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Restaurant Energy Performance Evaluation: How-To Guide and Spreadsheet

Commercial Building Energy Alliance Webinar

Kristin Field

November 16, 2011

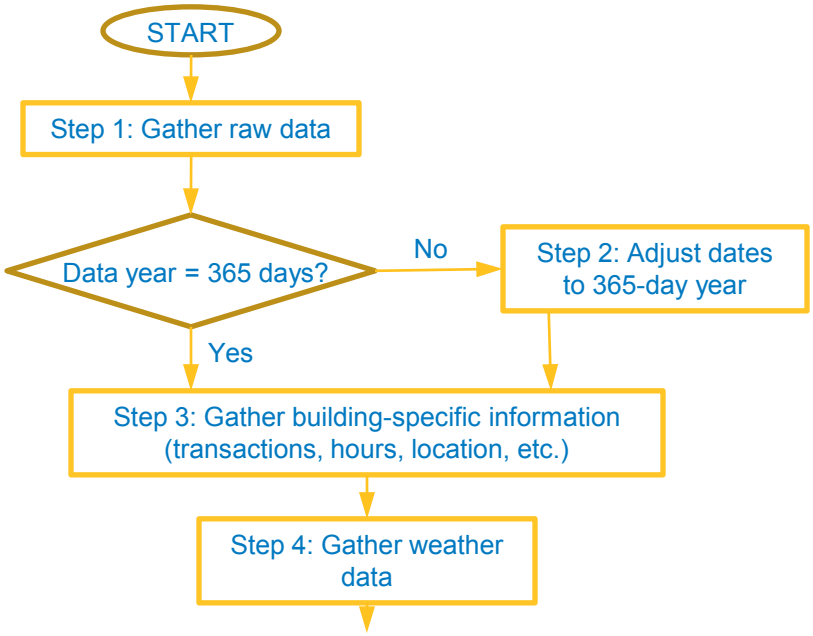
Overview

- **What?**
  - Resources for comparing restaurant energy performance to that of similar buildings within a portfolio
  - How-To Guide

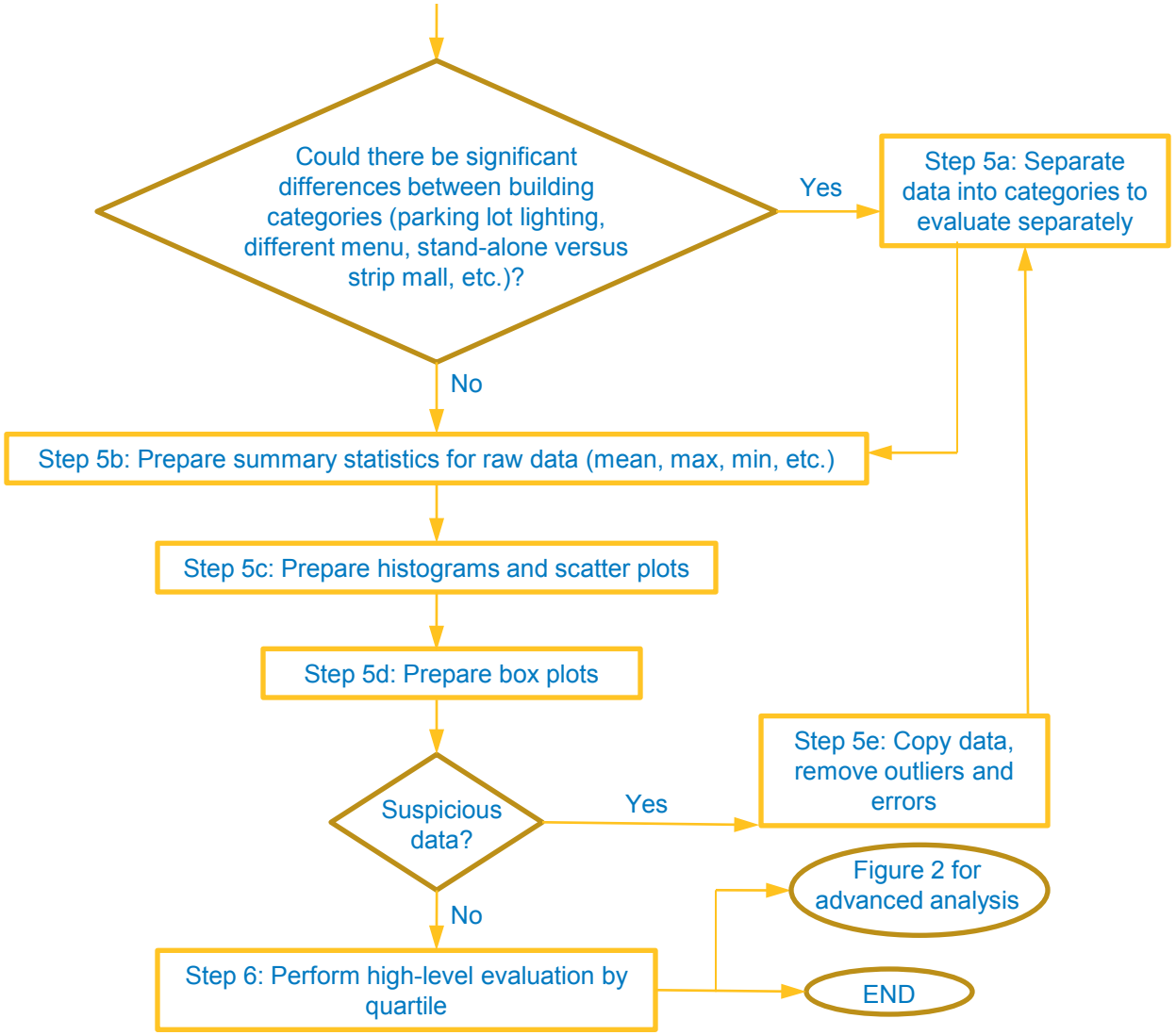
    http://apps1.eere.energy.gov/buildings/commercial_initiative/resource_database/detail.cfm?p=367
  - Spreadsheet

