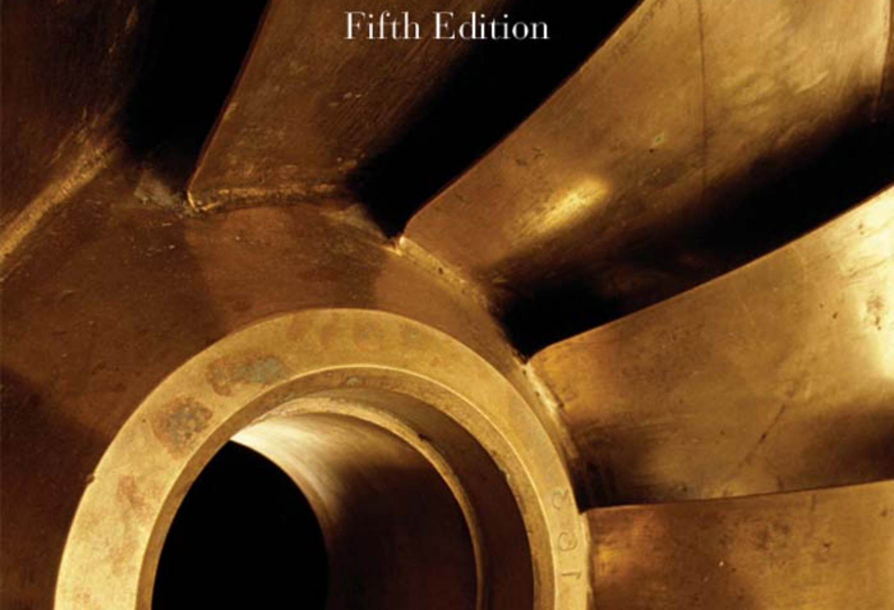
Klaus-Dieter Pawlik

SOLUTIONS MANUAL FOR GUIDE TO ENERGY MANAGEMENT

Fifth Edition



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for
Guide to Energy Management,
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Chapter 1

Introduction to Energy Management

Problem: For your university or organization, list some energy management projects that might be good "first ones," or early selections.

Solution: Early projects should have a rapid payback, a high probability of success, and few negative consequences (increasing/decreasing the air-conditioning/heat, or reducing lighting levels).

Examples:

Switching to a more efficient light source (especially in conditioned areas where one not only saves with the reduced power consumption of the lamps but also from reduced refrigeration or air-conditioning load).

Repairing steam leaks. Small steam leaks become large leaks over time.

Insulating hot fluid pipes and tanks.

Install high efficiency motors.

And many more

Problem: Again for your university or organization, assume you are starting a program and are defining goals. What are some potential first-year goals?

Solution: Goals should be tough but achievable, measurable, and specific.

Examples:

Total energy per unit of production will drop by 10 percent for the first and an additional 5 percent the second.

Within 2 years all energy consumers of 5 million British thermal units per hour (Btuh) or larger will be separately metered for monitoring purposes.

Each plant in the division will have an active energy management program by the end of the first year.

All plants will have contingency plans for gas curtailments of varying duration by the end of the first year.

All boilers of 50,000 lbm/hour or larger will be examined for waste heat recovery potential the first year.

Problem: Perform the following energy conversions and calculations:

a) A spherical balloon with a diameter of ten feet is filled with natural gas. How much energy is contained in that quantity of natural gas?

b) How many Btu are in 200 therms of natural gas? How many Btu in 500 gallons of 92 fuel oil?

c) An oil tanker is carrying 20,000 barrels of #2 fuel oil. If each gallon of fuel oil will generate 550 kWh of electric energy in a power plant, how many kWh can be generated from the oil in the tanker?

d) How much coal is required at a power plant with a heat rate of 10,000 Btu/kWh to run a 6 kW electric resistance heater constantly for 1 week (16 8 hours)?

e) A large city has a population which is served by a single electric utility which burns coal to generate electrical energy. If there are 500,000 utility customers using an average of 12,000 kWh per year, how many tons of coal must be burned in the power plants if the heat rate is 10,500 Btu/kWh?

f) Consider an electric heater with a 4,500 watt heating element. Assuming that the water heater is 98% efficient, how long will it take to heat 50 gallons of water from 70 degree F to 140 degree F?

Solution:

a) V = 4/3 (PI) P
= 4/3 × 3.14 × 5^3
523.33 ft^3

E = V × 1,000 Btu/cubic foot of natural gas
= 523.33 ft^3 X 1,000 Btu/ft^3
= ***523,333 Btu***

b) E = 200 therms × 100, 000 Btu/therm of natural gas
= *20,000,000 Btu*
E = 500 gallons × 140,000 Btu/gallon of #2 fuel oil
70,000,000 Btu

c) E = 20,000 barrels × 42 gal./barrel × 550 kWh/gal.
4.6E+08 kWh

d) V = 10,000 Btu/kWh × 6 kW × 168 h/25,000,000 Btu/ton coal
= ***0.40 tons of coal***

e) V = 500,000 cus. × 12,000 kWh/cus. × 10,500 Btu/kWh × I ton/25,000,000 Btu
= ***2,520,000 tons of coal***

f) E = 50 gal. × 8.34 lbm/gal. × (140F - 70F) × 1 Btu/F/lbm
= 29,190 Btu
= 29,190 Btu/3,412 Btu/kWh
= 8.56 kWh
= 8.56 kWh/4.5 kW/0.98
= ***1.94 h***

Problem: If you were a member of the upper level management in charge of implementing an energy management program at your university or organization, what actions would you take to reward participating individuals and to reinforce commitment to energy management?

