

ENERGY

# HVAC-4 Deemed Measures Uncertainty Study, Year 2

Public Webinar

for California Public Utilities Commission

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01 September 2016

Ungraded

# Presentation Outline

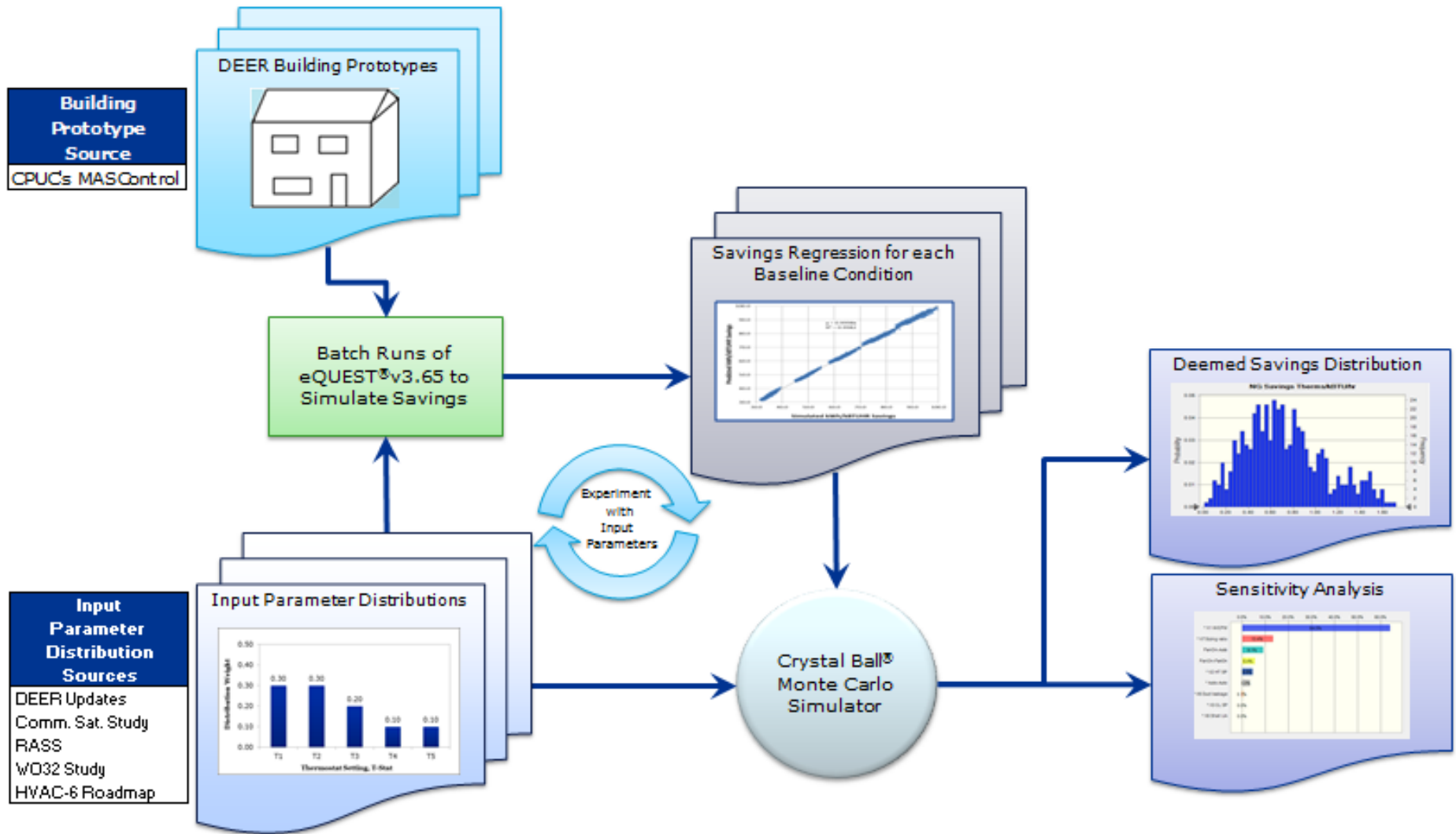
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- Measure Selection
- Description of eQUEST modelling and Monte Carlo simulation process
- Results for Year 2 measures:
  - **Residential Furnaces**
    - AFUE 95
    - ECM retrofits
  - **Nonresidential Boilers**
  - **Nonresidential VFDs at HVAC fans**
- Larger benefits of uncertainty analysis
- Year 3 study plans

