Sample Energy Problems Answer Key for Energy Management Professional Study

Updated May 2019

Units of Measure – Conversions

British Thermal Unit (Btu) – measure of heat (energy) content of fuels. The quantity of heat required to raise the temperature of 1 pound of liquid water by 1°F at the temperature that water has its greatest density (approx. 39°F).

Electricity	1 kilowatt hour	= 3,412 Btu
Natural Gas	1 cubic foot	= 1,023 Btu
Motor Gasoline	1 gallon	= 124,238 Btu
Diesel Fuel	1 gallon	= 138,690 Btu
Heating Oil	1 gallon	= 139,600 Btu
Propane	1 gallon	= 91,333 Btu
Electric horsepower	1 HP	= 2,545 Btu

BTUH – BTUs per hour (often used to define equipment capacity)
Ton of refrigeration = 12,000 BTUH

Use Consistent Units through Calculations

#1 - Heating Degree Days

The average daily temperatures for one week in January in Asheville, NC are as follows:

- Monday 48°F
- Tuesday 52°F
- Wednesday 53°F
- Thursday 66°F
- Friday 49°F
- Saturday 47°F
- Sunday 50°F

What is the total number of Heating Degree Days (HDD) for the one week period?

#1 - Heating Degree Days

Subtract the average daily temperature for each day from 65°F, provided the average daily temperature is below 65°F, to calculate the number of heating degree days for that day:

• Monday	65°F - 48°F = 17
• Tuesday	65°F - 52°F = 13
• Wednesday	65°F - 53°F = 12
• Thursday	(Average above 65°F)
• Friday	65°F - 49°F = 16
• Saturday	65°F - 47°F = 18
• Sunday	65°F - 50°F = 15

Total HDD for the week = 91

#2 - Cooling Degree Days

The average daily temperatures for one week in May in Asheville, NC are as follows:

- Monday 88°F
- Tuesday 79°F
- Wednesday 77°F
- Thursday 78°F
- Friday 64°F
- Saturday 79°F
- Sunday 72°F

What is the total number of Cooling Degree Days (CDD) for the one week period?

#2 - Cooling Degree Days

Subtract 65°F from the average daily temperature for each day, provided the average daily temperature is above 65°F, to calculate the number of cooling degree days for that day:

- Monday 88°F - 65°F = 23
- Tuesday 79°F - 65°F = 14
- Wednesday 77°F - 65°F = 12
- Thursday 78°F - 65°F = 13
- Friday 64°F - 65°F = 0 (Average below 65 °F)
- Saturday 79°F - 65°F = 14
- Sunday 72°F - 65°F = 7

Total CDD for the week = 83

#3 - Performance Metrics – EUI Problem

A client owns and manages a 180,000 SF office building and wants to know how it is performing. The client provides the following information to the EMP, (next slide).

What is the Energy Use Index (EUI) for the building?

#3 - Performance Metrics – EUI Problem

Month	Electrical (kWh)	Natural Gas (MCF)
January	170,000	903
February	160,400	794
March	180,880	856
April	192,000	706
May	240,900	648
June	262,500	581
July	241,700	521
August	234,650	509
September	234,000	572
October	228,000	713
November	195,700	761
December	186,200	817
TOTAL	____________kWh_	__________MCF_

#3 - Performance Metrics – EUI Problem

2,526,930 kWh x 3.412 kBTU/ kWh = 8,621,885 kBTU
8,381 MCF x 1,023 kBTU/ MCF = 8,573,763 kBTU

$$EUI = \frac{8{,}621{,}885 \text{ kBTU} + 8{,}573{,}763 \text{kBTU}}{180{,}000 \text{ SF}} = 95.53 \text{ kBTU/SF}$$

#4 – Site EUI / Source EUI Problem

An 80,000 SF office building includes gas boilers for heating and has a ‘demand response’ agreement with the local utility to utilize its on-site generator during high demand periods. Its annual metered energy usage, per fuel, is as follows:

- Electricity: 859,000 kWh
- Natural Gas: 1,499,641 cu. ft.
- Diesel oil: 2,000 gallons

1. What is the Site EUI?
2. What is the Source EUI?

#4 – EUI / Site Energy

Convert all inputs into kBtu

- 859,000 kWh/yr x 3.412 kBtu/kWh = 2,930,908 kBtu/yr
- 1,499,641 cu. ft./yr x 1,023 Btu/cu. ft. x 1 kBtu/1000 Btu = 1,534,133 kBtu/yr
- 2,000 gallons/yr x 138,690 Btu/gal x 1 kBtu/1000 Btu = 277,380 kBtu/yr

$$\text{Site EUI} = \frac{(2{,}930{,}908 + 1{,}534{,}133 + 277{,}380)\ \text{kBtu/yr}}{80{,}000\ \text{SF}} = 59.28\ \text{(kBtu/yr) per SF}$$

#4 – EUI / Source Energy

Use Portfolio Manager's Source-Site Ratios

- 2,930,908 site kBtu/yr x 3.34 = 9,789,233 source kBtu/yr
- 1,534,133 site kBtu/yr x 1.047 = 1,606,237 source kBtu/yr
- 277,380 site kBtu/yr x 1.01 = 280,154 source kBtu/yr

$$\text{Source EUI} = \frac{(9{,}789{,}233 + 1{,}606{,}237 + 280{,}154)\ \text{kBtu/yr}}{80{,}000\ \text{SF}} = 145.95\ \text{kBtu/yr}$$

#5 - Alternate EUI Metrics

Sometimes Owners use more than one EUI metric for a building.

A hotel has a floor area of 200,000 SF, 400 guest rooms, and 50 employees. The annual energy bills, converted to a common unit, total 20,000,000 BTU/yr.

What are the EUI values for each of the following metrics?

- BTU/SF per year
- BTU/guest room per year
- BTU/ employee per year

#5 - Alternate EUI Metrics

What are the EUI values for each of the following metrics:

1. BTU/SF per year =
   (20,000,000 BTU/yr)/ 200,000 SF = 100 BTU/ SF/ yr

2. BTU/guest room per year =
   (20,000,000 BTU/yr)/ 400 rooms = 50,000 BTU/ room/ yr

3. BTU/ employee per year =
   (20,000,000 BTU/yr)/ 50 emp. = 400,000 BTU/ emp/ yr

#6 – Energy Performance Indicators

An industrial plant makes ‘widgets’ and management forecasts a 12% increase in annual production during 2018 over their production in 2017. The production (process) electricity is metered separately from the balance of the plant. Using the information below:

1. What is the expected monthly electrical cost in 2018?
2. What is the total electricity cost for each widget the plant produces in 2018?

- Every widget requires 0.2875 kWh of electricity (intensity)
- 2017 production volume = 12,500,000 widgets
- Monthly electrical consumption unrelated to production = 224,373 kWh
- Pro-rated electricity cost (demand and consumption) = $0.075 / kWh

#6 – Energy Performance Indicators

1. What is the expected monthly electrical cost in 2018?

12,500,000 x 1.12 = 14,000,000 ÷ 12 = 1,166,667 widgets / mo.

(0.2875 kWh / widg. x 1,166,667 widg.) + 224,373 kWh = 559,790 kWh

At $0.075 per kWh x 559,790 kWh = $41,984.

