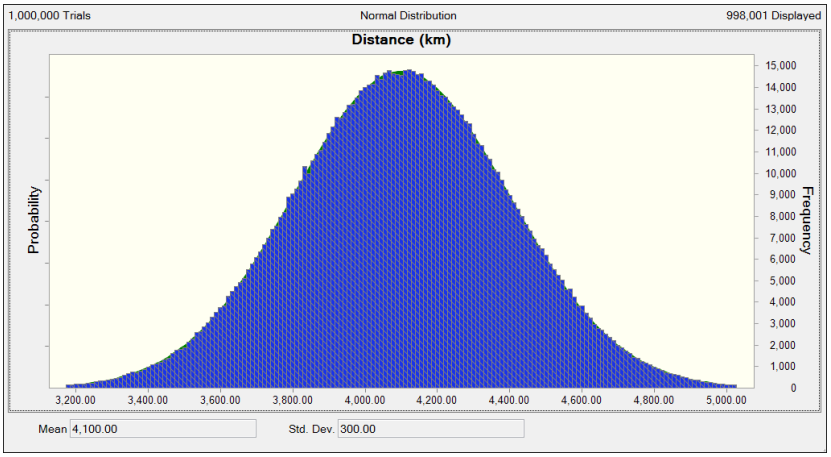
Solar insolation for San Francisco



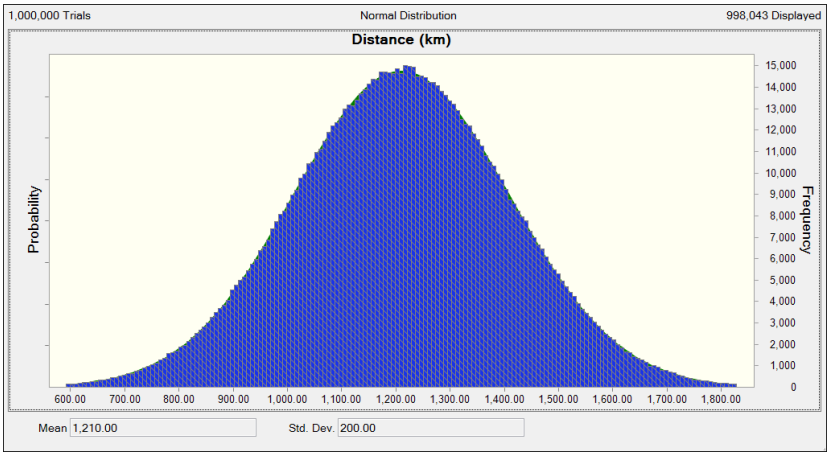
Road transport distance to Chicago



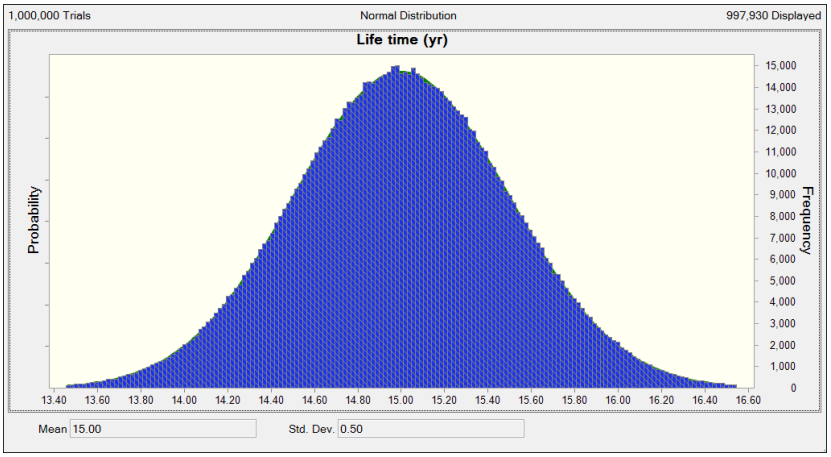
Road transport distance to NYC



Road transport distance to San Francisco



Life time



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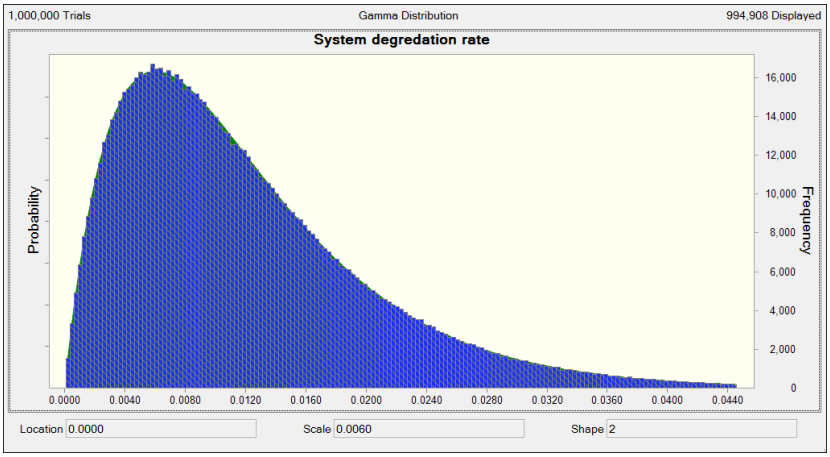
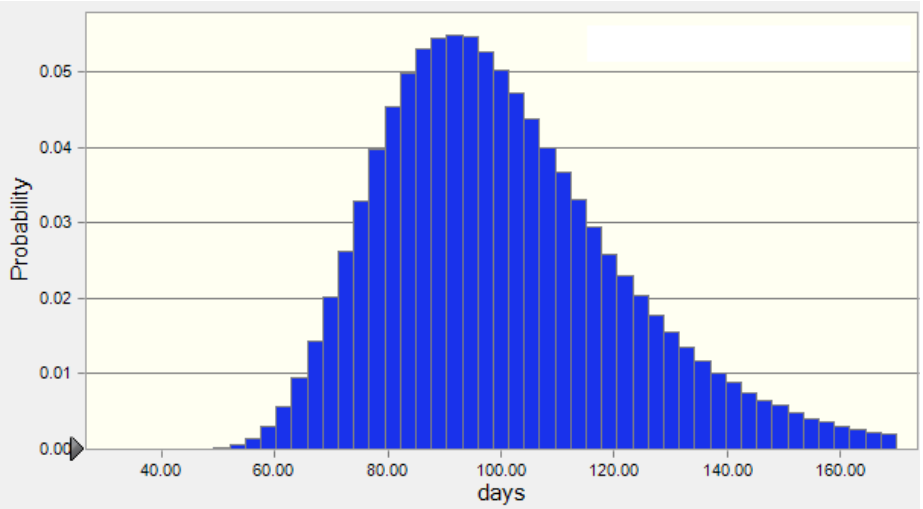
System degradation rate