# Measure Selection: Selection Criteria

Selection Criteria	Residential Furnaces		Nonresidential Boilers	Nonresidential VFDs-HVAC Fans
	ECM Motor, Electric	AFUE 95, Gas	Gas	Electric
High savers in HVAC Roadmap	No (but growing)	✓	✓	✓
Growing participation	✓ (particularly with ECMs)			
Not currently being evaluated	✓		✓	✓

# Monte Carlo Simulations of Outputs of DEER Prototypes



## Sources for Distributions of Input Parameters

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### Sources

DEER Updates

Commercial Saturation Study

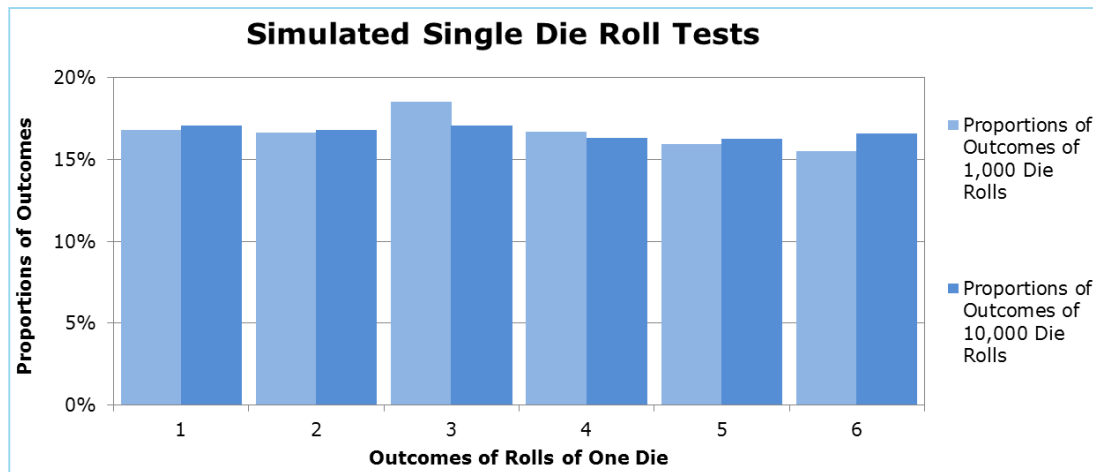
Residential Appliance Saturation Study

WO32 Evaluation Report

HVAC-6 Roadmap Evaluation Results

# Description of Monte Carlo Simulations: General

- Monte Carlo simulation was named for Monte Carlo, Monaco
- Crystal Ball<sup>®</sup> is a Microsoft Excel<sup>®</sup> add-in for performing Monte Carlo simulations
- To set up Monte Carlo simulations, define the conditions of the input variable—in this case, an integer between 1 and 6, inclusive, of equal likelihood of outcomes.

