Energy Audits for Small and Medium-sized Enterprises

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Goals of Energy Audits

- Identify and quantify types and costs of energy use
- Understand ***how*** energy is used—and possibly wasted
- Identify and evaluate energy alternatives
  - improved operational techniques
  - new equipment, new processes, new technology
- Determine economic and technical feasibility of those alternatives

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Energy efficiency professional organizations

Association of Energy Engineers (AEE)

American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE)

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Energy audit types/levels

- ***AEE Type 1 / ASHRAE Level I*** - walk-thru inspection
  - identify operational & maintenance issues
  - identify deficient equipment
  - identify areas for more detailed analysis
- ***AEE Type 2***
  - economic calculations
  - may include performing monitoring/metering/testing to identify actual energy consumption and losses.
- ***ASHRAE Level II***
  - energy survey and analysis

Additional energy audit types/levels

- ***AEE Type 3***
  - computer modeling to determine the actual year-round energy consumption.
- ***ASHRAE Level III***
  - detailed analysis of Capital Intensive Modifications
- **Investment Grade Audit**
  - Adds weighing **risk** into economic calculations
  - Utilized to obtain funding for the projects identified.

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Audit steps

1. Walk–through
2. Utility bill evaluation
3. Assessment and benchmark:
   - Building envelope
   - HVAC system
   - Electrical supply system
   - Lighting
   - Boiler and steam system
   - Domestic hot water system
   - Compressed air system
   - Motors
   - Process equipment
4. Options identification
5. Options evaluation
   - Technical feasibility
   - Economic feasibility
6. Implementation planning

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Walk-through – qualitative assessment

- Objectives:
  - determine ***where*** energy is used
  - and lost
  - determine ***how*** energy is used
  - determine ***what*** fuels are used
  - and ***why***

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Walk-through – think systemically

Advanced new-model commercial dishwasher

Uses less energy, water, and detergent than predecessor

More heat into small room

Operator discomfort

New air conditioner

Increased net energy use!

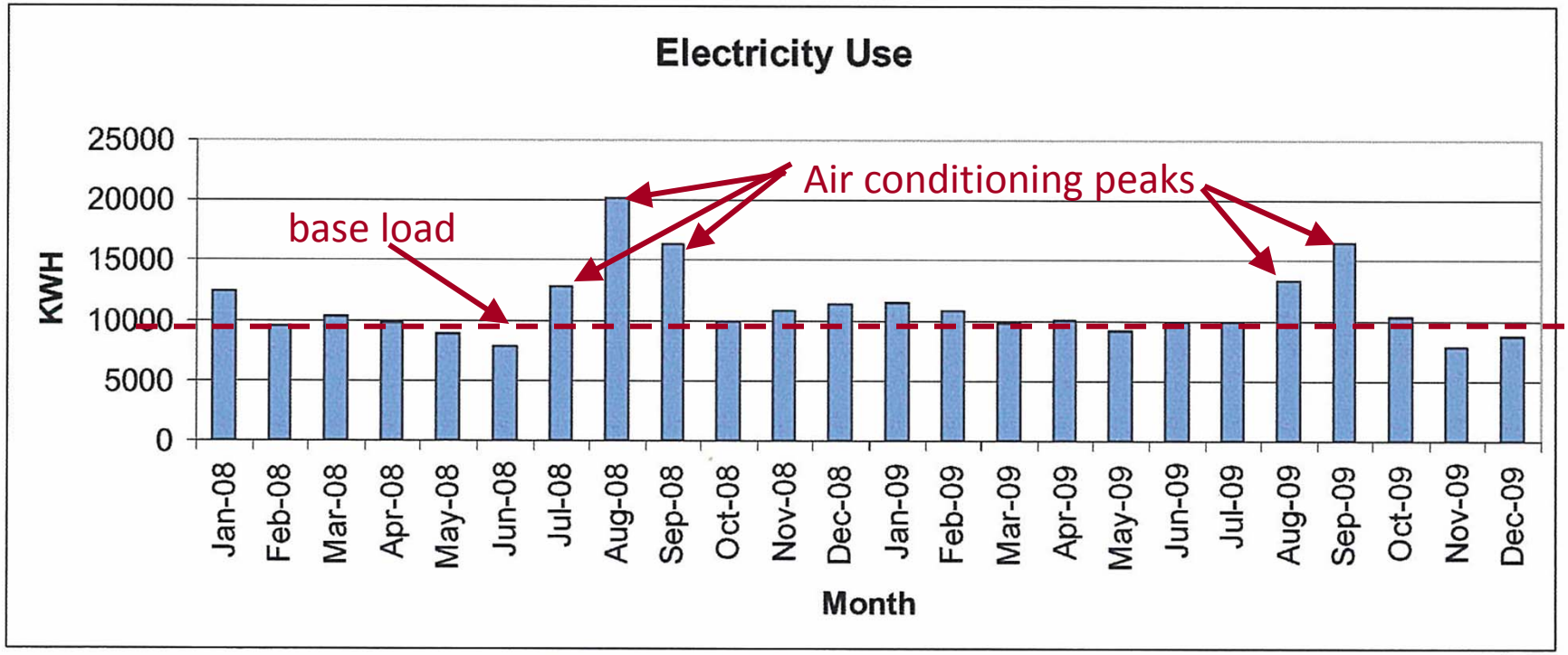
Utility evaluations

- 2-years' billing data
  - Electricity
  - Natural gas
  - Propane
  - Oil
  - Water

NOTE – supply and delivery may be separate bills!

- Graph use vs time
- Determine proportions of energy use and cost by fuel
- Normalize by Unit of Product, area, etc.
- Evaluate utility cost structure impact on cost
  - Tiered pricing
  - Supplier choice
  - Demand charges
  - Peak use charges
  - Power factor

Electricity use evaluation



Why is September higher than July?

Why winter base load = summer base load? (Too many lights in summer?)