    http://apps1.eere.energy.gov/buildings/commercial_initiative/resource_database/detail.cfm?p=368
- **Why?**
  - Lack of benchmarking guidance for restaurants
    - If you don't know how much energy a restaurant is supposed to consume, how do you know when it's consuming too much?
  - Help with retrofit prioritization
- **How?**
  - Document outlines process in steps
    - 6 steps for high-level evaluation
    - 10 steps for advanced evaluation
  - Spreadsheet gets calculations started and shows an example from real data

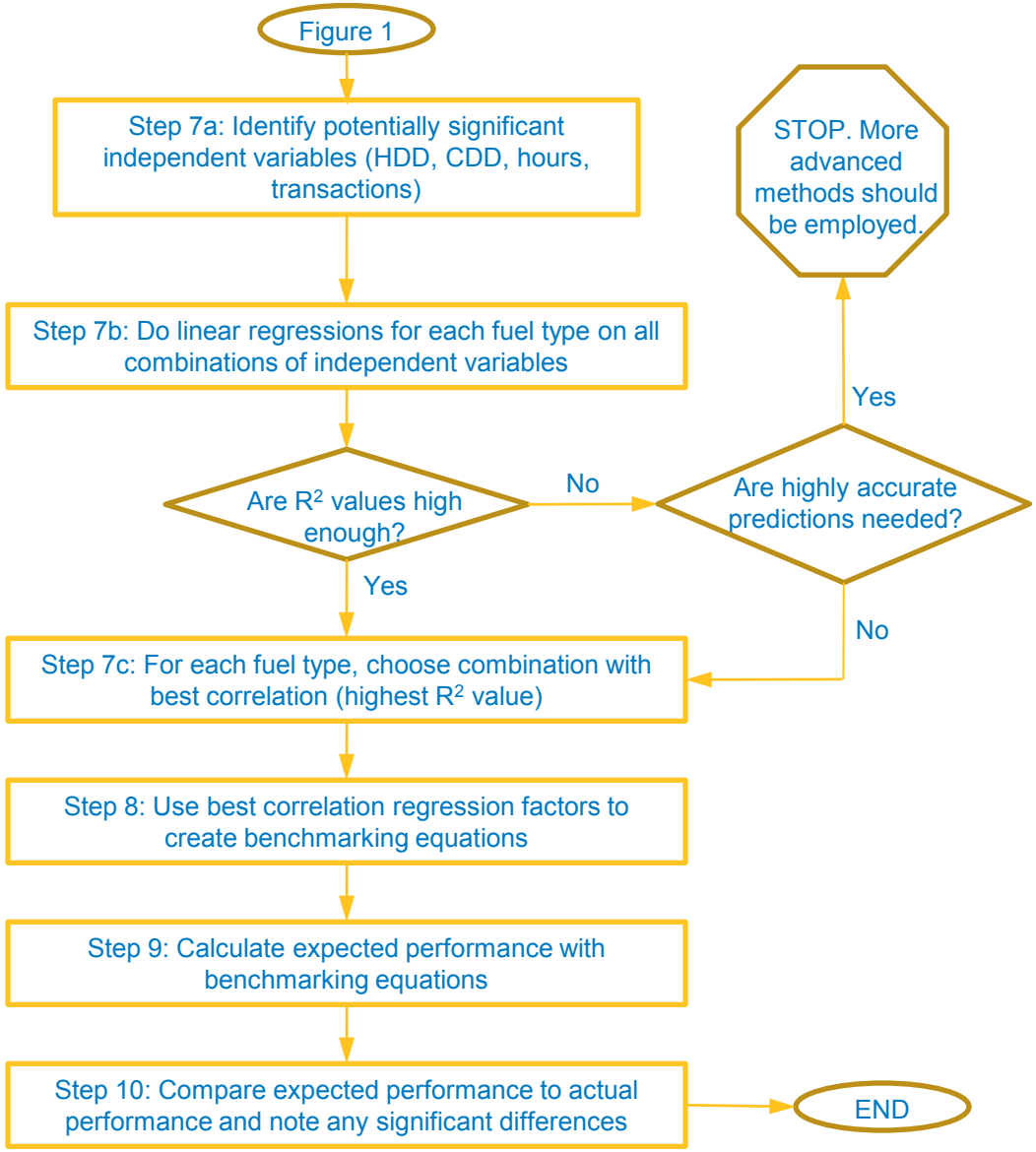
Benchmarking Process Flowchart #1



Benchmarking Process Flowchart #1 (continued)



Benchmarking Process Flowchart #2



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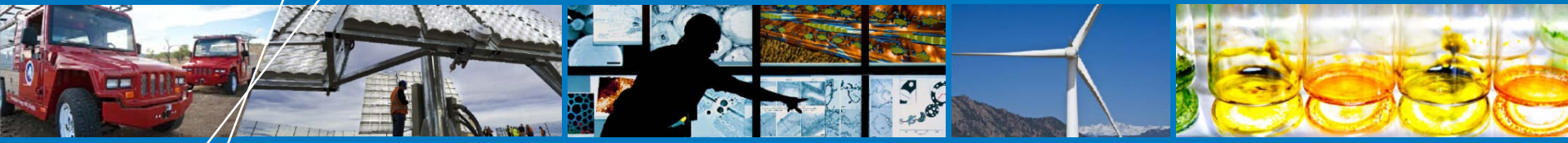


High-Level Evaluation

Step 1: Gather Raw Data

- **Gather raw data:**
  - Utility consumption
    - Electricity
    - Natural gas
    - Propane
    - Water/sewer
  - Utility costs

Weekly Hours	Normalized Weekly Transactions	Sq Ft	Weekly Hours	CDD65	HDD50	Annual Electric Usage (kWh)	Annual NG/Propane Usage (therms)
						See General Instructions Step H-v	
121	0.3709	2781	121	1294	27	289,200	9,773
168	0.6443	4200	168	1299	15	362,513	12,845
168	0.4816	4008	168	1299	15	295,711	13,236
126	0.5425	2759	126	404	56	289,488	11,154
126	0.5253	2968	126	1506	10	275,280	10,108