2. What is the total electricity cost for each widget the plant produces in 2018?

$41,984 ÷ 1,166,667 = $0.036 or 3.6¢

#7 – Evaluating Energy Opportunities

An EMP identifies three ECMs with the following estimated costs and projected annual savings.

	Cost ($)	Annual Savings ($)
ECM #1	5,400	1,200
ECM #2	3,500	800
ECM #3	4,700	1,000

The Owner decides to implement all three of the measures.

What is the simple payback for the project?

What is the projected ROI for the project?

#7 – Evaluating Energy Opportunities

Simple Payback

(\$5,400 + 3,500 + 4,700 Cost) / (\$1,200 + 800 + 1,000 Savings/ yr)

= \$13,600 Cost / \$3,000 Savings/ yr

= 4.53 years to payback

Return on Investment (Annual)

((\$1,200 + 800 + 1,000 Savings/ yr) / (\$5,400 + 3,500 + 4,700 Cost)

= \$3,000 Savings/ yr / \$13,600 Cost

= 22.06 % annual return on investment

#8 – Evaluating Energy Opportunities

If a school's O&M staff has only enough time to implement one of the following ECMs during the next school break, which one would you recommend based on the District's criteria to maximize investment across a 10 year payback period? The school has the budget to afford any one of the following project costs.

ECM Number	Initial Cost	Savings, $/yr	SPB, years	10 years savings	10 year savings minus Initial Cost
1	$500	$1000	0.50		
2	$4000	$4000	1.00		
3	$11,000	$10,000	1.10		
4	$20,000	$15,000	1.33		

#8 – Evaluating Energy Opportunities

ECM Number	Initial Cost	Savings, $/yr	SPB, years	10 years savings	10 year savings minus Initial Cost
1	$500	$1000	0.50	$10,000	$9,500
2	$4000	$4000	1.00	$40,000	$36,000
3	$11,000	$10,000	1.10	$100,000	$89,900
4	$20,000	$15,000	1.33	$150,000	$130,000

ECM #4 best meets the District's criteria to maximize investment across a 10 year payback period.

#9 – Coefficient of Performance (COP)

If an absorption chiller load is 600 tons, the required heat input (Btu/Hr) to a chiller with a COP of 0.80 is most nearly:

A. 6.4×10^6
B. 7.6×10^6
C. 8.2×10^6
D. 9.0×10^6

#9 – Coefficient of Performance (COP)

* D. 9.0×10^6

$$COP = \frac{Q_{\text{evap effect}}}{Q_{\text{gen input}}}$$

$$Q_{\text{gen input}} = \frac{Q_{\text{evap effect}}}{COP} = \frac{600 \text{ tons} \times 12{,}000 \text{ Btu/hr/ton}}{0.80}$$

$$= 9{,}000{,}000 \text{ Btu/hr.}$$

#10 - ECM – Calculating Savings

During an energy audit, it is discovered that a laboratory hood exhaust fan is operating continuously; 24 hours a day, 365 days a year.

In discussion with the Users of the building, it is determined that the fan only needs to operate from 8:00 AM to 5:00 PM for five (5) days a week.

The fan motor is ½ horsepower, single phase with a power factor of .85. The nameplate on the motor lists 4.9 amps at 230 volts.

The electricity costs $.06 / kWH.

By reducing the run time of the fan, what are the approximate savings per year?

#10 - ECM – Calculating Savings

0.85 (PF) x 230 (V) x 4.9 amps = 958 watts

(958 / 1000) x 15 hrs. / day x 5 days / week x 52 weeks / yr. = 3,736.2 kWhs saved

plus,

(958 / 1000) x 24 hrs. / day x 2 days / week x 52 weeks / yr. = 2,391.2 kWhs saved

6127.4 kWhs x $.06 / kWh = $367.64

Pump and Fan – Affinity Laws

$$\left(\frac{P1}{P2}\right) = \left(\frac{N1}{N2}\right)^3$$

$$\left(\frac{Q1}{Q2}\right) = \left(\frac{N1}{N2}\right)$$

$$\left(\frac{H1}{H2}\right) = \left(\frac{N1}{N2}\right)^2$$

$$\left(\frac{Q1}{Q2}\right) = \left(\frac{D1}{D2}\right)$$

$$\left(\frac{P1}{P2}\right) = \left(\frac{D1}{D2}\right)^3$$

$$\left(\frac{H1}{H2}\right) = \left(\frac{D1}{D2}\right)^2$$

P – Power (e.g. hp, kW)

N – Speed (e.g. rpm, Hz)

Q – Volumetric Flow (e.g. gpm, cfm)

H – Head Pressure (e.g. ft H_2O), psi, in. H_2O)

D – Impeller Diameter (e.g. inches)

$$\text{Fan Power } (hp) = \frac{(CFM)(in)}{(6{,}346)(\%\ eff)}$$

$$\text{Pump Power } (hp) = \frac{(GPM)(ft)}{(3{,}960)(\%\ eff)}$$

$$\text{Fan Efficiency} = \frac{CFM \text{ x } TP}{6{,}356 \text{ x } BHP}$$

#11 - ECM - Pump Laws

An EMP has been engaged by an industrial client for energy-related services. During the course of his work, the client identifies a process pump that currently operates at a capacity of 150 gpm, with a 10 HP motor operating at 1800 rpm.

The client wants to increase the pump capacity to 300 gpm, but would like to know the impact on horsepower.

Assuming a constant diameter impeller, what resulting changes to pump speed and horsepower are required to meet the increase to 300 gpm?

#11 - ECM - Pump Laws

Refer to Pump Laws:

Variables: $N_1 = 1800$ rpm $Q_1 = 150$ gpm $P_1 = 10$ hp

$N_2 =$ _______ rpm $Q_2 = 300$ gpm $P_2 =$ ______ hp

Solving for new speed

$$\frac{N_2}{N_1} = \frac{Q_2}{Q_1}$$

$$N_2 = N_1 \times (Q_2 \div Q_1)$$

$$N_2 = 1800 \times (300 \div 150)$$

$$N_2 = 3600 \text{ rpm}$$

#11 - ECM - Pump Laws

Refer to Pump Laws:

Variables: $N_1 = 1800$ rpm $Q_1 = 150$ gpm $P_1 = 10$ hp

$N_2 = 3600$ rpm $Q_2 = 300$ gpm $P_2 =$ _____ hp

Solving for required brake horsepower

$$\frac{P_2}{P_1} = \left(\frac{Q_2}{Q_1}\right)^3$$

$$P_2 = P_1 \times (Q_2 \div Q_1)^3$$

$$P_2 = 10 \times (300 \div 150)^3 = 80$$

$$P_2 = 80$$

Required P is 80. Standard motor sizes are 75, 100 and 125. Select 100 HP

#12 – ECM - Affinity Law

An EMP notices that several spaces within a subject building require lower airflow than the capacity available through the existing fans. The fans are all equipped with VFDs.

The EMP knows that in reducing air flow from 100% of the fan rating to 80% airflow (by reducing the fan speed via the VFD), approximately 50% of the fans power consumption can be saved.

Use the Affinity Laws to identify the anticipated savings in the following scenario:

An existing 10 hp fan produces 10,000 cfm when the VFD is a 100%. What would the savings in electric power input to this fan be if the airflow is reduced to 8,000 cfm?

