Solutions Manual
for
Guide to Energy Management,
Seventh Edition

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THE FAIRMONT PRESS, INC.

CRC Press
Taylor & Francis Group

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Published by The Fairmont Press, Inc.
700 Indian Trail
Lilburn, GA 30047
tel: 770-925-9388; fax: 770-381-9865
http://www.fairmontpress.com

Distributed by Taylor & Francis Ltd.
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487
tel: 800-272-7737; fax: 800-374-3401
Email: orders@crcpress.com

Distributed by Taylor & Francis Ltd.
23-25 Blades Court
Deodar Road
London SW15 2NU
United Kingdom
Email: uk.tandf@thomsonpublishingservices.co.uk

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-88173-673-2 (The Fairmont Press, Inc. Print Version)
ISBN 0-88173-674-0 (The Fairmont Press, Inc. Electronic Version)
ISBN 978-1-4398-9392-0 (Taylor & Francis Ltd.)

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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
= $4/3 \times 3.14 \times 5^3$
$523.33\ ft^3$

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:

E = 10 min × 3 gal./min × 8.34 lbm/gal × (110 F - 65 F) × 1 Btu/lbm/F
= 11,259 Btu

V = 11,259 Btu × 1 cubic foot/1,000 Btu/0.70
= ***16.08 cubic feet of natural gas***

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(elect.) = 1,000,000 kWh/yr. × 3,412 Btu/kWh
= 3,412,000,000 Btu/yr.

E(#2 fuel) = 3,000 gal./yr. × 140,000 Btu/gal.
= 420,000,000 Btu/yr.

E = 3,832,000,000 Btu/yr.

EUI = 3,832,000,000 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	

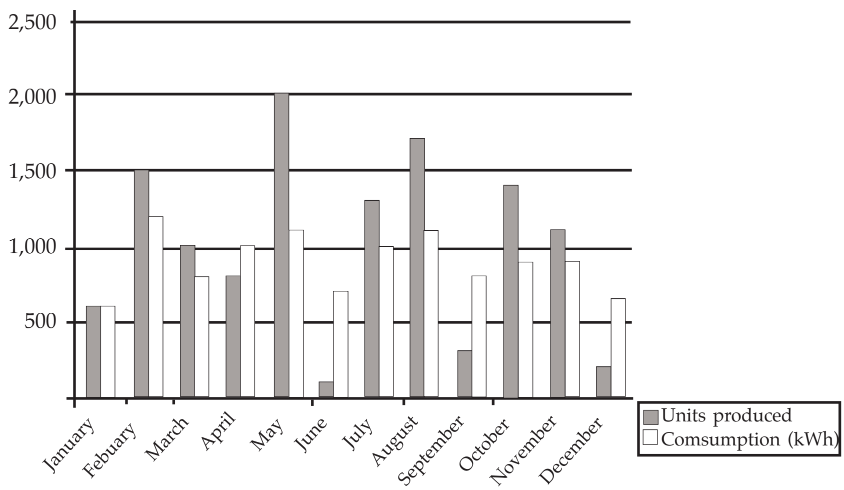
Solution: First, since June and December have special circumstances, we ignore these months. We then run a regression to find the slope and intercept of the process model. We assume that with the exception of the vacation and the shutdown that nothing other then the number of units produced affects the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

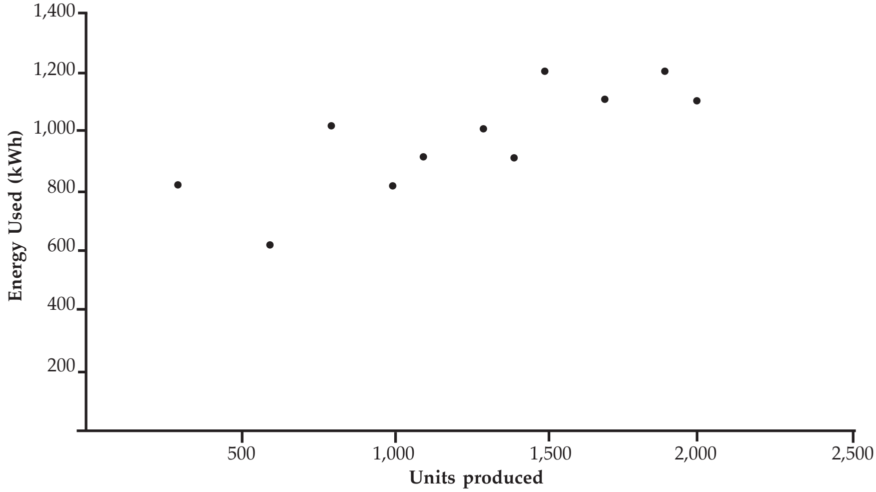
Units Month	Consumption produced	Average (kWh)	(kWh/unit)
January	600	600	1.00
February	1,500	1,200	0.80
March	1,000	800	0.80
April	800	1,000	1.25
May	2,000	1,100	0.55
July	1,300	1,000	0.77
August	1,700	1,100	0.65
September	300	800	2.67
October	1,400	900	0.64
November	1,100	900	0.82
January	1,900	1,200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

