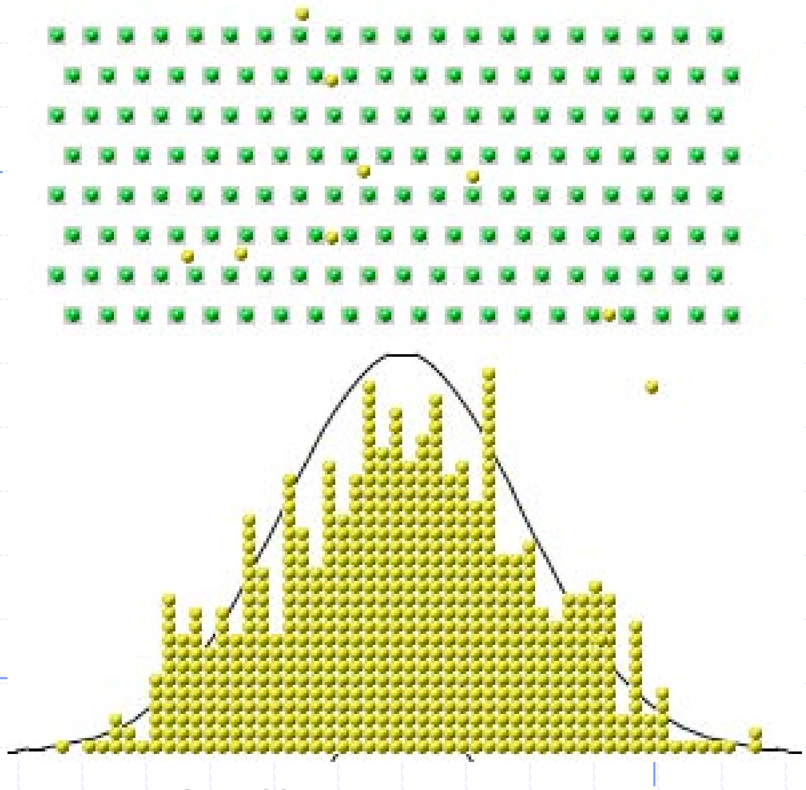
Benchmarking:
What's Your Building's Energy IQ?



Evan Mills, Ph.D.

Lawrence Berkeley National Laboratory

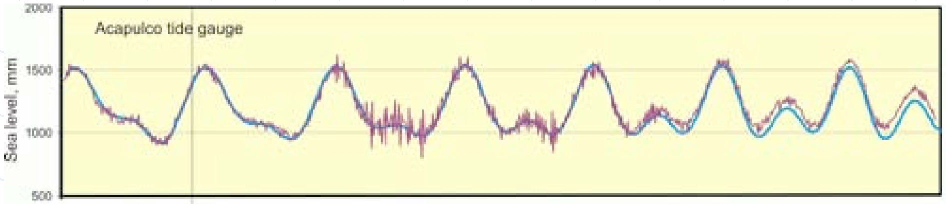
EMills@lbl.gov

California Energy Commission
Green Building Initiative Benchmarking Staff Workshop
April 7, 2005

Describing complex systems; Informing action

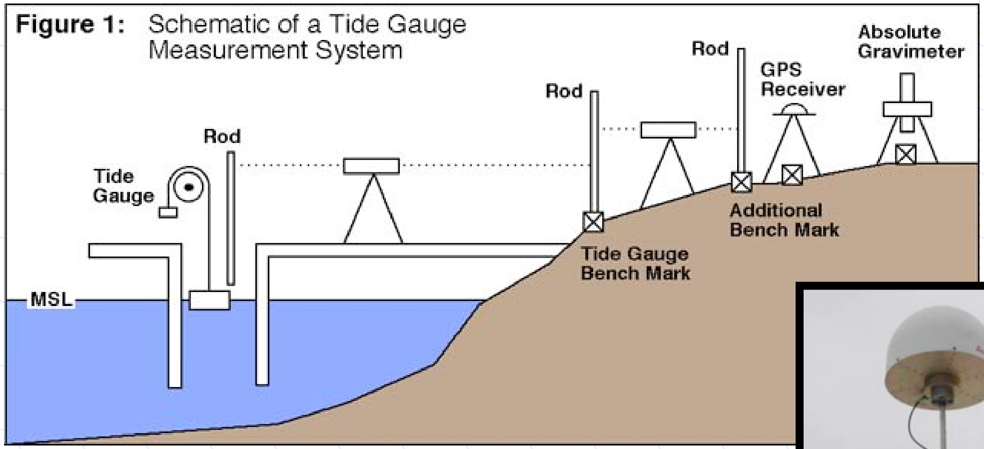
….e.g., the moon's effect on earth

Tides in Acapulco (tsunami 12/26/2004 in red, superimposed on normals)



Origins: Sea-level observation ("bench" is old word for shore)

Tasmanian coastal Benchmark c.1841



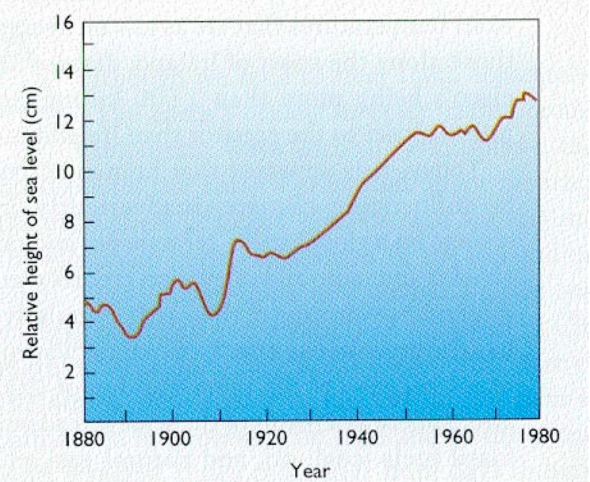
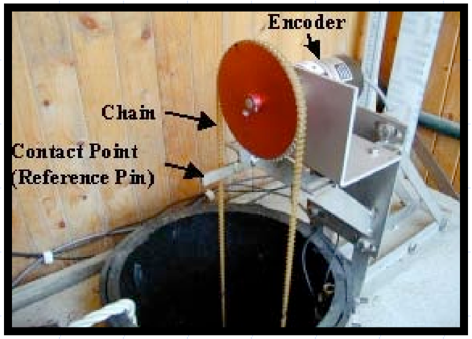
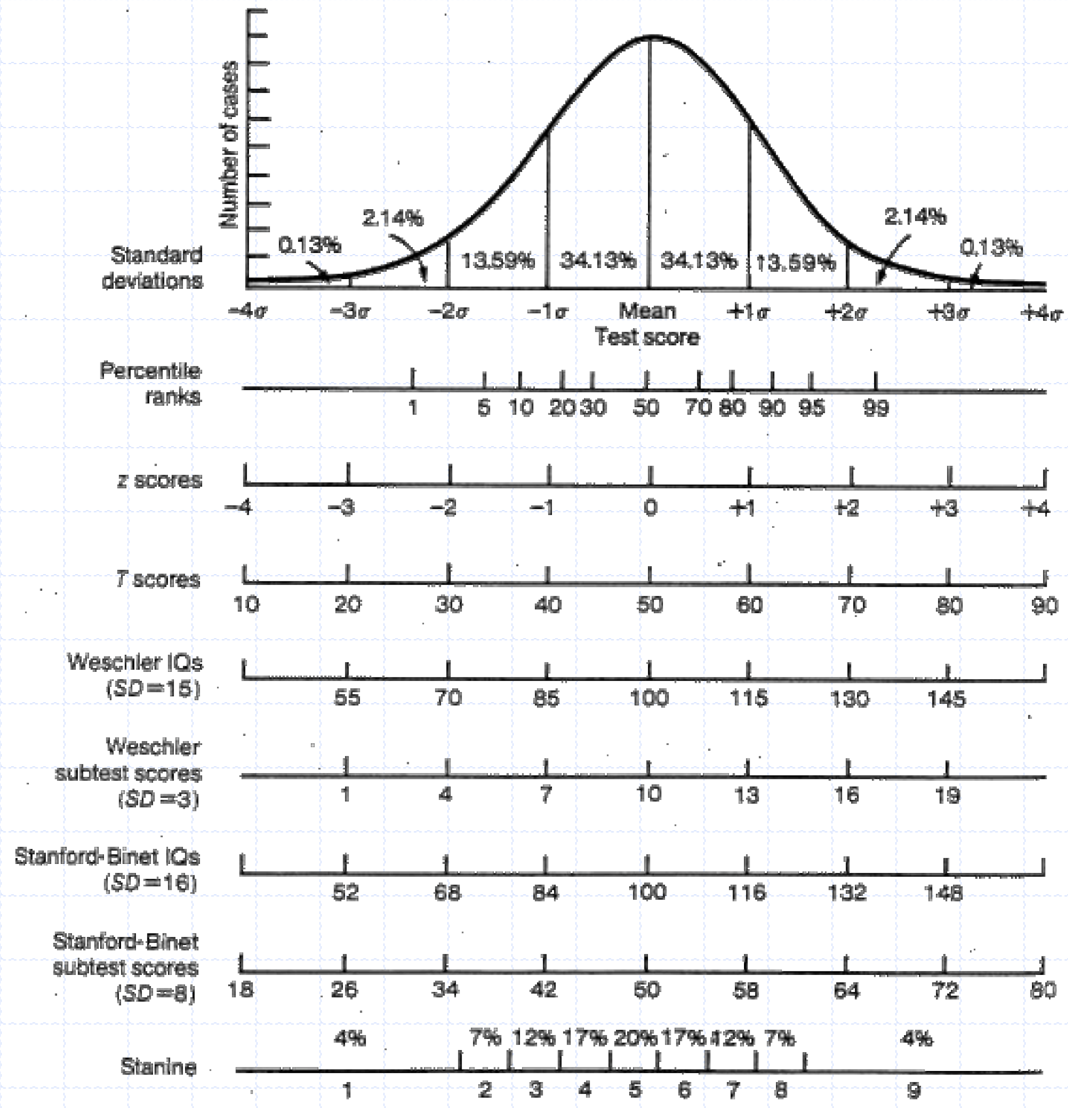


FIGURE 15-19

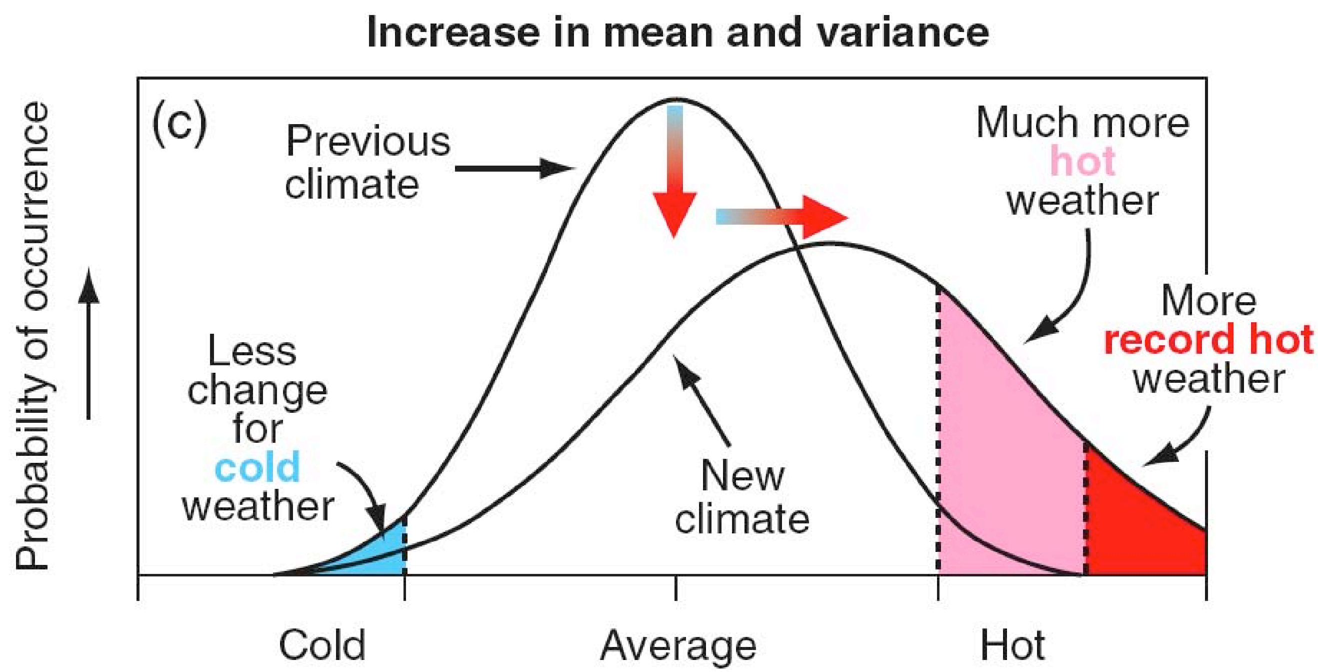
Sea levels. The recent global rise of sea level. [Adapted from V. Gornits, S. Lebedeff, and J. Hausen, *Science* 215 (1982): 1611–14.]