#12 – ECM - Affinity Law

Refer to Affinity Laws:

Variables: Q_1 = ________ cfm P_1 = ______ hp

Q_2 = ________ cfm P_2 = ______ hp

Solving for required brake horsepower

$$(Q_1 \div Q_2) = (N_1 \div N_2)$$

$$(P_1 \div P_2) = (N_1 \div N_2)^3$$

therefore, $(P_1 \div P_2) = (Q_2 \div Q_1)^3$

To find P_2 reorganize the equation: $P_2 = [P_1 / (Q_2 \div Q_1)^3]$

Then solve the equation: P_2 hp $= [10 \text{ hp} / (10{,}000 \text{ cfm} \div 8{,}000 \text{ cfm})^3]$

#12 – ECM - Affinity Law

Using the Affinity Laws:

To find P_2 reorganize the equation: $P_2 = [P_1 / (Q_2 \div Q_1)^3]$

Then solve the equation: P_2 hp $= [10 \text{ hp} / (10{,}000 \text{ cfm} \div 8{,}000 \text{ cfm})^3]$

P_2 hp $= 5.12$ hp

#13 - ECM - U-value / Insulation

An EMP is exploring the feasibility of adding insulation to the walls of a warehouse to decrease the heat loss. He has calculated the existing U-value of the wall as 0.20 and the R-value of the proposed insulation is 11.0.

The building has a total of 40,000 SF of exterior wall (no windows) and the design temperatures are 24 deg. F outside and 70 deg. F inside.

What is the decrease in heat loss (Btuh) if the insulation is added?

#13 - ECM - U-value / Insulation

Existing heat loss = Q = U *A * (T_o – T_i)

Q = 0.20 * 40,000 SF * (70 ºF -24 ºF) = 368,000 Btuh

Existing wall R-value = 1/U-value = 5.0

New wall R-value = 5.0 + 11.0 = 16.0

New wall U-value = 1/R-value = 1/16 = 0.0625

New heat loss = Q = 0.0625 * 40,000 SF * (70 ºF -24 ºF) = 115,000 Btuh

Decrease in heat loss = 368,000 Btuh – 115,000 Btuh = 253,000 Btuh

#13 - ECM - U-value / Insulation

Alternate solution:

$Q = (U_1 - U_2) * A * (T_o - T_i)$

$Q = (0.20 - 0.0625) * 40{,}000 * (70 - 24) = 253{,}000$ Btuh

#14 - Interactions – Lighting & Cooling Energy

An EMP is evaluating an ECM upgrading a building with a more efficient lighting system. The existing lighting load is 3,200 kW and will be reduced to 1,800 kW with the upgrade.

Existing operating hours for the lighting system in July is 200 hours (no anticipated change)

The air conditioning system uses 1 kWh of cooling energy to remove the heat from 3 kWh of lighting energy.

What is the total electricity savings in kWh for the month of July considering both lighting and cooling system savings?

#14 - Interactions – Lighting & Cooling Energy

Existing lighting kW x Existing operating hours in July = Existing lighting kWh
3,200 kW x 200 hours = 640,000 kWh
Existing lighting kWh = 640,000 kWh

Proposed lighting kW x Proposed operating hours in July = Proposed lighting kWh
1,800 kW x 200 hours = 360,000 kWh
Proposed lighting kWh = 360,000 kWh

Existing lighting kW - Proposed lighting kW = Lighting energy savings
640,000 kWh - 360,000 kWh = 280,000 kWh
Lighting energy savings in July: 280,000 kWh

#14 - Interactions – Lighting & Cooling Energy

The air conditioning system uses 1 kWh of cooling energy to remove the heat from 3 kWh of lighting energy.

Cooling energy savings in July = 280,000 kWh ltg energy savings x (1 kWh clg energy / 3 kWh ltg energy)

Lighting energy savings in July: 280,000 kWh

Cooling energy savings in July: 93,333 kWh

Total energy savings in July: 373,333 kWh

#15 – Interactions - Lighting & Cooling Energy

An EMP is analyzing a potential ECM for a 10,000 SF single-story office space in Orlando, FL. The building manager indicated lighting operation is 11 hours per day, 5 days per week.

There are 120 existing 2x4 lay-in troffer fixtures, each with (3) T-8, 32W lamps. Ballast loss is estimated to be 5%.

The option being considered is a 4-foot T-8 fixture LED retrofit kit which consumes 36W. The Owner can direct purchase the fixtures for $85 each. The Owner's on-contract electrician has quoted $70 each for installation (including disposal charges for the existing lamps and ballasts).

#15 – Interactions - Lighting & Cooling Energy

The EMP has previously calculated the following for this building and fixture type:

- BLENDED energy cost of $0.100 /kWh
- A cooling season of 46 weeks
- A previously-calculated overall HVAC system efficiency of 0.9 kW/ton
- Calculated annual maintenance cost differential, per fixture, of $12

Per the Owner, prospective ECMs must meet a simple payback threshold of 4.0 years or less to be considered for implementation. Does this ECM meet the threshold?

#15 – Interactions - Lighting & Cooling Energy

For A/C system power consumption, convert to kW (elec) / kW (cooling):

0.9 kW/ton x (1 / 12,000 Btuh/ton) x (3412 Btuh/kW) = 0.2559 kW_{clg}/kW_{elec}

Annual run time: 11 hrs. x 5 days x 52 weeks = 2860 hrs.

Each fixture has (3) 32 W lamps + 5% ballast loss = 3 x 32 x 105% = 100.8 W per fixture.

EXISTING direct power consumption & cost:

120 x 2860 hrs. x 100.8 W / 1,000 (W/kW) = 34,595 kWh

At power rate of $0.10 /kWh: 34,595 x $0.10 = $3,459 per year

EXISTING indirect power consumption & cost:

34,595 kWh x 0.2559 kW_{clg}/kW_{elec} x (46/52) = 7,831 kWh

At power rate of $0.10 /kWh: 7,831 x $0.10 = $783 per year

EXISTING total power cost: $3,459 + $783 = $4,242 annually

#15 – Interactions - Lighting & Cooling Energy

NEW direct power consumption & cost:

120 x 2860 hrs. x 36 W / 1,000 (W/kW) = 12,355 kWh

At an energy rate of $0.10 /kWh: 12,355 x $0.10 = $1,236 per year

NEW indirect power consumption & cost:

12,355 kWh x 0.2559 kW_{clg}/kW_{elec} x (46/52) = 2,797 kWh

At an energy rate of $0.10 /kWh: 2,797 x $0.10 = $280 per year

NEW total power cost: $1,236 + $280 = $1,516 annually

Annual Maintenance cost savings:

$12/fixture x 120 fixtures = $1,440

#15 – Interactions - Lighting & Cooling Energy

IMPLEMENTATION Cost

$85 parts + $70 labor = $155 each x 120 fixtures = $18,600

Annual power cost savings = $4,242 – $1,516 = $2,726

Annual Maintenance cost savings: $1,440

TOTAL Annual savings: $2,726 + $1,440 = $4,166

Simple Payback: $18,600 / $4,166 = 4.5 years > Owner threshold of 4.0 years.

NOTE: A blended rate of $0.12 /kWh yields a 3.9 year payback.

#16 - ECM – Domestic Hot Water

An EMP is performing an energy audit of a community center. During the audit, it is discovered the domestic water heating system serving the locker room showers has been leaking 0.5 gal. / minute from an old storage tank.