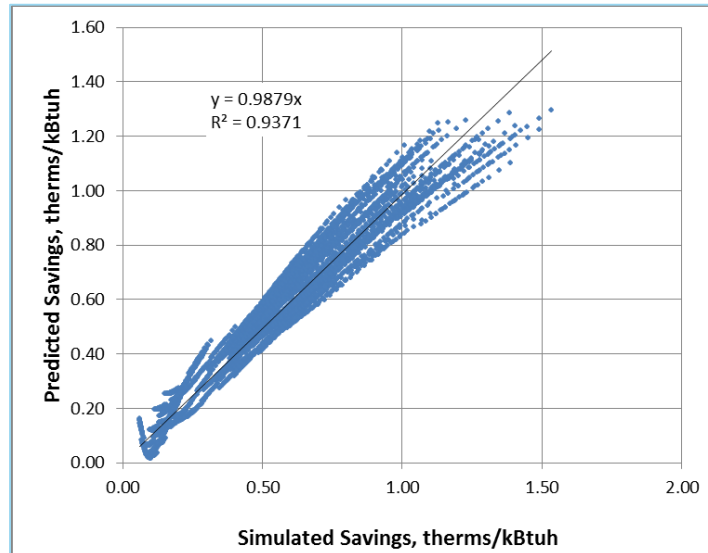


# Residential Furnaces: 95 AFUE eQUEST Simulation Set-up/Results

Efficient Furnace Measure**	Baseline Efficiency	Post-retrofit Efficiencies	Fan Control	Fan Motor	Thermostat Bins	Building Vintage Bins	Duct Leakage Proportions	Furnace Sizing Ratios
<b>95 AFUE</b> Single Family Home CZ12	= 80 AFUE	95.0	Auto-controlled	PSC	T1	Before 1975	0.09	0.8
		95.5			T2	1975-1985	0.12	0.9
		96.0	Always on	ECM	T3	1985-1996	0.19	1.0
		96.5			T4	1996-2003	0.24	1.1
		97.0			T5	2003-2007	0.40	1.2
					2007-2011			
					2011-2014			

\*\* 17,500 permutations run in eQUEST

## eQUEST Batch Run Results for furnaces with auto-controlled ECMs:

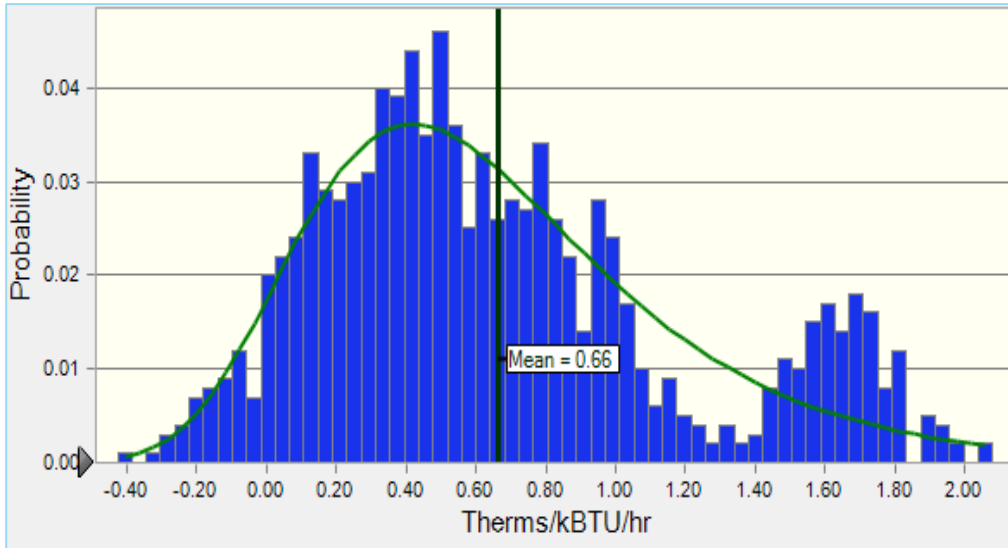


# Residential Furnaces: Monte Carlo Simulation Results

## AFUE 95 Furnace Savings Comparison

Annual Savings Ratio, therm/kBtuh	Uncertainty Analysis	DEER Savings
Average Savings	0.66	0.64
Standard Deviation of Average Savings	0.54	N/A

## Savings Distribution & Input Parameter Sensitivity



Input Parameters	Relative Contribution to Variance
Heating Setpoint	93.9%
Building Vintage Bin weights	4.0%
Furnace Sizing Ratio	1.3%
Δ Furnace Efficiency	0.4%
Fan Motor/Control Strategy	0.2%
Duct Leakage Proportion	0.1%
Cooling Setpoint	0.1%