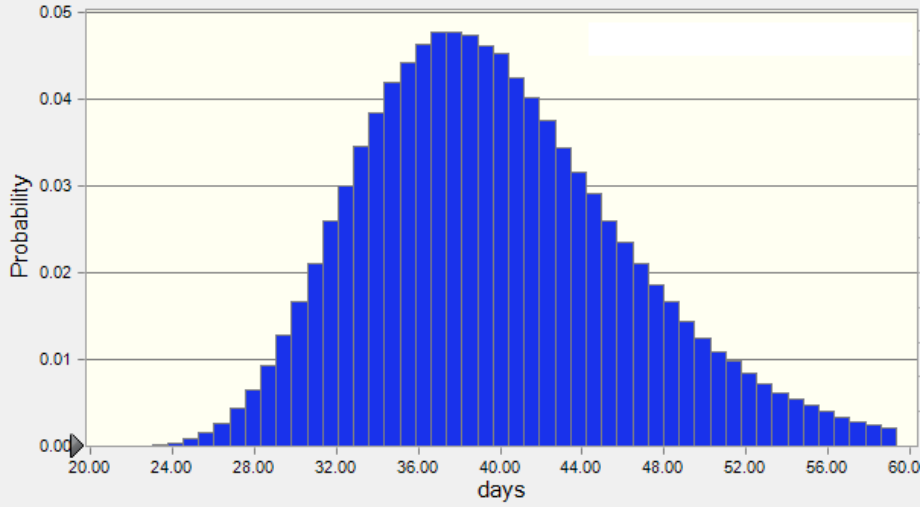
3. Probability distribution for forecasts

EPBT in Chicago

Scenario 1



Scenario



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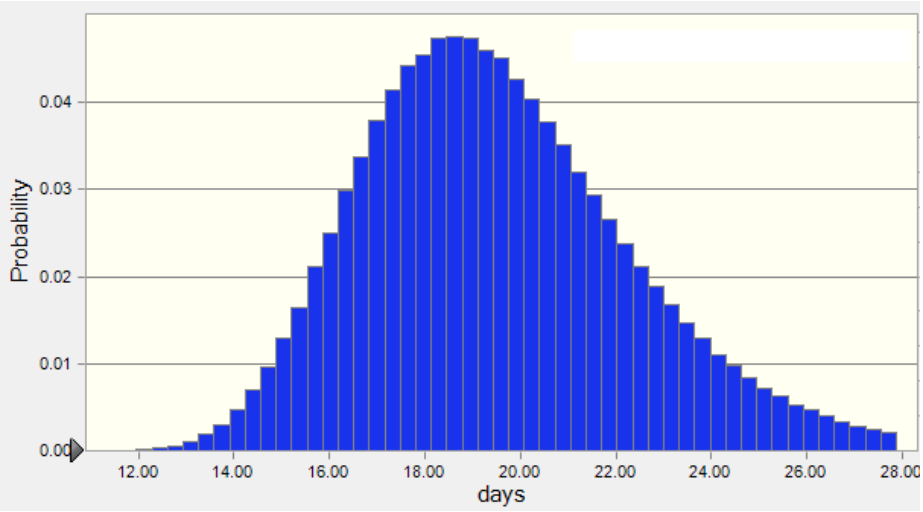
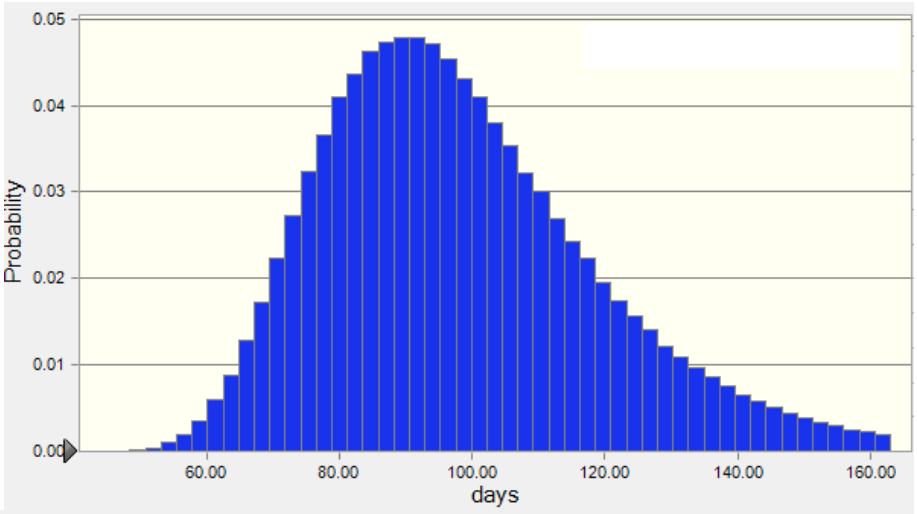
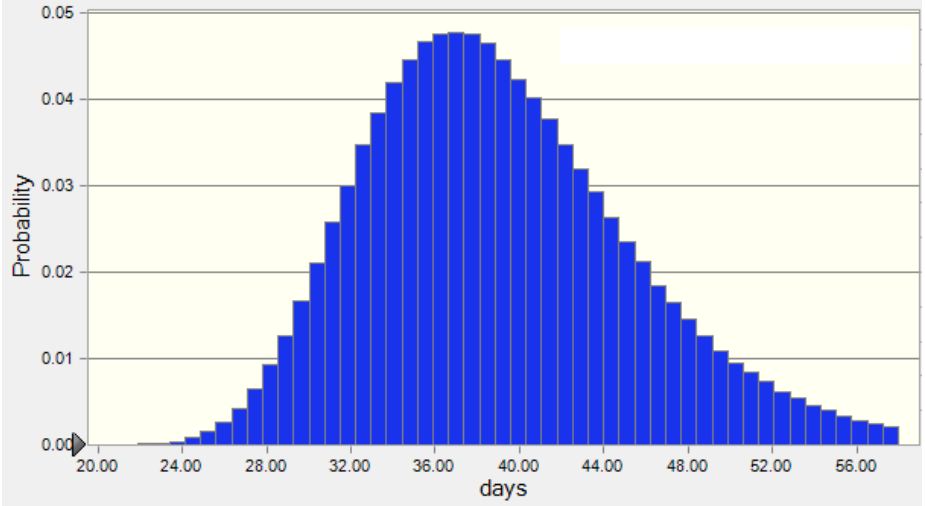