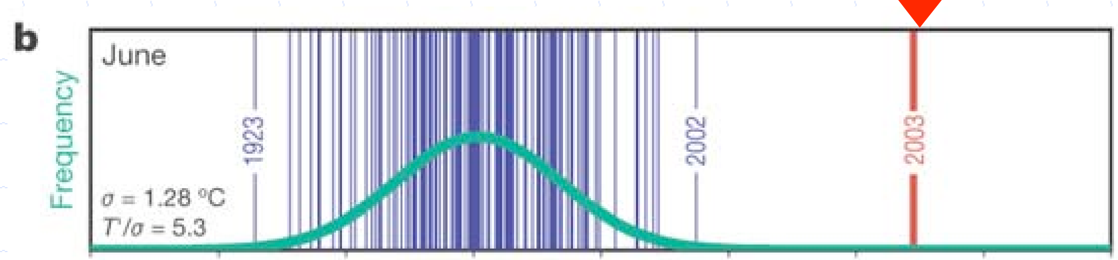
Familiar Benchmarks: IQ



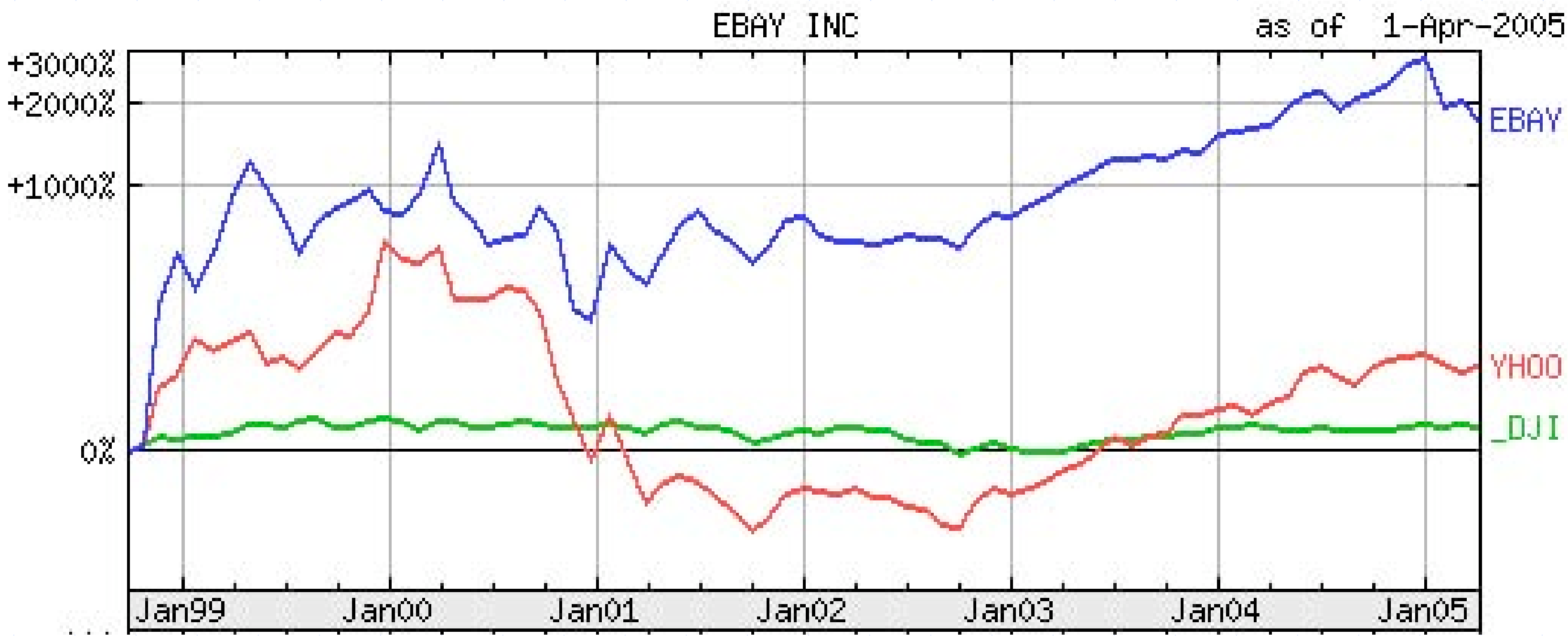
Climate Change



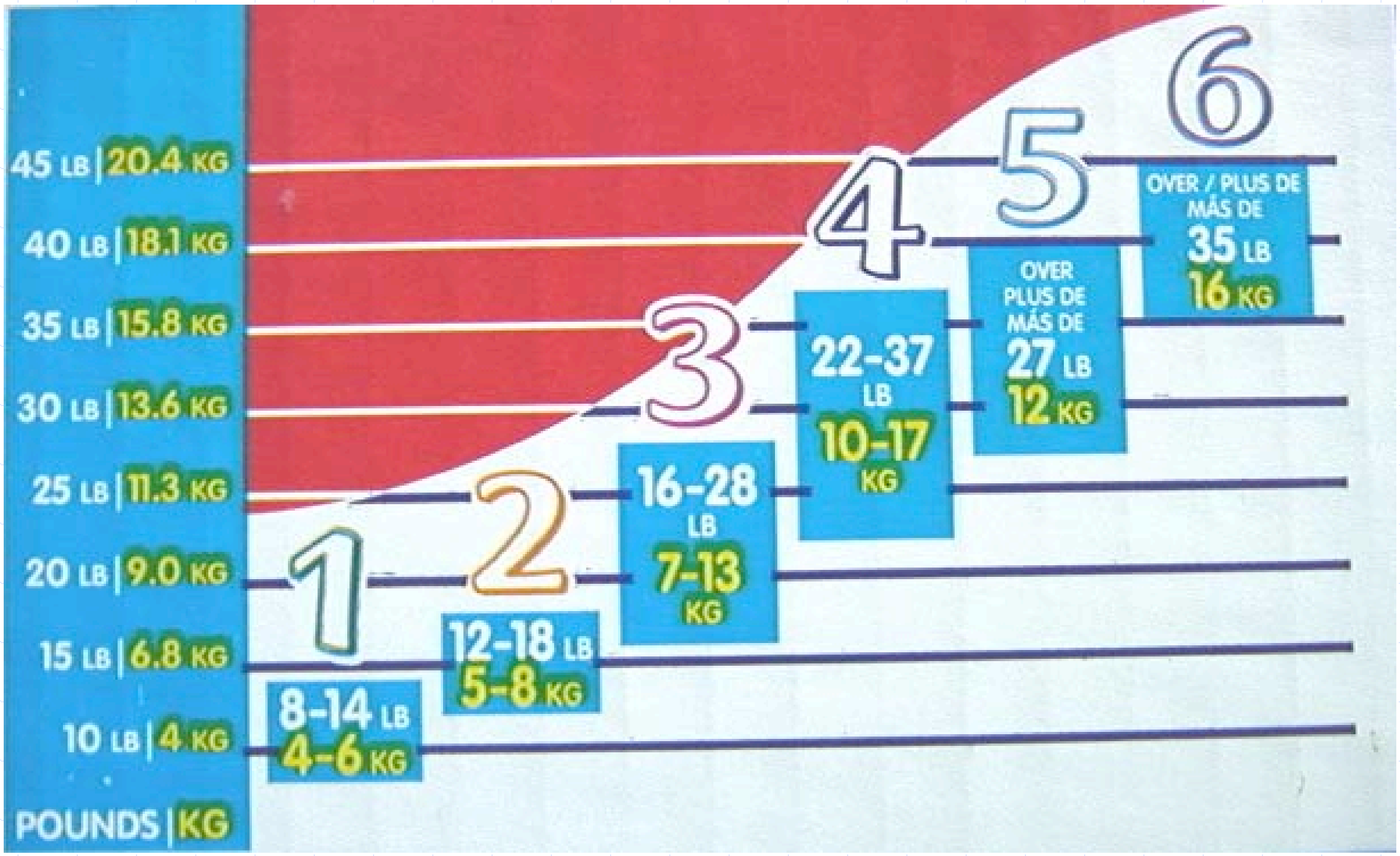
Europe Summer Temperatures: 2003



Benchmarks are Everywhere



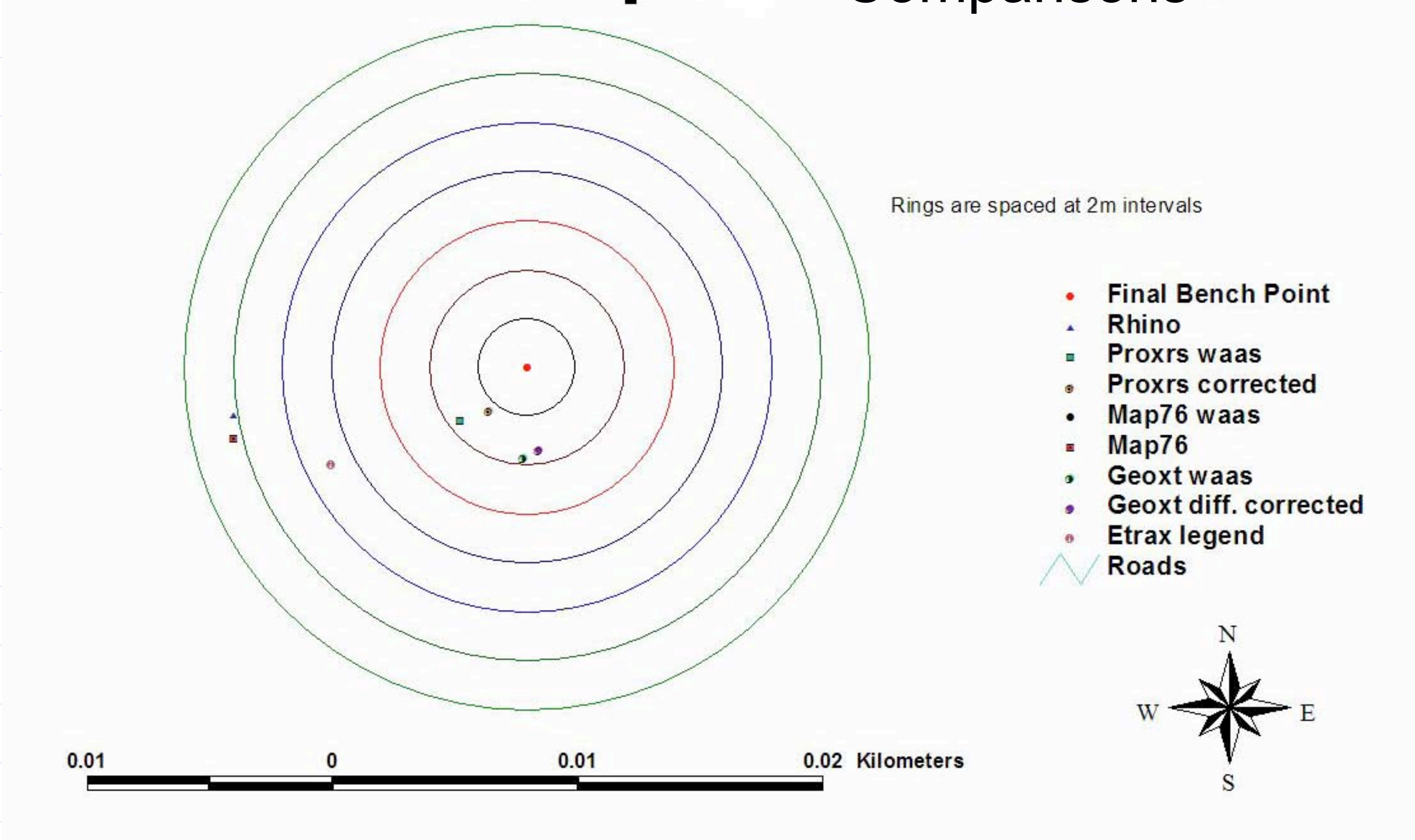
Huggies: Diaper Size as Function of Child Weight



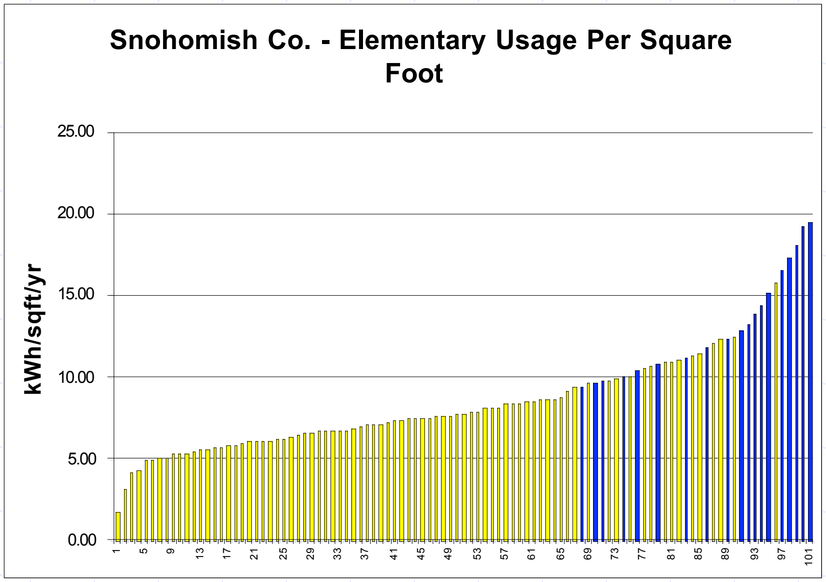
Nice chart; dubious value in real world
(parents don't pick diapers based on child's weight)

Bullseye

GPS Accuracy Comparisons



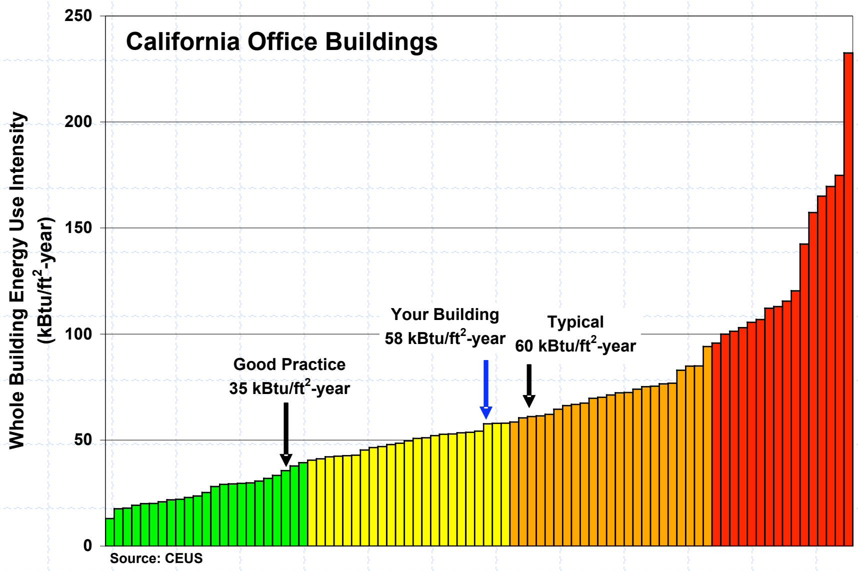
Why Benchmark Energy Use?



