Energy Conservation – Best Know Methods

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Introduction

▶Why do we need energy reduction?

- Need for sustainable development
- Public pressure – Customers and NGOs
- Legislative trends (EuP, Kyoto Protocol)
- Corporate Citizenship
  - CO_2 Reductions
- Industry Goals to improve performance
- Save Money
- Financial performance determines a company’s market capitalization

- Energy Costs for new High Volume Fab can be over $25M/year by 2012 the cost could be $75M/year.

Introduction

- Why many don't save energy
- Very risk-averse culture
  - Fab energy consumption is "so small"
  - "Copy exact" philosophy impedes innovation
- Organizational issues
  - Barriers and tribal behavior between process/manufacturing & facilities
  - Nobody owns losses or gets rewarded for savings
  - Schedule: there's never a good time to design for efficiency
- Lack of regulatory pressure
- Key data are seldom measured or displayed
  - Only a few fabs in the world accurately measure their energy consumption; therefore progress is hard to measure
- Energy reduction is always priority #2


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101 WAYS TO Conserve Energy
Gas-energy Prices Skyrocket
ED FISCHER

Semiconductor Industry Position

- A joint White Paper (White Paper for Energy Conservation on Equipment) was agreed to by WSC and SEMI in 9th meeting of WSC, May 2005
- The WSC believes that the *efficient utilization of energy resources* is an important factor in the realization of cost effective manufacturing for both semiconductor makers and their suppliers,
- The WSC recognizes that strategic suppliers in the semiconductor industry have important roles to play in the achievement of *energy-saving targets*, and has been working with suppliers to solve various problems in this area.
- *Best practices are shared* as part of the effort to reduce energy use across the industry.
- **Results:** 2001 to 2005: >100% growth in silicon produced, 10% absolute increase and 23% reduction in normalized energy consumption

Savings begin with measurement

- ▶WSC Data: Best in Class Performance to Worst: 54× range of kWh/cm^2
- ▶One fab's rated chilled-water-plant COP varied so widely that the worst fab's was 42% below the best fab's, despite having a less difficult climate
- ▶Only one fab's chilled-water plant was measured; it averaged 21% below its rated COP. Only actual measured performance counts, not claims or guesses!
- ▶That best COP was >20% below the BIC for hot/humid climates (6.54 or 0.54 kW/t), which costs less to build
  - With dual chilled-water temperature, such as 5.5˚C and 15˚C, the BIC for the whole system is COP 7.5 (0.47 kW/t)
- ▶Those fabs' owner was losing well over $1M/yr just by not sharing its own best practice among its fabs

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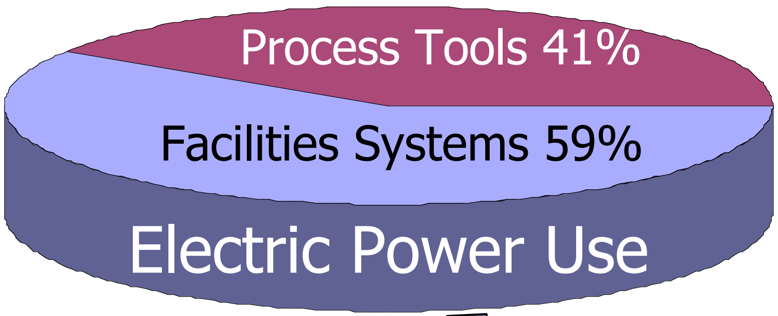
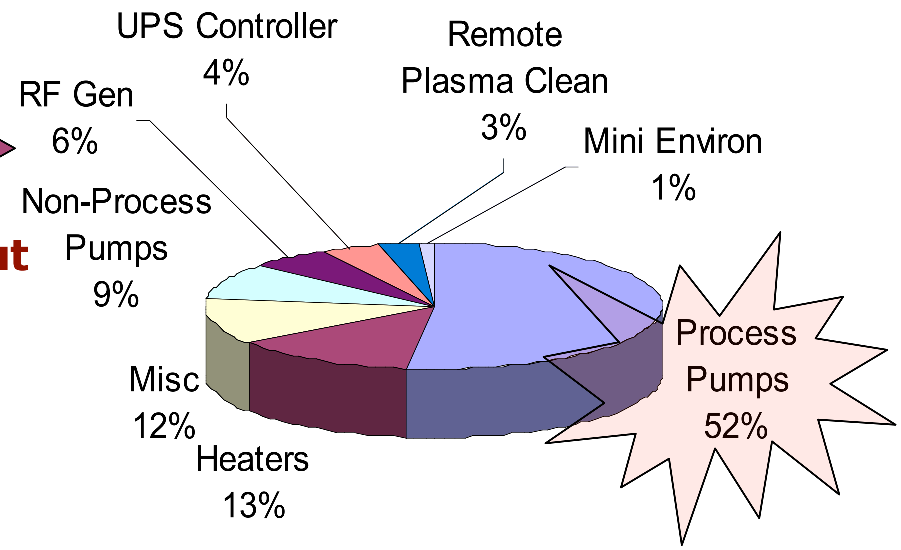
Typical Texas Fab Energy