EPBT in New York

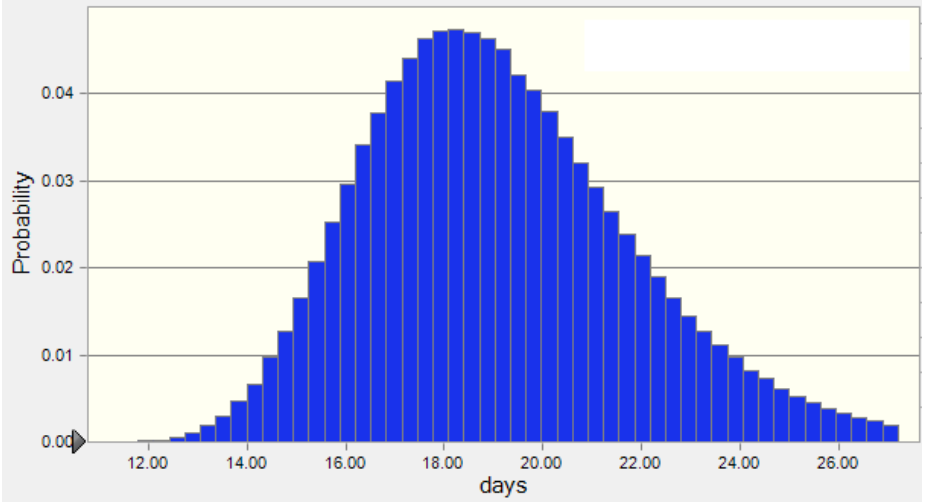
Scenario 1



Scenario

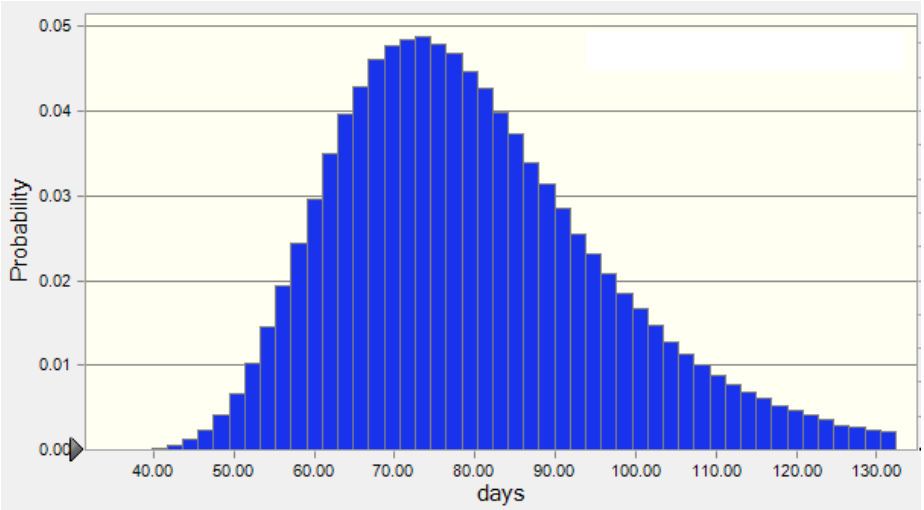


Scenario

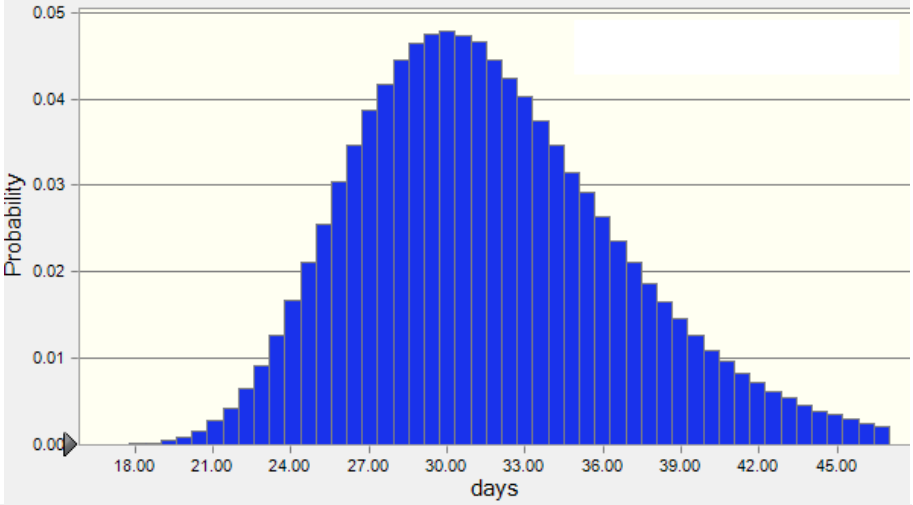


EPBT in San Francisco

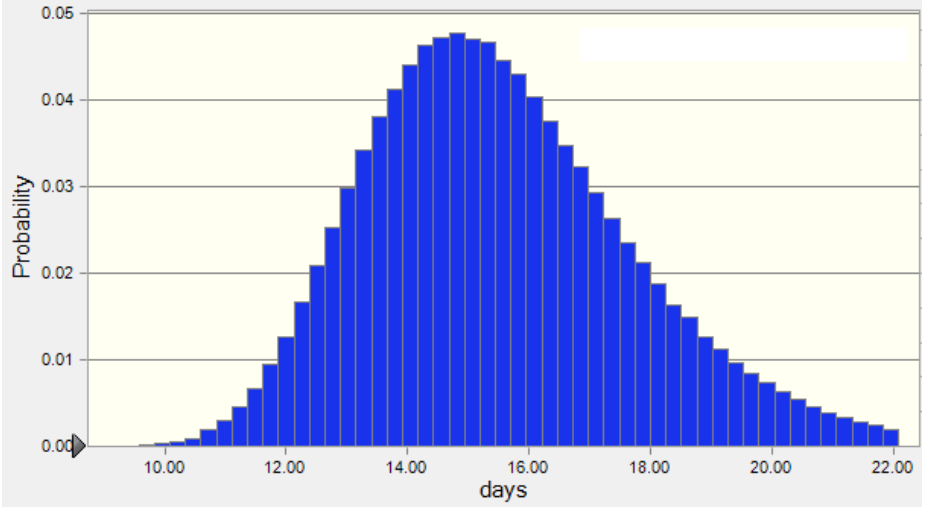
Scenario 1



Scenario

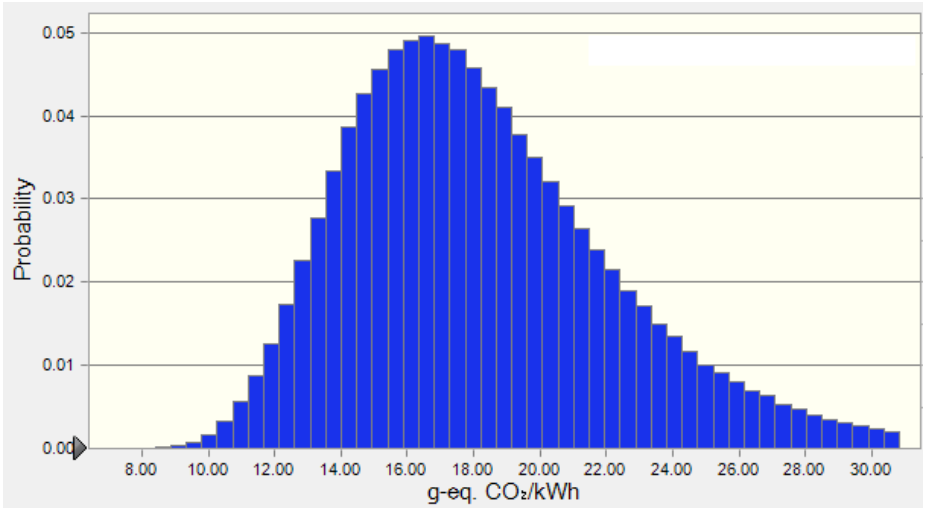


Scenario

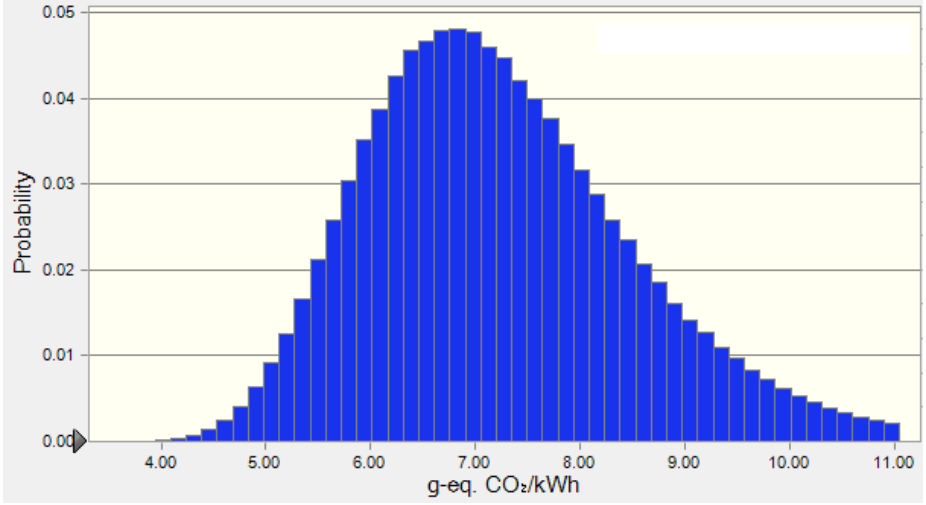