133	0.4378	4003	133	1903	180	280,663	11,210
156	0.6403	3333	156	1186	14	315,615	12,650
168	0.4412	2545	168	1299	15	290,800	13,130
112	0.2141	1967	112	1294	27	193,875	8,513
126	0.3876	3198	126	1735	613	243,216	11,545
126	0.3710	2192	126	543	32	197,157	9,581
133	0.3219	4083	133	1528	424	222,720	12,031
122	0.2900	2112	122	1294	27	178,400	8,955
126	0.3620	2112	126	1294	27	231,920	10,289

Step 2: Adjust Dates to 365-Day Year

- **365-day year length**
  - Standardizes analysis period
  - Corresponds to year lengths used in external studies, if applicable
- **Most utility records not kept in 365-day periods**
- **Suggested adjustment: add/subtract average daily values from first and last months**

Step 3: Gather Building-Specific Information

- **Building information**
  - Data you think are relevant to restaurant building performance
  - Spreadsheet example uses:
    - Transactions (normalized for anonymity)
    - Hours of operation
    - Floor area
- **Used mostly for advanced analysis (steps 6–10), but useful to gather up front**
- **Potentially used in Step 5a**

Step 4: Gather Weather Data

- **Annual weather data for each location**
- **Suggested metrics, used in spreadsheet example:**
  - HDD50
  - CDD65
- **Potentially time consuming for large portfolio**
  - Normal degree data are a less time-consuming, but less accurate, alternative