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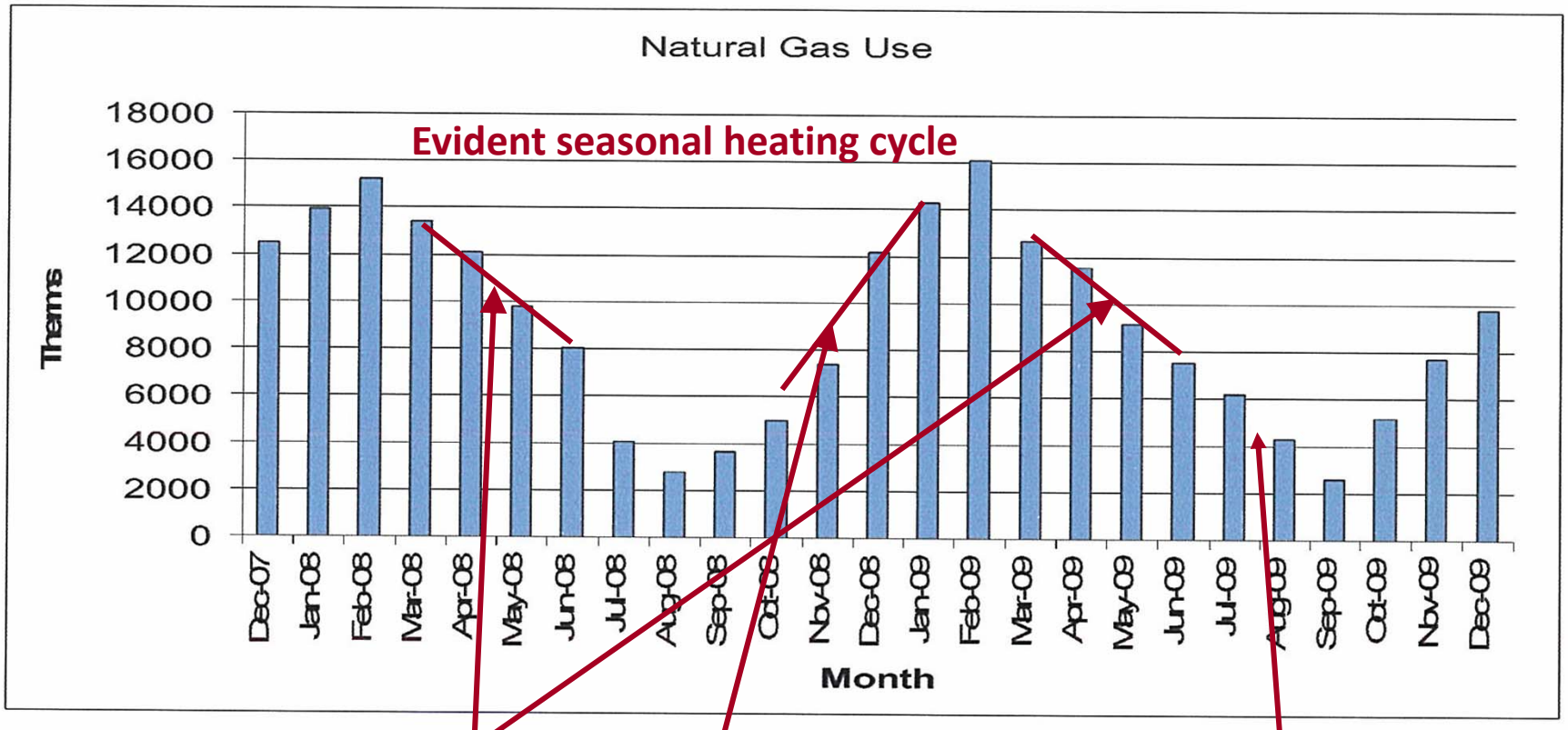
Natural gas use evaluation



Slow spring drop-off and rapid autumn ramp-up – why?

Heating in summer?

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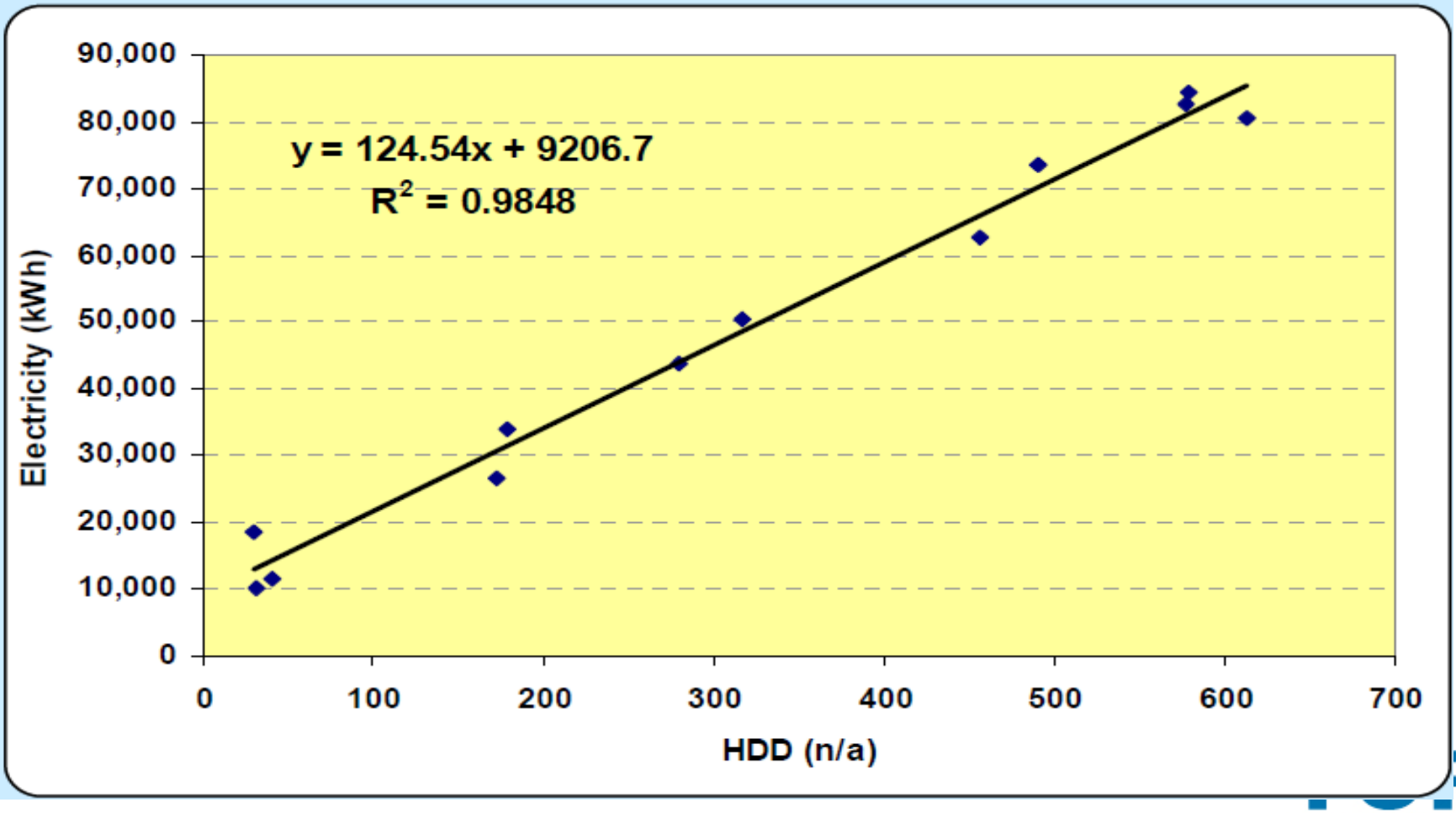
Dependence on Heating / Cooling Degree Days