CO_2 emissions factor in Chicago

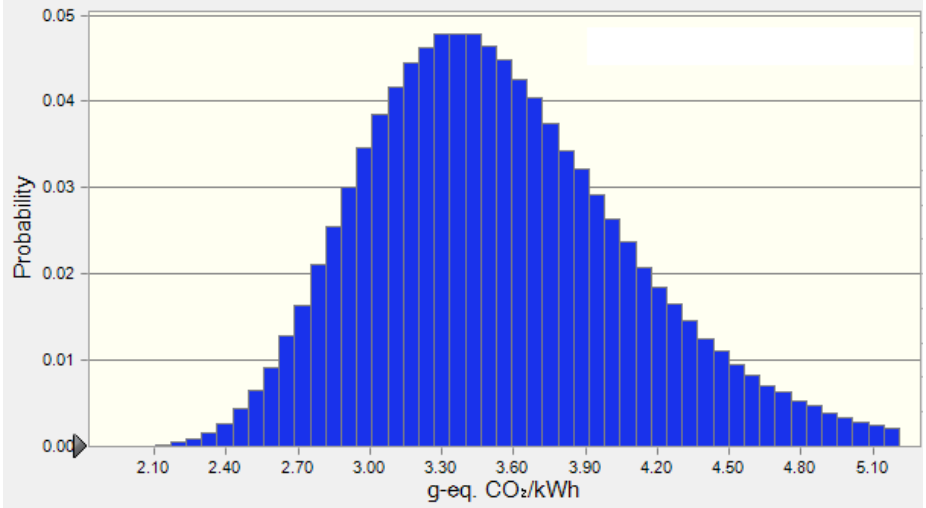
Scenario 1



Scenario

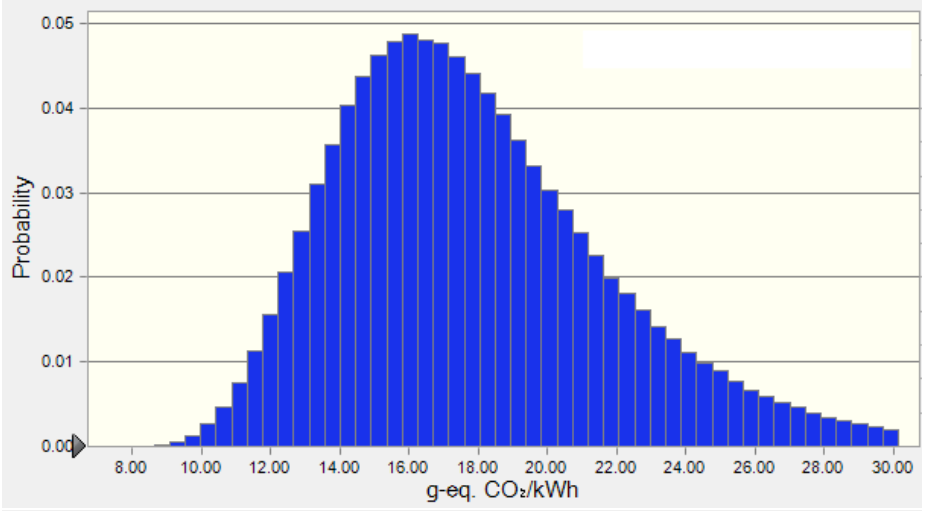


Scenario

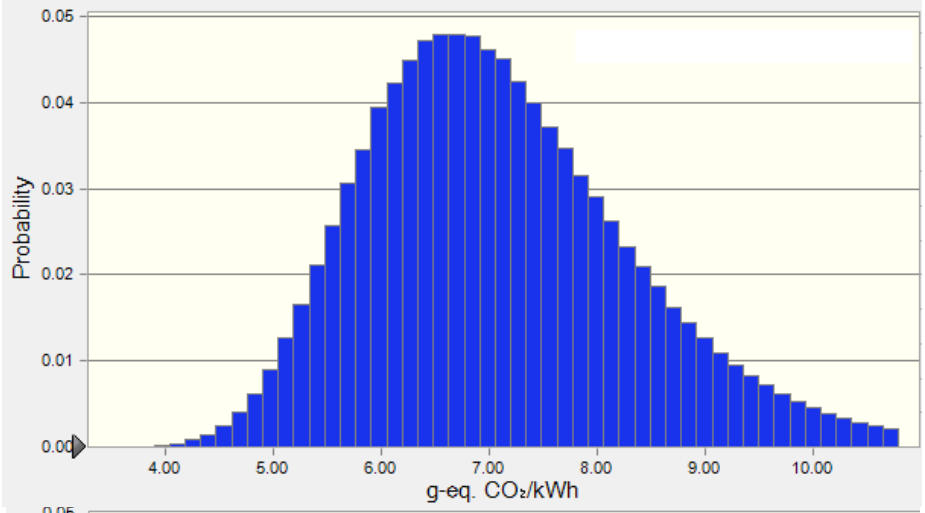


CO_2 emissions factor in New York

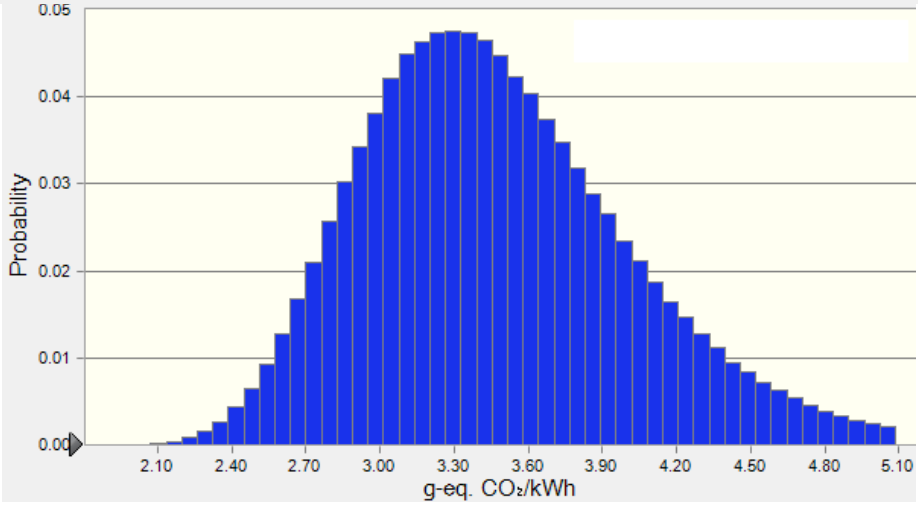
Scenario 1



Scenario

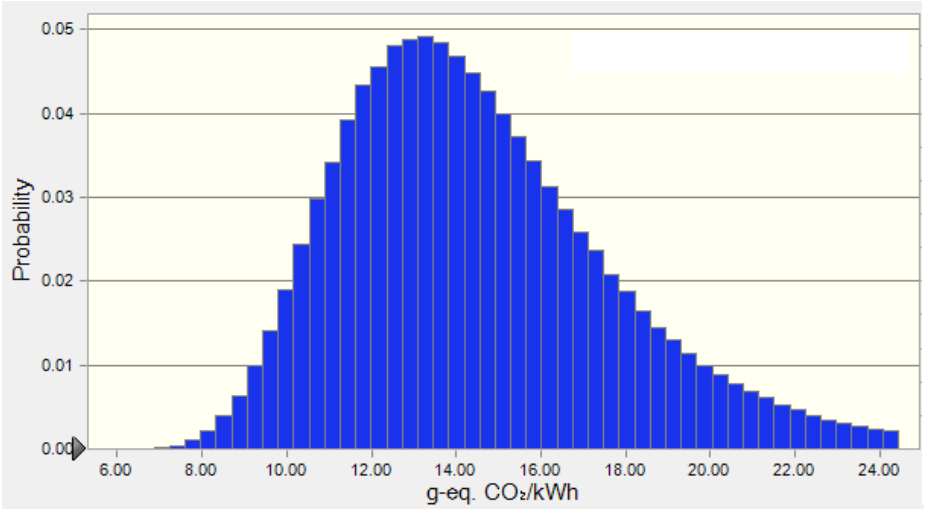


Scenario

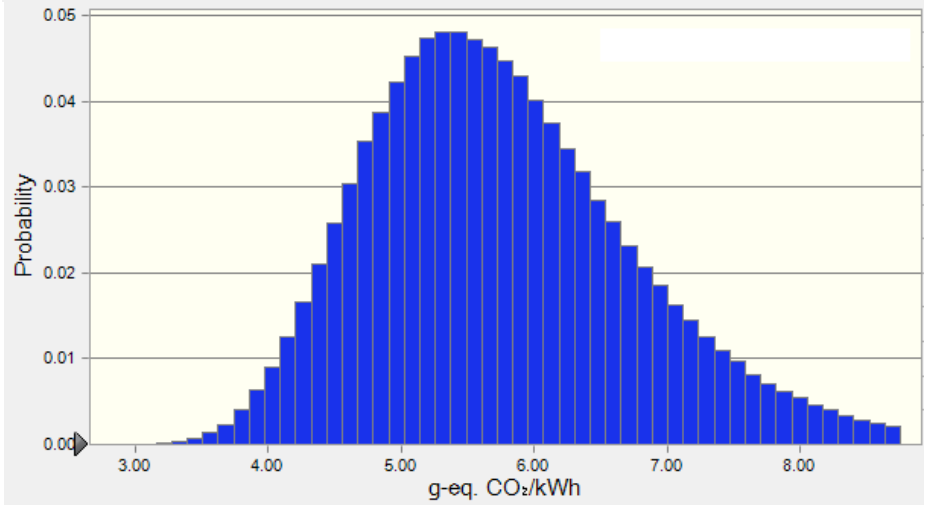