Step 5: Choose Subdatasets

- **Step 5 separated into 5 substeps**
  - Step 5a: Separate data into categories
  - Step 5b: Prepare summary statistics for raw data
  - Step 5c: Prepare histograms and scatter plots
  - Step 5d: Prepare box plots
  - Step 5e: Remove outliers
- **May need to iterate all substeps until plots and summary statistics show datasets with:**
  - More linearity
  - Less scatter
  - Few outliers

Step 5a: Separate Into Categories

- **Separate into subdatasets by**
  - Store type
    - Stand-alone
    - Strip mall
    - Food court
    - Etc.
  - Inclusion of parking lot lighting in use
  - Menu type
  - Other relevant factors
- **Each subdataset should have at least 50 stores for statistical significance**

Step 5b: Prepare Summary Statistics for Raw Data

- **Examine raw data using summary statistics**
  - By category (from Step 5a) and all together
  - Summary statistics include:
    - Maximum
    - Minimum
    - Mean (average)
    - Median (50th percentile)
    - Standard deviation
- **Do summary statistics support categories chosen in Step 5a?**
  - Are maximum and minimum reasonable numbers?
  - Is standard deviation reasonable?

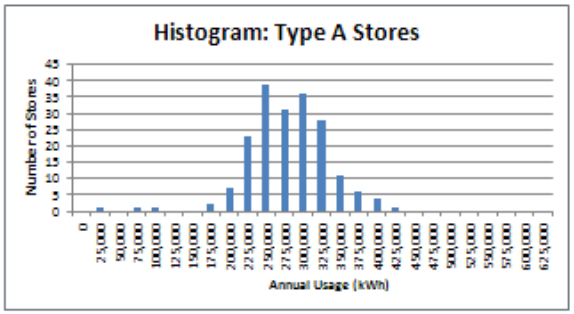
Step 5c: Prepare Histograms

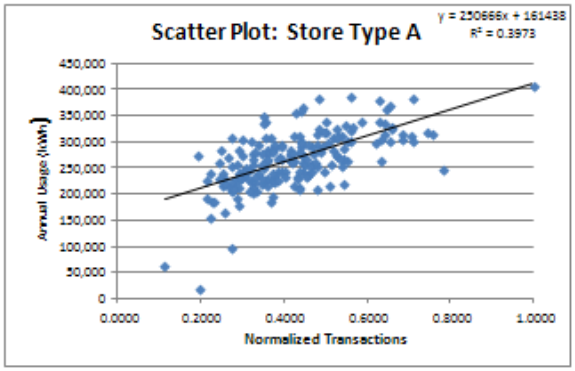
- Show entire distribution of data, instead of just significant points
- Automatically generated by spreadsheet tool

Type A Store Electricity Data

HISTOGRAM		
Bin	Count	Cum. Count
0	0	0
25,000	1	1
50,000	0	1
75,000	1	2
100,000	1	3
125,000	0	3
150,000	0	3
175,000	2	5
200,000	7	12
225,000	23	35
250,000	39	74
275,000	31	105
300,000	36	141
325,000	28	169
350,000	11	180
375,000	6	186
400,000	4	190
425,000	1	191
450,000	0	191
475,000	0	191
500,000	0	191
525,000	0	191
550,000	0	191
575,000	0	191
600,000	0	191
625,000	0	191

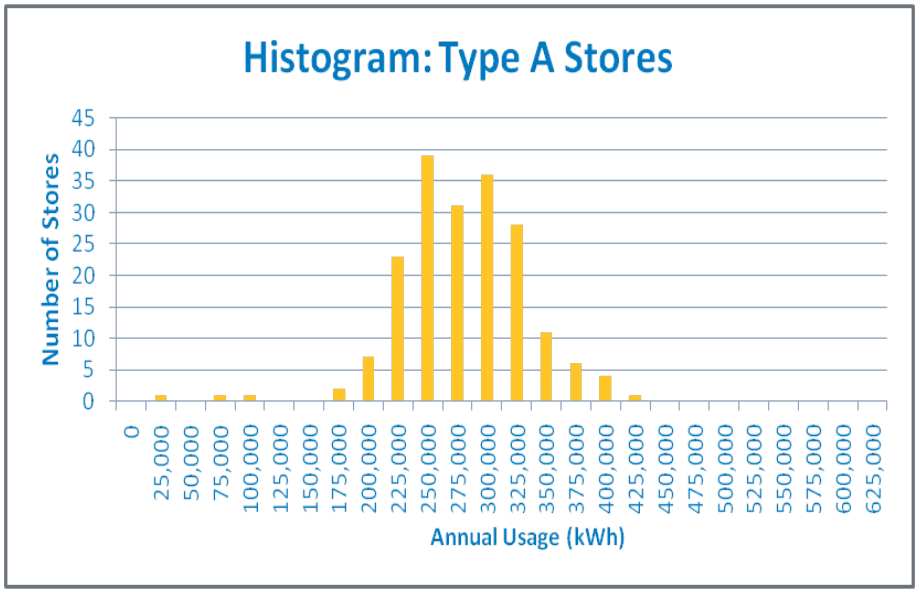
Statistics	
max	406,720
min	18,560
mean	266,661
std dev	53,526
median	267,080
Q1	232,200
Q3	301,426
count	191