Sematech (14 fabs)

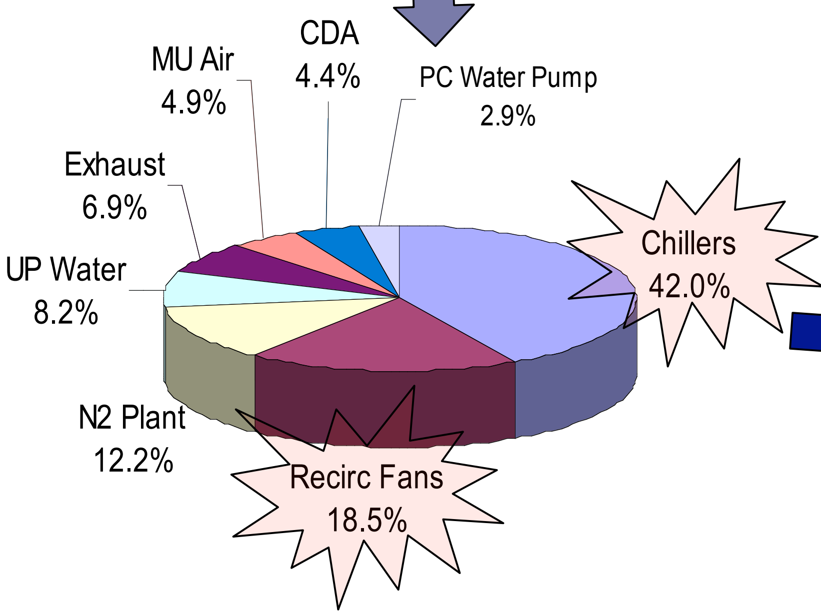
Newer 300mm fabs are moving closer to a 50% / 50% ratio.