CO_2 emissions factor in San Francisco

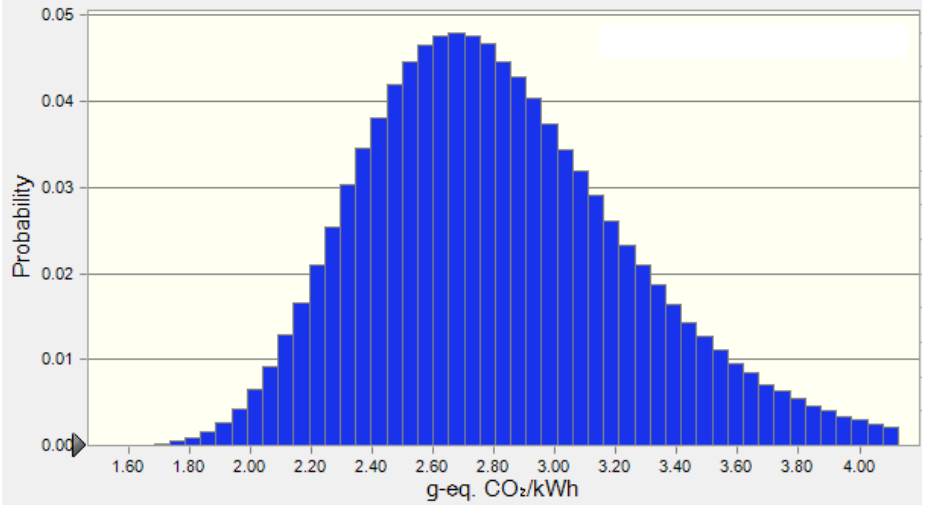
Scenario 1



Scenario



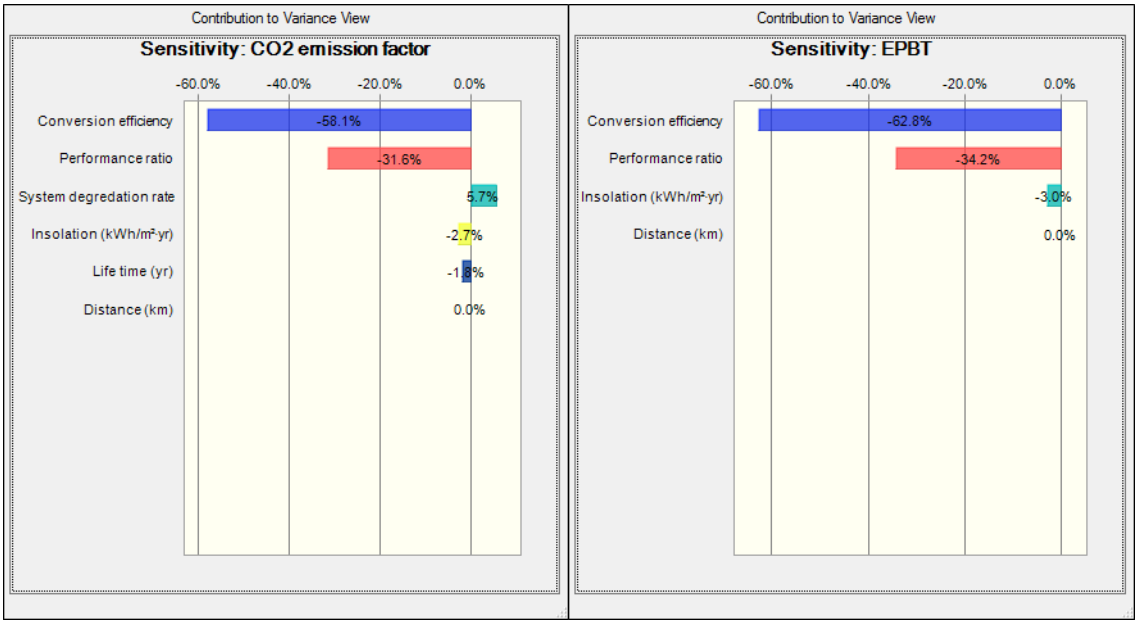
Scenario



4. Sensitivity Analysis

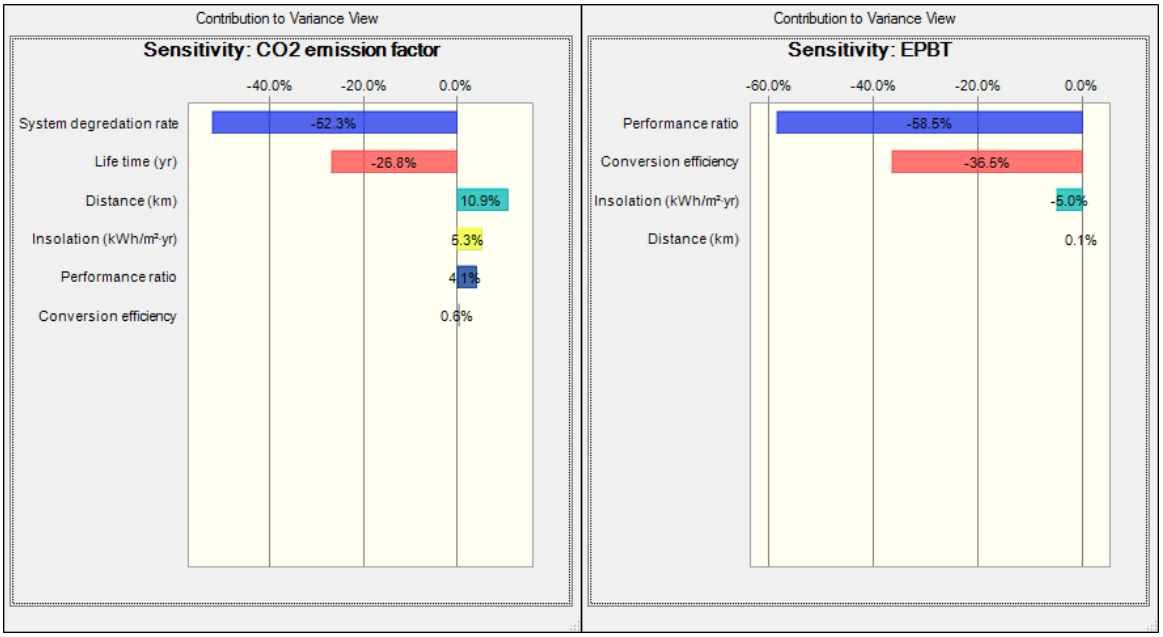
Chicago

Scenario 1



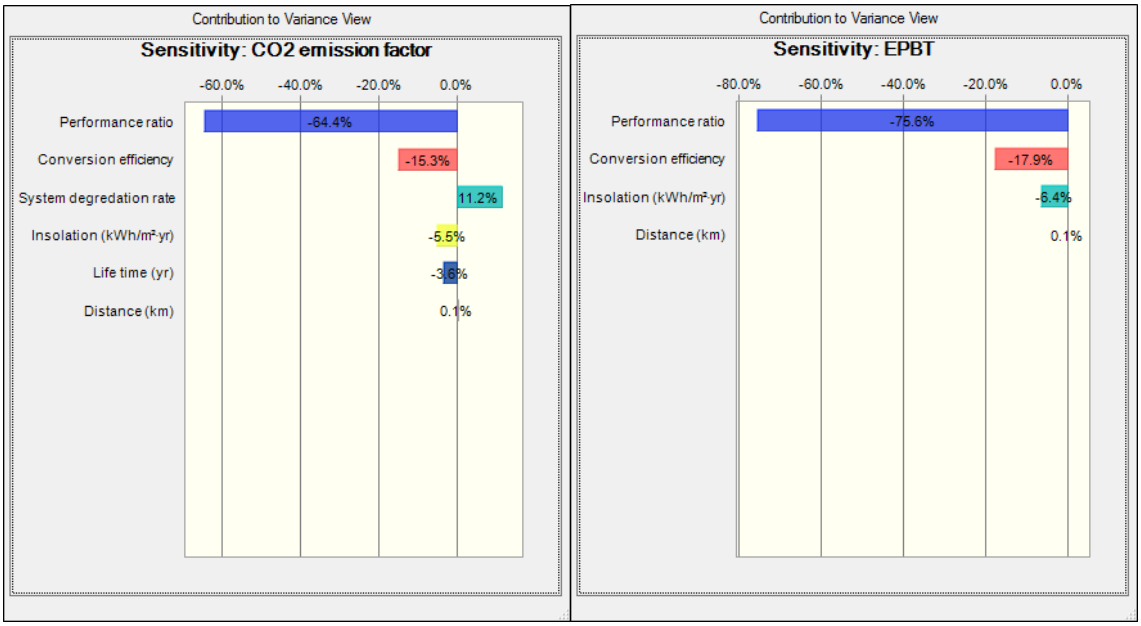
The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 1 (Percentage active area= 45%) for Chicago are shown above.

Scenario 2



The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 2 (Percentage active area= 67%) for Chicago are shown above.

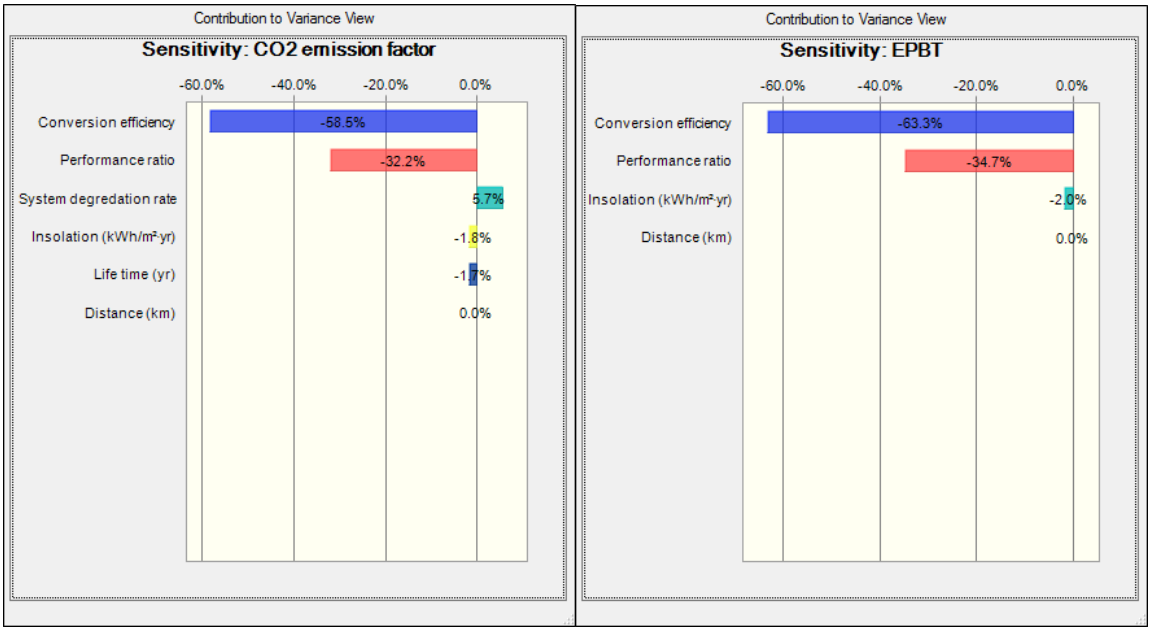
Scenario 3



The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 3 (Percentage active area= 85%) for Chicago are shown above.

