



**ENERGY MANAGEMENT AND AUDIT - CEM
REFRESHER TRAINING COURSE**

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CEM REFRESHER TRAINING COURSE





**ENERGY ACCOUNTING AND
BENCHMARKING
FOR ENERGY PROFESSIONALS**

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WHAT SHOULD YOU LEARN





Energy Use Index (EUI)
Energy Cost Index
Energy Benchmarking for Buildings
Benchmarking Audit
Benchmarking Tools
Energy Monitoring, Targeting and Reporting
Objectives and Benefits of an MT&R Program

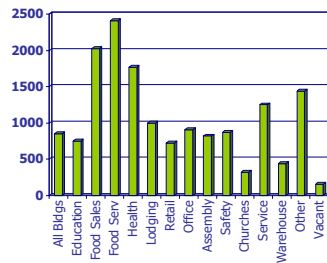


ENERGY USE INDEX (EUI)

- ✓ Basic measure of a facility's energy performance
- ✓ A statement of the number of MJ of energy used annually per square metre of conditioned space
- ✓ To compute the EUI
 - ▀ Identify all the forms of energy used in the facility
 - ▀ Tabulate the total energy in MJ used in the facility
 - ▀ Determine the total number of square metres of conditioned space
- ✓ The Energy Use Index is the ratio of the total MJ used per year to the total number of square metres of conditioned space.
- ✓ A typical office building in the US has an EUI of around 900 MJ/square metre/year.
- ✓ Food sales and food service facilities in the US have the highest average EUI's of over 2000 MJ/square metre/year. Health care facilities are next at about 1750 MJ/square metre/year.

ENERGY USE INDEX FOR COMMERCIAL BUILDINGS

MJ/SQ METRE/YR



EUI COMPUTATION EXAMPLE

- ✓ An office building has 10,000 square metres of conditioned floor space and uses 2.0 million kWh and 6800 GJ of natural gas in one year.
- ✓ Convert the electric and gas use into MJ by finding the appropriate conversion factor.

Energy Conversion Unit Table

1 kWh	3.6 MJ
1 m ³ natural gas	37 MJ
1 kg #2 fuel oil	42 MJ
1 litre gasoline.....	35 MJ
1 m ³ #2 fuel oil	39 GJ
1 m ³ propane (LPG)	25.5 GJ
1 kg propane (LPG)	45.65 MJ
1 MJ	1000 kJ
1 GJ	10 ⁶ kJ
1 MW	10 ⁶ watts

EUI COMPUTATION EXAMPLE +

- ☑ One kWh electric energy is equal to MJ.
- ☑ Thus, 2.0 million kWh is equal to
- ☑ One GJ of natural gas is 1000 MJ, so 6800 GJ of gas is equal to
- ☑ The EUI is then MJ divided by square metres, and is equal to MJ/square metre/year
- ☑ One kWh electric energy is equal to 3.6 MJ.
- ☑ Thus, 2.0 million kWh is equal to $3.6 \text{ MJ/kWh} \times 2,000,000 \text{ kWh} = 7,200,000 \text{ MJ}$
- ☑ One GJ of natural gas is 1000 MJ, so 6800 GJ of gas is equal to $6800 \text{ GJ} \times 1000 = 6,800,000 \text{ MJ}$
- ☑ The EUI is then 14,000,000 MJ divided by 10,000 square metres, and is equal to 1400 MJ/square metre/year

EUI COMPUTATION EXAMPLE +

This value of MJ/square metre/year is larger than the EUI for an average US building of 850 MJ/square metre/year, and also larger than the average EUI for a US office building of 905 MJ/square metre/year.

US National average information on the Energy Use Index for different types of commercial buildings is shown on the next slide.

This value of 1400 MJ/square metre/year is larger than the EUI for an average US building of 850 MJ/square metre/year, and also larger than the average EUI for a US office building of 905 MJ/square metre/year.

US National average information on the Energy Use Index for different types of commercial buildings is shown on the next slide.

CBECs EUI DATA - USA MJ/M2/YR

All Bldgs	850		
Education	750	Vacant	160
Food Sales	2020	Food Service	2410
Health Care	1765	Lodging	1000
Retail Stores	720	Office	905
Assembly	820	Safety	870
Churches	320	Service	1245
Warehouse	440	Other	1440

ENERGY COST INDEX

The EUI has some fairly obvious limitations.