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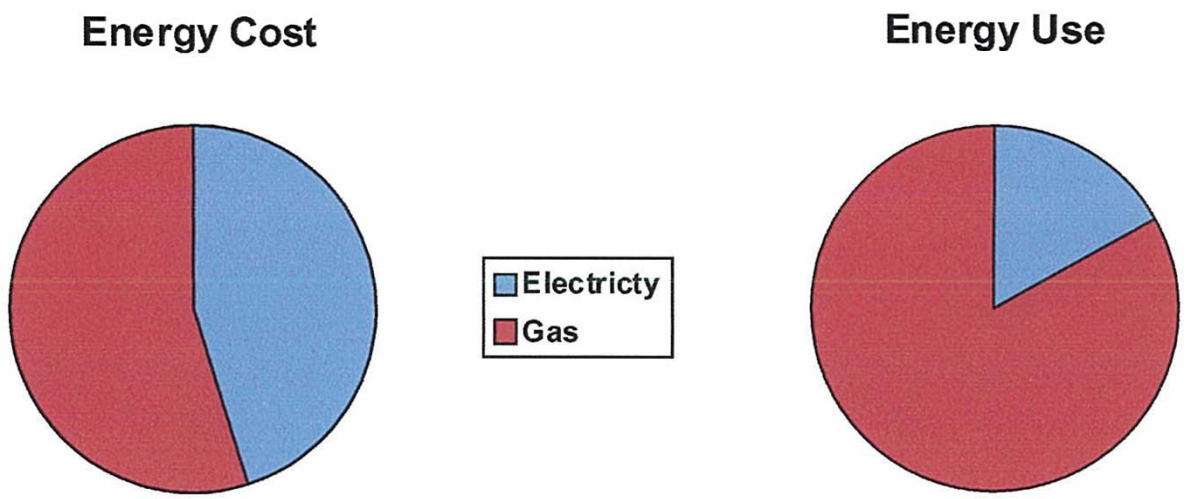
Usage vs cost

Nov 2008 – Nov 2009 Energy Use Summary					
	Annual consumption	Equivalent Millions BTU's	Percent of energy use	Annual cost	Percent of energy cost
Electricity	1,410,640 KWh	4,815	17%	$266,200	45%
Gas	119,349 Therms	24,298	83%	$319,500	55%
Total		29,113	100%	$585,700	100%



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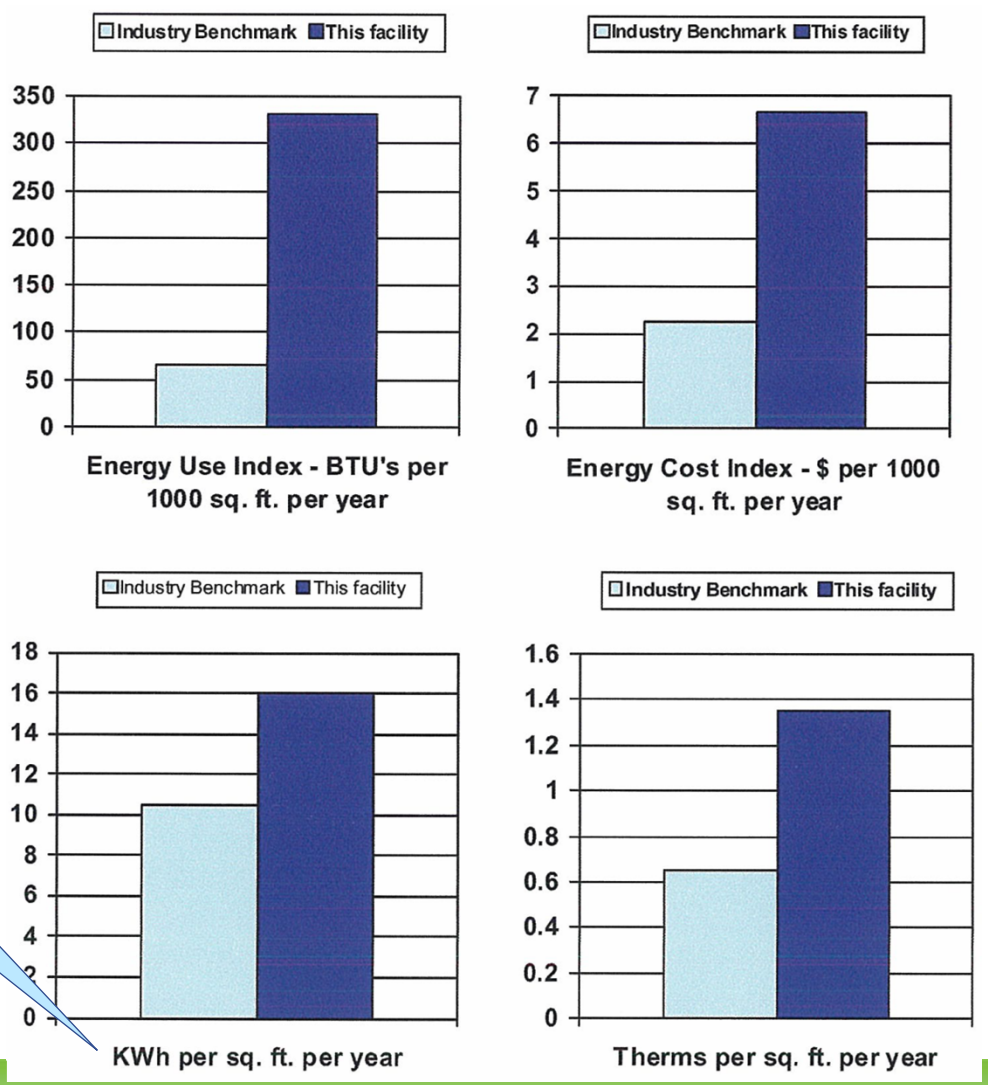
Energy Use Index & Energy Cost Index



Remind you of anything?