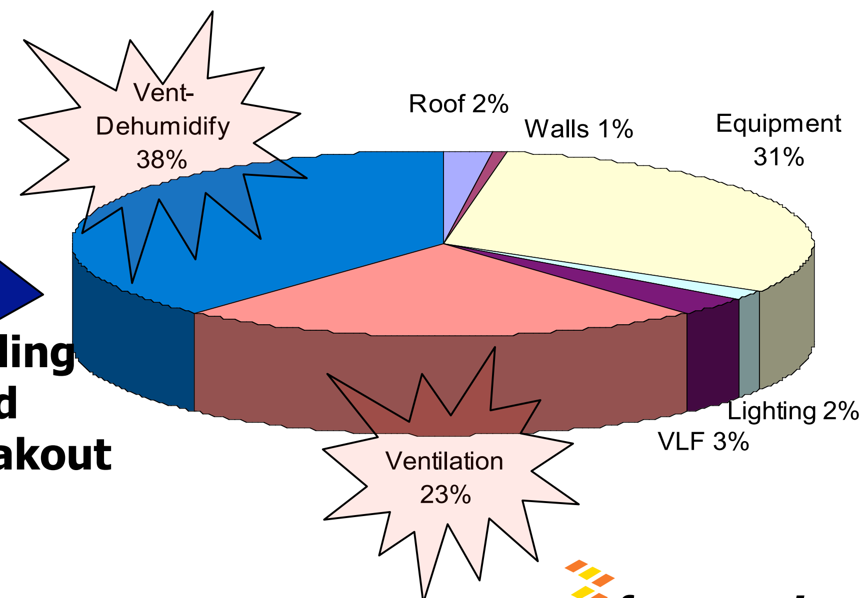
Process Breakout



Facilities Breakout



Cooling Load Breakout



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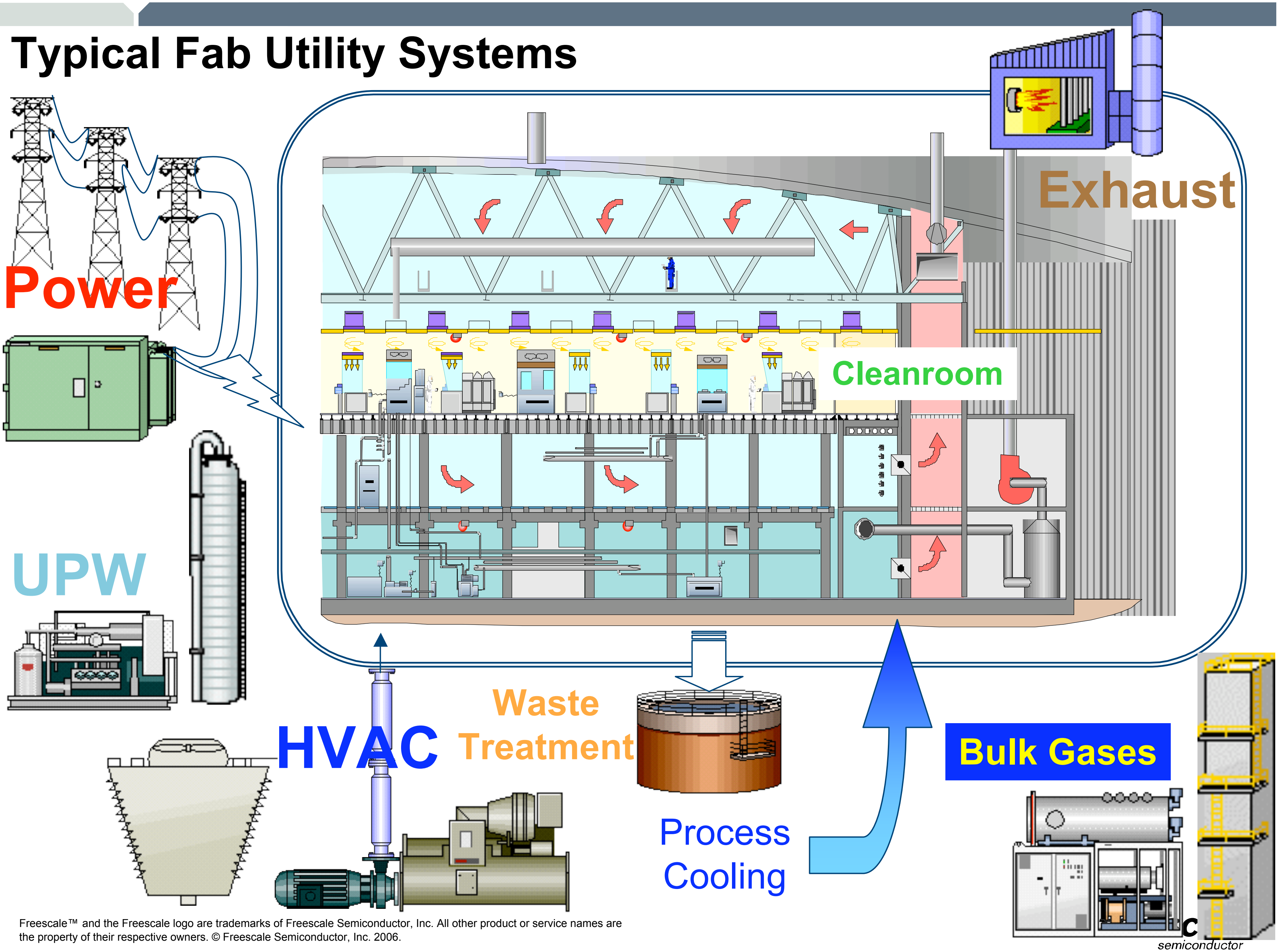
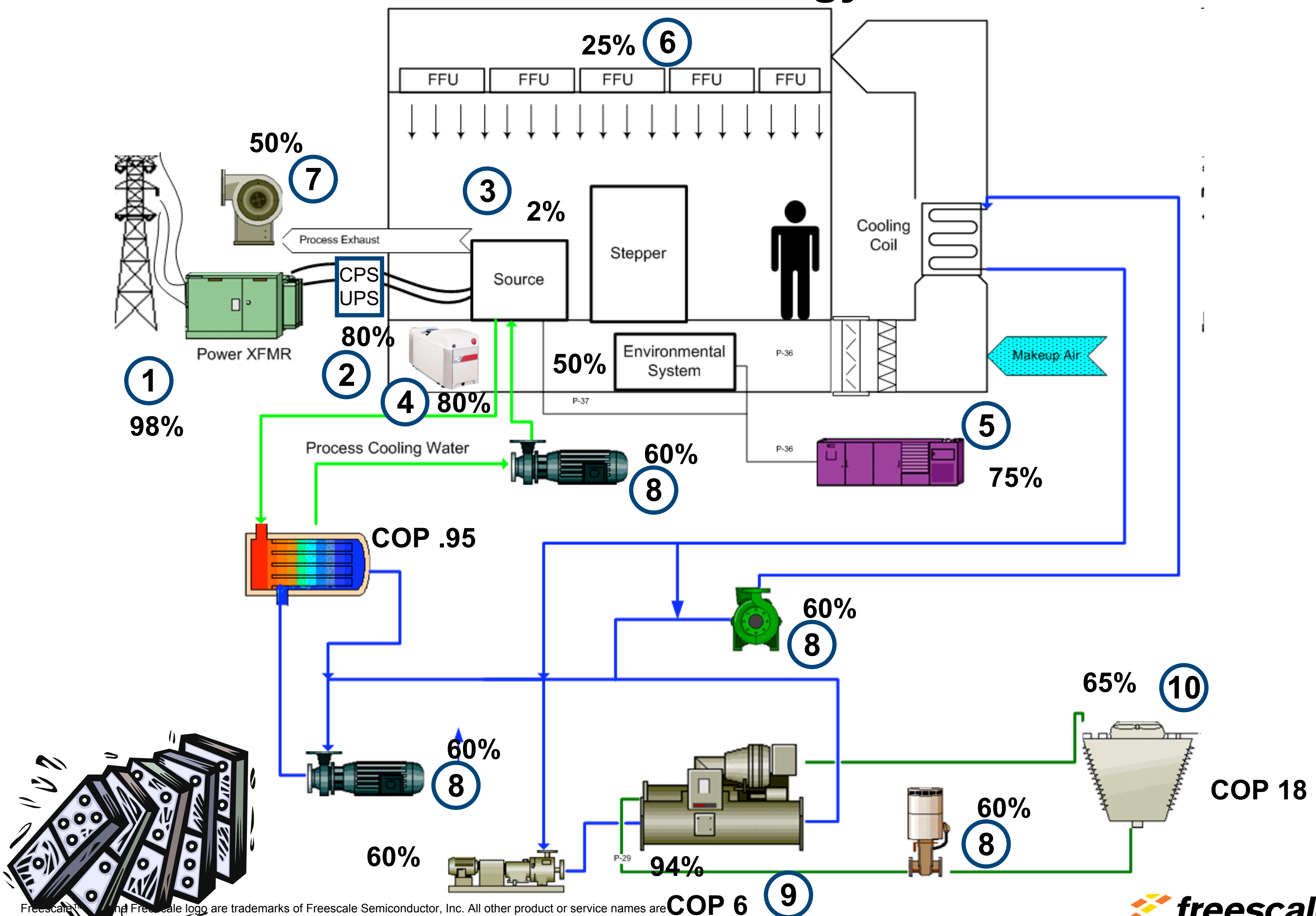
Typical Fab Utility Systems