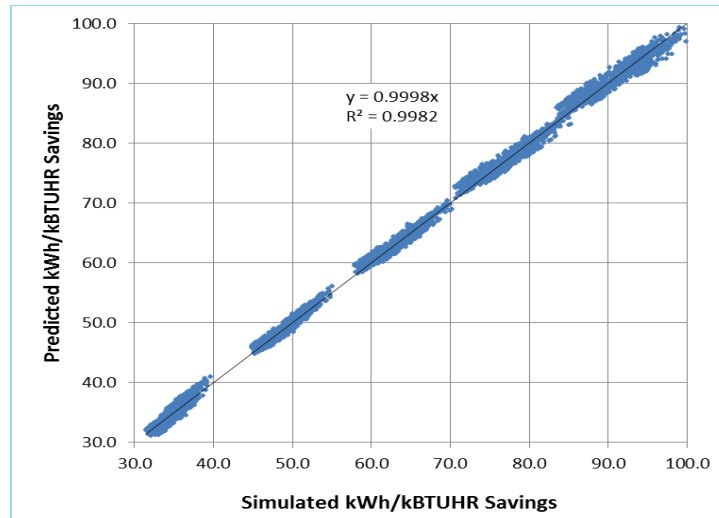


# Residential Furnaces: ECM eQUEST Simulation Set-up/Results

ECM Measure at Furnace*	Baseline PSC-motor Fan Control	Post-retrofit Fan Control	Furnace Efficiencies	Thermostat Bins	Building Vintage Bins	Duct Leakage Proportions	Furnace Sizing Ratios
ECM Single Family Home CZ12	Auto-controlled	Auto-controlled	95.0	T1	Before 1975	0.09	0.8
			95.5	T2	1975-1985	0.12	0.9
	96.0	T3	1985-1996	0.19	1.0		
	96.5	T4	1996-2003	0.24	1.1		
	97.0	T5	2003-2007	0.40	1.2		
	Always on	Always on			2007-2011		
					2011-2014		

\* 17,500 Permutations run in eQUEST

**eQUEST Batch Run Results  
for furnace ECMs,  
always on baseline &  
always on post-retrofit:**

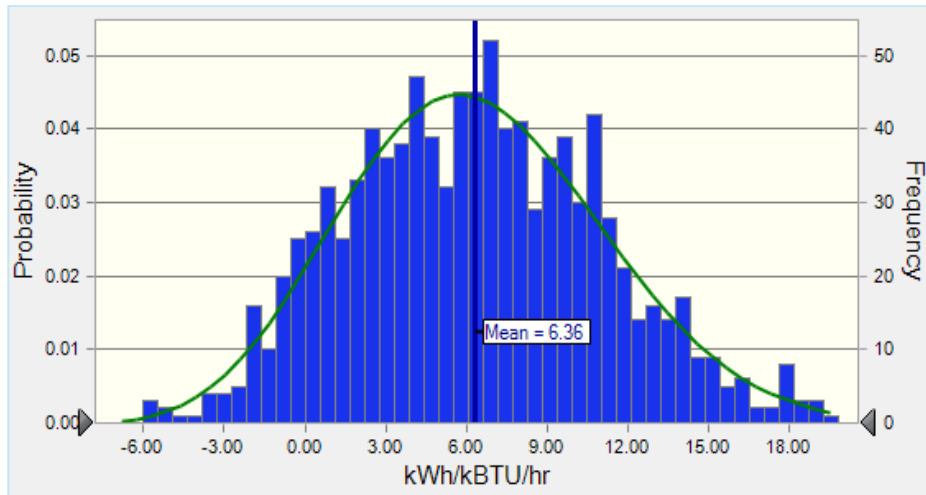


# Residential Furnaces: Monte Carlo Simulation Results

## ECM Measure Savings Comparison

Annual Savings Ratio, kW/kBtuh	Uncertainty Analysis	DEER
Average Savings	6.36	N/A
Standard Deviation of Average Savings	4.81	