Problem with mix of fuel and electricity

Looks only at site energy - not source energy

With site energy, 1 kWh is valued at 3.6 MJ, but back at the thermal power plant, it took around 11-12 MJ of primary energy to produce the 3.6 MJ value of that 1 kWh



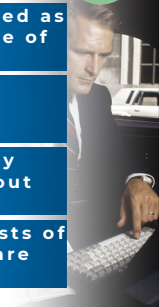
ENERGY COST INDEX +

The Energy Cost Index is sometimes used as a simpler and more meaningful measure of energy efficiency.

✓ The Energy Use Index is somewhat misleading since all MJ are not really equal.

✓ Electric energy is much higher quality energy than oil or gas, and it costs about three times as much per end use MJ.

✓ The Energy Cost Index adds up all costs of energy and divides result by total square metres of conditioned space.



ENERGY COST INDEX EXAMPLE

✓ For the 10,000 square metre office building looked at earlier, the cost of electricity is \$153,200 per year, and the cost of gas is \$52,500 per year.

The ECI is then \$ divided by 10,000 square metres, for an ECI of \$/square metre/year.

✓ The ECI is easy to calculate, and is very useful.

✓ It is another simple benchmark that can be used.



ENERGY COST INDEX EXAMPLE



- ✓ For the 10,000 square metre office building looked at earlier, the cost of electricity is \$153,200 per year, and the cost of gas is \$52,500 per year. The ECI is then \$ 205,700 divided by 10,000 square metres, for an ECI of \$ 20.57/square metre/year.

- ✓ The ECI is easy to calculate, and is very useful.
- ✓ It is another simple benchmark that can be used.



BENCHMARKING



- ✓ A benchmark is a value you compare something against.
- ✓ Building energy benchmarking is the comparison of whole-building energy use relative to a set of similar buildings.
- ✓ It provides a useful starting point for individual energy audits & for targeting buildings for energy-saving measures in multiple-site audits.
- ✓ Benchmarking is of interest and practical use to a number of groups.
 - Energy service companies and performance contractors communicate energy savings potential with “typical” and “best-practice” benchmarks.



ENERGY BENCHMARKING +



- ✓ Control companies and utilities can provide direct tracking of energy use and combine data from multiple buildings for benchmarking.
- ✓ Benchmarking is also useful in the design stage of a new building or retrofit to determine if a design is relatively efficient.
- ✓ Energy managers & building owners have an ongoing interest in comparing energy performance to others.
- ✓ Large corporations, schools, & government agencies with numerous facilities also use benchmarking methods to compare their buildings to each other.



BENCHMARKING AUDIT



✓ Audits are associated with the idea that after the energy bill data is collected and processed, some facility information will be collected on a walk-through, and the data will be run through some benchmark to determine if there is a potential for significant improvement in energy efficiency and reduction in energy operating cost.

✓ Examples of existing benchmarking programs are: Gigajoule and Energy Intensity Calculator from Natural Resources Canada. And for US IP units - EPA's Portfolio Manager, LEED-EB, California Energy Benchmarking, Chevron BM, ARCH, etc. SI data is easily approximated for these program inputs.

BENCHMARKING CRITERIA



✓ Energy Use Index - MJ/m²/year

⇒ Total, Electric, Gas, Oil

✓ Energy Cost Index - \$/m²/year

⇒ Total, Electric, Gas, Oil

✓ Productivity Index

⇒ kJ/kg, kJ/person, kJ/student, kJ/tonne, kJ/item

⇒ kWh/kg, kWh/person/ kWh/tonne, kWh/item

⇒ L H₂O/kg, or /student, or /item (also sewer)

✓ System performances

⇒ kW_e/kW cooling, LPS/kW air, kWh/L pumping

TYPES OF BENCHMARKS



✓ Internal - An internal benchmark is based on the performance of your own building or facility.

For example, the EUI of your own building over the past year.

✓ External - An external benchmark is based on some large group of similar buildings or facilities.

