SUPPLEMENTAL MATERIALS

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Energy Profiles of Nine Water Treatment Plants in the Salt Lake City Area of Utah and Implications for Planning, Design, and Operation

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Benchmarking Example

The following calculation demonstrates how the regression model could be used for benchmarking a facilities energy use relative to others. It involves computing the theoretical energy use or energy intensity and then examining the ratio of actual energy use or energy intensity by the predicted energy use or energy intensity.

Regression Model:

$$y = \beta_0 + \beta_1 * x_1 + \cdots + \beta_n * x_n$$

Where

y is the predicted variable (i.e., natural log of energy use or energy intensity)

β_0 is the model intercept

β_n is the nth model coefficient

x_n is the nth input variable for the nth model coefficient

Consider the energy intensity (Model 1) for Site A given its first month's data. Predicted energy intensity is:

$$y = \ln(En) = 4.88 + 0.52 * (\ln(wp)) - 1.19 * (dc) + 3.82 * 10^{-5} * (FAm2) + 1.62 * 10^{-3} * (HDD) - 0.63 * (phyp) - 0.54 * (pgas) + 0.18 * (poz) + 0.41 * (puv)$$

Where

$\ln(En)$ is the natural logarithm of predicted energy use

$\ln(wp)$ is the natural logarithm of water production (m^3)

dc is percent design capacity, monthly flow divided by plant capacity (%)

$FAm2$ is the climate-controlled floor area (m^2)

HDD is Heating Degree Days (base 18° C)

$phyp$ is an indicator variable for use of sodium hypochlorite (yes = 1, no = 0)

$pgas$ is an indicator variable for use if gaseous chlorine (yes = 1, no = 0)

poz is an indicator variable use of ozone (yes = 1, no = 0)

puv is an indicator variable use of ultraviolet disinfection (yes = 1, no = 0)

Then

$$y = \ln(En) = 4.88 + 0.52 * (\ln(3{,}781{,}851)) - 1.19 * (0.20) + +3.82 * 10^{-5} * (23{,}900) + 1.62 * 10^{-3} * (561) - 0.63 * (0) - 0.54 * (0) + 0.18 * (1) + 0.41 * (0) = 14.5196$$

Predicted energy use: $En = \exp(14.5196) = 2{,}021{,}957$ kWh

Actual energy use: 2,449,292 kWh

Ratio of actual energy use to average: 2,449,292 kWh / 2,021,957 kWh = 1.21 (21% higher energy use relative to average)

Result of taking averages across all data for each facility are shown in Table S1 below. Sites C, D, and G are on average exhibiting a higher energy intensity relative to other facilities. Sites H and I exhibited relatively lower energy intensities.

Table S1. Resulting Energy Intensity Ratio of Facilities

Site	Average Ratio
A	5%
B	1%
C	20%
D	57%
E	5%
F	5%
G	34%
H	-31%
I	-27%

Survey Spreadsheet

Data for this study were collected using the spreadsheet form shown in Fig. S1.

GENERAL INFO			
Plant Name			
Water Source(s)			
Preparer Name		Date	

PROCESSES			
Plant capacity (MGD)			
Water Source			
Gravity surface water	No		
Pumped surface water	No	Approx. head added (ft)	
Clarification			
Rapid mixing	No		
Flocculation	No		
Sedimentation	No		
Microfiltration (in place of sedimentation)	No		
Ultafiltration	No		
Dissolved air flotation	No		
Air stripping	No		
Repumping within treatment plant	No		
Filtration & Solids Handling			
Backwash water pumps	No		
Residuals pumping	No		
Thickened solids pumping	No		
Disinfection & Pumping			
Onsite chlorine generation	No		
Ozone disinfection	No		
Ultraviolet disinfection	No		
Finished water pumping	No	Approx. head added (ft)	
Other Facilities and Processes			
Other processes: Please explain			
Other major facilities (e.g., pump station) on same electric meter(s) but not part of plant?			
Please explain			

Fig. S1. Survey spreadsheet.

ENERGY AND PRODUCTION DATA			
Year 1	Month	Energy Use (kWh)	Finished Water (MG)
20xx	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		
	11		
	12		
Year 2	Month	Energy Use (kWh)	Finished Water (MG)
20xx	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		
	11		
	12		
Year 3	Month	Energy Use (kWh)	Finished Water (MG)
20xx	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		
	11		
	12		

NOTES
Notable water quality issues, unusual processes or operations, data limitations, etc.