Step 5c: Prepare Histograms (continued)

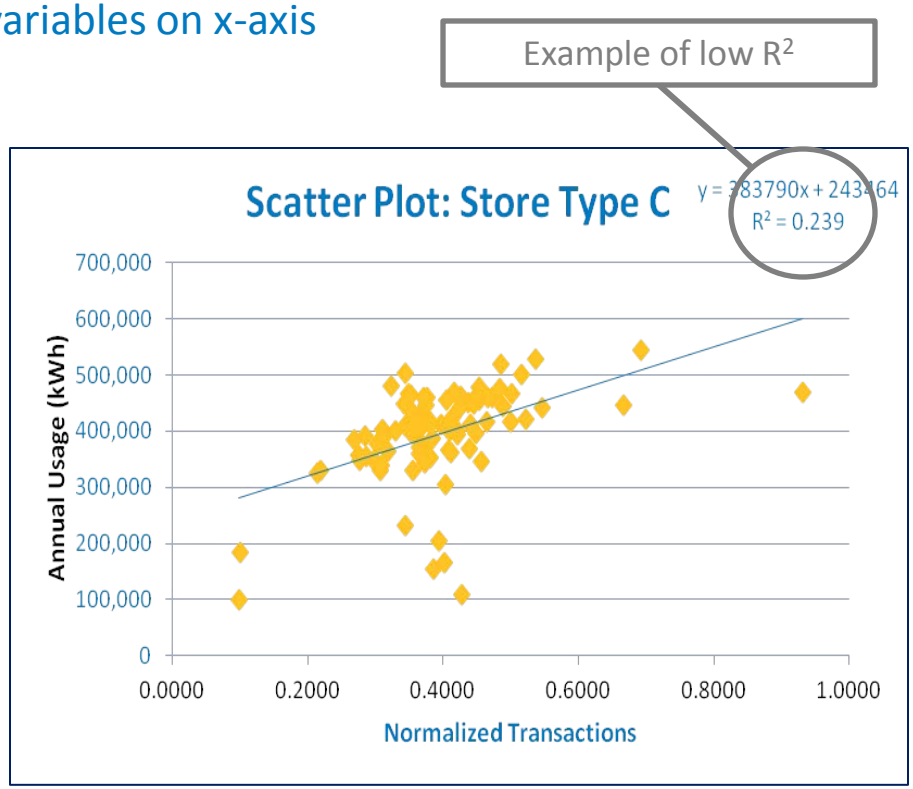
- **Histograms display:**
  - Y-axis: count of stores (this case) falling within bins shown on x-axis
  - X-axis: bins for variable of interest (electricity consumption in example)
    - Less confusing if bins are all equally sized
- **Histograms can tell you:**
  - Rough numbers to expect for most stores
  - How many outliers
  - Whether values are widely spread or tightly clustered