Energy Path and Efficiencies



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What's Efficiency Worth Over 20 years?

- ▶Example: A typical microchip factory, at 5.9¢/kWh:
- ▶1 watt of cleanroom heat = $0.7/yr operating cost, + HVAC capital cost = >$11 in 20-yr present value
  - Typical Fab contains 8,000,000 watts of heat
- ▶Each percentage point of efficiency increase in a 1-hp continuous-duty motor = $7/yr = $84 PV
  - Typical fab contains > 15,000 HP in motors
- ▶Fan towers: 1 Pa (0.0040"w.g.) of avoided pressure drop = $870/y = $10,800 in 20-yr present value (PV)
  - Typical Fab Fan Tower Pressure is 400 Pa
- ▶1 m^3/h (0.6 cfm) cleanroom exhaust = $3/yr = $40 PV
  - Typical Fab moves > 500,000 m^3/h of exhaust

Some of the biggest retrofit savings are the simplest

- ▶Turn off things you're not using
- ▶Run existing cooling towers properly—run all towers all the time at variable speed
  - Big slow fans use far less energy than slow fast fans
- ▶Use "free cooling": Savings from hot streams and cold streams can be easily recovered with savings <50%
- ▶Having all PCs go to standby mode: >70% savings compared to no standby
- ▶Accurately designing for actual equipment loads

Losses multiply

- ▶Fab designers typically assume that tools will use ~2–5x more energy than they actually use
- ▶Typical tool duty ~0.3–0.4; load diversity is ignored
- ▶Phantom loads mean hundreds of extra tons ($2k/ton capital cost) and incur HVAC part-load penalties
- ▶Inflated loads mean deep coils, big pressure drops, oversized fans (heating air as much as tools do!)
- ▶Bigger fans, coils, silencers, chillers, towers, pipes, valves, ducts, motors, electricals, land, foundations, UPS & losses,…HENCE CAPITAL COST
- ▶More filters, resins, O&M, noise, insurance,....

Saving 1–2% of total costs matters

- Saved energy costs, like any saved overhead, drop straight to the bottom line

- Basic energy efficiency retrofits can often add one percentage *point* to total net profit

- If new chip sales earn (say) 10% profit, then saving $1 worth of energy increases profits by the same as $10 of new sales—harder and less certain (especially nowadays) than saving energy!

- If you're short of capital, *don't waste it* on oversized and overcomplex utility plant