Domestic water arrives at the building from underground piping at 70°F and is heated and stored at 140°F, before being distributed through a thermostatic mixing valve.

What is the rate of heat loss?

#16 - ECM – Domestic Hot Water

Water that leaks from the storage tank at 140° deg. F must be replaced. The domestic water entering the system at 70°F must be heated to 140°F, for a 70°F delta T

Convert leakage / replacement rate:

0.50 gal. / min. x 60 min. / hr. = 30 gal. /hr.

Calculate heating requirement:

30 gal. hr. x 8.34 lb. / gal. x 70 deg. F = 17,514 lb. – deg. F / hr.

= 17,514 Btu / hr.

#17 - Utility Rate Problem

An EMP is preparing for an upcoming audit and retro-commissioning project on a state university campus. The state university facilities operations staff has provided the combined previous 12 months of electric and natural gas data for the buildings that will be included in the project. The EMP has also obtained the utility rate structure that is applicable.

Month	Electrical Consumption (kWh)	Electrical Demand (kW)	Natural Gas (MCF)
Jan	180,000	1,480	950
Feb	168,800	1,526	836
Mar	190,400	1,782	901
Apr	202,000	1,966	743
May	253,600	2,214	682
Jun	276,400	2,348	612

Month	Electrical Consumption (kWh)	Electrical Demand (kW)	Natural Gas (MCF)
Jul	254,400	2,456	548
Aug	247,000	2,648	536
Sep	246,400	2,342	602
Oct	240,000	2,134	751
Nov	206,000	1,896	801
Dec	196,000	1,688	860
Total	**2,661,000**	**24,480**	**8,822**

#17 - Utility Rate Problem

- The utility tariff that applies for the campus has the following components:
- Winter Energy Charge - $0.043/kWh
- Summer Energy Charge - $0.068/kWh
- T & D Charges - $0.076/kWh
- Demand - $10.00/kW
- Local Usage Tax – 4.0%
- Winter Natural Gas tariff - $8.34/MCF
- Summer Natural Gas tariff - $6.86/MCF
- Summer – May to September, inclusive

What is the blended electric rate that should be used for preliminary assessment of ECMs?

#17 - Utility Rate Problem

Summer Consumption Cost (May through September)	
1,277,800 kWh x $0.068 / kWh =	$ 86,890.40
Winter Consumption Cost	
1,383,200 kWh x $0.043 / kWh =	$ 59,477.60
Demand Charges	
24,480 kW x $10.00 / kW =	$244,800.00
T & D Charges	
2,661,000 kWh x $0.076 / kWh =	$202,236.00
TOTAL $593,404 ÷ 2,661,000 =	$0.223 / kWh

#18 - Utility Bill Analysis

Using the consumption information for the same project, identify what dollar savings would be achieved on the July bill for a cooling ECM that saves 100,000 kWh and 5 kW.

Month	Electrical Consumption (kWh)	Electrical Demand (kW)	Natural Gas (MCF)
Jan	180,000	1,480	950
Feb	168,800	1,526	836
Mar	190,400	1,782	901
Apr	202,000	1,966	743
May	253,600	2,214	682
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Month	Electrical Consumption (kWh)	Electrical Demand (kW)	Natural Gas (MCF)
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Nov	206,000	1,896	801
Dec	196,000	1,688	860
Total	**2,661,000**	**24,480**	**8,822**

#18 - Utility Bill Analysis

Energy dollar savings

100,000 kWh x 0.068 $/ kWh = $ 6,800

T & D dollar savings

100,000 kWh x 0.076 $/ kWh = $ 7,600

Demand Charge

5 kW x $10 / kW = $ 50

Sub-Total = $ 14,450

Local Usage Tax

4.0% x $14,450 = $ 578

TOTAL $ 15,028

#19 - Utility Invoice Audit

Month	Electrical Consumption (kWh)	Electric Demand (kW)	Natural Gas (MCF)
Jan	300,000	12,000	1100
Feb	298,000	16,000	900
Mar	355,500	14,500	901
Apr	425,200	16,800	899
May	555,500	17,000	750
Jun	688,800	18,200	612
Jul	825,000	19,300	599
Aug	900,000	20,000	536
Sep	855,000	19,500	602
Oct	769,000	16,900	751
Nov	627,900	14,900	827
Dec	550,000	13,200	1050
Total	7,149,900	198,300	9,527

Consumption (Charge) = $0.074/kWH

T&D = $0.083/kWH

Demand = $5.00/kW

What are the demand charges for August?

What is the total electrical cost for August?

What is the blended electrical energy rate?

#19 - Utility Invoice Audit

Calculate demand charges in August

- Demand = 20,000 kW
- Demand: 20,000 kW x $5.00 / kW = $100,000

Calculate total electrical cost for August

- Consumption: 900,000 kWh x $0.074 / kWh = $66,600
- Demand: 20,000 kW x $5.00 / kW = $100,000
- T&D = 900,000 kWh x $0.083 kWh = $74,700
- Total: $241,300

Calculate the blended electrical rate

- Consumption = 7,149,900 kWh x $0.074 / kWh = $529,092.60
- Demand = 198,300 kW x $5 = $991,500
- T&D = 7,149,900kWh x $0.083 / kWh = $593,441.70
- Cost = $2,114,034
- Blended rate = $2,114,034 ÷ 7,149,900 = $0.296

#20 - Utility Rate Analysis

Utility charges and terminology changes from one Utility Company to the next. Sometimes, charges and terminology can be a little complicated.

See actual utility rate charges from a San Antonio, TX provider company:

MONTHLY BILL

Rate	
$ 8.75	Service Availability Charge
	Energy Charge
	Summer Billing (June - September)
$ 0.0691	Per KWH for all KWH
	Non-Summer Billing (October - May)
$ 0.0691	Per KWH for the first 600 KWH
$ 0.0592	Per KWH for all KWH in excess of 600 KWH
	Peak Capacity Charge*
$ 0.0198	Per KWH for all KWH in excess of 600 KWH

*Peak Capacity Charge is applicable only during the summer billing period (June - September).

#20 - Utility Rate Analysis

Month	Total kWh	First block kWh	Second block kWh	Service Availability Charge	Energy Charge per kWh, first block	Energy Charge per kWh, second block	Peak Capacity Charge per kWh	Total charge per kWh, first block	Total charge per kWh, second block
Jan	1000								
July	2000								

1. Complete the Table using the Utility rate structure on the previous slide.
2. What are two differences between Summer and Winter rates at this Utility ?

#20 - Utility Rate Analysis

Month	Total kWh	First block kWh	Second block kWh	Service Availability Charge	Energy Charge per kWh, first block	Energy Charge per kWh, second block	Peak Capacity Charge per kWh	Total charge per kWh, first block	Total charge per kWh, second block
Jan	1000	600	400	$8.75	.0691	.0592	n/a	.0691	.0592
July	2000	600	1400	$8.75	.0691	.0691	.0198	.0691	.0889

Two differences between Summer and Winter rates at this Utility is that Summer has no separate block energy charge and Winter does not have a Peak Capacity Charge.

#21 - EUI Calculation

A client owns and manages an apartment building that is 130,000 SF and wants to know how it compares to other buildings of similar nature. The client provides the following information to the energy manager.