Step 5c: Prepare Scatter Plots

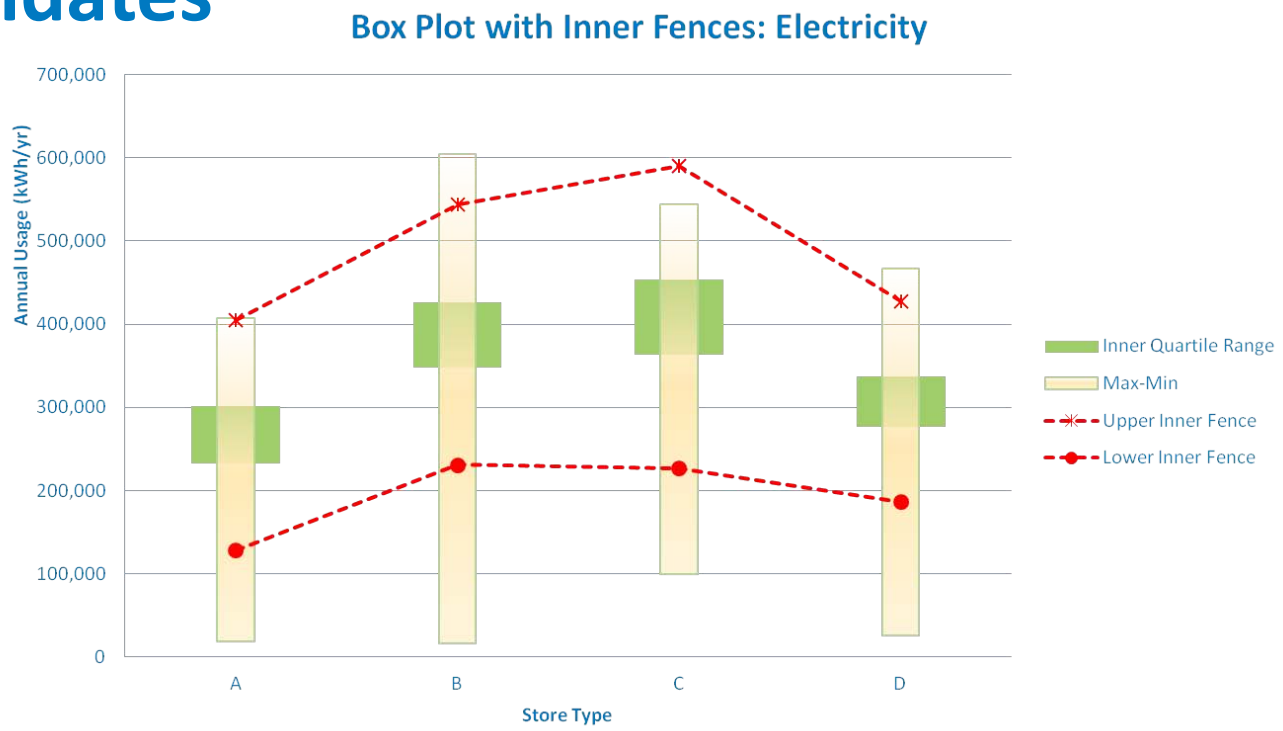
- **Scatter plots display:**
  - Y-axis: individual data point values (electricity consumption in example)
  - X-axis: individual data point values (normalized transactions in example)
    - Could be helpful to try different variables on x-axis

- **Scatter plots can tell you:**
  - Rough numbers to expect for most stores
  - How many outliers
  - Whether values are widely spread or tightly clustered
  - Does x-axis value seem to affect y-axis value?
  - How strong is the correlation? (R^2 value with Excel trendline)



Step 5d: Prepare Box Plots

- Useful display for data in middle of distribution
- Visually identifies preliminary retrofit candidates



Step 5e: Remove Outliers

- **Steps 5a–5d help identify outliers**
- **Spreadsheet also highlights potential outliers in gray on "Complete Inputs" tab**
- **Mild or extreme**
  - Remove mild outliers?
- **Outliers caused by:**
  - Missing data
  - Additional data (double month)
  - Problem with meter
  - Renovations
  - Other unusual activity
- **After removing outliers, repeat steps 5a–5d to see if statistics/plots have improved**
  - Reasonable numbers
  - Scatter
  - Skew