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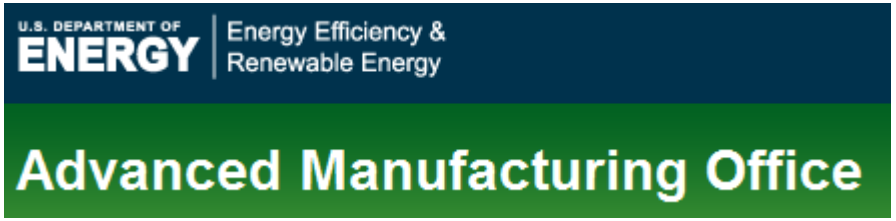
Sources of benchmark data

- DOE Advanced Manufacturing Office
- Energy Star Portfolio Manager
- LEED-EB
- Several IT-related benchmarking tools from IBM, Sun, others
- On-line search



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2003 Energy Use Index Data

In 1000 Btu/ft^2/yr

- All Bldgs 91.0
- Education 83.1
- Vacant 20.9
- Food Sales 199.7
- Food Service 241.2
- Health Care 187.7
- Inpatient 249.2
- Outpatient 94.6
- Lodging 100.0
- Retail - Non mall 73.9
- Retail – mall 102.2
- Office 92.9
- Public Assembly 93.9
- Safety 115.8
- Churches 43.5
- Service 77.0
- Warehouse 45.2
- Other 164.4

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Energy Unit Conversions

Electricity:

1 KWh = 3,413 BTU (energy)

1 KW = 3,413 BTU/hr (power)

Natural gas:

1 Cu Ft Natural Gas = 1030 BTU

1 CCF = 100 Cu Ft = 1 Therm = 103,000 BTU

1 MCF = 1,000 Cu Ft = 10 Therms = 1,034,000 BTU = 1.034 MMBTU

Propane:

1 Gal Propane = 91,600 BTU

1 Cu Ft Propane = 2,500 BTU

Fuel Oil:

1 Gal of #2 Fuel Oil = 139,000 BTU

1 Gal of #4 Fuel Oil = 145,000 BTU

1 Gal of #6 Fuel Oil = 150,000 BTU

1 joule = 0.00095 BTU

1 BTU = 1,055 joules

1 BTU = 252 calories

1 BTU= .293 watt

1 ton of refrigeration = 12,000 BTU/hr

1hp = 746 watts

1hp = 33, 479 BTU/hr (boiler)

1hp = 33,000 foot-lbs./min

1hp = 42,440 BTU/min

1 watt = 3.413 BTU

1 kilowatt = 1,000 watts

1 kilowatt = 1.341 horsepower

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Energy = Power x Time

KWh = KW x hours

BTU = BTU/hr x hours

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Understanding utility bills

- Supplier, transmission, and delivery (distribution) may be different
  - Suppler: energy use charge
  - Transmission: transmission charge
  - Distributor: energy distribution charge
  - Could be separate bills
  - Could be combined bills
- Energy use, transmission, and distribution charges:
  - $/KWh
  - $/therm
  - etc.
- ‘Meter’ or ‘User’ charge – fixed amount per month
- Other charges – e.g., Renewable Energy Trust

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Tiered rates

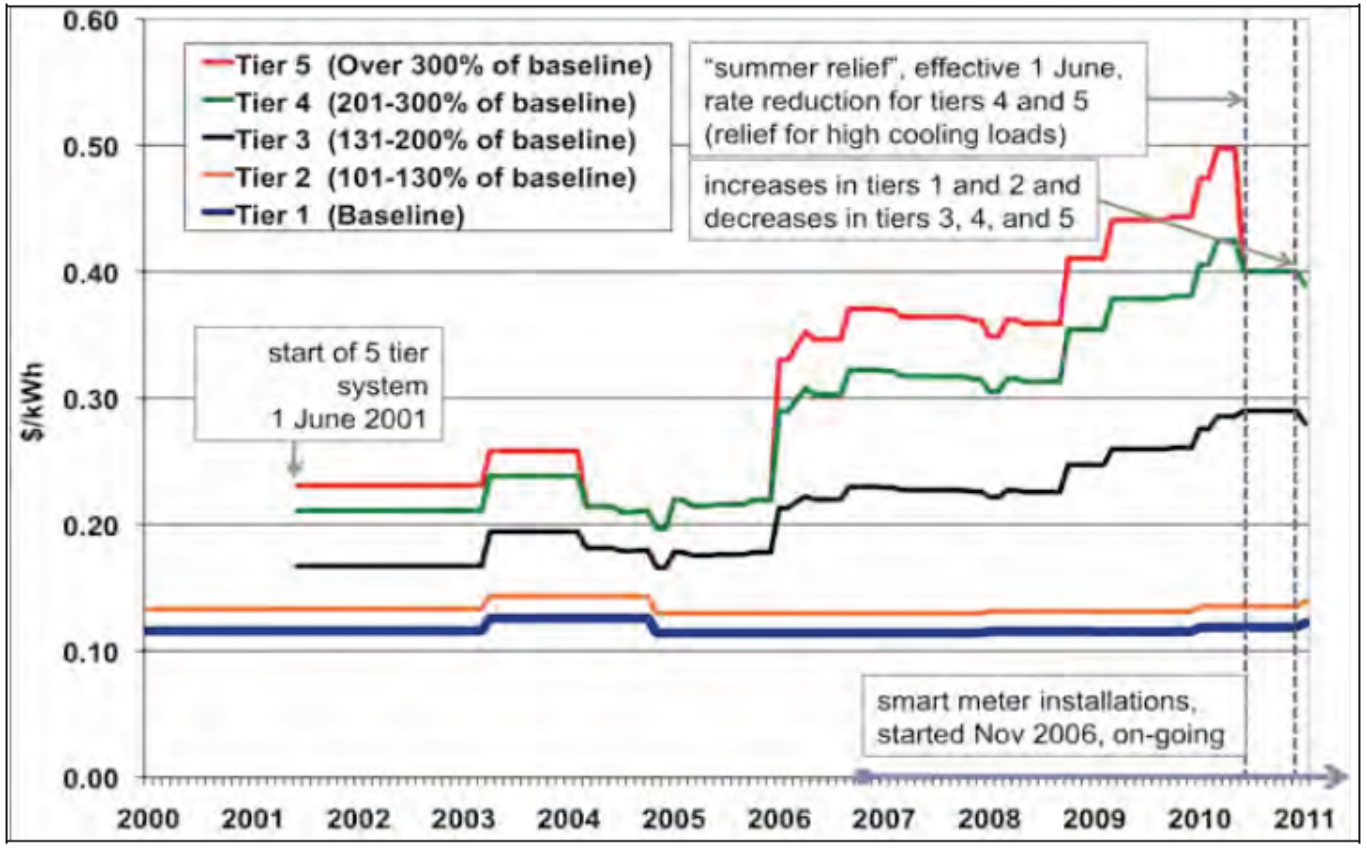

Figure 1. History of PG&E residential electricity tier pricing, year 2000 to present.

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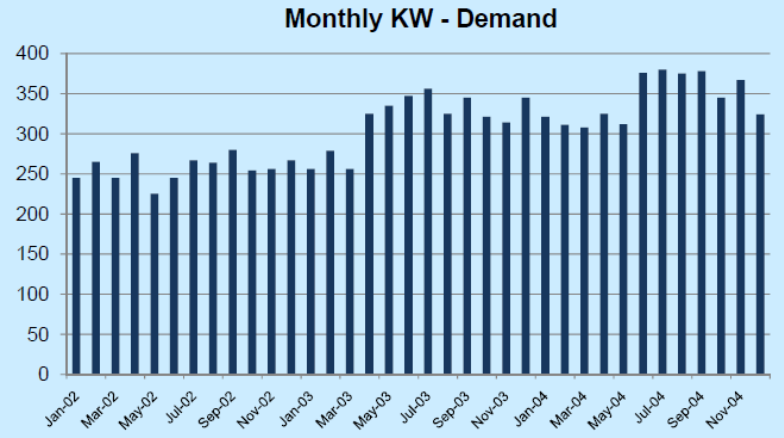
Demand charges

- Peak demand – based on peak *power*



- Demand ratchet – based on peak *energy*
  - raises energy charge if energy demand exceeds predetermined threshold
  - may be retroactive!