Month	Electrical Consumption (kWh)	Natural Gas Consumption (MCF)
Jan	180,000	950
Feb	168,800	836
Mar	190,400	901
Apr	202,000	743
May	253,600	682
Jun	276,400	612
Jul	254,400	548
Aug	247,000	536
Sep	246,400	602
Oct	240,000	751
Nov	206,000	801
Dec	196,000	860
Total	2,661,000	8,822

#21 - EUI Calculation

What is the approximate EUI for the building?

A. 21

B. 70

C. 88

* D. 139

(Convert all consumption to BTU then divide total energy use (BTU) by facility gross square feet (GSF)

*Only use the total data – monthly data is a distraction, overall is important. (2,661,000 kWh * 3.412 kWh/kBtu + 8,822 MCF *1025 kBtu/MCF)/130,000 SF = 139.4 kBtu/ft^2*

#22 – Energy Audit and RCx

An energy manager is preparing for an upcoming audit and retro-commissioning project on a corporate campus. As part of the preparation, the energy manager is requesting that the client provide certain information.

Which of the following items should be requested from the client by the energy manager?

A. Age of the facilities
B. Planned changes in schedules
C. Utility rate schedules
D. Maintenance staff capabilities

#22 – Energy Audit and RCx

Age of facilities is not important, does not show condition of equipment or impact energy use. That depends on materials and maintenance.

** B. Planned changes in schedules impact energy use and can "make or break" an ECM or FIM.*

Utility rate schedules can be obtained from local utility providers. Information from owner may be required if on a deregulated contract or utilities are provided from a district plant. That information is not included in the question.

Maintenance staff capabilities do not impact the audit or the financial viability of an ECM, unless labor is assumed to be done in-house. That requirement or information is not included in the question.

#23 – Analyzing Energy Data

After reviewing 12 months of energy consumption following an equipment chiller replacement, the energy manager notes, that costs actually increased over the previous year, see below.

Month	Baseline Energy Consumption Electricity (kWh)	Post-EEM Energy Consumption Electricity (kWh)
Jan	142,500	190,000
Feb	148,512	190,400
Mar	135,040	168,800
Apr	165,640	202,000
May	215,560	254,600
Jun	248,760	276,400
Jul	228,960	253,400
Aug	217,888	246,600
Sept	204,512	247,400
Oct	199,200	240,000
Nov	160,680	206,000
Dec	135,000	180,000
Year	2,202,252	2,655,600

#23 – Analyzing Energy Data

What is <u>MOST</u> likely to be the cause of the increased energy use?

A. boiler water set points not resetting
B. negative pressure in lobby
C. building operating schedule overridden ON
D. lights left on

#23 – Analyzing Energy Data

What is MOST likely to be the cause of the increased energy use?

A. boiler water set points not resetting
B. negative pressure in lobby
* C. building operating schedule overridden ON
D. lights left on

By comparing the kwh usage per month to the previous year, we see that every month is above the previous kwh usage, which leads us to:

C. The building operating schedule was overridden ON

#24 – Heating Degree Days

The average temperature for 4 days is 60 degrees F.

What is the number of __Heating Degree Days (HDD)__ for the 4-day period.

A. *5 Degrees F*
B. *10 Degrees F*
C. *15 Degrees F*
* D. *20 Degrees F*

HDD= (65-60) x 4 days = 20

#25 – Metering

An organization enters into sell all/buy all agreement with a utility company by installing a photovoltaic system to offset part of their electric consumption.

What is required to be metered in this type of agreement?

A. HVAC and domestic hot water loads
B. Solar panels and inverters
* C. Power generated and power purchased
D. Plug loads and lighting loads

* C. Power generated and power purchased
This requires knowledge of renewable energy systems and utility companies' typical agreements for metering and purchasing power.

#26 – Equipment Familiarization

Which of the following equipment could be found in a refrigeration plant?

A. DOAS unit (dedicated outdoor air system)
B. Variable refrigerant flow (VRF) condensing unit
C. Reverse Osmosis (RO) unit
* D. Absorption chiller

* D. Absorption chiller
This requires knowledge of mechanical systems and equipment. An absorption chiller runs on steam and is typically found in tri-generation plants

#27 – Energy Conservation Strategies

To reduce compressor energy use, the EMP should consider which of the following energy conservation strategies:

A. Increase chilled water flow through the chiller

* B. Reset leaving water temperature of the chiller

C. Increase condenser water flow through the chiller

D. Increase insulation around the evaporator shell of the chiller

#27 – Energy Conservation Strategies

* B. Reset leaving water temperature of the chiller

Raising the leaving water temperature should reduce the "lift" across the compressor, and maintaining the same delta T, at the higher chilled water temperature, the compressor suction will be higher. (e.g. it takes less energy to chill the water when you raise the discharge temperature). While you could also lower the lift by decreasing the condenser water temperature, this is not explicitly stated. Although it may be assumed that by increasing the CW flow, you are passing more water through the cooling tower and decreasing its temperature, you are also increasing the pump energy expended.

#28 – ECM Implementation

An energy audit yields a number of favorable ECMs, exhibiting energy savings as well as projected reductions in maintenance costs and improved performance. However, the total cost for implementation of these measures will exceed the Owner's budget. The Energy Management Professional meets with the Owner and offers several strategies to consider in developing a plan for implementation, including:

A. Engage an ESCO to perform the work under a performance contract

* B. Investigate alternative funding sources such as utility company incentives, government grants and/or low cost loans

C. Discuss priorities with the Owner regarding postponing select ECMs for future implementation

D. Investigate whether some ECMs can be implemented by in-house O&M staff

#28 – ECM Implementation

In which order should these strategies be considered; i.e. best to least favorable?

A. a. – b. – d. – c.
B. d. – b. – c. – a.
C. b. – a. – d. – c.
D. b. – d. – a. – c.

The Owner has budget problems and we are looking for the least expensive ways for him to accomplish the favorable ECMs. It should be understood that ESCOs charge a premium for performance contracts to cover their risks. The order of preference is "B." - d. (using in-house staff, already on the payroll), b. (alternate low cost funding (or rebates) from utilities or government agencies), c. (temporarily postponing implementation of select ECMs, until $$$ are available), then a. (engaging an ESCO)

#29 – Evaluating Energy Performance

What is the best method for an energy manager to compare energy performance between various buildings in his portfolio?

A. Compare the total costs of all metered utilities for each building

* B. Calculate the Energy Use Index (EUI) of each facility

C. Utilize submetering to identify and compare major energy-consuming loads.

D. Compare the energy consumption per occupant, based upon full time occupants.

* B. - utilizing a standard measurement (EUI) compares energy performance in kBTU/SF between buildings

Alternate A. is comparing costs but not "energy performance"
Alternate C. is only comparing major loads which will vary between buildings based upon their use, system types, etc.
Alternate D. may be another method of benchmarking, but if occupant density varies greatly (data centers, labs, manufacturing, warehouses, etc.) it is not a valid comparison

#30 – Evaluating Energy Performance

An energy management professional does not have data from field M&V instruments, but does have limited trend log data from the BAS; only reflecting operational status of the HVAC and lighting systems connected to same. For which of the following ECMs can the EMP verify improvement without the field data.