For example, the EUI of a group of similar buildings or facilities from EIA/CBECS, EPA, BOMA, CA, etc

BENCHMARKING COMPARISON OF ENERGY EFFICIENCY AND WATER USE



Figure 6 Benchmarking Comparison of Energy Efficiency and Water Usage

Building	Conditioned Sq. ft.	Electric BTU/Sq.Ft./Yr	Nat Gas BTU/Sq.Ft./Yr	Total BTU/Sq.Ft./Yr	Wtr/Sewer Gall/sq.ft.Yr	Electric \$/KWH	Nat Gas \$/MCF	Wtr/Sewer \$/K Gallon
1	4,411,494	83,866	13,389	97,255	10.7	\$0.0446	\$7.042	\$4.75
2	602,181	91,948	4,404	96,353	4.1	\$0.0486	\$7.597	\$5.90
3	214,156	83,060	649	83,709	40.6	\$0.0492	\$8.593	\$3.70
4	291,092	70,044	13,952	83,996	91.8	\$0.0876	\$8.542	\$0.83
5	427,000	75,409	25,638	101,047	17.2	\$0.0547	\$4.392	\$2.14
6	523,558	66,647	8,433	75,080	24.0	\$0.0835	\$11.180	\$4.66
7	366,183	95,875	14,799	110,674	41.2	\$0.0505	\$9.395	\$6.41



BENCHMARKING TOOLS



Several benchmarking tools have emerged on the market in recent years. Some were developed as a service to utility and ESCO customers or as a component of an enterprise tools providing a broader range of functions.

There are also a number of online tools, many of which are free.

A list of online benchmarking tools and information relevant to benchmarking commercial building energy use (in Btu/square foot/year) can currently be found at:



BENCHMARKING TOOLS +



<https://www.energystar.gov/buildings/benchmark>

As a close approximation, conversion between IP and SI gives $\text{MJ/m}^2/\text{year} = (\text{Btu/ft}^2/\text{year})/100$
 Using 1 kJ is about 1 Btu and 1 m² is about 10 ft²
 The benchmarking programs easily found online can be categorized into four different types of benchmarking services: simple benchmarking, load shape libraries, utility services, and enterprise tools.



ARCH TEXT RESULTS FOR EXAMPLE BUILDING



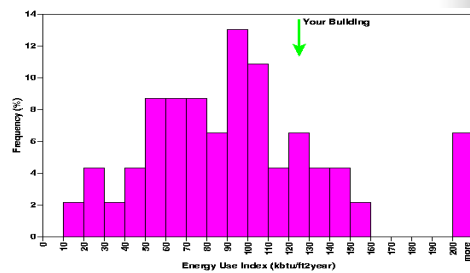
- ☒ The green arrow indicates your building's energy use. This graph is of site energy.
- ☒ You entered a Floor Area of 100,000 square feet, so buildings with areas between 50,000 and 200,000 are used. The number of buildings on this graph is 45.
- ☒ Your building consumes 14,000,000 kBtu/year of energy, which is 140 kBtu/ft²/year.

CONVERSIONS TO SI UNITS



- ☒ 100,000 square feet is approximately 10,000 square metres
- ☒ So, multiply square metres by 10 and enter as square feet
- ☒ The program output says the Energy Use Index for the building is 125,000 Btu/ft²/year
- ☒ One Btu is approximately 1 kJ One MJ is 1000 kJ
- ☒ So, divide this EUI by 100 to get 1250 MJ/m²/yr

EUI BENCHMARK FROM ARCH



GIGA JOULE AND ENERGY INTENSITY CALCULATOR – NATURAL RESOURCES CANADA



- ✓ Electricity * kWh × 0.0036 = 7200 GJ
- ✓ Oil #2 (light) litres × 0.038680 GJ
- ✓ Natural Gas m³ × 0.03720 GJ
- ✓ Natural Gas GJ × 1 = 6800 GJ
- ✓ Steam kg × 0.002250 GJ
- ✓ Total = 14000 GJ
- ✓ Area in square metres m² = 10000 m²
- ✓ Energy Intensity = 1.4 GJ/m²

ENERGY MONITORING, TARGETING AND REPORTING



MT&R is a powerful management technique for

- ✓ Analyzing the historical energy performance of industrial, commercial, and institutional facilities
- ✓ Setting energy reduction targets
- ✓ Controlling current energy performance and,
- ✓ Projecting future energy budgets.

The working definitions that commonly apply are the following:
Energy Monitoring is the regular collection and analysis of information on energy use.



ENERGY CONVERSION UNIT TABLE



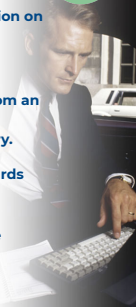
Energy Monitoring is the regular collection and analysis of information on energy use.

Its purpose is to:

- ✓ Establish a basis of management control
- ✓ To determine when and why energy consumption is deviating from an established pattern
- ✓ To provide a basis for taking management action where necessary.

Targeting is the identification of levels of energy consumption towards which it is desirable, as a management objective, to work.