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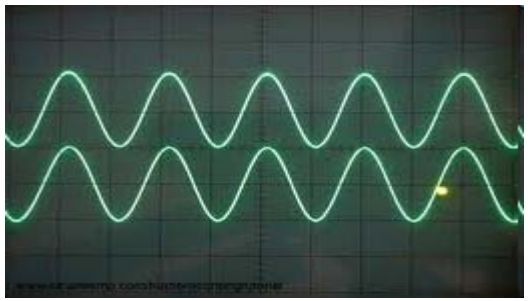
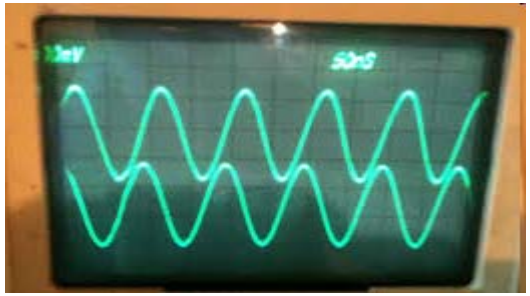
Power Factor





- Most (resistive) loads: voltage and current are in phase: ***Power Factor = 1***
- Motors' & transformers' voltage and current are out of phase: ***Phase difference lowers Power Factor***.
- Power Factor < (e.g.) .96 results in $ charge.

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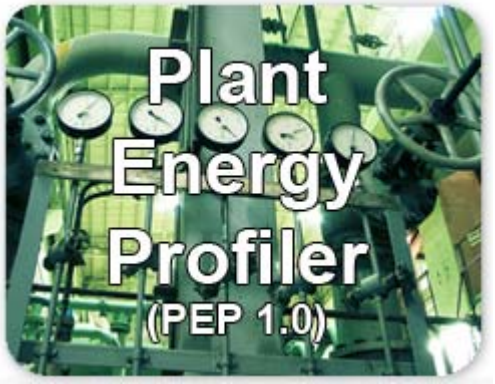
Audit tools & equipment

- Voltage / Current Clamp Meter
- Watt Meter
- Thermocouple Probe
- IR Non Contact Temp
- Sling Psychrometer
- Lux Meter
- Air Velocity Meter
- Combustion Meter
- Ultrasonic Leak Detector
- Infrared Thermographic Camera

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Advanced Manufacturing Office

https://ecenter.ee.doe.gov



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Lighting assessment

- Consider *task lighting* instead of *area lighting*
- Warehouse space – convert from mercury vapor to modern fluorescents or LEDs and use motion sensors
- Motion Sensors wherever feasible

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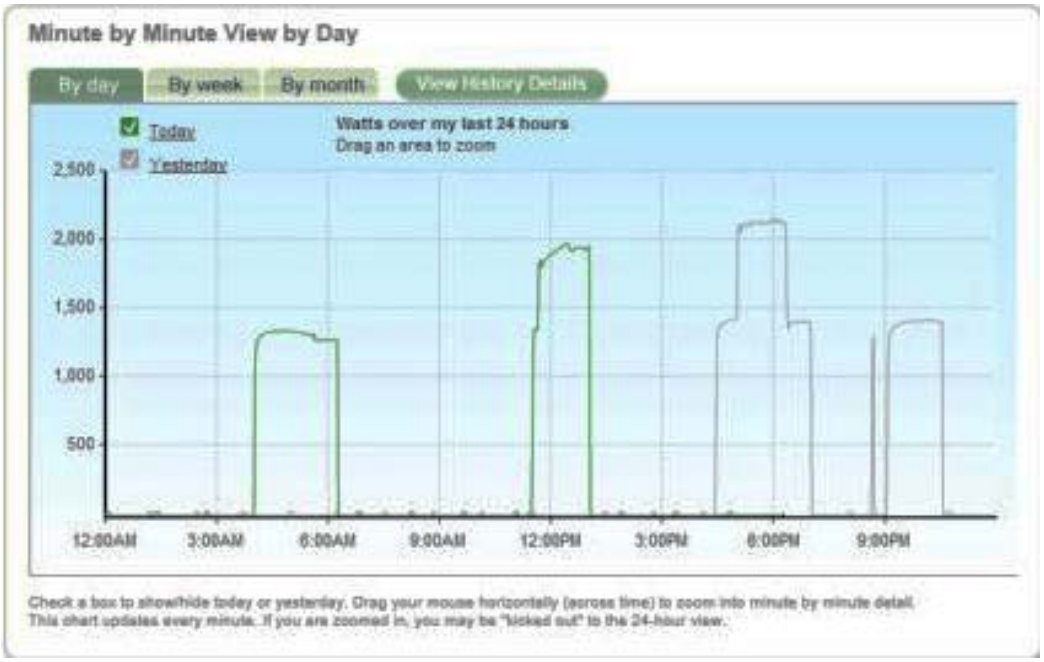
Lamp equivalences

Equivalent wattages and light output of Incandescent, CFL and LED bulbs

Light Output	LEDs	CFLs	Incandescents
Lumens	Watts	Watts	Watts
450	4 - 5	8 - 12	40
300 - 900	6 - 8	13 - 18	60
1100 - 1300	9 - 13	18 - 22	75 - 100
1600 - 1800	16 - 20	23 - 30	100
2600 - 2800	25 - 28	30 - 55	150