## Savings Distribution & Input Parameter Sensitivity



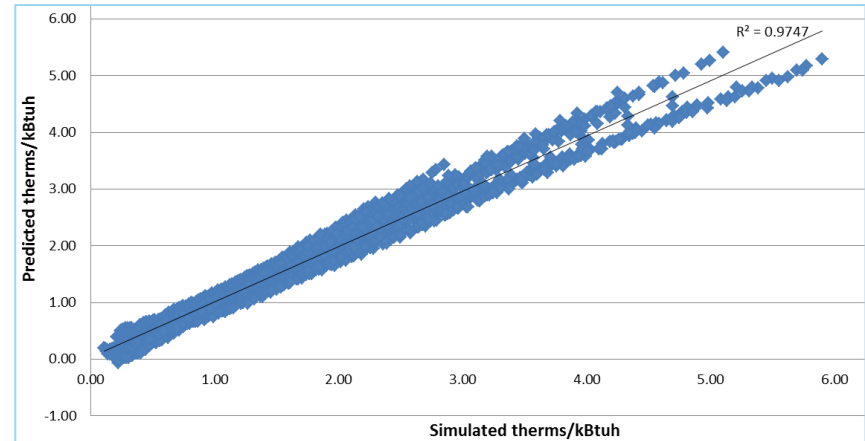
Input Parameters	Relative Contribution to Variance
Fan Power Index (W/cfm)	59.2%
Furnace Sizing Ratio	16.0%
Fan-motor Control Strategy	13.1%
Heating Setpoint	10.2%
Building Vintage Bin Weights	0.9%
Cooling Setpoint	0.4%
Duct Leakage Proportion	0.2%

# Nonresidential Boilers: eQUEST Simulation Set-up

Boiler Retrofit*	$\Delta$ Thermal Efficiencies	Minimum Supply Airflow Ratios	Boiler Sizing Ratios	Building Vintage Bins
Efficient Boiler Office Building CZ04	0.00	0.2	0.8	Before 1975
	0.09	0.3	1.0	1975-1985
	0.10	0.4		1985-1996
	0.15	0.5	1.2	1996-2003
	0.17	0.6	1.4	2003-2007
	0.19	0.7		2007-2011
	0.21	0.8	1.8	2011-2014
		0.9		

\* 1,960 Permutations run in eQUEST

## eQUEST Batch Run Results:

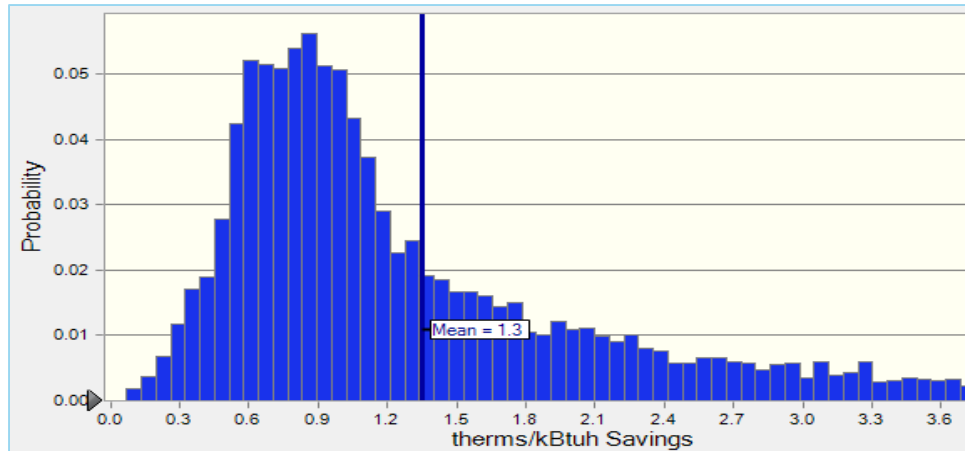


# Nonresidential Boilers: Monte Carlo Simulation Results

## Boiler Savings Comparison

Annual Savings Ratio, therm/kBtuh	Uncertainty Analysis	DEER
Average Savings	1.3	0.75
Standard Deviation of Average Savings	0.9	N/A

## Savings Distribution & Input Parameter Sensitivity



Input Parameters	Relative Contribution to Variance
Minimum Airflow Ratio	82.5%
$\Delta$ Thermal Efficiency	16.7%
Boiler Sizing Ratio	0.8%
Building Vintage Bin weights	0.0%