Reporting closes the loop, by putting the management information generated in a form that enables ongoing control of energy use, the achievement of reduction targets, and the verification of savings.



THE KEY STEPS IN AN EFFECTIVE MT&R PROCESS ARE

- ✓ Measurement of energy consumption over time
- ✓ Measurement of the independent variables that influence energy consumption (weather, production, occupancy) over corresponding time intervals
- ✓ Development of a relationship (the energy performance model) between energy and the independent variables
- ✓ Historical analysis of energy performance ; and trends into the future
- ✓ Definition of reduction targets
- ✓ Frequent comparison of actual consumption to targets
- ✓ Reporting of consumption and target variances
- ✓ Taking action to address variances and ensure targets are met.



INDEPENDENT VARIABLES

In addition to energy data for each ECC, the applicable factors of influence, or independent variables, must be measured. Some examples include:

Operating Hours/Occupancy In office buildings, schools, hospitals, retail stores, warehouses, accommodation facilities, energy consumption depends primarily on the weather through the heating and cooling systems, and secondarily on patterns of use such as operating hours and occupancy. Electricity and fuel each have their own dependencies or combination of dependencies specific to each facility's systems.



INDEPENDENT VARIABLES

Production Level Energy use in manufacturing and industrial facilities depends strongly on production level or a measure of the facility's output, in units, tons, or some other appropriate unit. Also, energy use in these operations often exhibits a strong dependence upon weather.

Degree Days Degree days are a measure of the outside temperature for a given period and can often be used to predict the amount of heating and cooling energy a building requires.



EXAMPLE USING DEGREE DAYS

Table 1: Sample Energy Data for a School
Heating Degree Days Total Electricity kWh

Month		
Feb 01	577	82,800
Mar 01	613	80,640
Apr 01	490	73,440
May 01	279	43,920
Jun 01	179	33,840
Jul 01	29	18,720
Aug 01	31	10,080
Sep 01	40	11,520
Oct 01	172	26,640
Nov 01	316	50,400
Dec 01	456	62,640
Jan 02	579	84,240



USE STRAIGHT LINE LINEAR REGRESSION

$$Y = mX + b$$

Y = kWh of electric use per month

X = number of degree days per month

m, b are slope and intercept from analysis

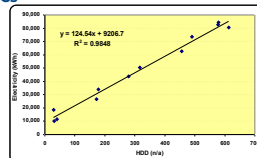
How do you do this?

Many calculators can do this Spreadsheet programs like Excel,

Lotus,

Statistical packages for PCs

School Building



ENERGY COST CENTER

The organizational basis for MT&R is the energy cost center (ECC).

An ECC is a unit for which energy use may be measured along with other factors that influence the energy consumption.

For example, the ECC might be: a single building in a portfolio of properties, a production unit or department in a plant, or a major energy consuming system such as the heating plant.

Basic criteria for the designation of an ECC are:

- Energy consumption can be measured in isolation
- The cost of measurement can be justified by potential savings
- The ECC must correspond to existing business structures
- Someone must be accountable for the ECC a factor of influence must be measurable.

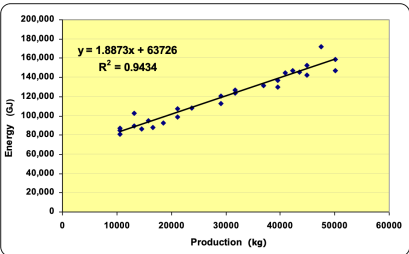


TABLE 2: SAMPLE ENERGY DATA FOR A FOOD PROCESSING PLANT

Table 2: Sample Energy Data for a Food Processing Plant

Month	Production, kg	Total Process Energy, GJ
Jan 02	39400	137244
Feb 02	21120	94630
Mar 02	15840	102494
Apr 02	13200	102494
May 02	44880	132445
Jun 02	47280	171792
Jul 02	31680	126754
Aug 02	10560	84505
Sep 02	29040	120310
Oct 02	23280	108651
Nov 02	10360	87491
Dec 02	13200	86379
Jan 03	39960	131255
Feb 03	40920	144886
Mar 03	42000	145882
Apr 03	50160	158760
May 03	10560	82302
Jun 03	14520	86234
Jul 03	29920	125613
Aug 03	21120	98710
Sep 03	16632	86233
Oct 03	25940	112443
Nov 03	18480	92312
Dec 03	46800	142386
Jan 04	50160	147453
Feb 04	42960	147231
Mar 04	31680	123359

FOOD PROCESSING PLANT



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