- Establish baseline and track performance
- Validate design
- Identify best practices; set goals or standards
- Identify savings potential
- Prioritize efforts
- Identify maintenance and control problems
- Educate; Inspire!

Energy benchmarking is one part of a broader energy management process

Many possible metrics



- Energy
  - (e.g. kBtu/ft^2-degree day)
- Single fuel
- Peak power
- Cost
- Emissions
- "Unit-less" point systems
- Service level

Many approaches

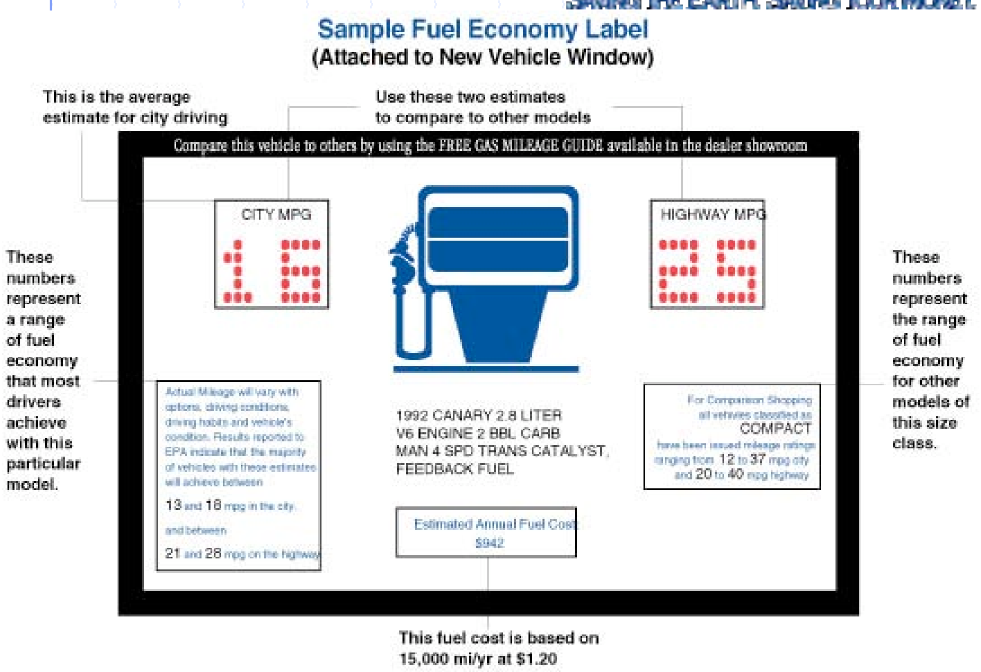
- Statistical (bell curve; vs. population)
- Point-estimates (vs. population avg.)
- Point-based (vs. best practice)
- Model-based (actual vs. efficient)
- Standardized (vs. test procedure)

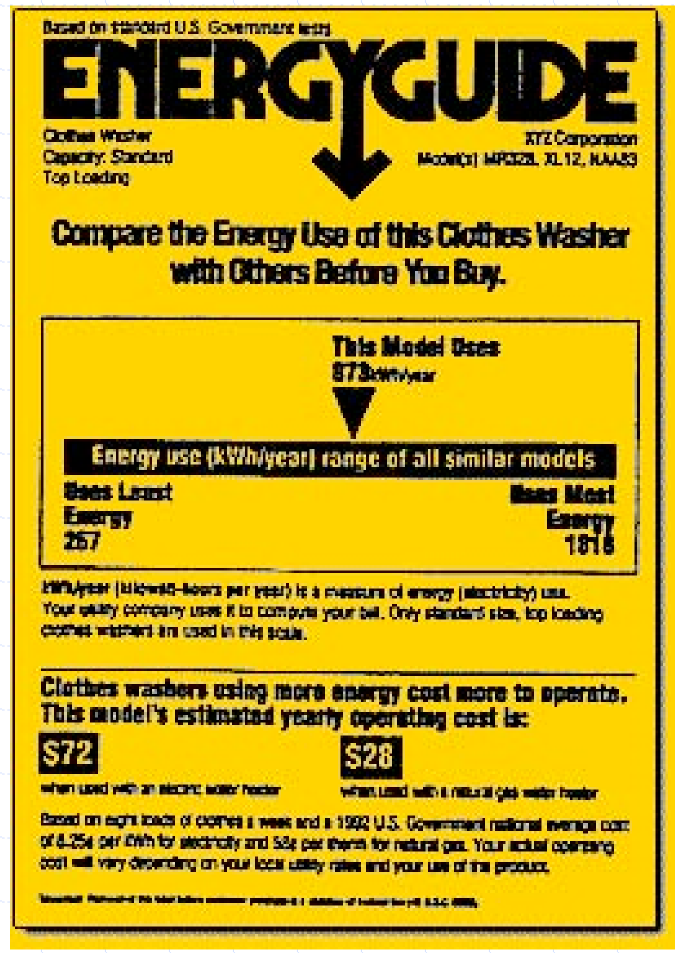
Scope: self-referential; enterprise; stock; relationship to codes

Timeframe: historic trends vs. current

Familiar Energy Benchmarks …

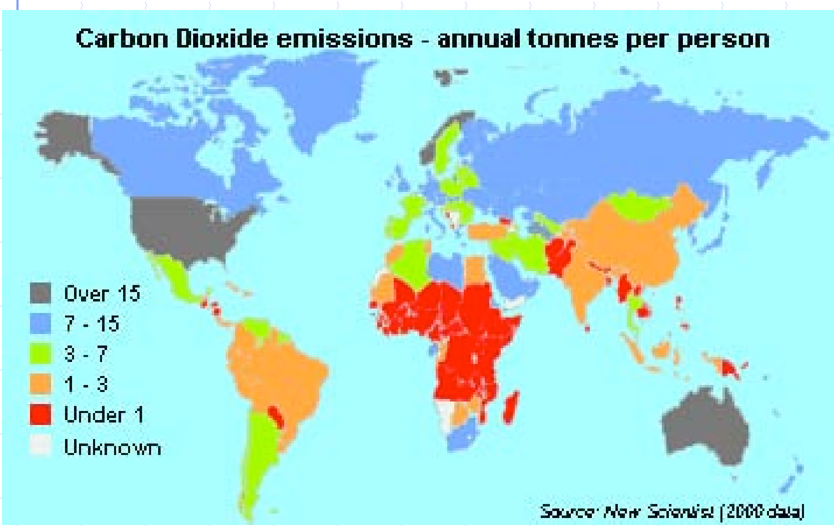
…Fundamental differences in approach



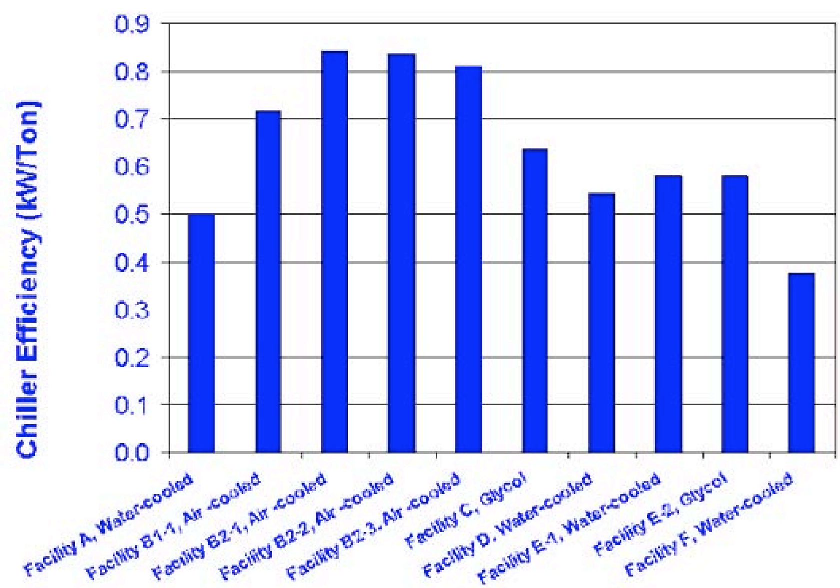


Benchmarking Can Be Done at Any Scale

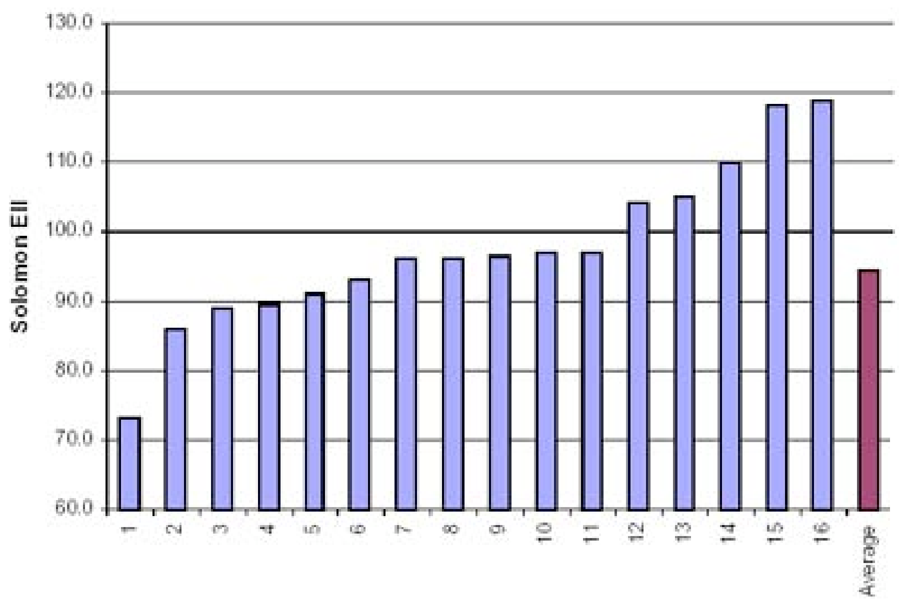
- Global CO2/Capita



- Chiller efficiency



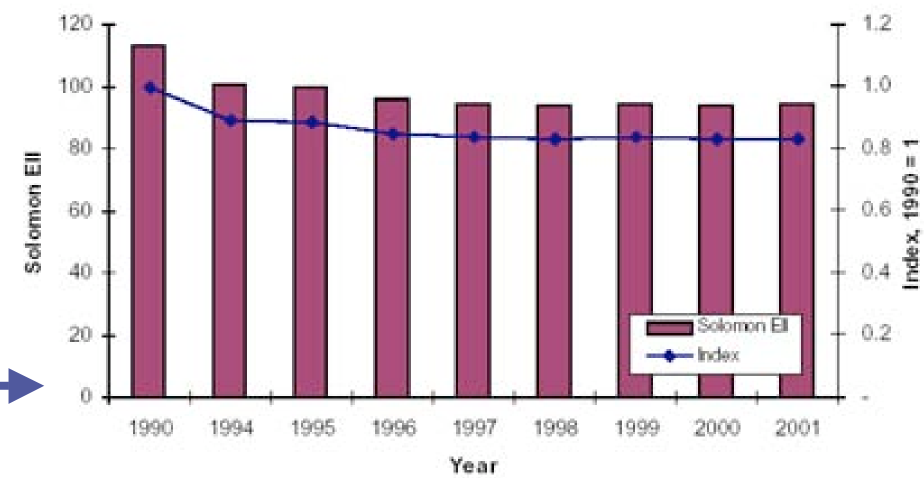
Lateral *vs.* Longitudinal: e.g. Oil Refineries



Solomon Energy Intensity Index of Participating Individual Refin
Source: CIEEDAC, 2002.