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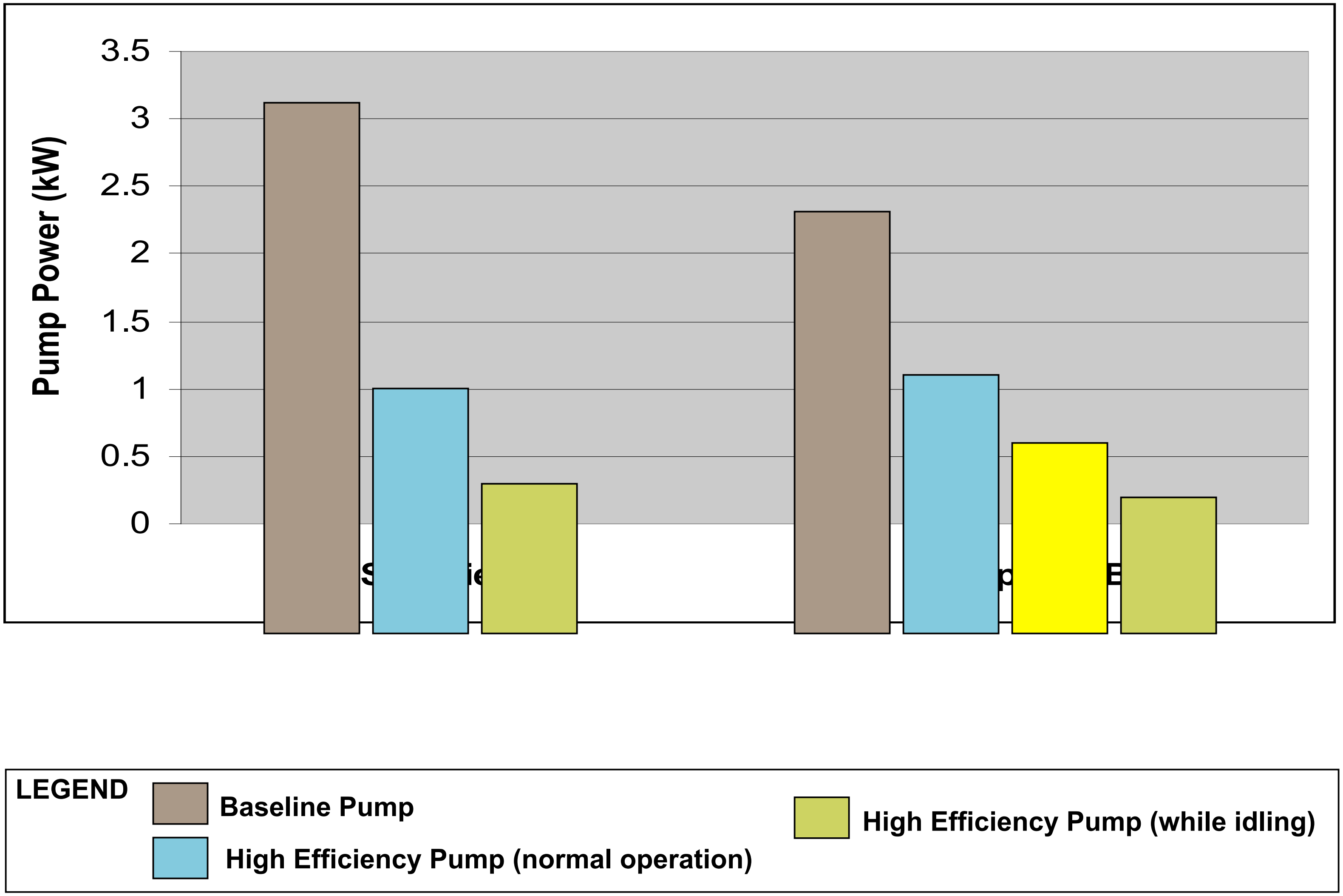
In the Fab Savings

- ▶CRT to Flat Panel Conversions
  - 20X reduction of replacement cost with respect to tool vendor.
  - Lower power consumption. (Average 17” CRT uses 80 watts while the equivalent LCD uses 35 watts)
  - Building cooling load reduction per monitor is an additional 20% in addition to the electrical savings.
  - Quantity of lead in a CRT is 6-7lbs while LCDs have 0.1lbs
- ▶Compressor water chillers to solid state water chillers
  - 10X Lower energy usage than Freon
  - 10X More precise process temperature control
  - >2X Better reliability
  - >3X Smaller size and lighter weight
  - Compressor Chillers Always Run at Full Power
  - Compressor Chillers Sized for the Worst Case Scenario

High Efficiency Vacuum Pumps and Idle Mode Implementation



Both tests were performed at ISMI member company fabs; Test A pumps from same supplier; Test B pumps from different suppliers

Factory Wide Application of Tool Idle Mode

▶New Fab Assumptions.