From eartheasy.com

Monitoring & submetering



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Monitoring & submetering

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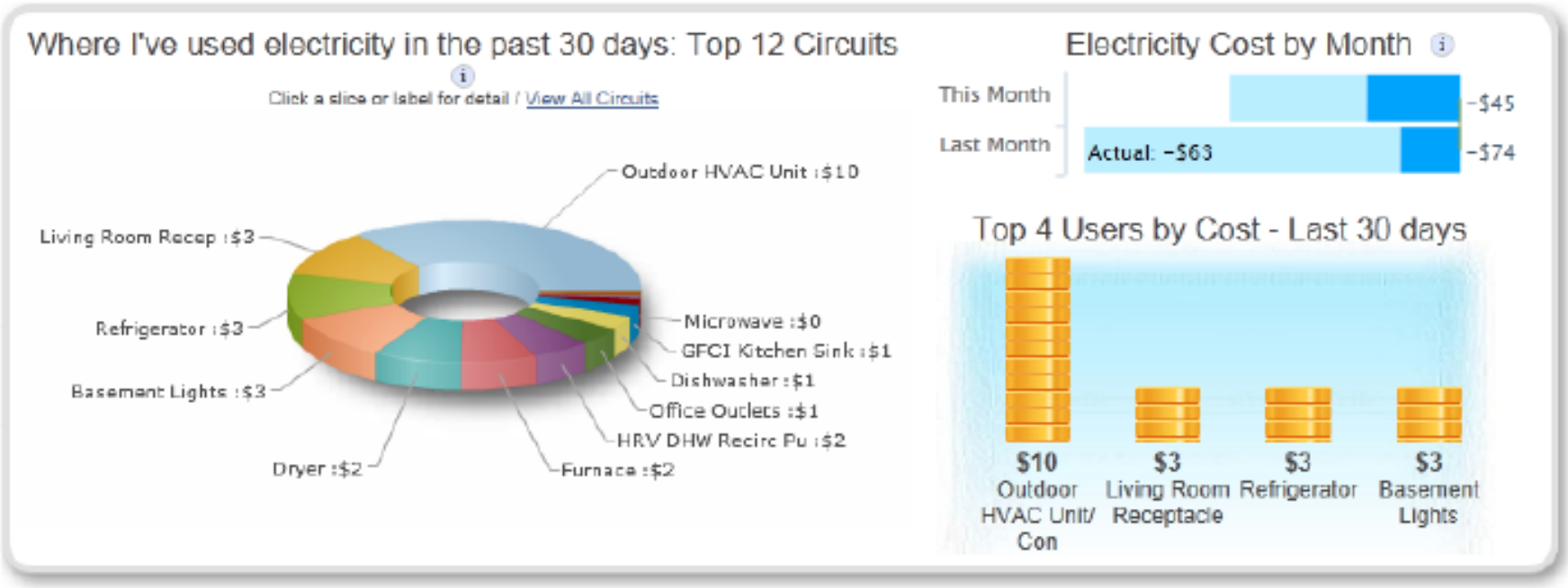

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Monitoring & submetering

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Example energy monitoring system

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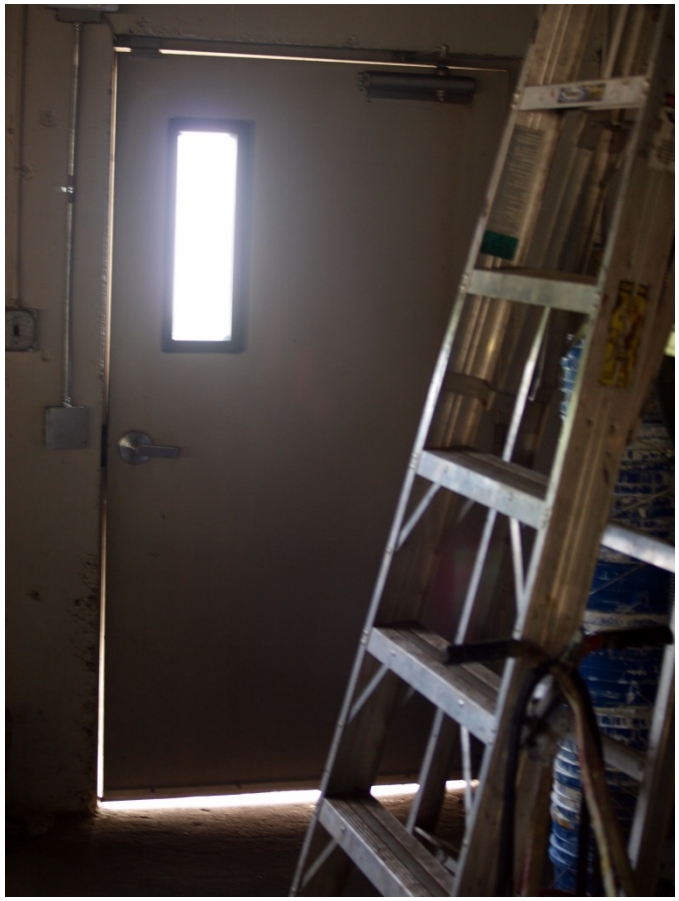
Building envelope



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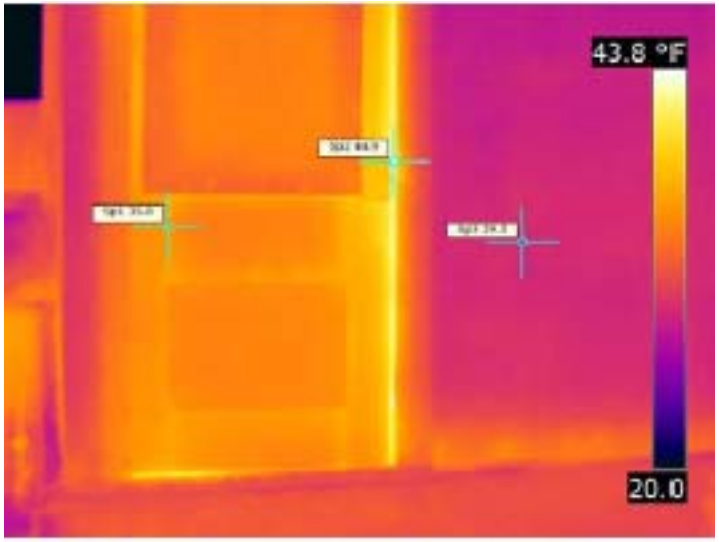
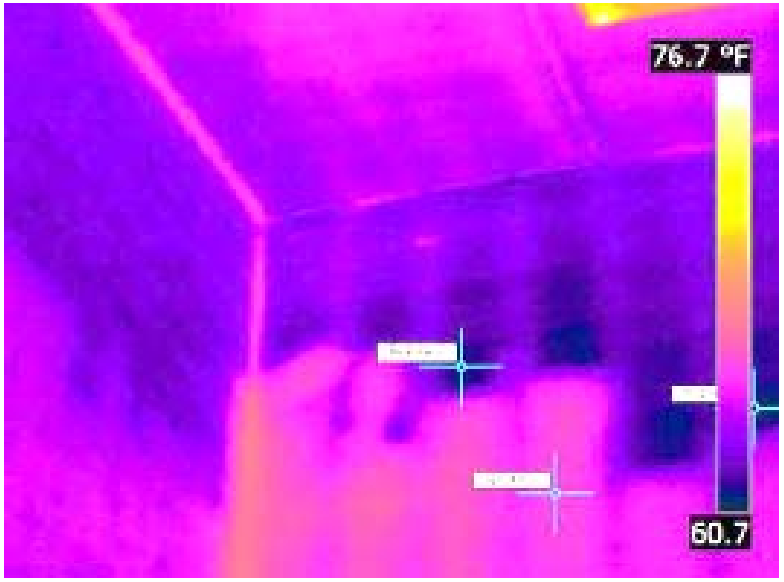
IR Thermography