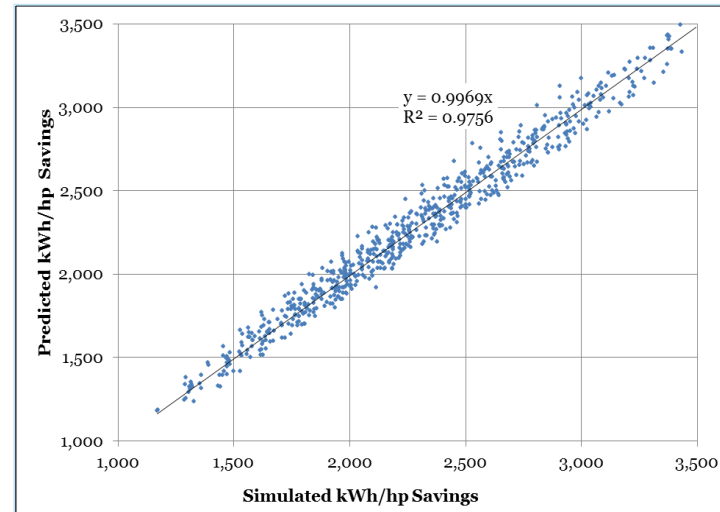
# Nonresidential VFDs at Fans: eQUEST Simulation Set-up/Results

VFDs at HVAC Fans*	Baseline Airflow Control	Fan Power Indices	Minimum Airflow Ratios	Building Vintage Bins	Thermostat/Fan Schedule Bins
Supply Air VFD Office Building CZ03	= Discharge Dampers Inlet Guide Vanes 2-speed Motor**	0.40	0.3	Before 1975	SCH1
		0.45	0.4	1975-1985	SCH2
		0.50	0.5	1985-1996	SCH3
		0.55	0.6	1996-2003	SCH4
		0.60	0.7	2003-2007	SCH5
				2007-2011	
				2011-2014	