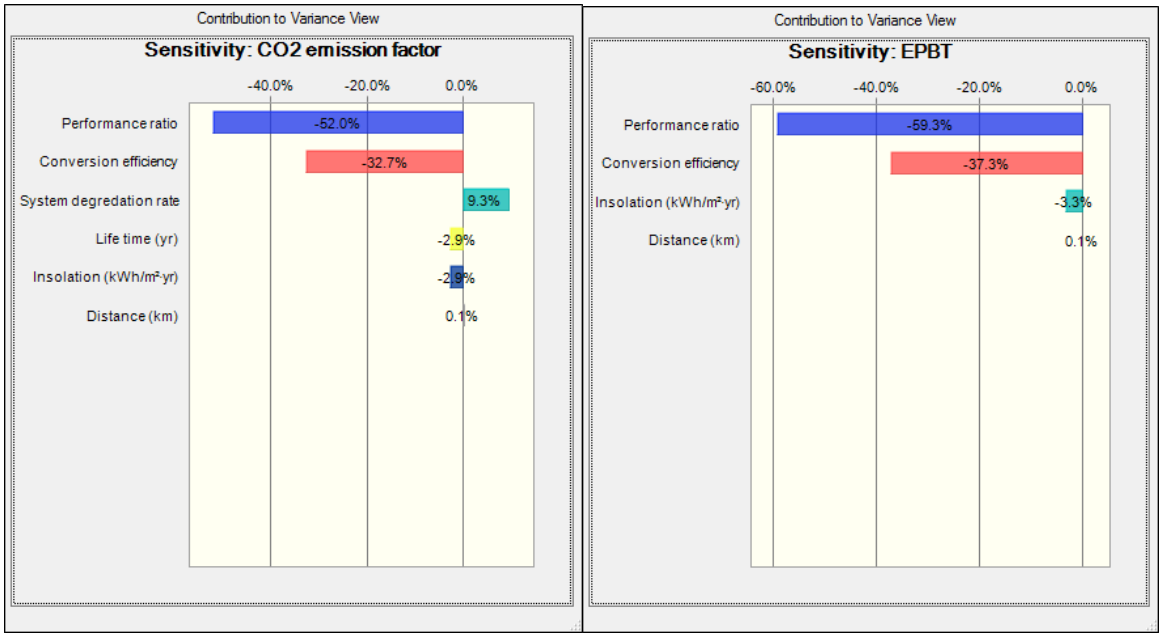
New York

Scenario 1



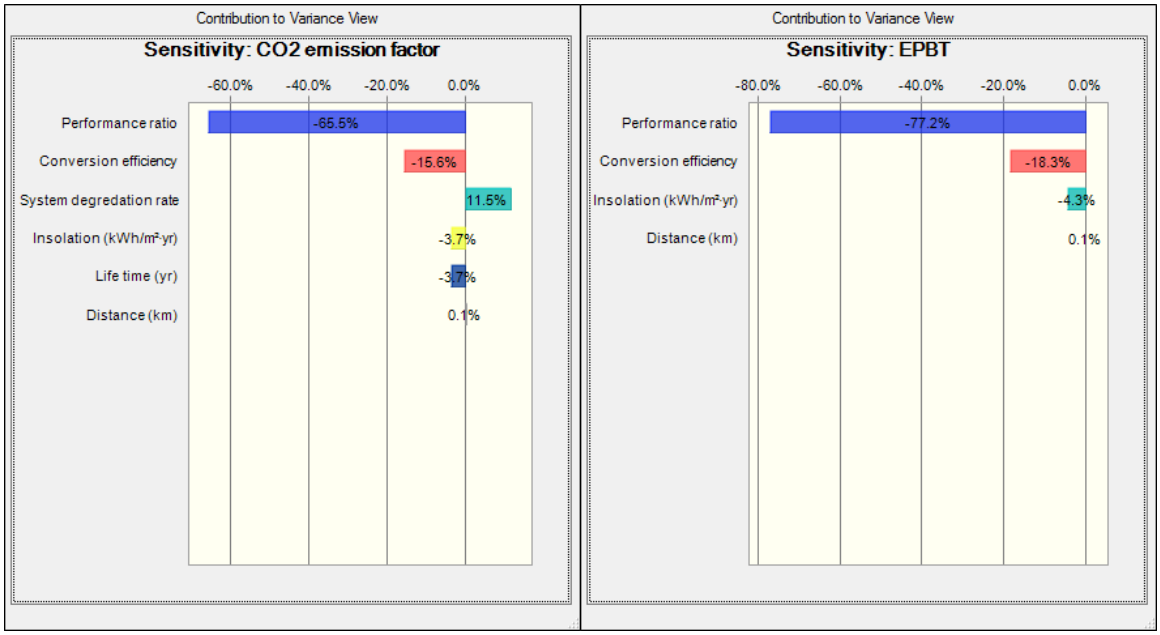
The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 1 (Percentage active area= 45%) for New York are shown above.

Scenario 2



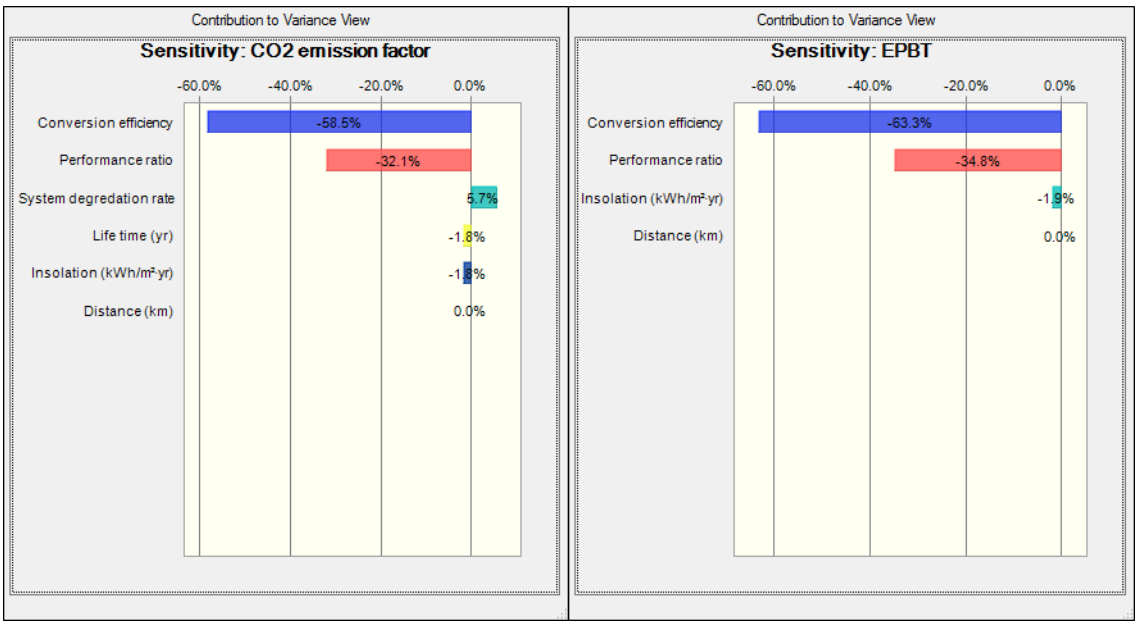
The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 2 (Percentage active area= 67%) for New York are shown above.