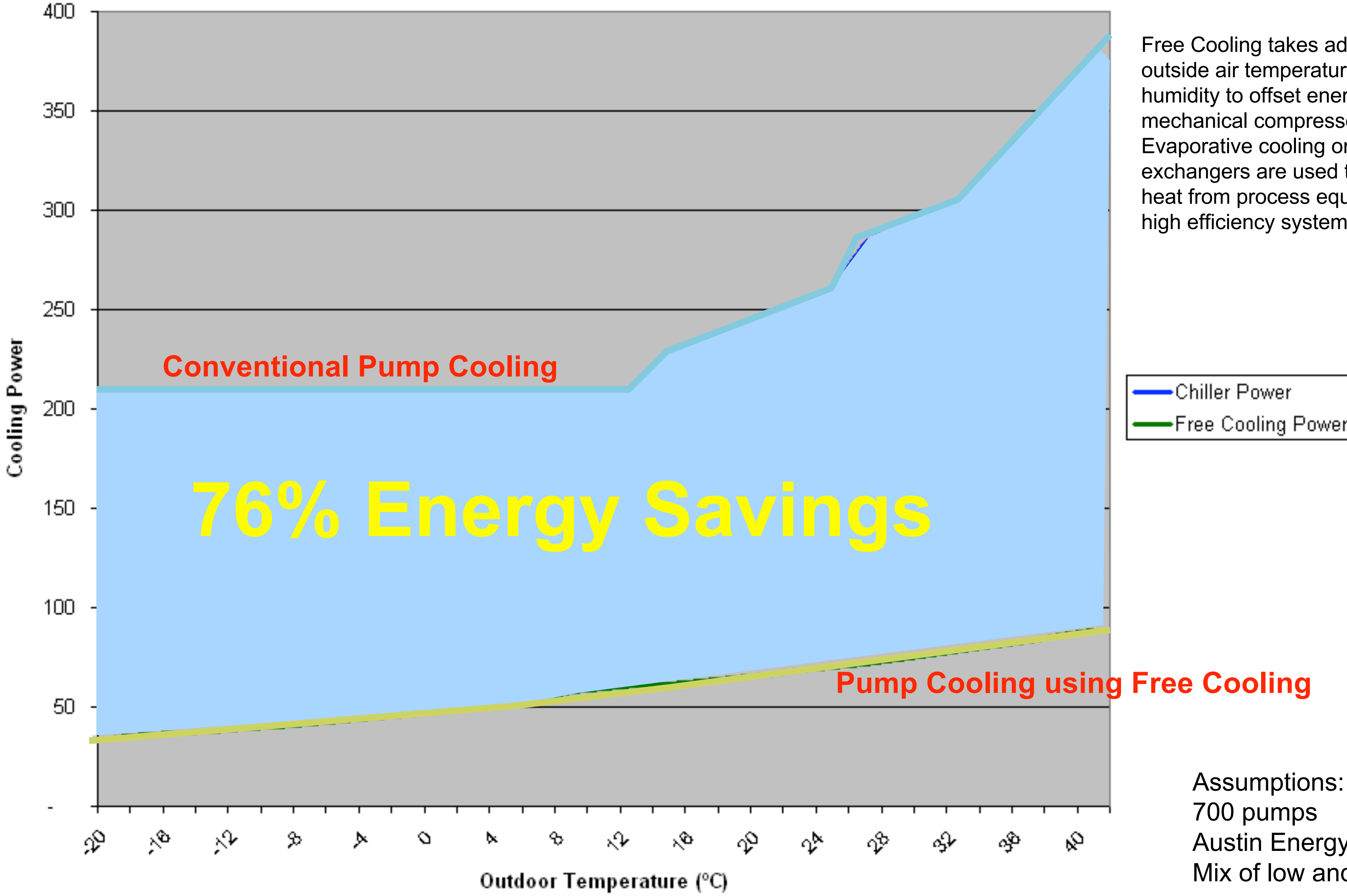
- 40K Wafer Starts per Month
- 50 MW Power demand and 300M kWh/ year energy
- Equipment Utilization rate of 90% with 20% for concurrent idle opportunity*
- Cost of power $0.06/kWh**

▶Results

- Fab Total Annual Power Cost: $20,000,000
- Estimate Idle Mode Savings:
- Impact to fab
  - Direct Equipment Energy Savings – $2M
  - Air Conditioning Savings – $500K
  - Nitrogen Cost – $350K***
- TOTAL SAVINGS POTENTIAL- $2.85M per Year

* Concurrent idle – equipment may be processing but idle states exist for some components
** Cost of power is based upon estimate of worldwide average
*** Nitrogen savings will be dependent upon contract type and may not be realized for all factories

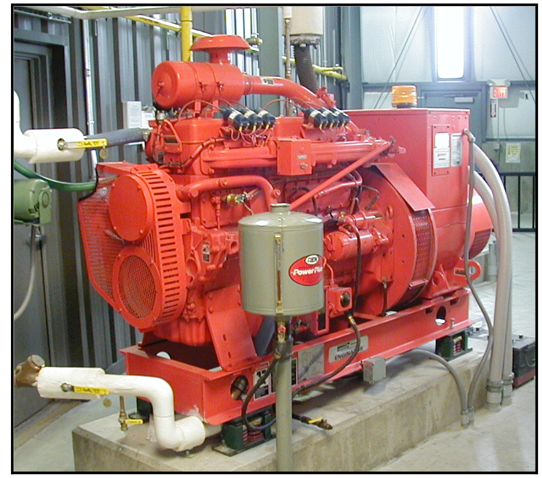
Potential Free Cooling Savings: Vacuum Pump Cooling



Free Cooling takes advantage of outside air temperature and humidity to offset energy used by mechanical compressors. Evaporative cooling or heat exchangers are used to transfer heat from process equipment to high efficiency systems