\* 2,625 Permutations run in eQUEST

\*\* 2-speed motors are disallowed by some programs

## eQUEST Batch Run Results:

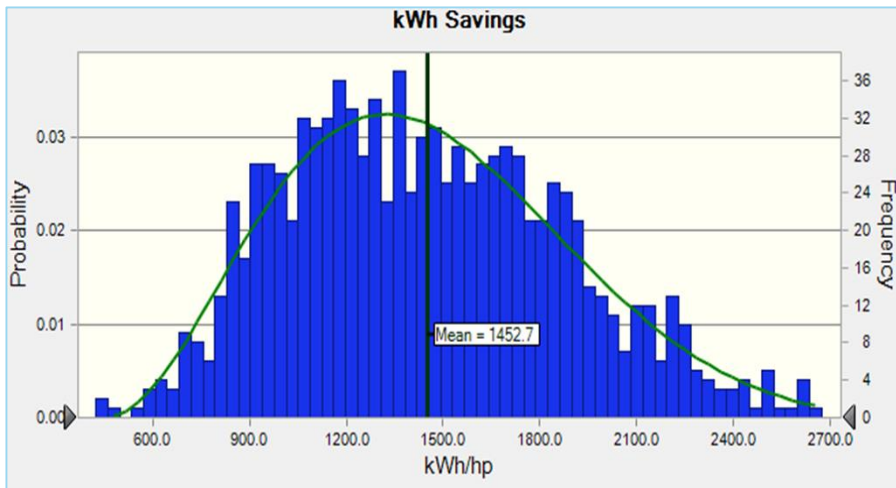


# Nonresidential VFDs at Fans: Monte Carlo Simulation Results

## VFD Savings Comparison

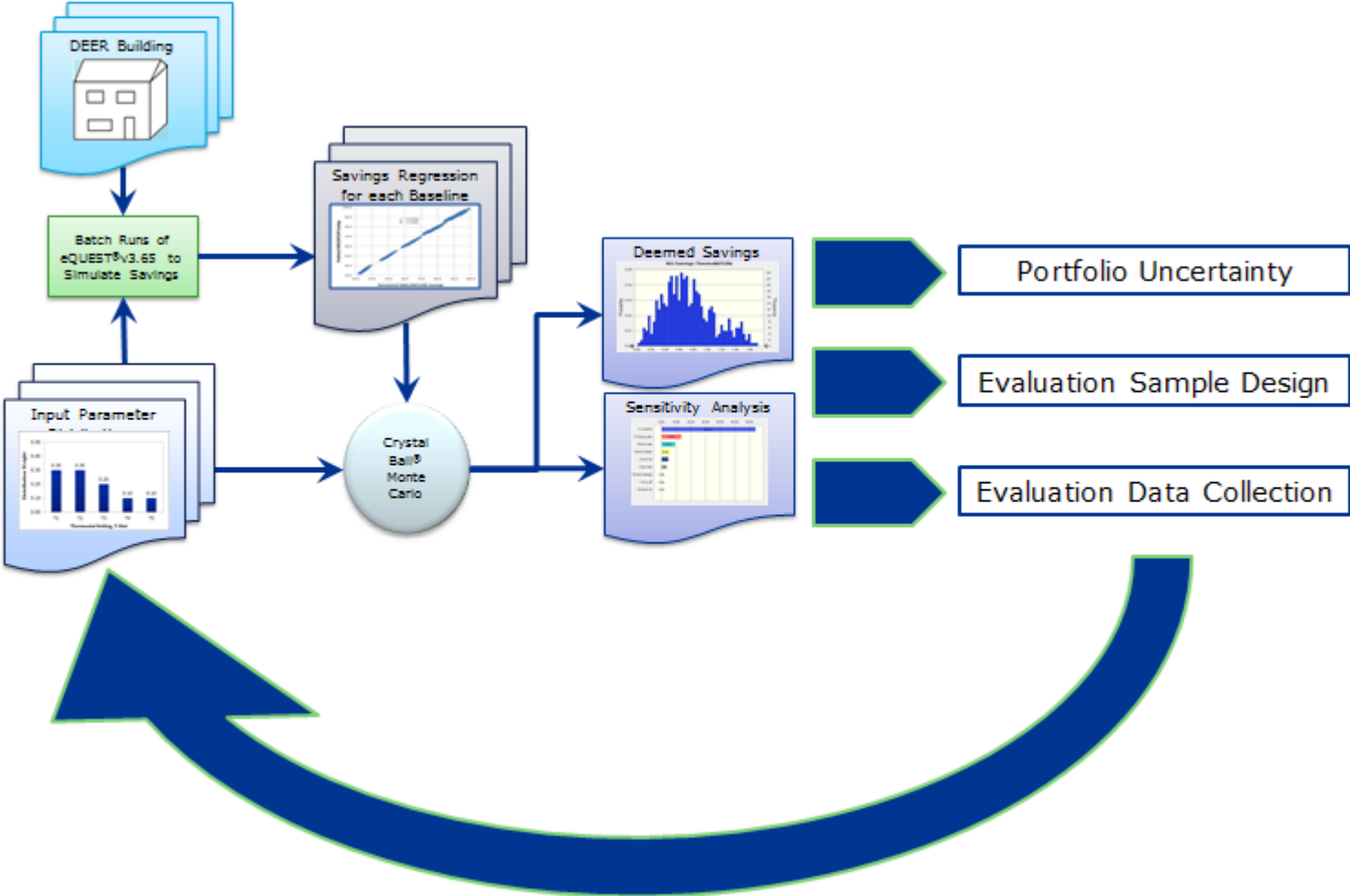
Savings with Discharge Damper Baseline, only, kWh	Uncertainty Analysis	DEER
Average Savings	1,512	1,030
Standard Deviation of Average Savings	448	N/A

## Savings Distribution & Input Parameter Sensitivity



Input Parameters	Relative Contribution to Variance
Fan Power Index (W/cfm)	42.4%
Minimum Airflow Ratio	28.5%
Fan Sizing Ratio	13.3%
Fan Schedule	6.8%
Baseline Airflow Control Strategy	5.1%
Building Vintage Bin weights	3.9%

# Benefits of Uncertainty Analysis



## Year 3 Plans

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- Repeat Year 2 process for the following nonresidential measures:
  - Unitary systems (<65 kBtu/h), currently being evaluated through HVAC 1
  - Air-cooled chillers, currently being evaluated through HVAC 1
  - Refrigerant charge adjustment, currently being evaluated through HVAC 3
  
- Replicate results for multiple climate zones via Excel workbooks
  
- Establish process for linking HVAC 4 results to portfolio-wide uncertainty analysis (P4)



**By Friday, September 16, 2016, post comments at Public Document Area at:**

**[energydataweb.com/cpuc/search.aspx](http://energydataweb.com/cpuc/search.aspx)**

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