Solution: The following actions should be taken to reward individuals and reinforce commitment to energy management:

Develop goals and a way of tracking their progress.

Develop an energy accounting system with a performance measure such as Btu/sq. ft or Btu/unit.

Assign energy costs to a cost center, profit center, an investment center or some other department that has an individual responsibility for cost or profit.

Reward (with a monetary bonus) all employees who control cost or profit relative to the level of cost or profit. At the risk of being repetitive, note that the level of cost or profit should include energy costs.

Problem: A person takes a shower for ten minutes. The water flow rate is three gallons per minute, the temperature of the shower water is 110 degrees E Assuming that cold water is at 65 degrees F, and that hot water from a 70% efficient gas water heater is at 140 degrees F, how many cubic feet of natural gas does it take to provide the hot water for the shower?

Solution:

$$\begin{aligned} E &= 10 \text{ min} \times 3 \text{ gal./min} \times 8.34 \text{ lbm/gal} \times \\ &\quad (110 \text{ F} - 65 \text{ F}) \times 1 \text{ Btu/lbm/F} \\ &= 11{,}259 \text{ Btu} \end{aligned}$$

$$\begin{aligned} V &= 11{,}259 \text{ Btu} \times 1 \text{ cubic foot}/1{,}000 \text{ Btu}/0.70 \\ &= \boldsymbol{16.08 \textit{ cubic feet of natural gas}} \end{aligned}$$

Problem: An office building uses 1 Million kWh of electric energy and 3,000 gallons of #2 fuel oil per year. The building has 45,000 square feet of conditioned space. Determine the Energy Use Index (EUI) and compare it to the average EUI of an office building.

Solution:

$$E(\text{elect.}) = 1{,}000{,}000 \text{ kWh/yr.} \times 3{,}412 \text{ Btu/kWh}$$
$$= 3{,}412{,}000{,}000 \text{ Btu/yr.}$$

$$E(\#2 \text{ fuel}) = 3{,}000 \text{ gal./yr.} \times 140{,}000 \text{ Btu/gal.}$$
$$= 420{,}000{,}000 \text{ Btu/yr.}$$

$$E = 3{,}832{,}000{,}000 \text{ Btu/yr.}$$

$$EUI = 3{,}832{,}000{,}000 \text{ Btu/yr./45,000 sq. ft}$$

= ***85,156 Btu/sq. ft/yr. which is less than the average office building***

Problem: The office building in Problem 1.6 pays $65,000 a year for electric energy and $3,300 a year for fuel oil. Determine the Energy Cost Index (ECI) for the building and compare it to the ECI for an average building.

Solution: ECI = ($65,000 + $3,300)/45,000 sq. ft

= ***$1.52/sq. ft/yr.***

which is greater than the average building

Problem: As a new energy manager, you have been asked to predict the energy consumption for electricity for next month (February). Assuming consumption is dependent on units produced, that 1,000 units will be produced in February, and that the following data are representative, determine your estimate for February.

Given:

Month	Units produced	Consumption (kWh)	Average (kWh/unit)	
January	600	600	1.00	
February	1,500	1,200	0.80	
March	1,000	800	0.80	
April	800	1,000	1.25	
May	2,000	1,100	0.55	
June	100	700	7.00	Vacation month
July	1,300	1,000	0.77	
August	1,700	1,100	0.65	
September	300	800	2.67	
October	1,400	900	0.64	
November	1,100	900	0.82	
December	200	650	3.25	1-week shutdown
January	1,900	1,200	0.63	