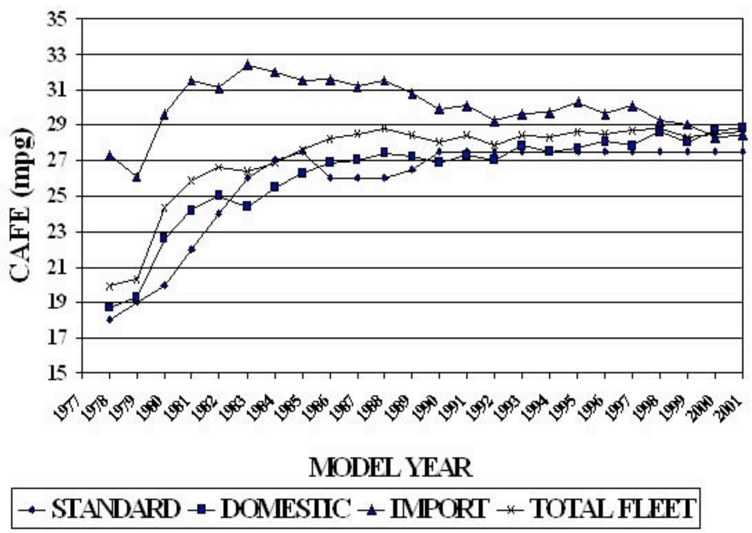
Comparing "peers" at one point in time

Following "fleet-wide" trends over time



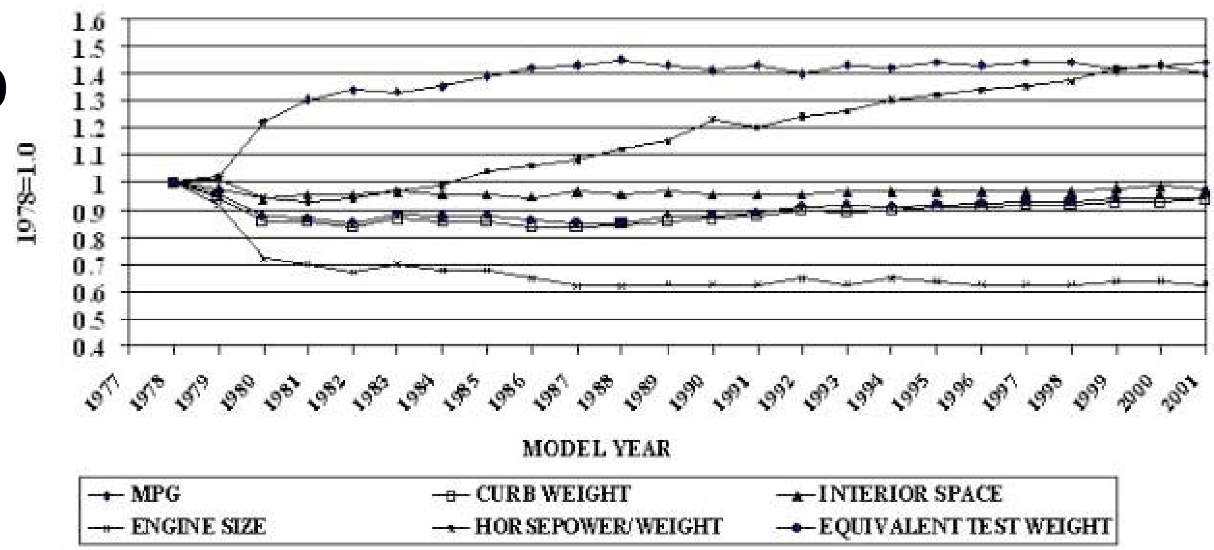
Average Refinery Energy Intensity based on a composite of Solomon EII for all known refineries.[4]

Decide What is Important Before Benchmarking



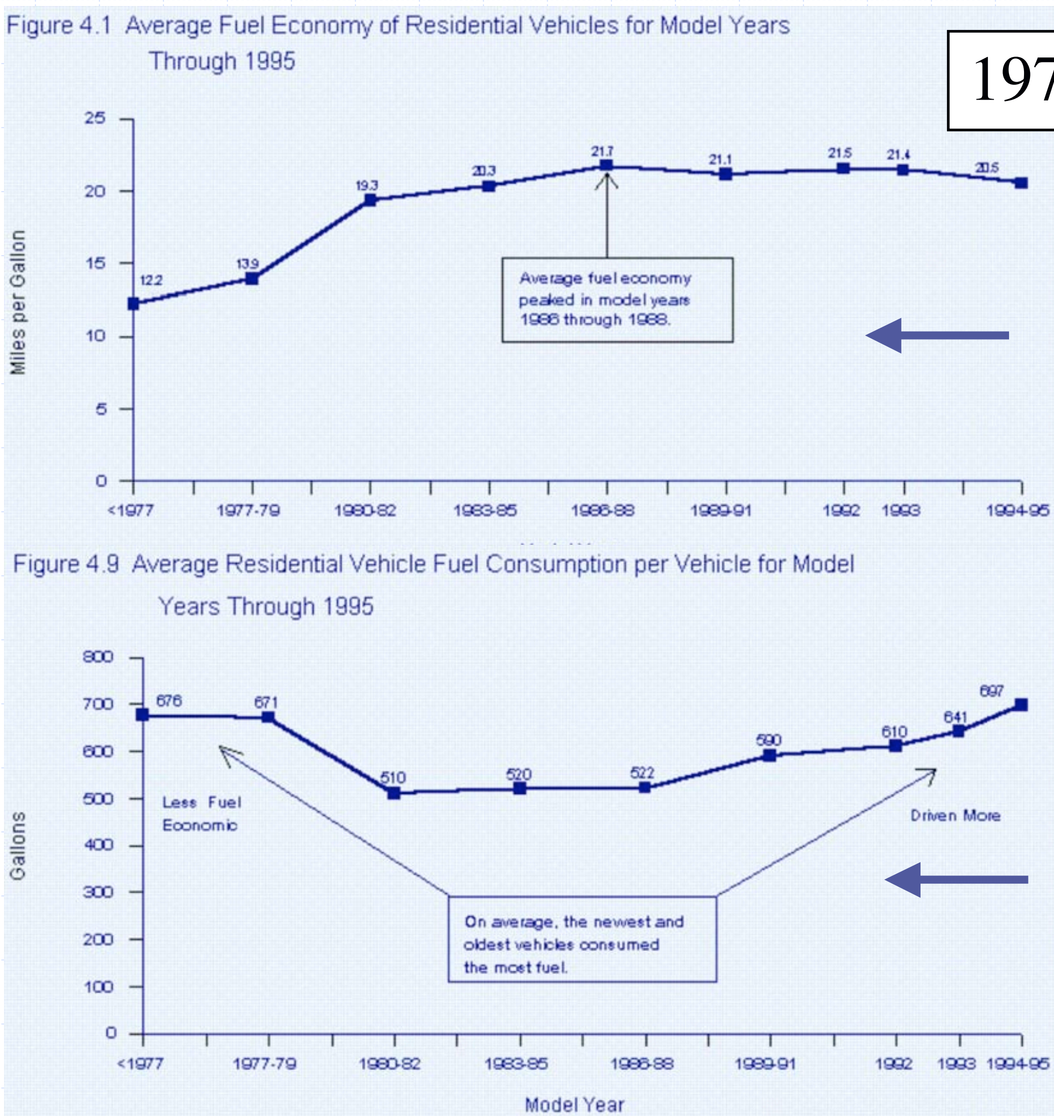
- Important to isolate sub-groups of interest

- Many ways to benchmark a given system



Source: NHTSA

Choice of Benchmark Determines Conclusion



1977-1995

Average US fuel economy increasing, then flat

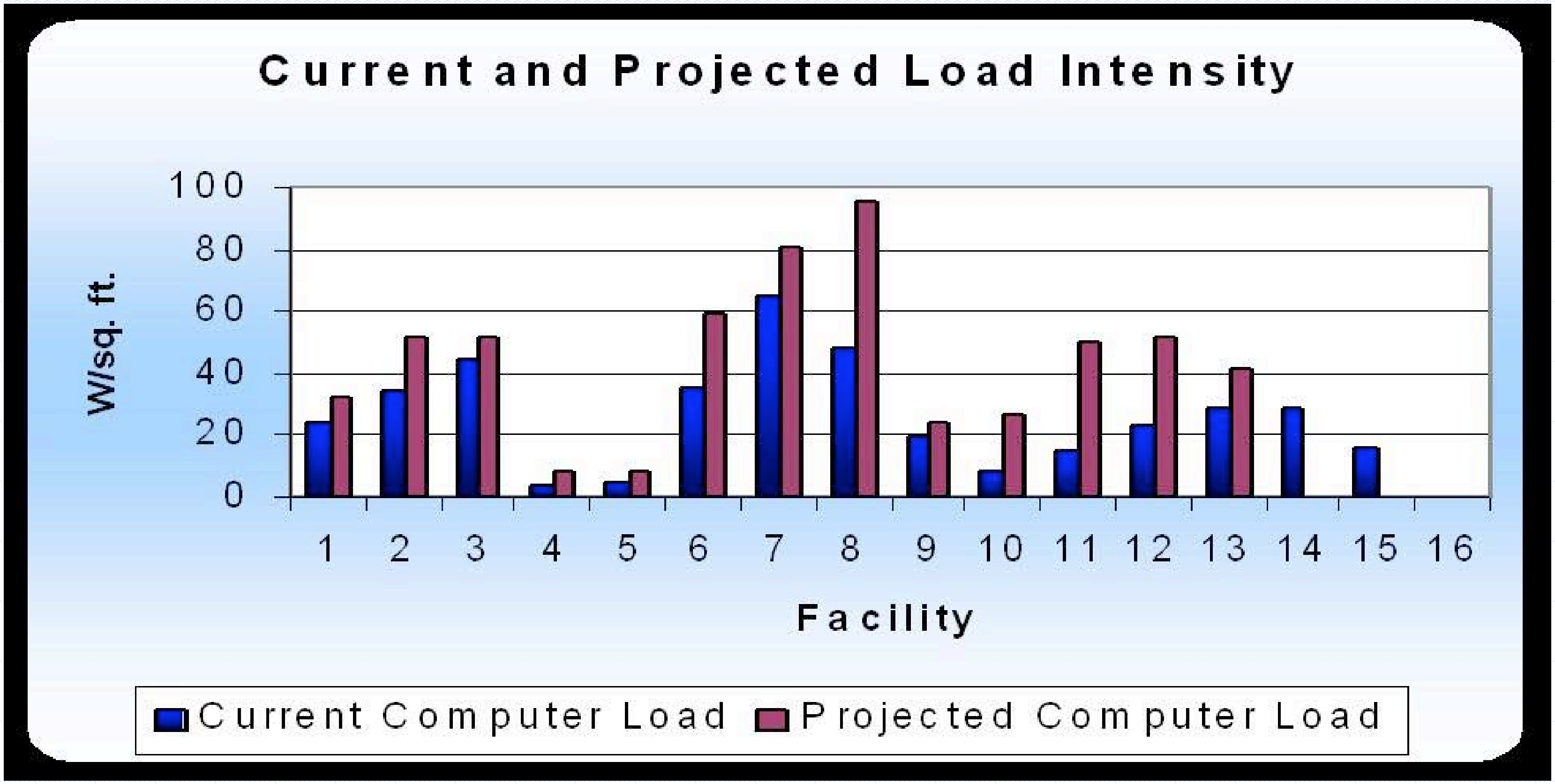
Average US vehicle fuel use declining, then rising

Source: USDOE/EIA

Benchmarks Can Provide a "Reality Check" for planners

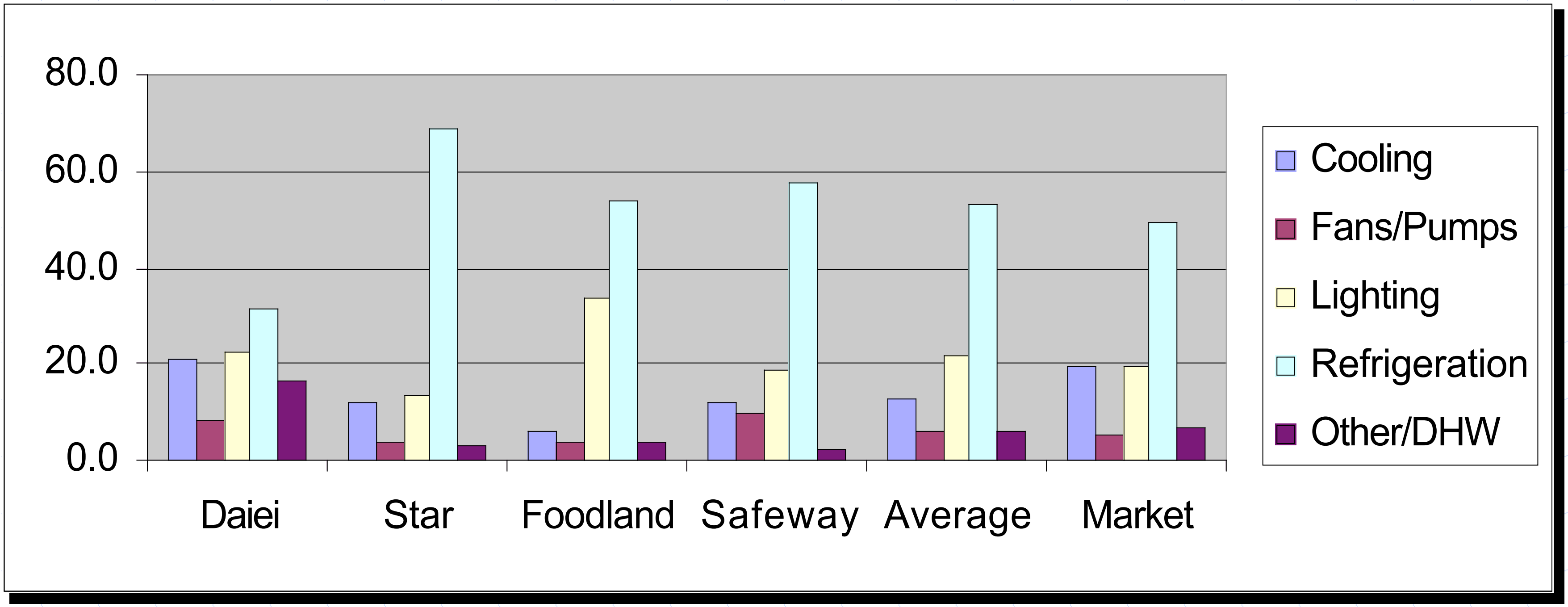
California Data Center owners claim a need of 250 W/ft²

Real data benchmarks the actual need between 10 and 100.