Increase in energy use
= CDD electric variance + Units electric variance
= 10,000 million Btu + 15,000 million Btu
= 25,000 million Btu

Increase cost due to increased energy use
= (Increase in energy use) × (Base cost of electricity)
= 25,000 billion Btu × $15/million Btu
= $375,000

Total cost of fuel switching
= Increase cost due to increased energy use
+ Increased cost due to cost variance
= $375,000 + $825,000
= ***$1,200,000***

Chapter 2

The Energy Audit Process: An Overview

Problem: Compute the number of heating degree days (HDD) associated with the following weather data.

Given:

Time Period	Temperature (degrees F)	Number of hours	65F -Temperature (degrees F)	Hours × dT
Midnight - 4:00 AM	20	4	45	180
4:00 AM - 7:00 AM	15	3	50	150
7:00 AM - 10:00 AM	18	3	47	141
10:00 AM - Noon	22	2	43	86
Noon - 5:00 PM	30	5	35	175
5:00 PM - 8:00 PM	25	3	40	120
8:00 PM - Midnight	21	4	44	176
				1,028

Solution: From the added columns in the given table, we see that the number of hours times the temperature difference from 65 degrees F is 1,028 F-hours. Therefore, the number of HDD can be calculated as follows:

HDD = 1,028 F-hours/24 h/day
= ***42.83*** degree-days

Problem: Select a specific type of manufacturing plant and describe the kinds of equipment that would likely be found in such a plant.
List the audit data that would need to be collected for each piece of equipment.
What particular safety aspects should be considered when touring the plant?
Would any special safety equipment or protection be required?

Solution: The following equipment could be found in a wide variety of manufacturing facilities:

Equipment	**Audit data**
Heaters	Power rating Use characteristics (annual use, used in conjunction with what other equipment, how is the equipment used?)
Boilers	*Power rating* Use characteristics Fuel used Air-to-fuel ratio Percent excess air
Air-conditioners Chillers Refrigeration	Power rating Efficiency Cooling capacity Use characteristics
Motors	Power rating Efficiency Use characteristics
Lighting	Power rating Use characteristics
Air-compressors	Power rating Use characteristics Efficiency Various air pressures An assessment of leaks

Specific process equipment for example for a metal furniture plant one may find some sort of electric arc welders for which one would collect its power rating and use characteristics.

The following include a basic list of some of the safety precautions that may be required and any safety equipment needed:

Safety precaution	*Safety equipment*
As a general rule of thumb the auditor should never touch anything: just collect data. If a measurement needs to be taken or equipment manipulated ask the operator.	
Beware of rotating machinery	
Beware of hot machinery/pipes	*Asbestos gloves*
Beware of live circuits	*Electrical gloves*
Have a trained electrician take any electrical measurements	
Avoid working on live circuits, if possible	
Securely lock and tag circuits and switches in the off/open position before working on a piece of equipment	
Always keep one hand in your pocket while making measurements on live circuits to help prevent accidental electrical shocks.	
When necessary, wear a full face respirator mask with adequate filtration particle size.	
Use activated carbon cartridges in the mask when working around low concentrations of noxious gases. Change cartridges on a regular basis.	
Use a self-contained breathing apparatus for work in toxic environments.	
Use foam insert plugs while working around loud machinery to reduce sound levels by nearly 30 decibels (in louder environments hearing protection rated at higher noise levels may be required)	
Always ask the facility contact about special safety precautions or equipment needed. Additional information can be found in OSHA literature.	
For our metal furniture plant:	
Avoid looking directly at the arc of the welders	*Tinted safety goggles*

Problem: Section 2.1.2 of the *Guide to Energy Management* provided a list of energy audit equipment that should be used. However, this list only specified the major items that might be needed. In addition, there are a number of smaller items such as hand tools that should also be carried. Make a list of these other items, and give an example of the need for each item.

How can these smaller items be conveniently carried to the audit?

Will any of these items require periodic maintenance or repair?

If so, how would you recommend that an audit team keep track of the need for this attention to the operating condition of the audit equipment?

Solution: Smaller useful audit equipment may include:

A flashlight
Extra batteries
A hand-held tachometer
A clamp-on ammeter
Recording devices

These smaller items can be conveniently be carried in a tool box.

As with most equipment, these items will require periodic maintenance. For example, the flashlight batteries and light bulbs will have to be changed.

For these smaller items, one could probably just include the periodic maintenance as part of a pre-audit checklist. For items that require more than just cursory maintenance, one could include the item in their periodic maintenance system.