A. Installation of a new high efficiency chiller

* B. Replacement of lighting fixtures with higher efficiency fixtures

C. Implementation of demand control ventilation for outdoor air

D. Conversion of a constant volume air handling system to a VAV system

* B - Assuming the “operational status” (On/Off) trend data is available pre-implementation and post-implementation and we know the difference in total power consumption (wattage) between the two lighting systems, we should be able to verify the improvement against what was anticipated.

The other alternates are affected by multiple analog variables; e.g. weather, ambient temperature, occupancy, internal loads, etc.

#31 – Evaluating Energy Performance

An Owner requests an energy management professional review the terms and conditions of a performance contract proposed by an Owner, prior to executing same. After performing an Investment Grade Audit and determining the baseline energy use, the ESCO has provided a guarantee of energy savings associated with the implemented ECMs.

Which of the following would typically be included in an ESCO contract for adjustments to the baseline energy usage?

A. Changes in occupancy; changes in operating schedules; projected escalation rates for utility costs; and changes due to abnormal weather conditions Heating Degree Days (HDD) and Cooling Degree Days (CDD)

* B. Changes in occupancy; changes in operating schedules; adjustments due to inadequate maintenance; and changes due to abnormal weather conditions Heating Degree Days (HDD) and Cooling Degree Days (CDD)

C. Changes in operating schedules, projected escalation rates for utility costs, adjustments due to inadequate maintenance; and changes due to abnormal weather conditions Heating Degree Days (HDD) and Cooling Degree Days (CDD)

D. Changes in occupancy, changes in operating schedules; projected escalation rates for utility costs, and adjustments due to inadequate maintenance

#31 – Evaluating Energy Performance

Option B. is the only option that does not include "projected escalation rates for utility costs". There is no reason to adjust baseline energy usage based upon projected escalation rates for utility costs.

#33 – Evaluating Energy Performance

An Owner is presented with four ECMs based on an ASHRAE Level 2 Audit by an EMP. Annual energy savings and project installation cost is outlined for each ECM in the table below.

	Annual Energy Savings (BTU)	Annual Energy Savings ($)	Installed Cost ($)
1	3,288,794,193	$56,179	$284,782
2	1,972,334,842	$28,397	$116,498
3	3,009,478,440	$101,442	$528,934
4	2,859,667,010	$49,905	$214,665
Total	11,130,274,485	$235,923	$1,144,879

#33 – Evaluating Energy Performance

What is the approximate simple payback to proceed with all four ECMs?

A. 2 years

B. 4 years

* C. 5 years

D. 7 years

** C. - ($1,144,879/ $235,923) = 4.85*
Installed Cost ($)/ Annual Energy Savings ($) = Simple Payback
See AABC Energy Management Guideline Section 1.B.3.a, p. 26.)

#34 – Evaluating Energy Performance

The Owner of a 10-year old commercial office building has directed the building's Facility Manager to invest up to $100,000 in energy saving projects to reduce the facility's carbon footprint and utility bills. The Owner will only invest in individual projects with a minimum energy savings of 25,000 kWh/yr due to local utility costs and a simple payback of two years or less. The following ECM Matrix was provided last week, as a result of an energy analysis.

#34 – Evaluating Energy Performance

Item	Description	Annual Electric Energy Savings (kWh/yr)	Annual Electric Cost Savings ($/yr)	Annual Nat Gas Energy Savings (therms/yr)	Annual Nat Gas Cost Savings ($/yr)	Installation Cost ($)	Simple Payback (years)
1	Turn Off AHU Serving Theater during Unocc Hours	36,420	$2,667	0	$0	$2,280	0.85
2	Operate AS-21 Only When Laundry is Being Used	7,159	$524	5,122	$4,393	$8,650	1.76
3	Coordinate Operation Schedules of Kit Exh Fan and MAU with Kitchen Use	51,068	$3,740	26,300	$22,556	$6,890	0.26
4	Repair Electric Radiant Floor Heating Controls	62,458	$4,574	0	$0	$6,600	1.44
5	Manage Water Flow thru Coils to Achieve Design Heat Transfer	253,477	$20,545	0	$0	$44,730	2.18

Which projects should the Energy Manager execute?

A. ECM 1, 3, 4 and 5

* B. ECM 1, 3 and 4

C. ECM 1, 2, 3, 4 and 5

D. ECM 1, 2, 3 and 4

A Implement 1, 3, 4, 5 to meet min 25,000 kWh/yr

* B Implement 1, 3, 4 to meet min 25,000 kWh/yr and <2 year payback

C Implement 1-4, All ECMs with <2 year payback

D Implement All ECMs $69,150

#35 – Evaluating ECMs

During a preliminary assessment, the EMP will conduct a building walk through to observe system conditions and begin to identify operational issues and potential FIMs and ECMs. Which of the following is a common example of a low-cost ECM?

A. Replace 2-way with 3-way valves

B. Implementing a Trending/ Data Logging Plan

C. Replace damaged dampers and actuators

* D. Thermostat calibration

A - Replacing valves is not generally a low cost activity.
B - Implementing a Trending/ Data Logging Plan is a Data Collection activity (not ECM)
C - replacing damaged dampers is more likely a FIM
* **D - Thermostat calibration is listed as a Common example of low-cost ECMs**

#36 – ECM Recommendation

An EMP has been engaged to conduct an energy study for a large school with several air handling units. After collecting operational information and analyzing AHU trend data, the EMP identifies that the AHU's Morning Warm Up cycle often had little or no impact on the RAT during startup hours, meaning that the building's temperature conditions on most days were about the same, whether or not Warm-Up was initiated.

Which of the following is the EMP's recommended ECM?

* A. Reprogram Morning Warm Up based upon an appropriate OAT

B. Reprogram to eliminate Morning Warm Up and Cool Down modes

C. Reprogram to increase the Outside Air flow rate

D. Have the manufacturer decrease the coil leaving air temperature

#36 – ECM Recommendation

((See AABC Energy Management Guideline Section Case Study 3.1, p. 95.

* **A. Warm Up should be used on cold days to pre-condition building.**

B. This data doesn't support eliminating Cool Down mode.

C. OA flow rate alone would not cause or correct RAT issue.

D. Lower coil LAT will not correct RAT issue.))

#37 – Blended Electric Rate

An EMP is preparing for an upcoming audit and retro-commissioning project on a state university campus. The state university facilities operations staff has provided the combined previous 12 months of electric and natural gas data for the buildings that will be included in the project. The EMP has also obtained the utility rate structure that is applicable.

Month	Electrical Consumption (kWh)	Electrical Demand (kW)	Natural Gas (MCF)
Jan	180,000	1,480	950
Feb	168,800	1,526	836
Mar	190,400	1,782	901
Apr	202,000	1,966	743
May	253,600	2,214	682
Jun	276,400	2,348	612

Month	Electrical Consumption (kWh)	Electrical Demand (kW)	Natural Gas (MCF)
Jul	254,400	2,456	548
Aug	247,000	2,648	536
Sep	246,400	2,342	602
Oct	240,000	2,134	751
Nov	206,000	1,896	801
Dec	196,000	1,688	860
Total	**2,661,000**	**24,480**	**8,822**

#37 – Blended Electric Rate

The utility tariff that applies for the campus has the following components:

- Winter Energy Charge - $0.043/kWh
- Summer Energy Charge - $0.068/kWh
- T & D Charges - $0.076/kWh
- Demand - $10.00/kW
- Local Usage Tax – 4.0%
- Winter Natural Gas tariff - $8.34/MCF
- Summer Natural Gas tariff - $6.86/MCF
- Summer – May to September, inclusive

What is the blended electric rate that should be used for preliminary assessment of ECMs?