End-Use Intensities

Hawaiian Grocery Stores (kWh/ft^2-year)

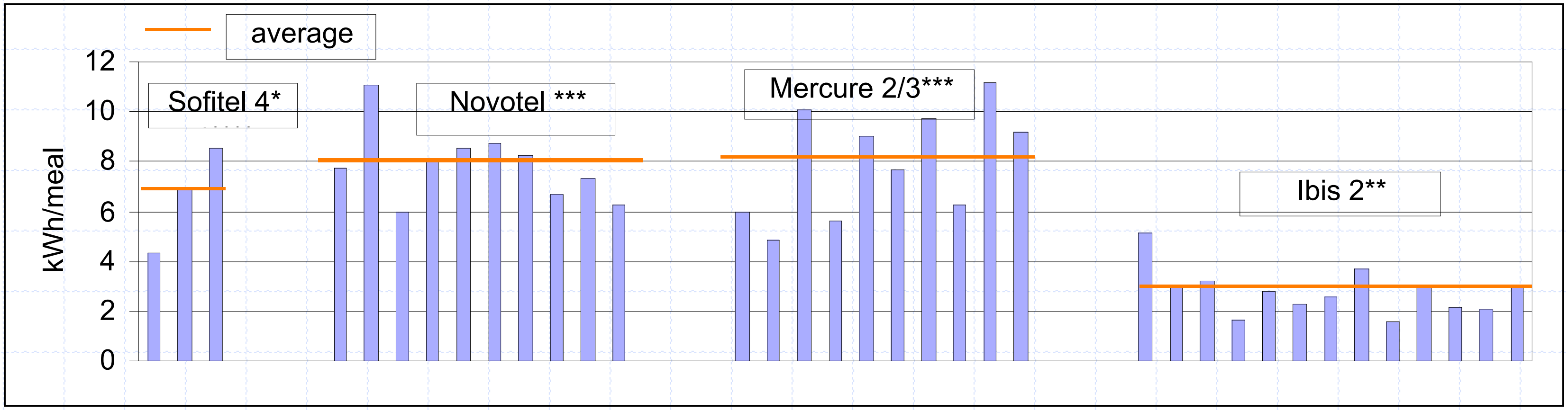


Source: HECO, Thomas D. Van Liew

Intensities x Enterprise

Energy per meal for 36 hotels, France

Std. Dev. 34% 27% 19% 32%



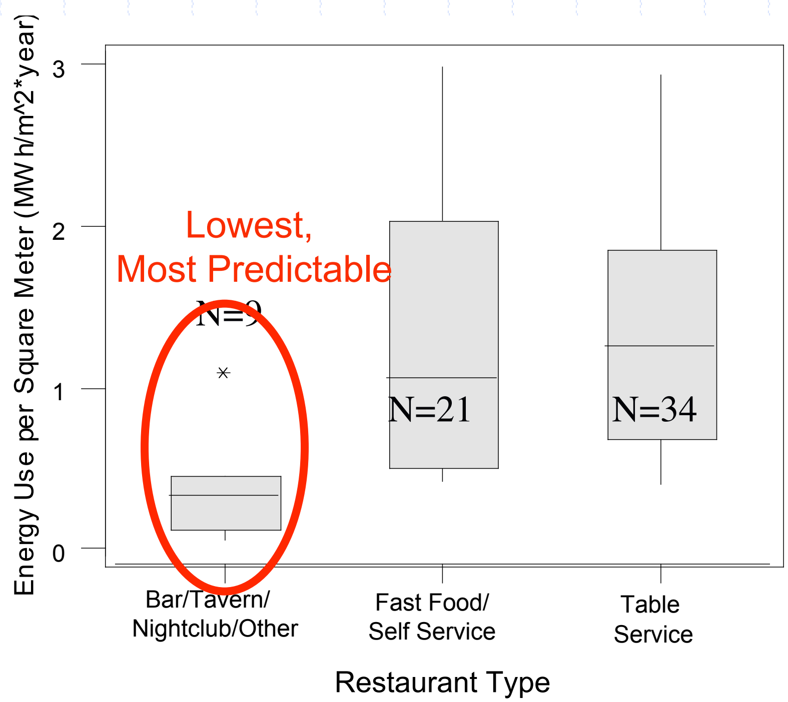
category of hotels	conservation kWh/meal	cooking kWh/meal	dishwashing kWh/meal	total kWh/meal	standard deviation
2**	0.44	2.08	0.25	2.77	0.94
2**/3***	3.81	3.89	0.25	7.95	2.18
3***	3.67	3.99	0.21	7.86	1.47
4****	2.53	3.92	0.13	6.58	2.13

Source: Le Strat et al., (1999)

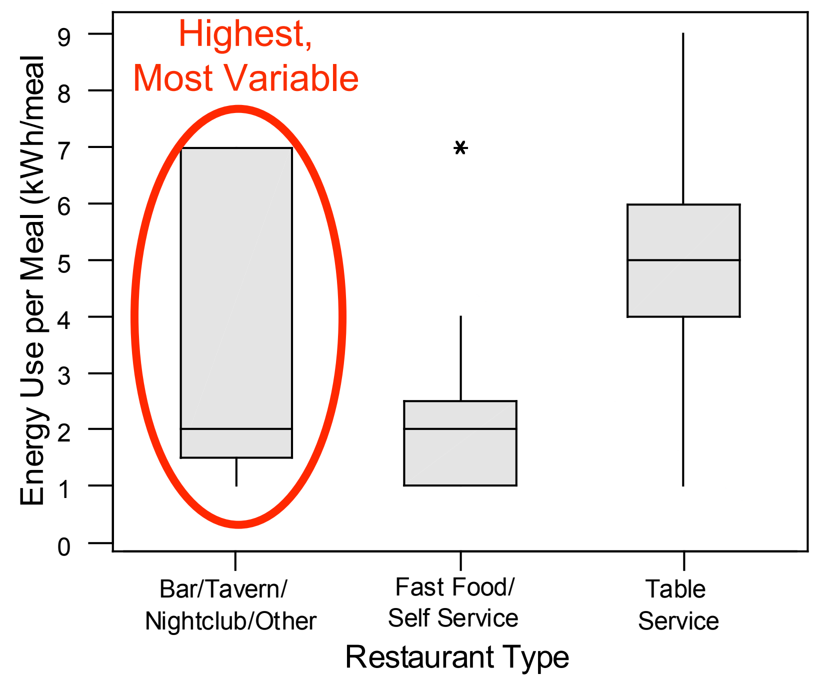
Choice of Indicator is Key

Restaurants

Energy per unit floor area



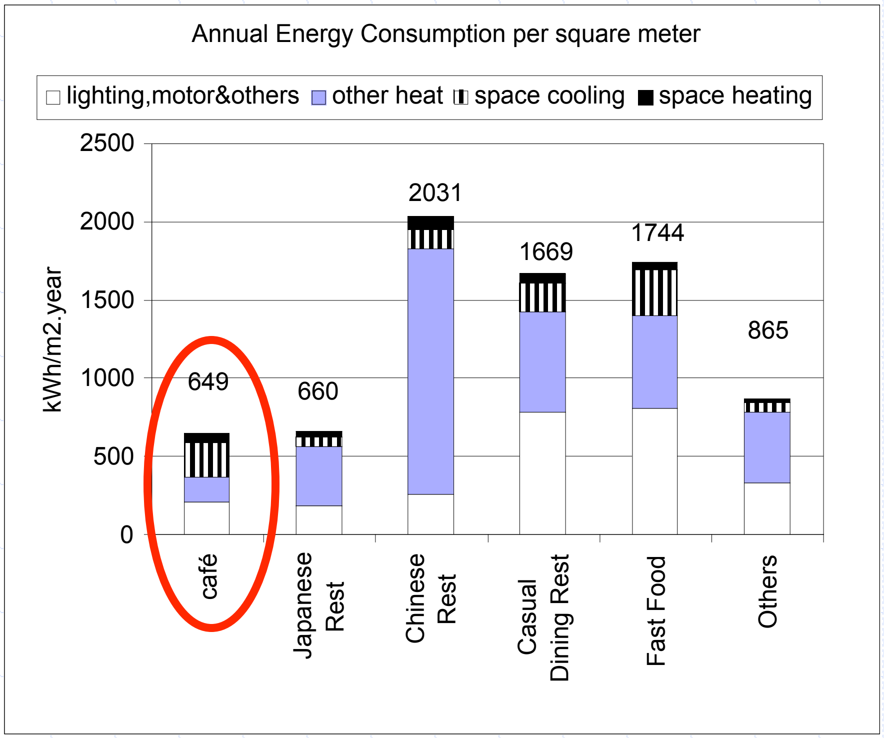
Energy per meal



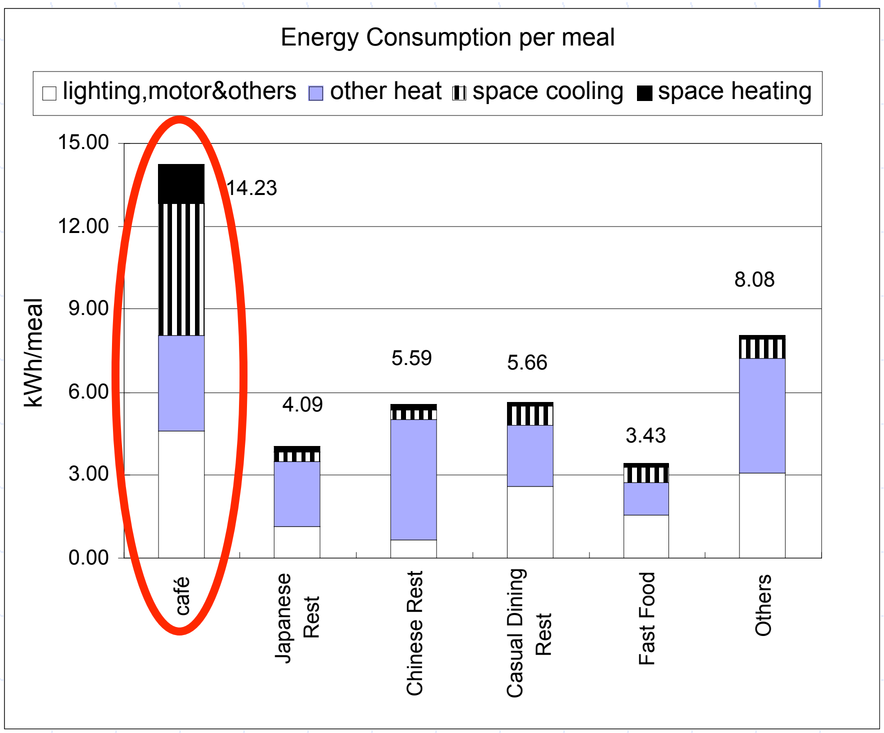
Source: 1996 California Commercial End Use Survey