R Values

- R denotes resistance to thermal conductivity
  - ***Higher R:*** better thermal efficiency
  - R is used to rate insulation, doors, wall materials
- R = °F x ft^2/BTU (in the US)
- R = ℃ x m^2/W (SI units everywhere else)
- $R_{US} \approx 6 \times R_{SI}$!!
- Thermal transmittance, **U = 1/R**
  - ***Lower U:*** better thermal efficiency
  - U is often used to rate windows

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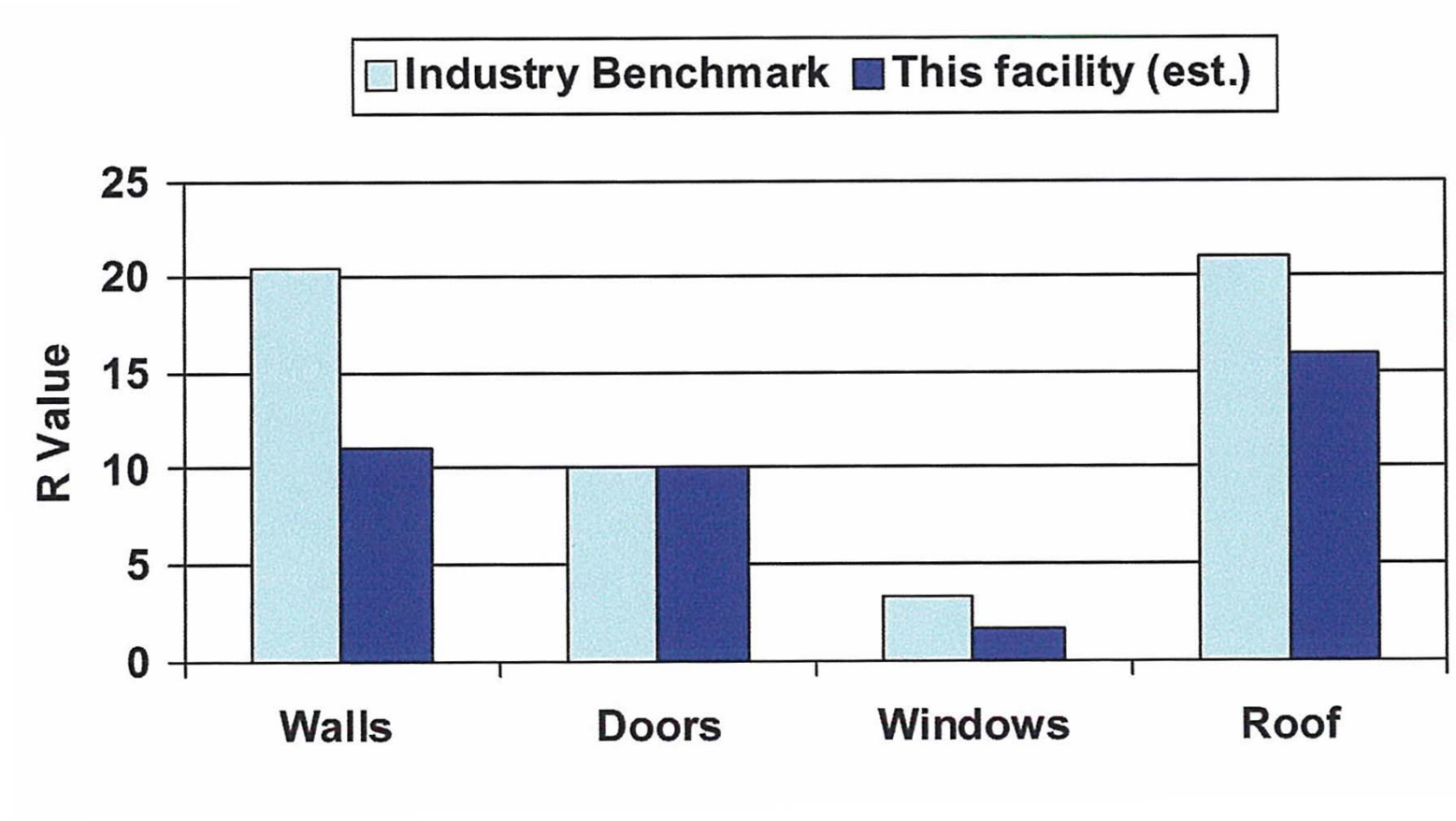
Building envelope – R Values



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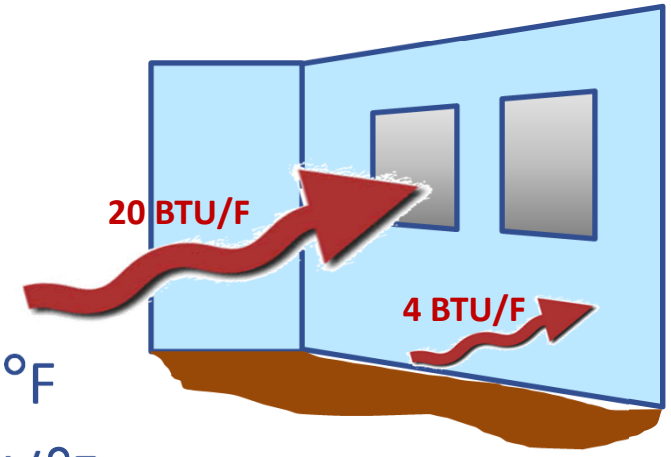
Beware parallel resistances!

$$\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2}$$

Example:

100 ft² Wall @ R=20 with

2-10 ft² Windows @ R=1



U_{wall} = 80 ft² x 1/20 (BTU/°F/ ft²) = 4 BTU/°F

$U_{windows}$ = 20 ft² x 1 (BTU/ °F/ ft²) = 20 BTU/°F

U_{total} = 20 + 4 = 24 (BTU/°F)

$R_{effective}$ = 1/24 = 4.2

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Standards and building codes

- ASHRAE std 90.1 for commercial/industrial buildings
  - http://www.energycodes.gov/comcheck
- Inside Air Quality – ASHRAE 62
  - Prescriptive -- 17 CFM outside air per person
  - Performance -- Measure CO_2 in return ducts of zone and keep CO_2 less than 1000 PPM.