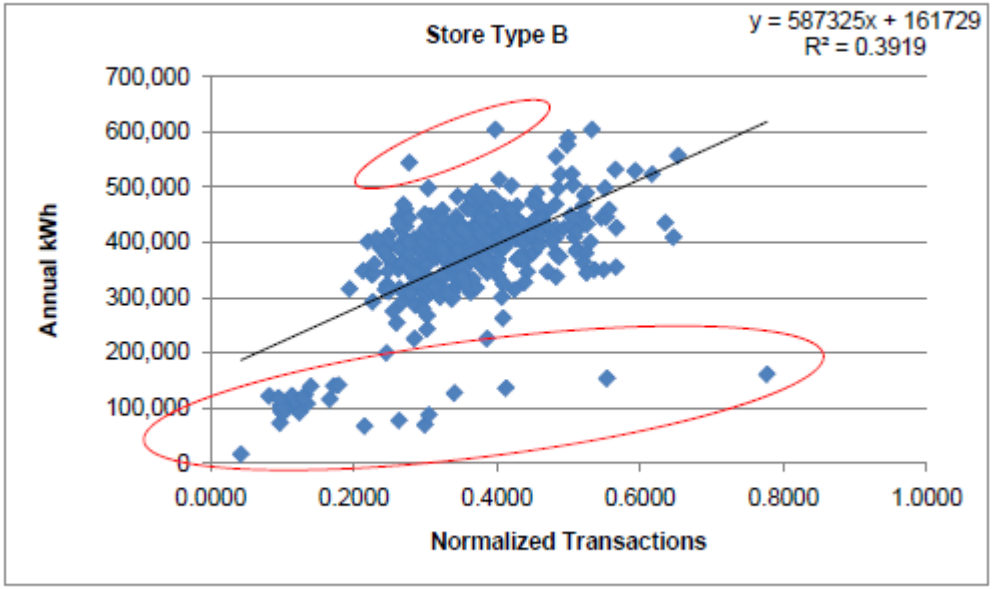


Figure 2-5 Example of annual electricity use scatter plot to show outliers

Step 6: Perform High-Level Evaluation

- **Gather and review information collected in Steps 1–5**
  - Are store categories significant? (Step 5a: stand-alone versus food court, etc.)
  - Range of performance (max–min)
  - Average performance
  - Distribution of performance
    - Scatter?
    - Skew? If so, high or low?
    - Many or few outliers?
- **Identify preliminary retrofit candidates**
  - Spreadsheet highlights in yellow on "Complete Inputs" tab
- **Decision:**
  - Stop after Step 6 and investigate preliminary retrofit candidates, or
  - Continue to Step 7 for advanced evaluation?
    - Develop benchmarking equations
    - Predict energy use given different operation
    - Strong correlations not guaranteed (may invest a lot of time for little confidence in results)

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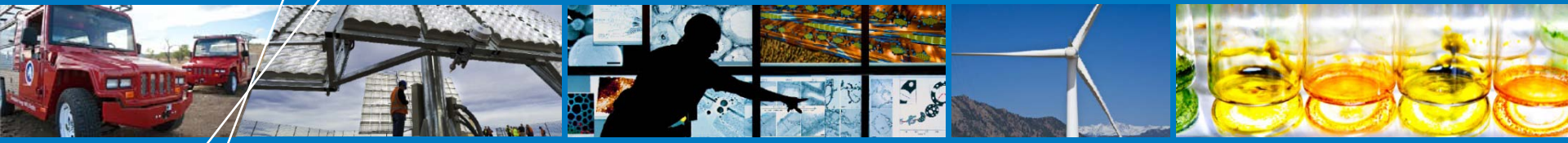

Advanced Evaluation

Step 7: Perform Linear Regressions

- **Step 7 separated into 3 substeps**
  - Step 7a: Identify significant variables
  - Step 7b: Perform linear regressions
  - Step 7c: Evaluate regression quality
- **Spreadsheet completes task automatically in "Regression Analysis" tab**

Step 7a: Identify Significant Variables

- **Which factors (independent variables) may be significant in predicting performance?**
  - Example includes:
    - Transactions (normalized for anonymity)
    - Weekly hours of operation
    - Floor area
    - Weather (HDD50, CDD65) for “normal” year
- **Performance by store type is typically electricity and natural gas consumption**

Step 7b: Perform Linear Regressions

- **Perform linear regression for each store type**
- **Example uses Excel's LINEST function**
- **Regression equation type example:**

kWh = a + b*(HDD50) + c*(Floor Area)

where:

a = constant

b = HDD50 slope

c = floor area slope

Step 7c: Evaluate Regression Quality

- **How well does regression predict performance?**
  - High R^2 value (greater than 70%–80%)
  - Other statistical parameter (P-factor, F-test)
  - Commercial statistical software output
- **For best results, evaluate strength of regressions using a variety of combinations of independent variables**

Independent Variable	Store Type
Transactions, Weekly Hours, Floor Area	A
	B
	C
	D
Transactions, Floor Area	A
	B
	C
	D
Transactions	A
	B
	C
	D
Floor Area, Weekly Hours	A
	B
	C
	D
Weekly Hours	A
	B
	C
	D
Floor Area	A
	B
	C
	D
Weekly Hours, Transactions	A
	B
	C
	D

Step 8: Create Benchmarking Equations

- **Choose strongest regression correlation**
- **Using the coefficients corresponding to the strongest correlation, create benchmarking equations for:**
  - Each fuel type (electricity, natural gas, etc.)
  - Each store type (stand-alone, strip mall, etc.)
- **Example:**

kWh = a + b*(Transactions) + c*(Floor Area) + d*(Weekly Hours) + e*(CDD) +f*(HDD)

where:

a = constant

b,c,d,e,f = regression coefficients (“slopes”)