Choice of Indicator is Key

Energy per unit floor area



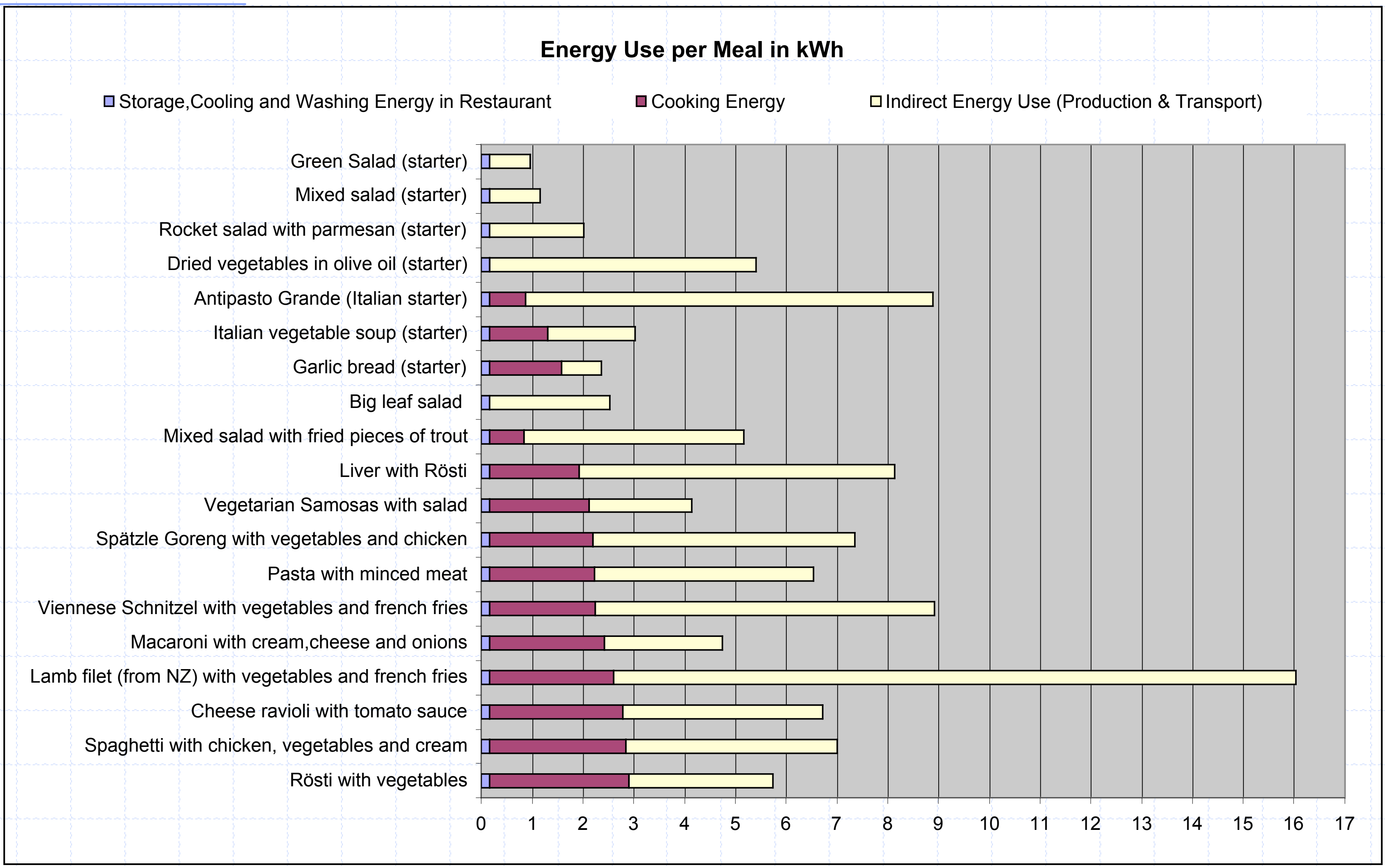
Energy per meal



Café ranks "best" by one benchmark and "worst" by the other

Source: The Energy Data and Modeling Center, 2001

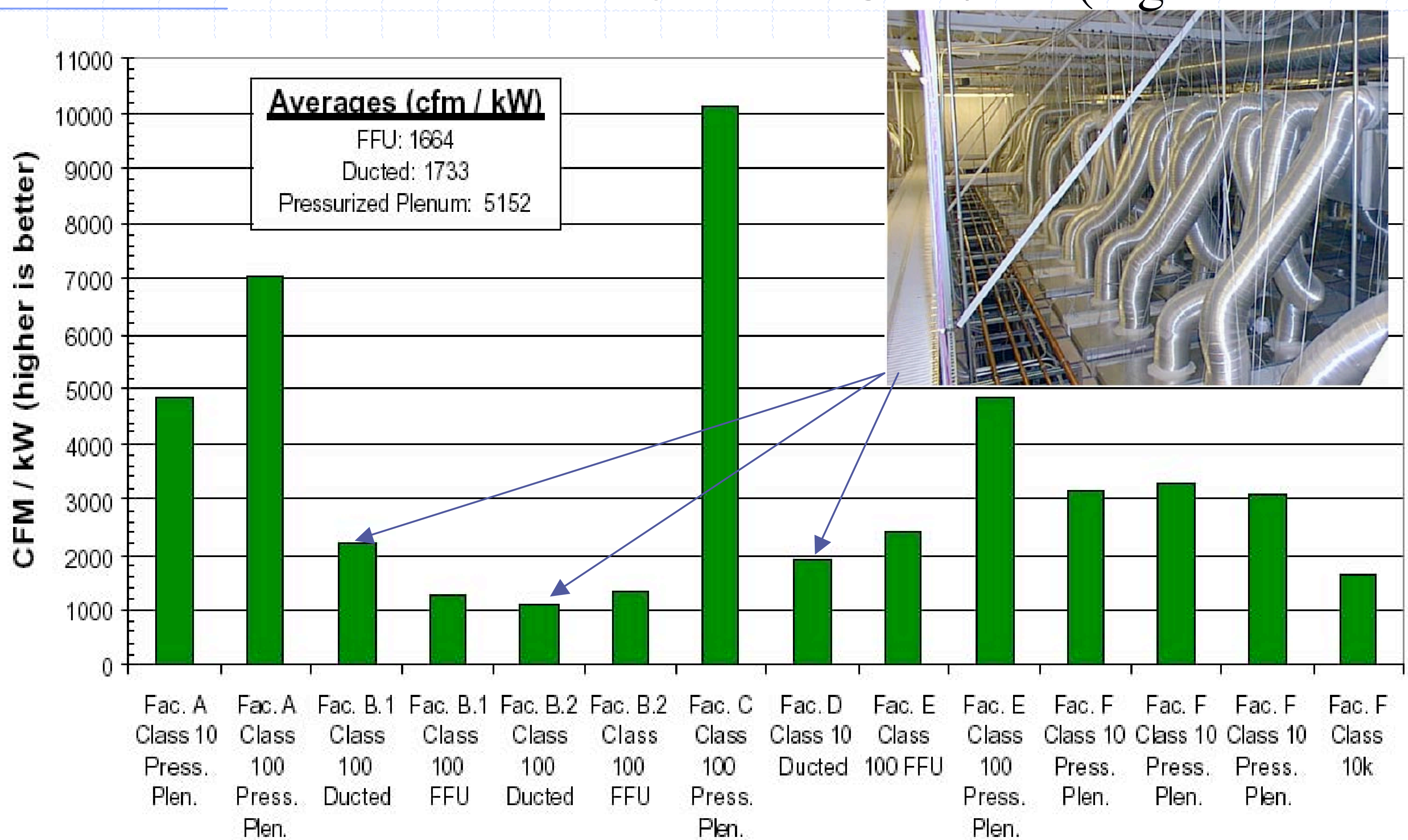
Beyond "Apples & Oranges": Pippins and Granny Smiths



Data for Switzerland. Source: Balmer and Hintermann, 2000

Delivery of Service Levels: Cleanrooms

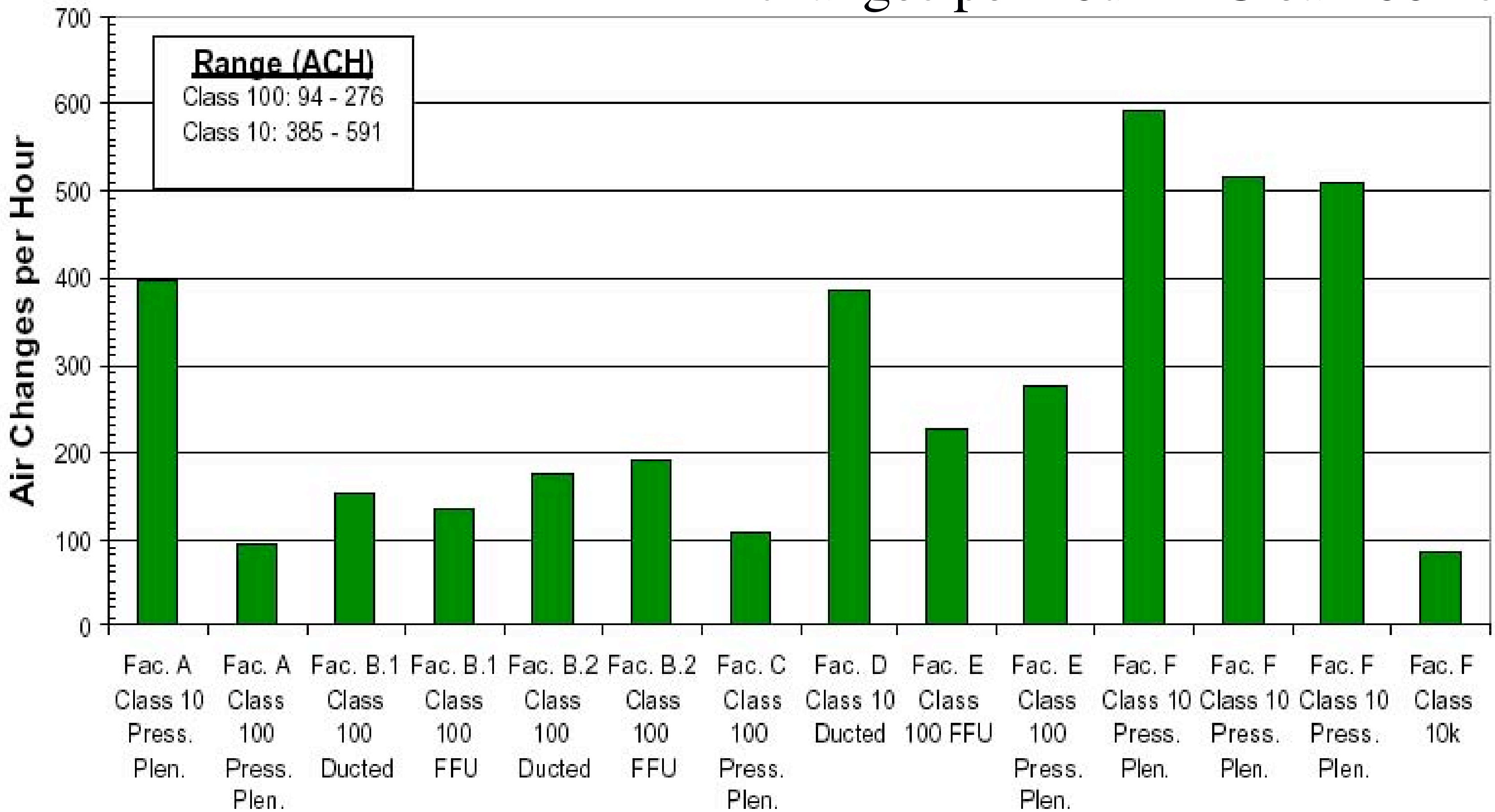
Air movement CFM/kW (higher is better)



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

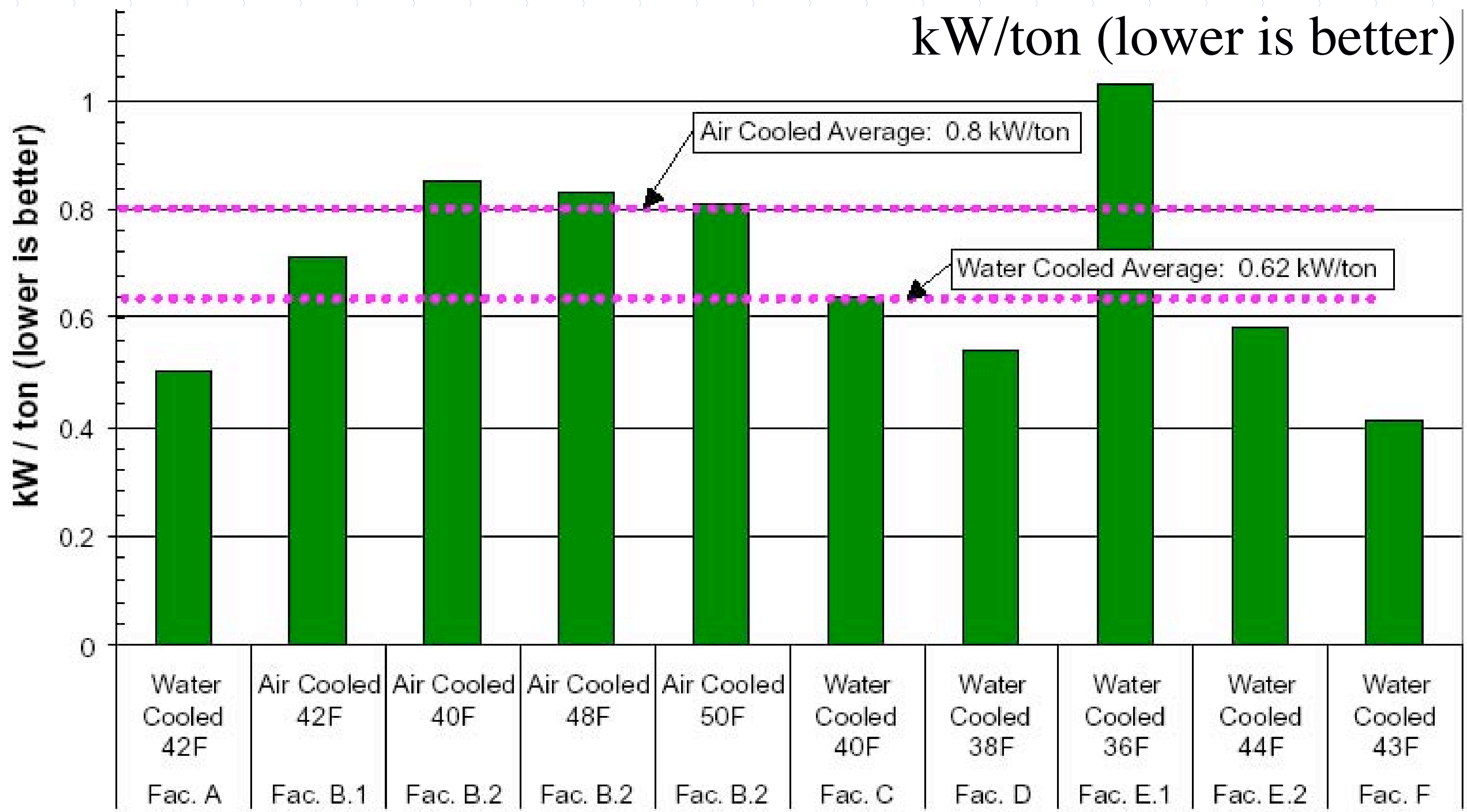
Some "Energy" Benchmarks Don't Even Include Energy