Accounting for energy costs

- Submetering enables Activity Based Accounting
  - Associate energy cost with specific production unit
  - Make individual production processes accountable

Financial incentives

www.dsireusa.org

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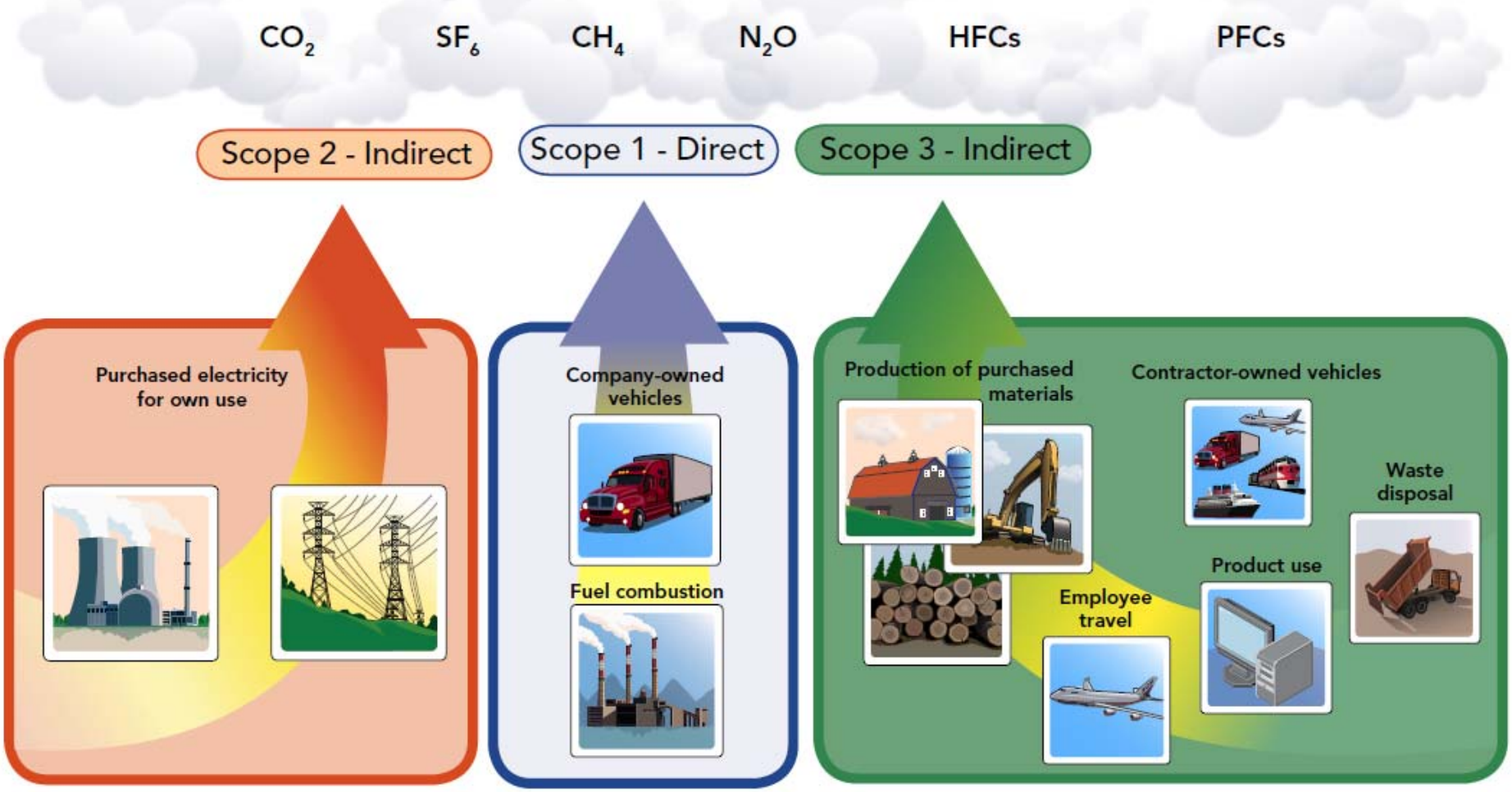
Greenhouse Gas Emissions



from Clean Air – Cool Planet

GHG emissions by fuel

Fuel	Lbs of CO_2 per Million Btu	Heat Rate (Million Btu per kWh)	Lbs CO_2 per kWh
Coal			
Bituminous	205.300	0.010128	2.03
Sub-bituminous	212.700	0.010128	2.10
Lignite	215.400	0.010128	2.13
Natural gas	117.080	0.010414	1.12
Distillate Oil (No. 2)	161.386	0.010414	1.55
Residual Oil (No. 6)	173.906	0.010414	1.67

For New England's electricity fuel mix,
1 KWh emits approx. 0.9 Lbs. CO_2e

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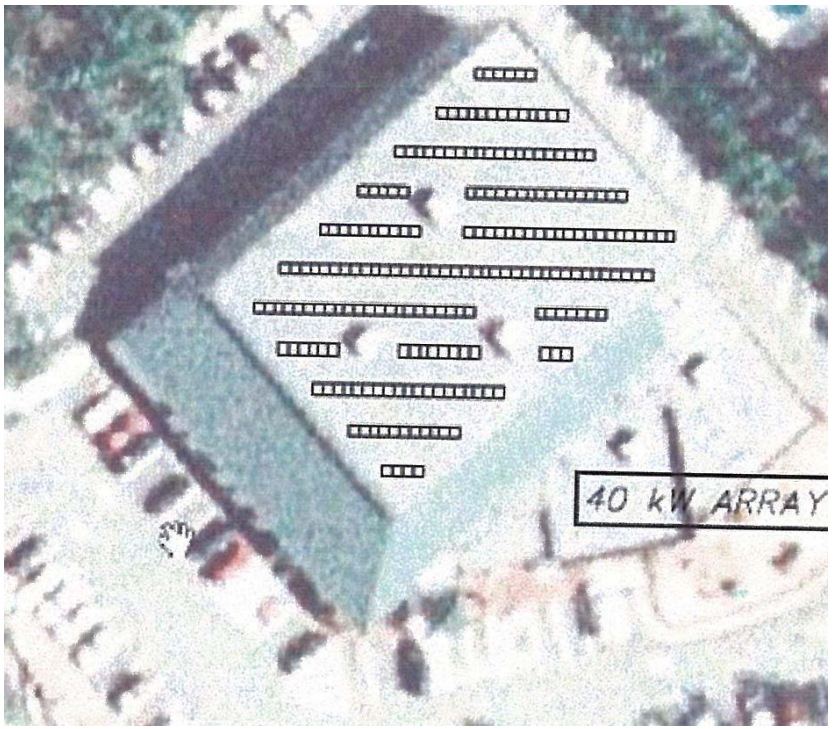
Renewables assessments

- solar
- wind
- Combined Heat and Power (CHP)



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Human factors assessment

- Efficiency vs conservation:
  - ***Efficiency relates to equipment:*** getting the most from each unit of energy, via technologies and process changes
    - LED lamps in place of T12 fluorecents
    - Replacing old boiler with new, more efficient unit
  - ***Conservation relates to behavior:*** using energy only when needed, not wasting
    - Motion sensors for lights
    - 'Smart' plug strips
    - Hypermiling

Engaging staff

- Staff awareness & training
- Solicit employee input
- Establishing policy
  - Plug loads & vampires
  - Procedures for powering & depowering equipment
  - Scheduling equipment use wisely
  - Etc.

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Thank you

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