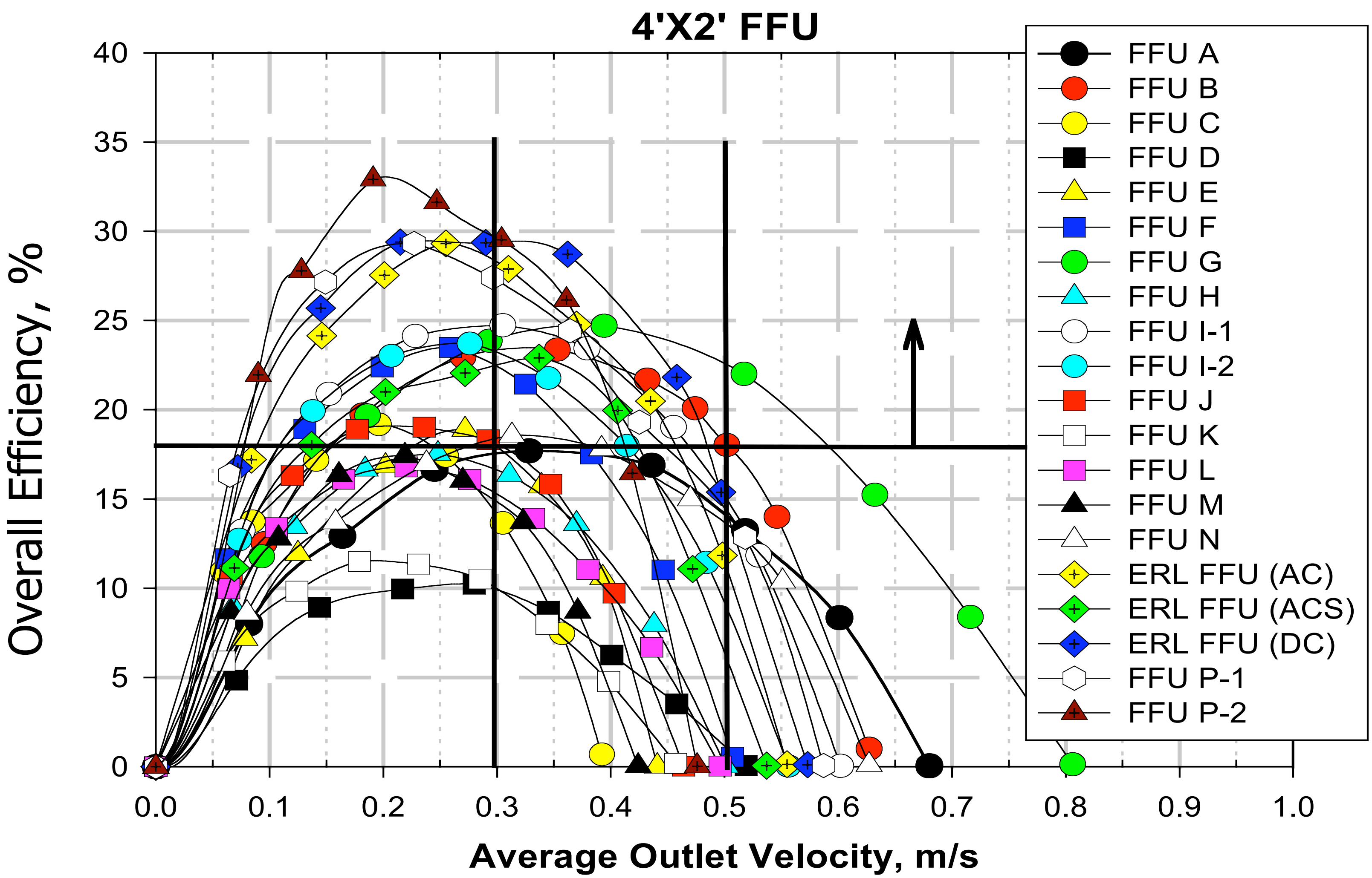
Assumptions:
700 pumps
Austin Energy Profile
Mix of low and high energy vacuum pumps