Air-changes per hour in Cleanrooms



Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

Component Benchmarking:
Cleanroom Chiller Efficiencies



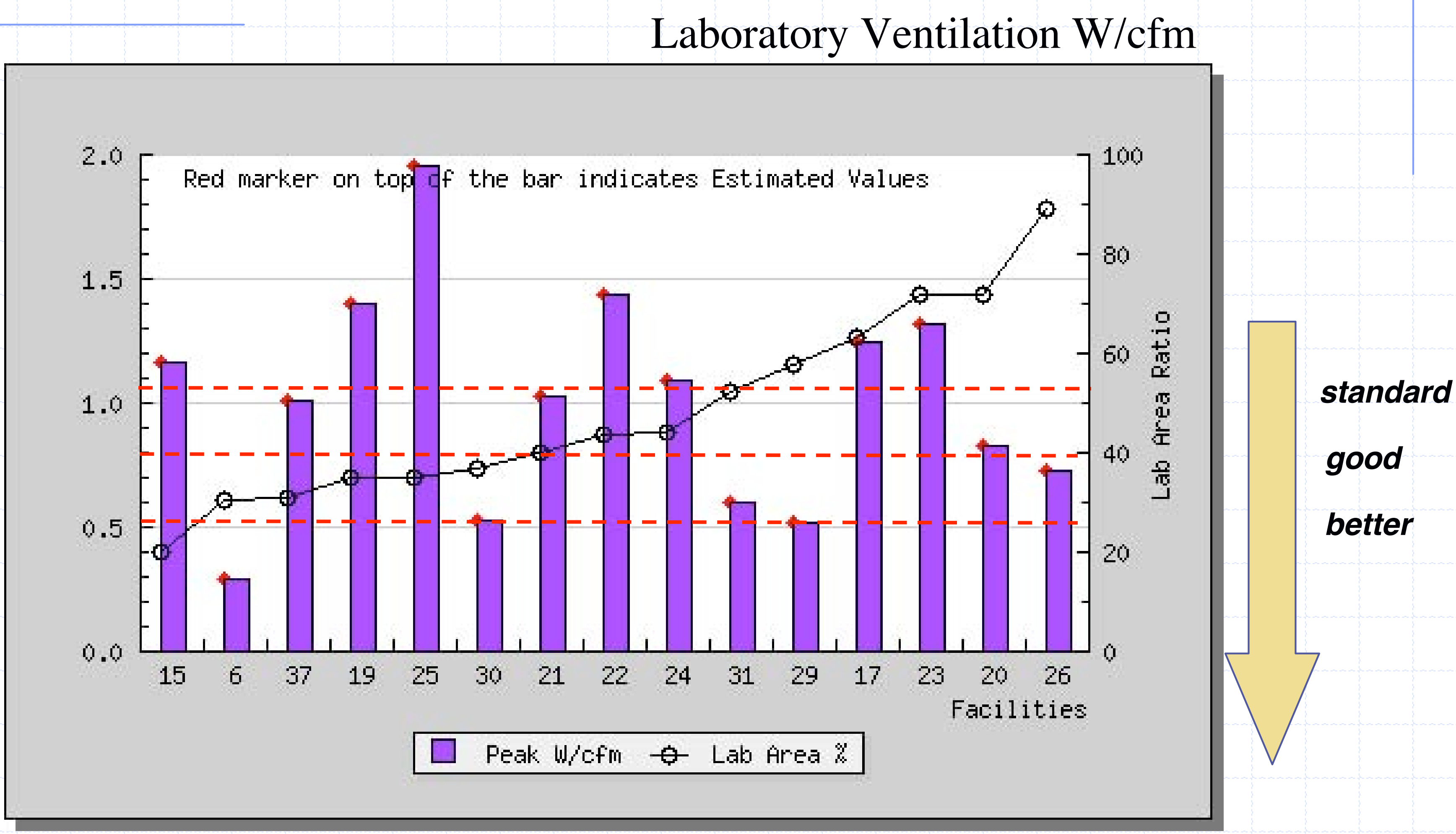
Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

Cleanroom Energy Metrics

•Recirculation air handler efficiency	•cfm/kW
•Makeup air handler efficiency	•cfm/kW
•Annual energy cost per cleanroom square foot	•$/ft^2
•Annual fuel usage	•MBtu/ft^2-yr
•Annual electricity usage	•kWh/ft^2-yr
•Annual energy usage	•MBtu/ft^2-yr
•Makeup air	•cfm/ft^2
•Recirculation air	•cfm/ft^2 or ach
•Chiller efficiency	•kW/ton
•Tower efficiency	•kW/ton
•Condenser water pump efficiency	•kW/ton
•Chilled water pump efficiency	•kW/ton
•Total chilled-water plant efficiency	•kW/ton
•Hot water pumping efficiency	•kW/MBtu
•Cooling load density	•ft^2/ton

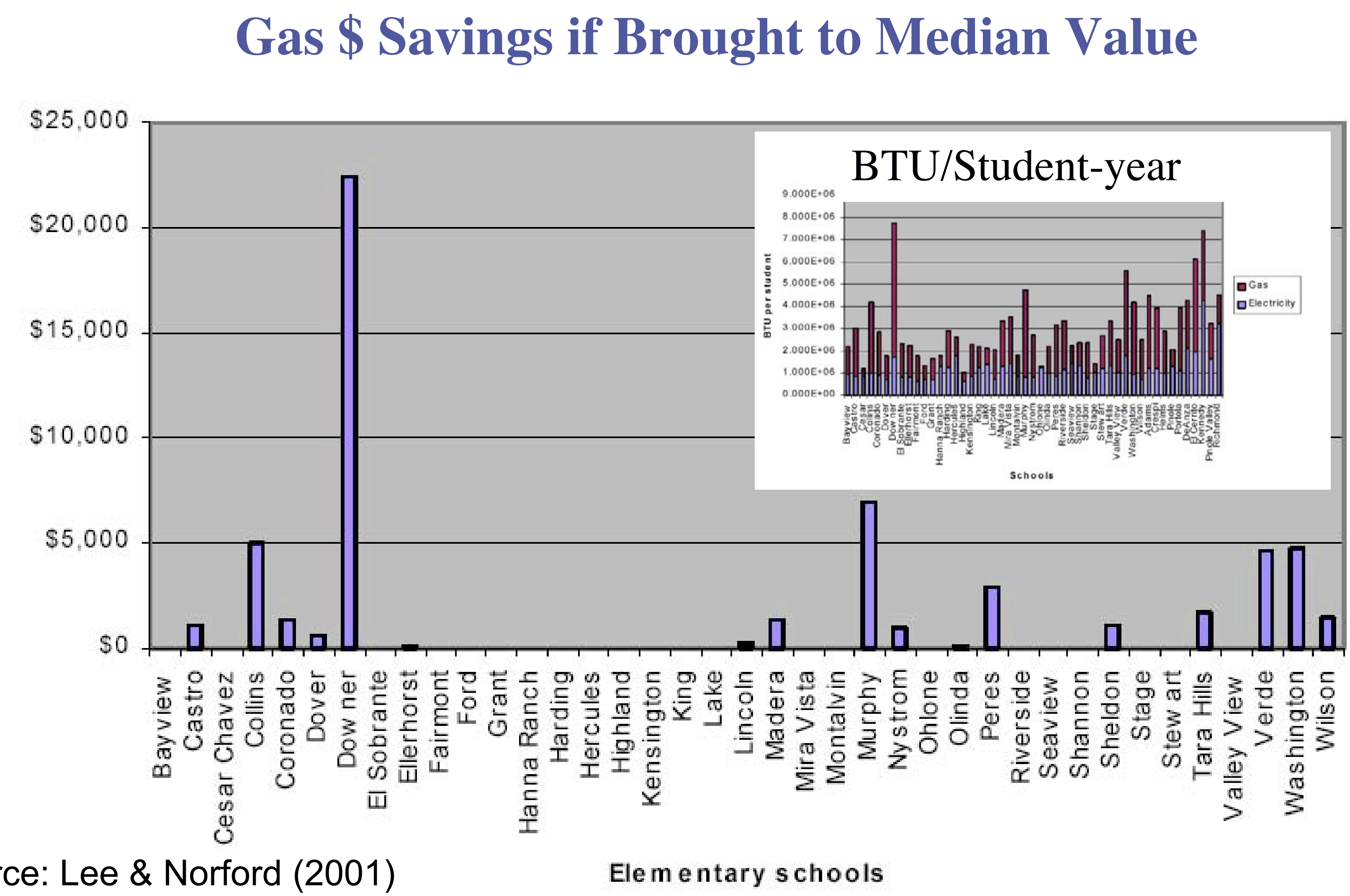
Tschudi and Xu, *ASHRAE Transactions*, KC-03-9-4 (2003)

From Benchmarking to Best Practices



Standard, good, better benchmarks as defined in
"How-low Can You go: Low-Pressure Drop Laboratory Design"
by Dale Sartor and John Weale, ASHRAE Journal