#37 – Blended Electric Rate

Summer Consumption Cost (May through September)		
1,277,800 kWh x $0.068 / kWh =		$ 86,890.40
Winter Consumption Cost		
1,383,200 kWh x $0.043 / kWh =		$ 59,477.60
Demand Charges		
24,480 kW x $10.00 / kW =		$244,800.00
T & D Charges		
2,661,000 kWh x $0.076 / kWh =		$202,236.00
TOTAL	**$593,404 ÷ 2,661,000 =**	**$0.223 / kWh**

#38 – Energy Consumption / Degree Days

What insight can be gained by analyzing historical monthly energy consumption versus degree days for a given location and time period?

A. Energy consumption versus general seasonal changes

B. Correlation of energy consumption to levels of daylight

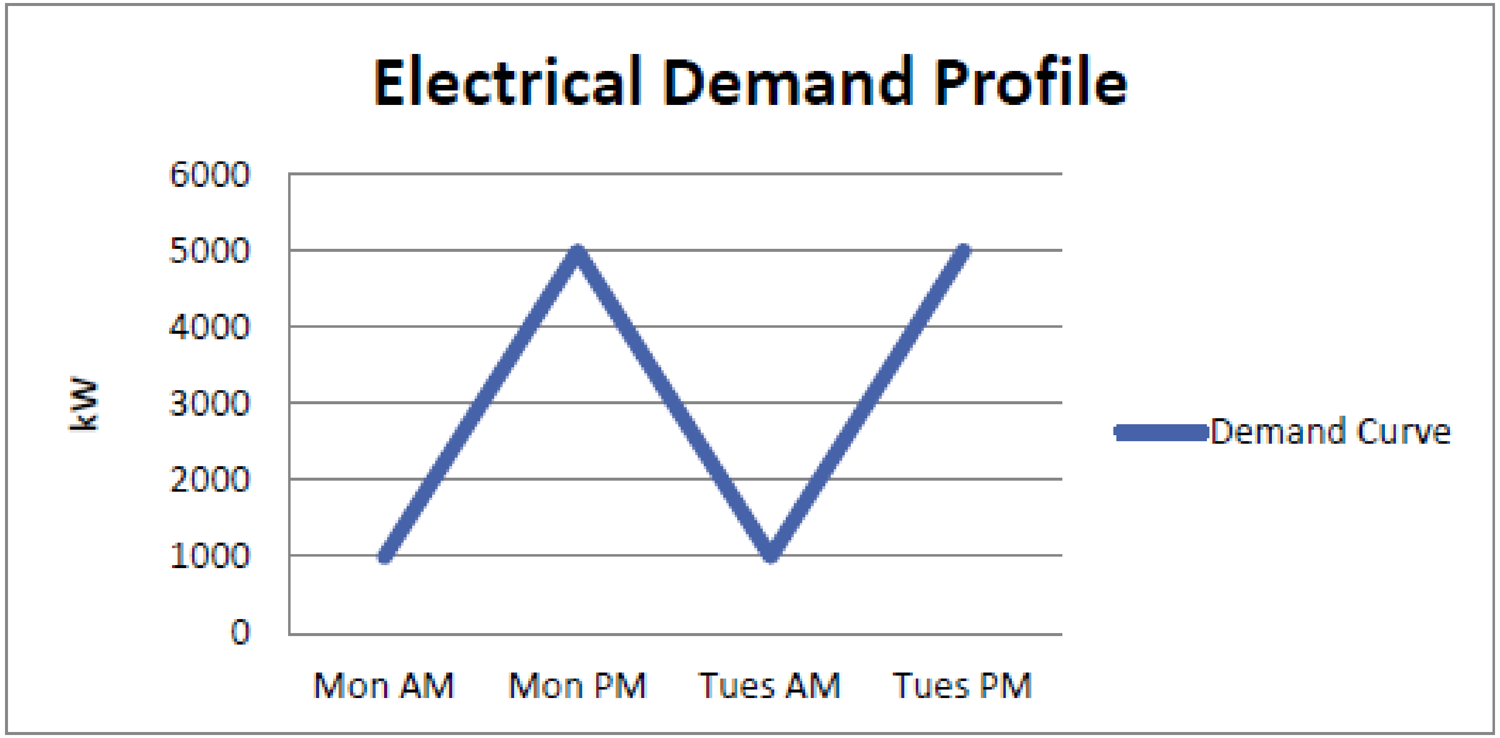
* C. Energy consumption correlation to weather-based loads

D. Energy consumption correlation to seasonal occupancy

* C. – Heating and cooling degree days are based upon dry bulb temperature variations against a base of 65 deg. F, thus, analyzing energy consumption correlation to weather-based loads

#39 – Evaluating Graphic Data

During an energy audit, an electrical demand profile graph takes the form of a saw tooth pattern with consistent equal steep “teeth”.



#39 – Evaluating Graphic Data

Which of the following ECMs does this graph suggest might be in play?

* A. Optimal start
B. Outdoor air temperature reset
C. Discharge air temperature reset
D. Demand Start

* A. – the gradual climb in demand during the early morning periods appear to align with an optimal start sequence.

#40 – Energy Conservation Behavior

An EMP invests in sub-meters to monitor energy consumed by each department of a company. One department has improved energy performance by reducing energy usage. The EMP wants to use that success to motivate other departments.

Which of the options below offers the best approach to motivate other departments based on one department's success?

A. Congratulate the successful department and thank them for their effort

B. Publish monthly department progress in the company newsletter

* C. Make reducing energy usage a competition between departments with modest incentive prizes for the winning department

D. Write an e-mail to the other departments notifying them that their energy efficiency methods are not acceptable

#40 – Energy Conservation Behavior

* C. Creating competition with incentives to engage other department has proven to be a successful approach for energy conservation.

#41 – Commissioning

On a project in a jurisdiction that has adopted the 2012 International Energy Conservation Code, (IeCC), what commissioning provisions would the EMP anticipate as project requirements.

* A. Lighting controls, HVAC, and HVAC Controls commissioning are required

B. Lighting controls, HVAC, HVAC Controls and electrical commissioning are required

C. HVAC, HVAC Controls, domestic hot water and renewable energy systems commissioning are required

D. Mechanical, plumbing, electrical and renewable energy systems commissioning are required

* A. – Knowledge of the IeCC and their commissioning requirements is required

#42 – Health Care Considerations

As part of a central utility plant upgrade project, an energy manager is tasked with making efficiency improvement recommendations. The central plant serves a multiple building healthcare campus. What priorities should the energy manager consider as a priority?

A. Energy efficiency impacts

B. First cost for construction

C. Total cost of ownership

* D. Operational resiliency

* D. - Operational resiliency is a priority for healthcare facilities due to patient safety and indoor environmental quality. Other items listed do not matter if you compromise Patient care and IEQ in a healthcare environment. Know your client and priorities from their line of business.