		Electricity						
			Transactions	Floor Area	Weekly Hours	CDD	HDD	
Independent Variable	Store Type	Intercept	Slope	Slope	Slope	Slope	Slope	R^2
Transactions, Weekly Hours, Floor Area, CDD, and HDD	A	-45,829.4	1.3	18.7	1,270.2	18.2	135,634.9	0.61
	B	187,551.8	-21.2	-8.7	-400.4	18.1	611,678.8	0.42
	C	517,680.3	-59.1	-66.7	-328.5	-11.5	93,694.2	0.34
	D	906.0	-0.2	24.3	756.9	22.9	33,692.0	0.48

Step 9: Calculate Expected Performance

- **Use benchmarking equations to calculate expected performance of each store**
  - Performance = y values
  - Given known operational characteristics = x values
    - Transactions
    - Hours of operation
    - Floor area
    - Weather
    - Etc.
  - Calculate y, given x's

Step 10: Compare Expected Versus Actual Performance

- **Compare expected performance (from Step 9) to actual performance (from collected data)**
  - Comparison in absolute numbers (e.g., kWh or therms)
  - Comparison in % usually more helpful
- **General guidelines for interpretation**
  - Less than 5% variation: in the noise
  - 5%–10% variation: note deviation
  - 10%–25% variation: consider energy audit
  - Greater than 25% variation: probably data error

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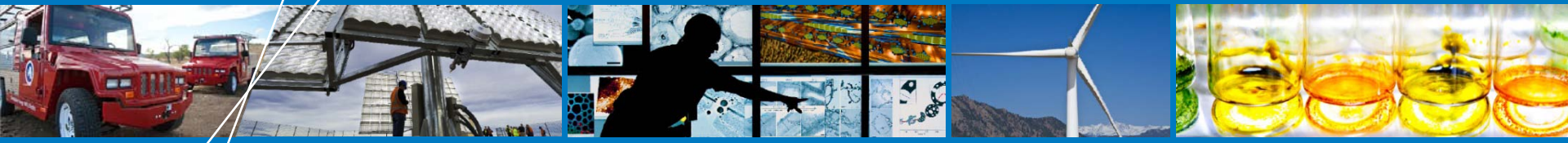

Next Steps

Next Steps

- **If any values have >25% variation, remove them as outliers and iterate calculations**
- **Look into stores with 10%–25% variation**
  - May warrant energy audit to help determine whether retrofits make sense
  - May indicate mild outliers
  - May have reasonable explanation for higher consumption
- **Any necessary customization of spreadsheet tool to meet the needs of an individual portfolio**
- **Feedback to DOE/NREL**

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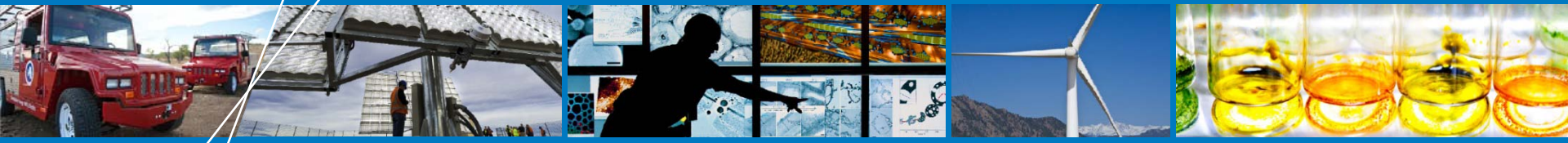

Acknowledgments

Acknowledgments

NREL gratefully acknowledges the contributions of the following individuals:

- Vernon Smith
- Roger Hedrick, Architectural Energy Corporation
- Rachel Romero, NREL
- Members of the REA-Restaurant Project Team

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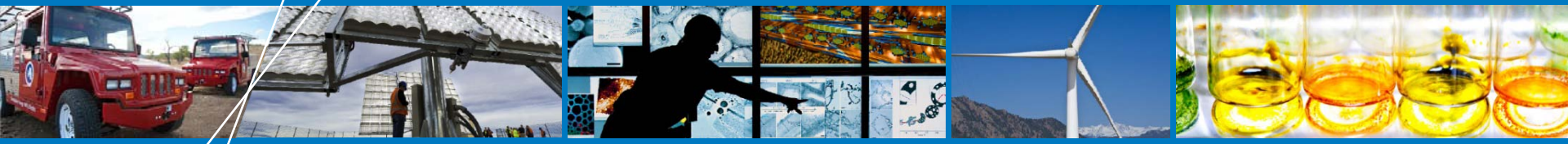

Questions?

Contact information:

Kristin.Field@nrel.gov