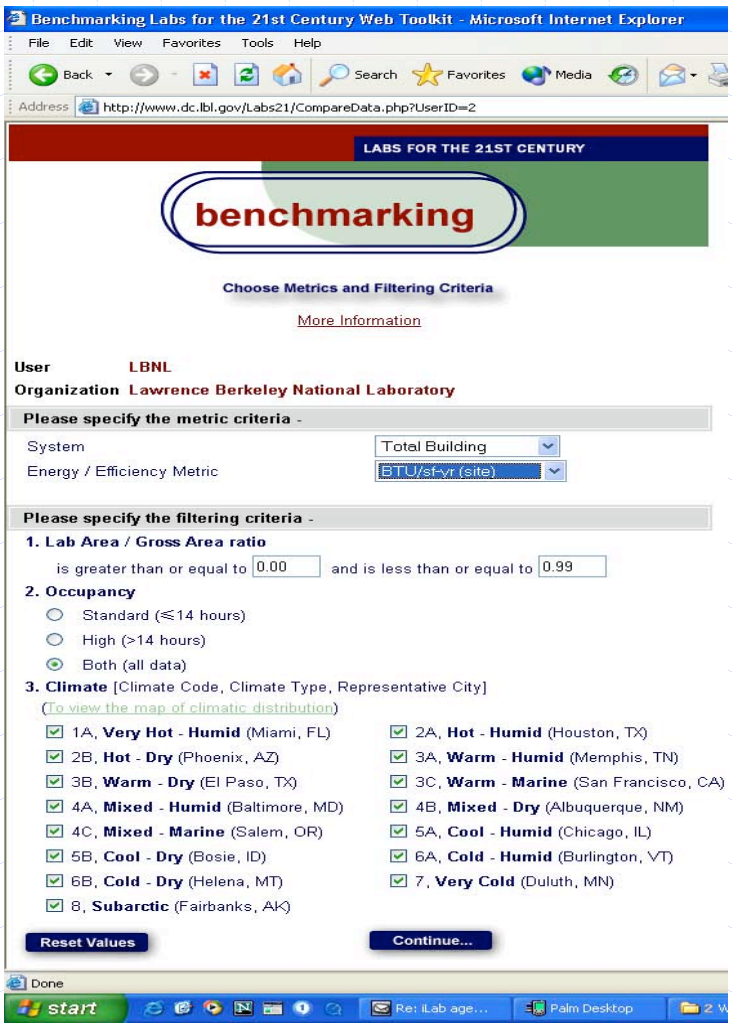
Benchmarks as Screening Tool

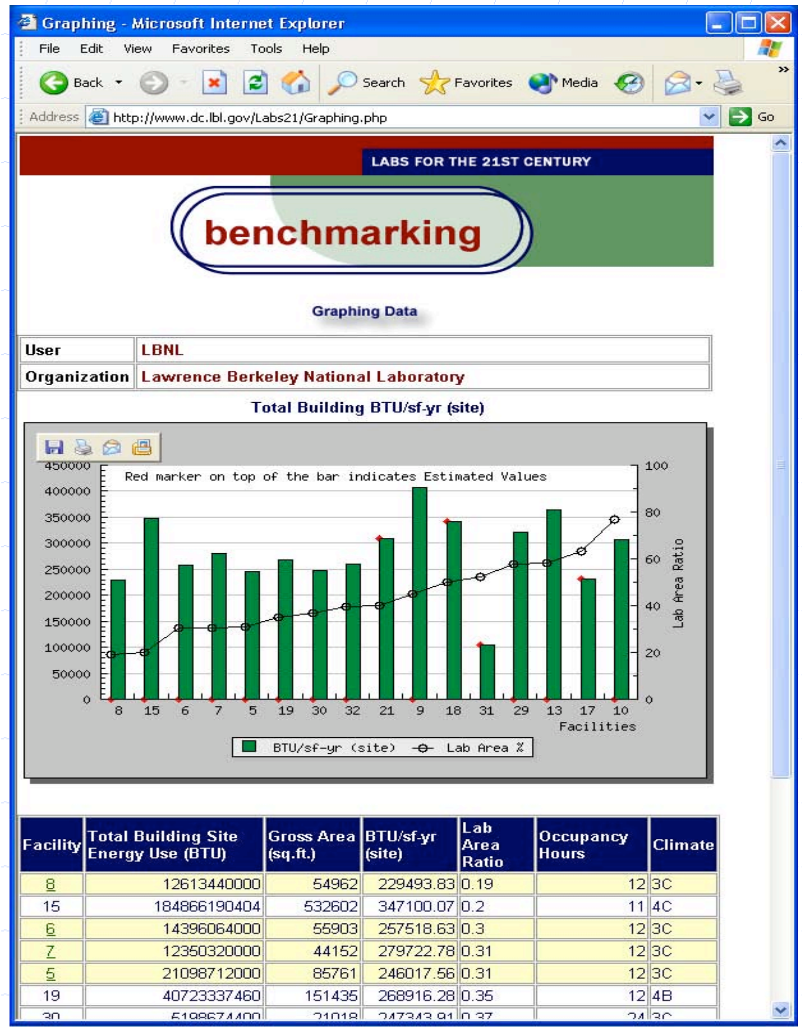


Source: Lee & Norford (2001)

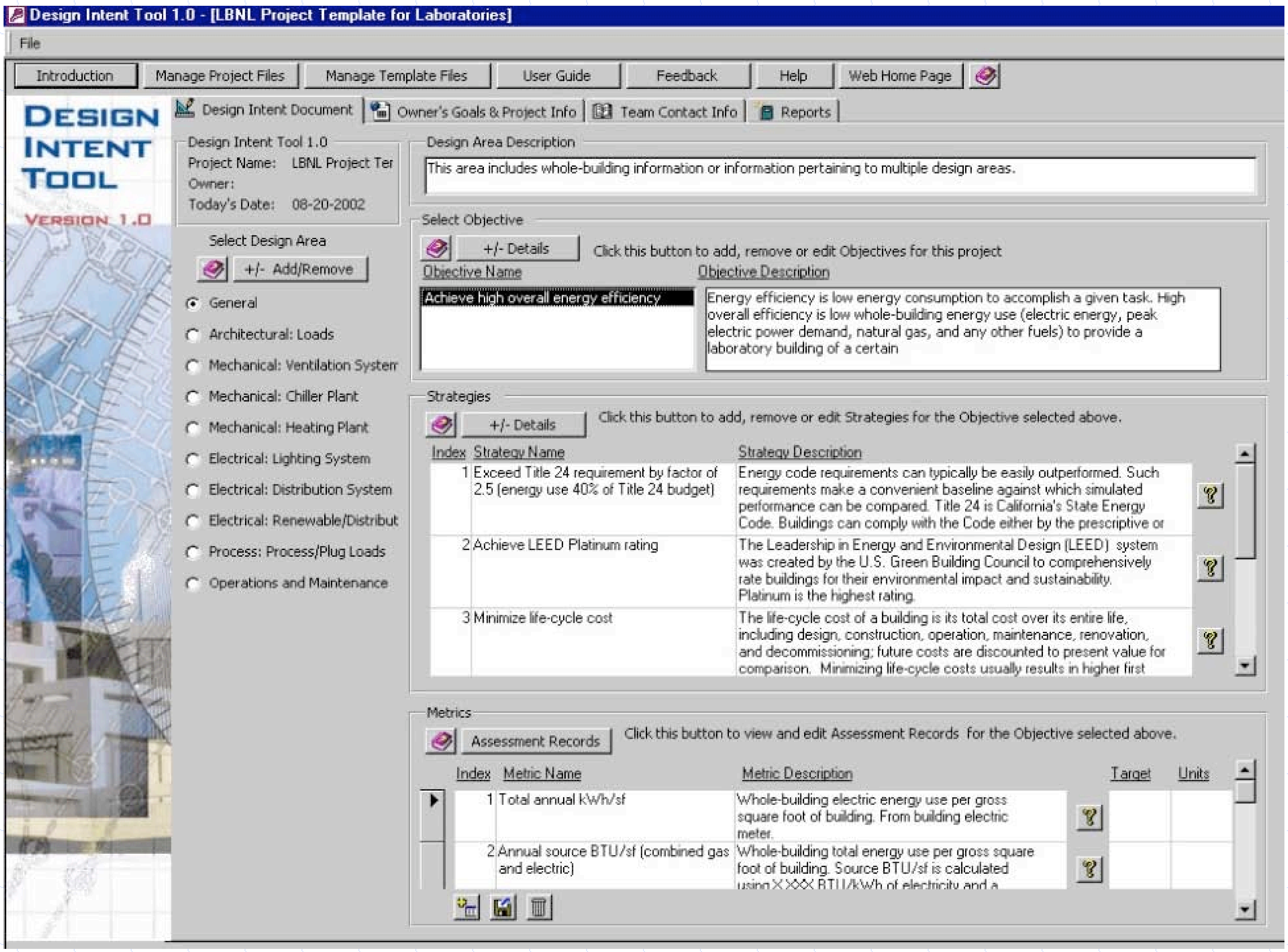
Labs21 Benchmarking Tool

Analysis



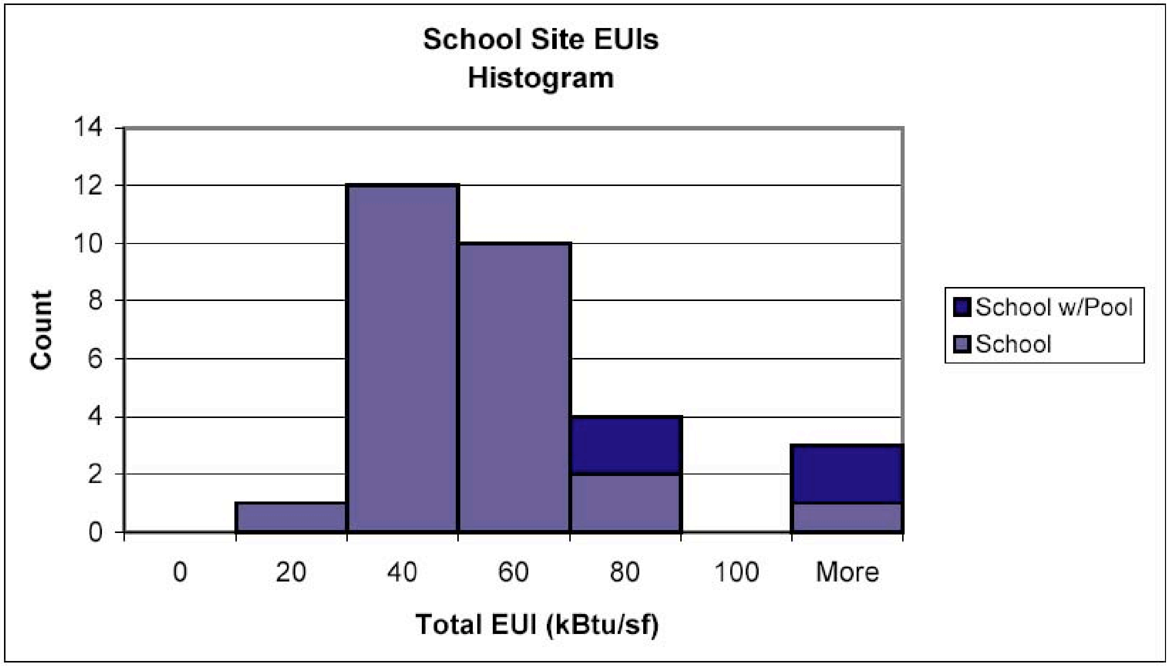


Capturing Benchmarks with Design Intent Documentation



Caveats & Pitfalls

- Intensity does not equal efficiency
- Hard to avoid apples-and-oranges comparisons (want energy per unit of service)
- Normalization
  - weather
  - floor area
  - schedule
  - plug loads
  - indoor conditions
  - energy price
  - more….



Recommendations

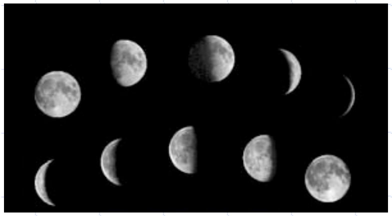
- Decide how benchmark is to be used
  - Choose type(s) of benchmarks
  - Define "figures of merit" (metrics)
  - Be creative -- think of audience
- Need practical data collection and analysis strategy
- Recognize and possibly integrate with existing <u>non-energy</u> benchmarking systems
- Benchmarking is a one-handed clap
  - A means to an end…. What will be done with the information?

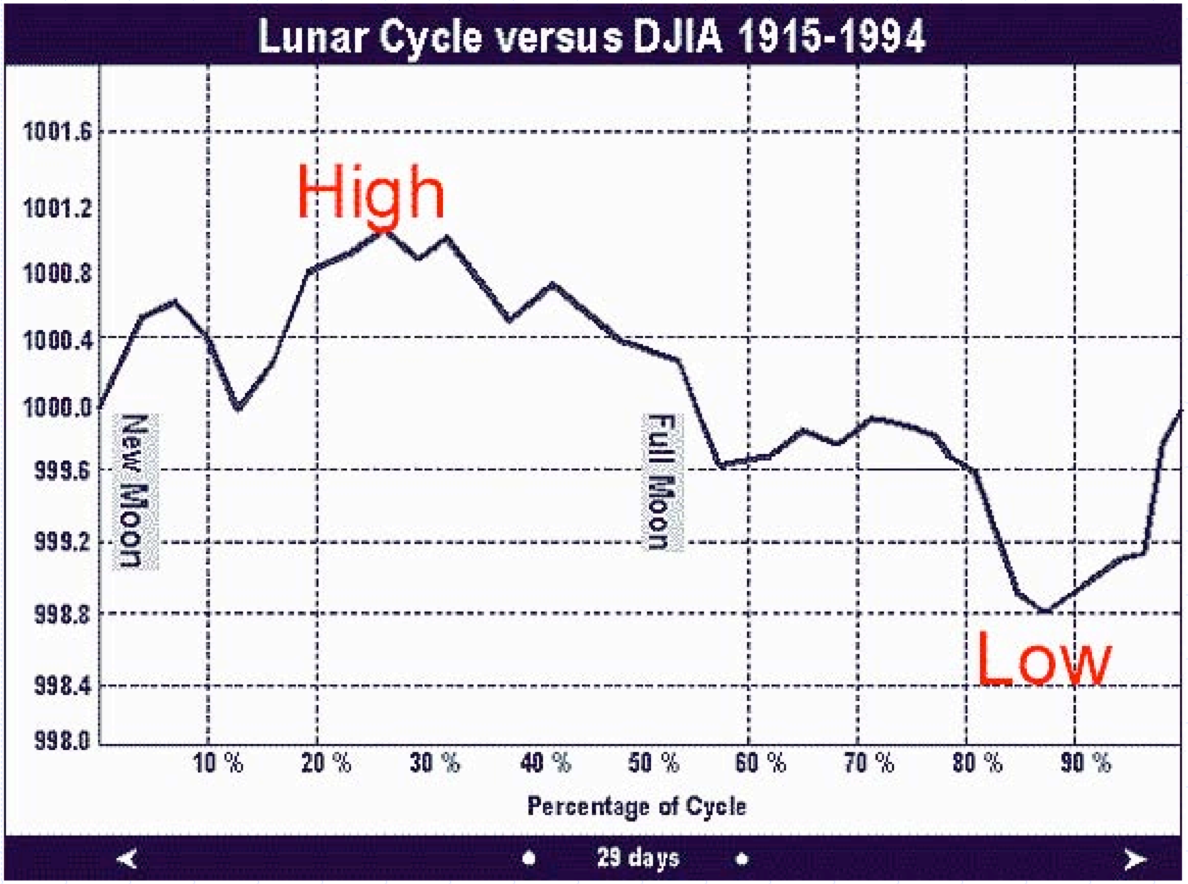
Moral of the Story

"To define an energy efficiency indicator is not only a technical challenge, but also a pre-structuring of the subsequent policy choice."

- Aebischer, et al. (2003)

Correlation is Not Causation!





Advice for Traders: “moon-trading is by no means a stand-alone approach”