#43 – AHU Analysis

An EMP suspects an air handling system is utilizing a higher percentage of outdoor air than originally designed. He cannot directly measure the outdoor air but collects the following measurements:

Supply Air = 25,000 CFM
Outdoor air temp. = 98º F
Return air temp. = 75º F
Mixed air temp. = 82º F

What is the percentage of outdoor air at these conditions?

What is the mixed air temperature required for 15% outdoor air?

How would you balance to achieve 15% outdoor air?

#43 – AHU Analysis

$$\text{Percentage of OA} = \frac{(\text{MAT} - \text{RAT}) \times 100}{(\text{OAT} - \text{RAT})}$$

Percentage of OA = (82-75) x 100 / (98-75) = 700 / 23 = 30.4%

Mixed air temp. = (% RA x RAT) + (% OA x OAT)
Mixed air temp. = (0.85 x 75) + (0.15 x 98)
Mixed air temp. = 78.5 deg. F

Adjust the minimum outdoor air dampers until an average temperature of 78.5°F is measured in the mixed air plenum.

#44 – AHU Analysis

An EMP takes the following measurements at an air handling unit cooling coil in the field in an effort to discern its performance.

Airflow across the coil: 24,000 CFM
Entering air temperature to coil: 76° F (dry bulb) / 66°F (wet bulb)
Leaving air temperature from coil: 58° F (dry bulb) / 56°F (wet bulb)

What is the cooling capacity being provided by the coil in Btuh?
(Note: the enthalpy of the entering air is 30.83 Btu / lb. and the enthalpy of the leaving air is 23.84 Btu / lb.)

What is the cooling capacity being provided by the coil in tons of refrigeration?

#44 – AHU Analysis

Normally taken from a psychrometric chart (or table); the enthalpy of the entering air (30.83 Btu / lb.) and the enthalpy of the leaving air (23.84 Btu / lb.) was given to you for the problem.

Q (Btuh) = CFM x 4.5 x Δ h

= 24,000 x 4.5 x (30.83 – 23.84)

= 754,920 Btuh

754,920 Btuh / 12,000 Btuh per ton = 62.9 tons

#45 – Coil Analysis

In the previous problem where the EMP has determined the coil's cooling capacity, he also takes entering and leaving water temperatures:

Entering water temperature to coil: 45° F
Leaving water temperature from coil: 55° F

If the coil is a counterflow coil, what is the water flow through the coil?

#45 – Coil Analysis

$$\text{Flow (gpm)} = \frac{\text{Q (Btuh)}}{500 \times \Delta T} = \frac{754{,}920}{500 \times 10} = 150.98 \text{ gpm}$$

#46 – Present Worth Analysis

An EMP is evaluating two alternate HVAC replacement systems, each with a life of 12 years (n) and assuming an annual interest rate, i = 10%. The costs associated with each alternative are shown below. Which alternate should be selected, based upon present worth analysis?

<u>Alternate No. 1</u>
First Cost: $25,000
Annual Operating Cost: $10,000
Salvage Value: $2,000

<u>Alternate No. 2</u>
First Cost: $35,000
Annual Operating Cost: $7,500
Salvage Value: $4,500

#46 – Present Worth Analysis

Equations to be used:

$$PW = \frac{\text{Future Value (F)}}{(1 + i)^n}$$

$$PW = \text{Annual Payment} * \frac{(1 + i)^n - 1}{i * (1 + i)^n}$$

#46 – Present Worth Analysis

Alternate No. 1:

$$PW = \frac{\$2,000}{(1 + 0.10)^{12}} = \$637.26$$

$$PW = \$10,000 * \frac{(1 + 0.10)^{12} - 1}{0.10 * (1 + 0.10)^{12}} = \$ - 68,136.63$$

$$PW_{Alt.\ No.\ 1} = \$ - 25,000 + \$ - 68,136.63 + \$637.26 = \$ - 92,499.37$$

#46 – Present Worth Analysis

Alternate No. 2:

$$PW = \frac{\$4,500}{(1 + 0.10)^{12}} = \$1,433.85$$

$$PW = \$7,500 * \frac{(1 + 0.10)^{12} - 1}{0.10 * (1 + 0.10)^{12}} = \$ - 51,102.47$$

$$PW_{Alt.\ No.\ 2} = \$ - 35,000 + \$ - 51,102.47 + \$1,433.85 = \$ - 84,668.62$$

Alternate No. 2 should be selected, since it has a lower PW cost

#47 – Analysis Comparing Annual Costs

An existing chilled water system is being evaluated for refurbishment, or replacement. Using the data below, which option has the least annual cost? Assume interest rate (i) of 5%.

Refurbishment

Cost: $58,000
Extends life: 10 years
Annual Maint. Cost: $1,000
Current Salvage Value: $32,000
Salvage Value at 10 yrs.: $12,000

Replacement

Cost: $142,000
Projected Life: 20 years
Annual Maint. Cost: $600
Salvage Value at 20 yrs.: $32,000

#47 – Analysis Comparing Annual Costs

Equations to be used:

$$A = \frac{PV}{\frac{(1 + i)^n - 1}{i * (1 + i)^n}}$$

$$A = \frac{\text{Future Value (F)} * i}{(1 + i)^n - 1}$$

#47 – Analysis Comparing Annual Costs

Refurbishment:

$$A = \frac{\$58{,}000 + \$32{,}000}{\dfrac{(1 + 0.05)^{10} - 1}{.05 * (1 + 0.05)^{10}}} = \$\ 11{,}655.41$$

$$A = \frac{(12{,}000) * 0.05}{(1 + 0.05)^{10} - 1} = \$ - 954.05$$

$$A_{Refurbishment} = \$\ 11{,}655.41 + \$\ 1{,}000.00 - \$\ 954.05 = \$\ 11{,}701.36$$

#47 – Analysis Comparing Annual Costs

Replacement:

$$A = \frac{\$142{,}000}{\dfrac{(1 + 0.05)^{20} - 1}{.05 * (1 + 0.05)^{20}}} = \$\ 11{,}394.45$$

$$A = \frac{(32{,}000) * 0.05}{(1 + 0.05)^{20} - 1} = \$ - 967.76$$

$A_{Replacement}$ = $ 11,394.45 + $ 600.00 - $ 967.76 = $ 11,026.69

Replacement has the least annual cost

#48 – HVAC Knowledge

The economizer section in an air handling unit consists of:

A. An automatic changeover thermostat and discharge air damper
B. A pre-heat coil and a pre-cooling coil
C. A supply damper, return air damper and an outdoor air damper
D. A return air damper, a relief air damper, and an outdoor air damper

#48 – HVAC Knowledge

The economizer section in an air handling unit consists of:

A. An automatic changeover thermostat and discharge air damper
B. A pre-heat coil and a pre-cooling coil
C. A supply damper, return air damper and an outdoor air damper
* D. A return air damper, a relief air damper, and an outdoor air damper

An economizer section uses outdoor air for free cooling by modulating the outdoor air with the return air and relieving the excess air.

#49 – HVAC Knowledge

A reversing valve can be found in:

A. A hermetic compressor
B. A water chiller
C. A heat pump
D. An absorption air-conditioning unit

#49 – HVAC Knowledge

A reversing valve can be found in:

A. A hermetic compressor
B. A water chiller
* C. A heat pump
D. An absorption air-conditioning unit

A reversing valve is used to change the refrigerant flow in a heat pump.