Standby Generation Losses



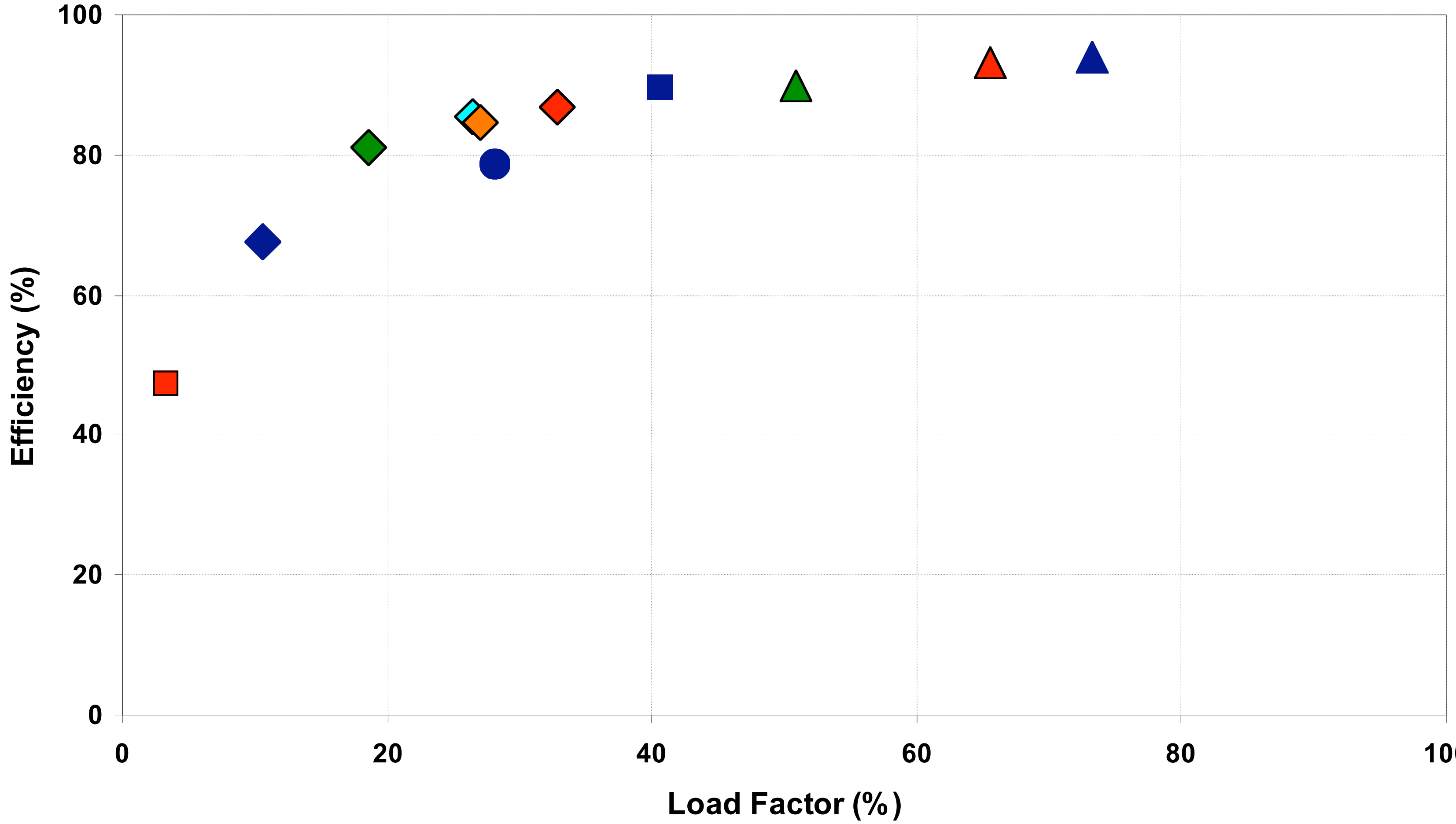
- Several Sources
  - Heaters
  - Battery chargers
  - Transfer switches
  - Fuel management systems
- Heaters alone (many operation hours) use more electricity than produced by the generator (few operating hours)
- May be possible to eliminate heaters, batteries, and chargers or too optimize use

Fan-Filter Unit Testing



UPS Systems

UPS System Benchmarking*



SEMATECH Company Energy Conservation Projects

PROJECT DESCRIPTION	Annual Savings per Fab
▶Cleanroom Laminar flow velocity reduction to 70 fpm ………………	$250K to $1M
▶Air handler unit (AHU) optimization ……………………………...........	$150K to $1M
▶Space cooling/heating optimization (temperature set point adjustment, free cooling)…………………………………………	$50K to $200K
▶Chilled water plant optimization…………………………..................	$50K to $200K
▶UPW city water make-up heating with condenser water……….……..	$600K to $1M
▶Auto boiler temperature control tied to weather conditions…………...	$100K to 500K
▶VOC optimization (temp reduction, waste heat recovery)……………	$200K to $400K
▶Tool utility optimization (reduce exhaust, increase PCW delta T, reduce N2, replace N2 with CDA, POU abatement)…..........................	$50K to $1M
▶CDA optimization (raise dew point from -100 ºF to - 40ºF)…………	$15K to $50K
▶Process utilities piping leakage and wastage elimination……………	$35K to $75K
▶Lighting optimization…………………………………………………	$25K to $10K
▶DI Water - Replace CA R/O with TF membranes ……………………	$300K to $1M

World Semiconductor Savings Potential

- Estimated world wide savings if all best practices were implemented*
- 2004 World Wide Demand:
  - Direct Tool Energy: 14.9×10^9 kWh
  - Support Systems (e.g. facilities) 18.1×10^9 kWh

- Direct tool savings 3.0×10^9 kWh
- Facility System Savings 1.8×10^9 kWh
- Total Savings 4.8×10^9 kWh
  - Almost 300,000 metric tons of C02

World Semiconductor Savings Potential According to ITRS

- Estimated world wide savings if all best practices were implemented*
- 2005 World Wide Demand:
  - Silicon demand: 34.9×10^9 cm^2
  - ITRS energy demand 1.4 kWh/cm^2
- 2015 Estimated demand
  - Silicon demand: 66.6×10^9 cm^2
  - ITRS energy demand 0.7 kWh/cm^2
- Potential Savings Compare to no improvements 46×10^9 kWh

Solving for pattern

- You know you’re on the right track when your solution for one problem accidentally solves several others.
  - — Paul Westbrook
- Avoiding problems is even better than solving them.
  - — Amory Lovins
- All the really important design errors are made on the first day.
  - — Design proverb