Problem: Section 2.2 of the *Guide to Energy Management* discussed the point of making an inspection visit to a facility at several different times to get information on when certain pieces of equipment need to be turned on and when they are unneeded. Using your school classroom or office building as a specific example, list some of the unnecessary uses of lights, air conditioners, and other pieces of equipment. How would you recommend that some of these uses that are not necessary be avoided? Should a person be given the responsibility of checking for this unneeded use? What kind of automated equipment could be used to eliminate or reduce this unneeded use?

Solution: Typically, one could visit a university at night and observe that the lights of classrooms are on even at midnight when no one is using the area. One idea would be to make the security force responsible for turning off non-security lights when they make their security tours at night. A better idea may be to install occupancy sensors so that the lights are on only when the area is in use. An additional benefit of an occupancy sensors could be security; many thieves or vandals would be startled when lights come on.

Problem: An outlying building has a 25 kW company-owned transformer that is connected all the time. A call to a local electrical contractor indicates that the core losses from comparable transformers are approximately 3% of rated capacity. Assume that the electrical costs are ten cents per kWh and $10/kW/month of peak demand, that the average building use is ten hours/month, and that the average month has 720 hours. Estimate the annual cost savings from installing a switch that would energize the transformer only when the building was being used.

Given:

Transformer power use	25	kW
Core losses	3%	
Electrical energy cost	$0.10	/kWh
Demand charge	$10/kW	/month
Building utilization	10 hrs	/mo
Hours in a month	720 hrs	/mo
Months in a year	12 mo	/yr

Solution: The energy savings (ES) from installing a switch that would energize the transformer only when the building was being used can be calculated as follows:

ES = (Percentage of core losses) (Transformer power use)(Hours in a month - Building utilization) (Months in a year)
= 3% × 25 kW × 720 - 10) hrs/mo × 12 mo/yr
= 6,390 kWh/yr

Since we do not expect the monthly peak demand to be reduced by installing this switch, the only savings will come from energy savings. Therefore, annual savings (AS) can be calculated as follows:

AS = ES × Electrical energy cost
= 6,390 kWh/yr × $ 0.10/kWh
= ***$ 639/yr***

Chapter 3

Understanding Energy Bill

Problem: By periodically turning off a fan, what is the total dollar savings per year to the company?

Given: In working with Ajax Manufacturing Company, you find six large exhaust fans are running constantly to exhaust general plant air (not localized heavy pollution). They are each powered by 30-hp electric motors with loads of 27 kW each. You find they can be turned off periodically with no adverse effects. You place them on a central timer so that each one is turned off for 10 minutes each hour. At any time, one of the fans is off, and the other five are running. The fans operate 10 h/day, 250 days/year. Assume the company is on the rate schedule given in Figure 3-10. Neglect any ratchet clauses. The company is on service level 3 (distribution service). (There may be significant HVAC savings since conditioned air is being exhausted but ignore that for now.)

Solution: Demand charge

On-peak $12.22/kW/mo	June-October	5 months/year
Off-peak $4.45/kW/mo	November-May	7 months/year

Energy charge
For first two million kWh $0.03431/kWh
All kWh over two million $0.03010/kWh

Assumptions (and possible explanations)
Assume the company uses well over two million kWh per month
The fuel cost adjustment is zero, since the utility's fuel cost is at the base rate.
There is no sales tax since the energy can be assumed to be used for production

The power factor is greater than 0.8

No franchise fees since the company is outside any municipality

The demand savings (DS) can be calculated as follows:

$$DS = [(DC \text{ on peak}) \times (N \text{ on peak}) + (DC \text{ off peak}) \times (N \text{ off peak})] \times DR$$

where,

DC = Demand charge for specified period
N = Number of months in a specified period
DR = Demand reduction, 27 kW since a motor using this amount is always turned off with the new policy

Therefore,

$$DS = [(\$12.22/kW/mo) \times (5\ mo/yr) + (\$4.45/kW/mo) \times (7\ mo/yr)] \times 27\ kW = \$2{,}491/yr$$

The energy savings (ES) can be calculated as follows:

$$ES = (EC > 2 \text{ million}) \times (10\ h/day) \times (250\ day/yr) \times DR$$

where

EC = Marginal energy charge

Therefore,

$$ES = (\$0.03010/kWh) \times (10\ h/day) \times (250\ day/yr) \times 27\ kW = \$2{,}032/yr$$

Finally, the total annual savings (TS) can be calculated as follows:

$$TS = DS + ES = \$4{,}523/yr$$

Additional Considerations
How much would these timers cost?
How much would it cost to install these timers? Or an alternate control system?
Does cycling these fans on and off cause the life of the fan motors to decrease?
What would the simple payback period be?
Net present value?
Internal rate of return?