Scenario 3



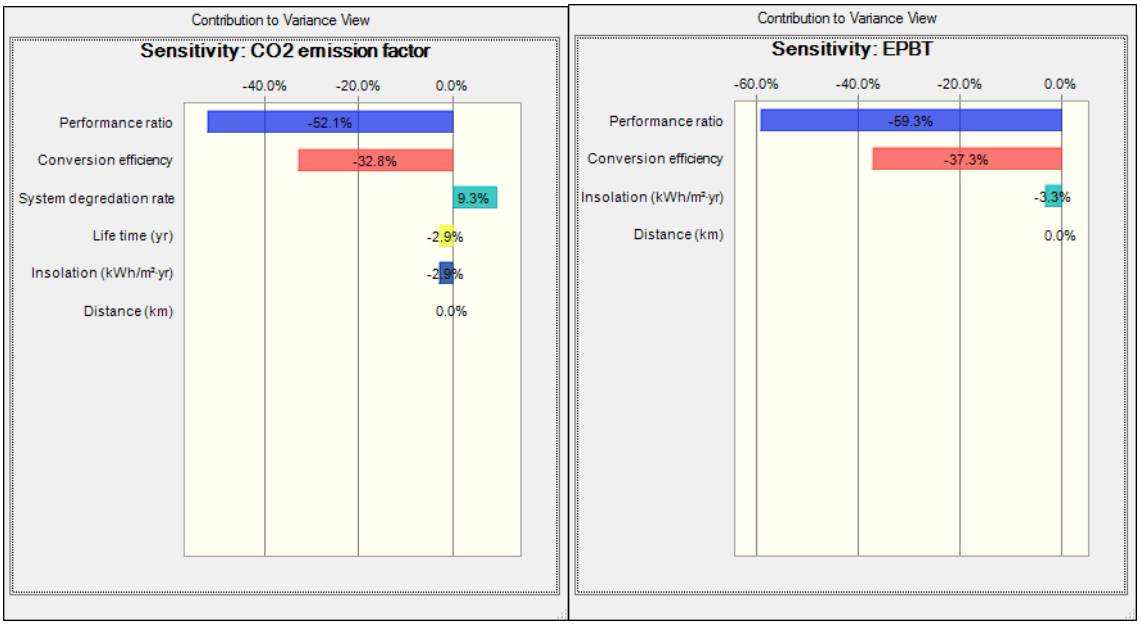
The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 3 (Percentage active area= 85%) for New York are shown above.

San Francisco
Scenario 1



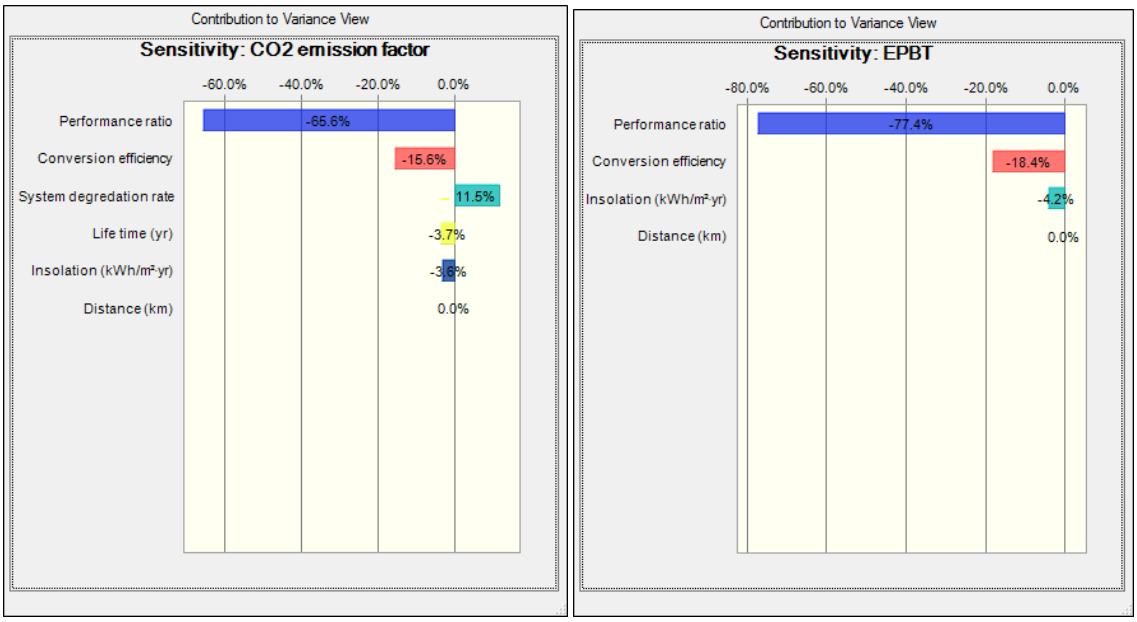
The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 1 (Percentage active area= 45%) for San Francisco are shown above.

Scenario 2



The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 2 (Percentage active area= 67%) for San Francisco are shown above.

Scenario 3



The sensitivity charts for the EPBT and the CO_2 emission factor for scenario 3 (Percentage active area= 85%) for San Francisco are shown above.

5. Deduction of Equation (4)

If the module's lifetime is *n* years, the total generated electricity over its lifetime would be the summation of the annual electricity generation over the *n* years.
The generic form of annual electricity generation is given below,

Year	1	2	3	…	*n*
Annual generated energy	EG	$EG \cdot sdr$	$EG \cdot sdr^2$		$EG \cdot sdr^{n-1}$

Thus total generated electricity is calculated as,

$$totalEG = EG + EG \cdot (1 - sdr) + EG \cdot (1 - sdr)^2 + ... + EG \cdot (1 - sdr)^{n-1}$$

$$= EG[1 + (1 - sdr) + (1 - sdr)^2 + ... + (1 - sdr)^{n-1}]$$

$$= EG \frac{1 - (1 - sdr)^n}{1 - (1 - sdr)}$$

$$= EG \frac{1 - (1 - sdr)^n}{sdr}$$

The CO_2 emissions factor is then calculated as the embodied CO_2 divided by the total generated electricity over the module's lifetime.

$$EF = \frac{EC}{totalEG} = \frac{EC \times sdr}{EG \times [1 - (1 - sdr)^n]}$$

Note that the expression is rigorous when the lifetime *n* is an integer, which may not necessarily be the case. However, we assume this calculation of the CO_2 emissions factor to be a proper estimation in all cases.