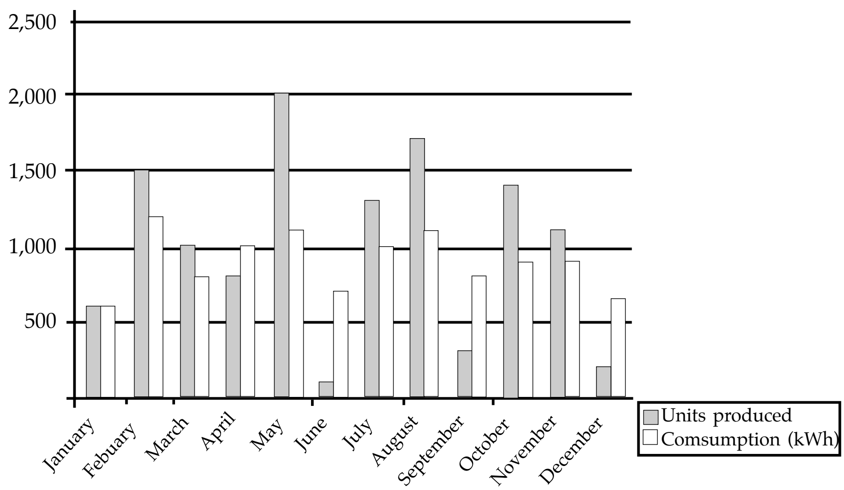
Solution: First, since June and December have special circumstances, we ignore these months. We then run a regression to find the slope and intercept of the process model. We assume that with the exception of the vacation and the shutdown that nothing other then the number of units produced affects the energy used. Another method of solving this problem may assume that the weather and temperature changes also affects the energy use.

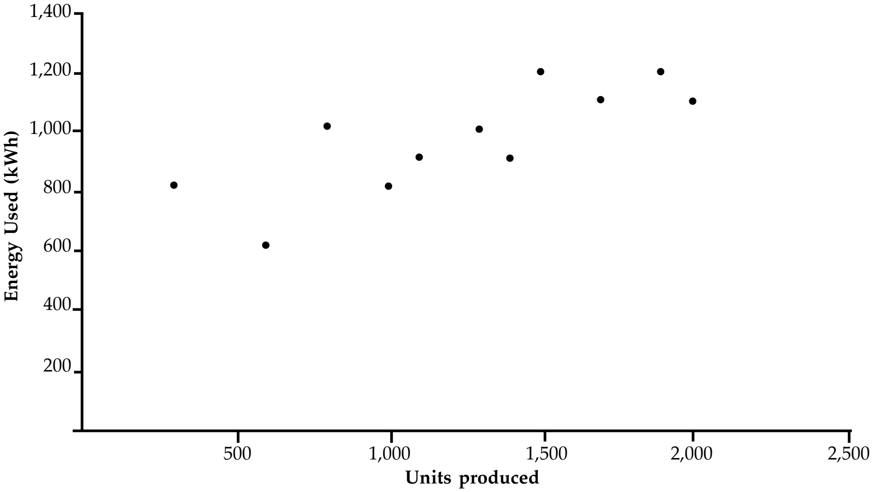
Units Month	Consumption produced	Average (kWh)	(kWh/unit)
January	600	600	1.00
February	1,500	1,200	0.80
March	1,000	800	0.80
April	800	1,000	1.25
May	2,000	1,100	0.55
July	1,300	1,000	0.77
August	1,700	1,100	0.65
September	300	800	2.67
October	1,400	900	0.64
November	1,100	900	0.82
January	1,900	1,200	0.63

From the ANOVA table, we see that if this process is modeled linearly the equation describing this is as follows:

kWh (1,000 units) = 623 + 0.28 × kWh/unit produced

= ***899 kWh***





SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.795822426
R Square	0.633333333
Adjusted R Square	0.592592593
Standard Effort	118.6342028
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	218787.9788	218787.9	15.54545	0.00339167
Residual	9	126666.6667	14074.07		
Total	10	345454.5455			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95. 0%*	*Upper 95.0%*
Intercept	623.1884058	93.46296795	6.667759	9.19E-05	411.7603222	834.616489	411.760322	834.6164893
X Variable 1	0,275362319	0.06993977	3.942772	0.003392	0,117373664	0.43335097	0.11737366	0.433350974

Problem: For the same data as given in Problem 1.8, what is the fixed energy consumption (at zero production, how much energy is consumed and for what is that energy used)?

Solution: *By* looking at the regression run for problem 1.8 (see ANOVA table), we can see the intercept for the process in question. This intercept is probably the best estimate of the fixed energy consumption:

623 kWh.

This energy is probably used for space conditioning and security lights.

Problem: Determine the cost of fuel switching, assuming there were 2,000 cooling degree days (CDD) and 1,000 units produced in each year.

Given: At the Gator Products Company, fuel switching caused an
increase in electric consumption as follows:

	Expected energy consumption	Actual energy consumption after switching fuel
Electric/CDD	75 million Btu	80 million Btu
Electric/units of production	100 million Btu	115 million Btu

The base year cost of electricity is $15 per million Btu, while this year's cost is $18 per million Btu.

Solution: Cost variance = $18/million Btu - $15/million Btu
= $3/million Btu

Increase cost due to cost variance
= Cost variance × Total Actual Energy Use
= ($3/million Btu) × ((80 million Btu/CDD) × (2,000 CDDs) + (115 million Btu/unit) × (1,000 units))
= $825,000

CDD electric variance
= 2,000 CDD × (80 - 75) million Btu/CDD
= 10,000 million Btu

Units electric variance
= 1,000 units × (115 - 100) million Btu/unit
= 15,000 million Btu