Fig. 1. (Continued.)

Model Fit

Fig. S2 shows model fit for the four regression models by comparing predicted and observed energy use.

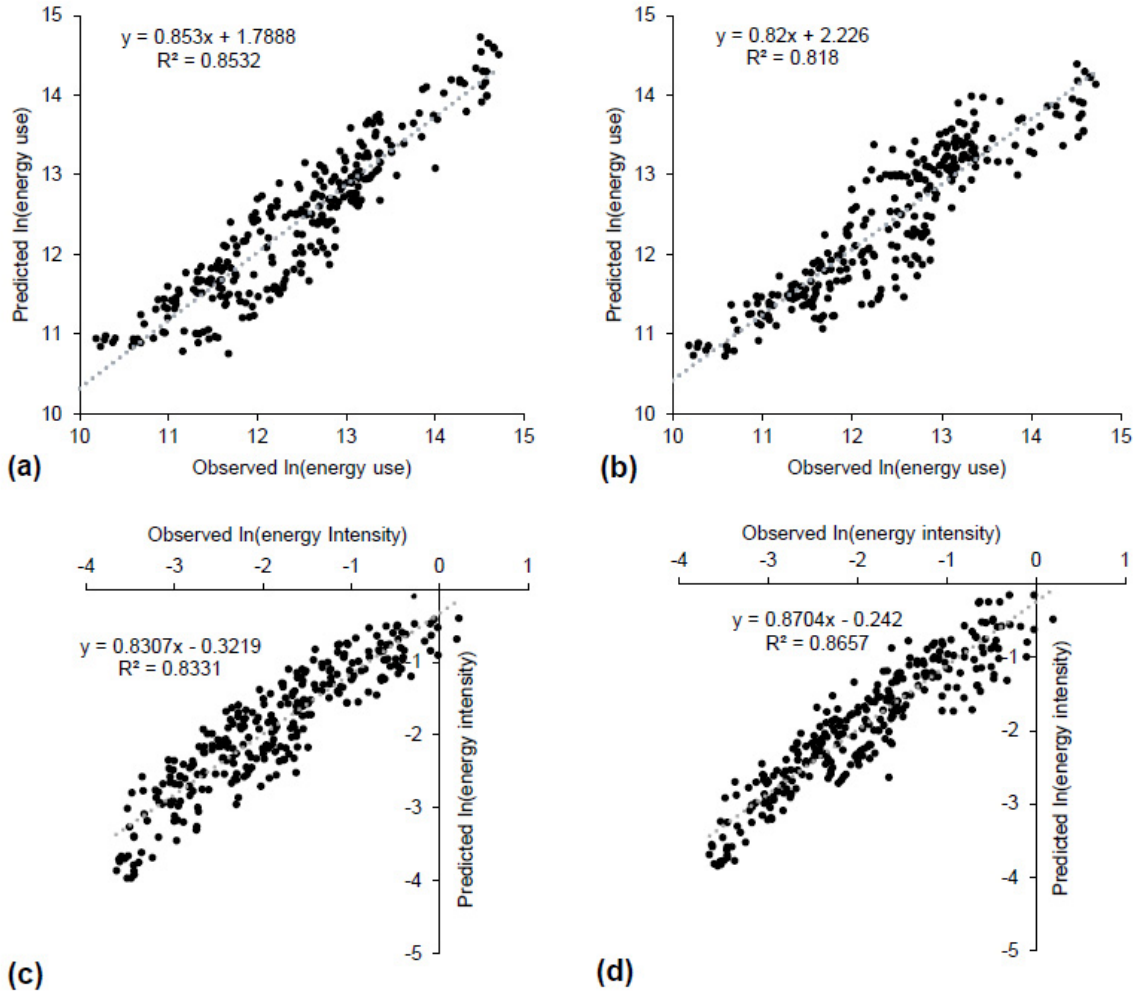

Fig. S2. Fit of energy use and energy intensity models: (a) Model 1, (b) Model 2, (c) Model 3, (d) Model 4.