Disruptive tech experience: Surprises during monitoring

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Overview

- Purpose: generating *actual, verifiable* energy savings.
- Energy M & V and Commissioning is an *investment*, not an expense.
- Focus: what is cost-effective?
- This shows “lessons learned”.

Summary of main points

- 1. Energy-saving opportunities abound, including many "1-yr paybacks".
- 2. To achieve actual, verifiable energy savings, commissioning is necessary.
- 3. To achieve actual, verifiable energy savings, energy analysis (M&V) is necessary.
- 4. Daily energy analysis (diagnostic) is best.
- 5. Temperature baselines are usually best.

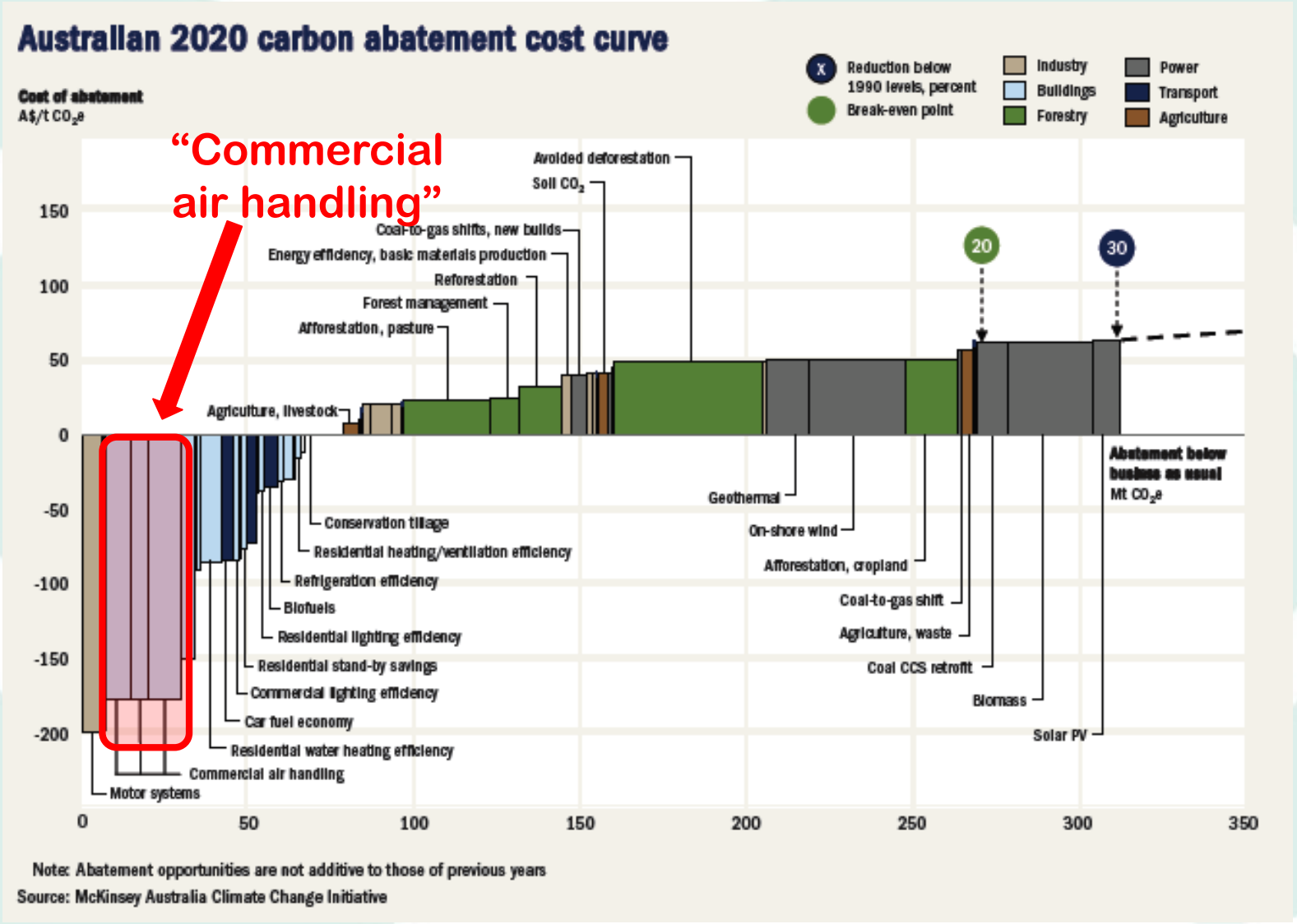
Main points (continued)

- 6. % savings (from baseline) is the best metric.
- 7. Don't assume meters are correct.
- 8. Don't assume controls are correct.
- 9. Better metering (TOU gas meters) is normally cost-effective.
- 10. Most HVAC problems / opportunities are hidden; comfort problems = opportunities.

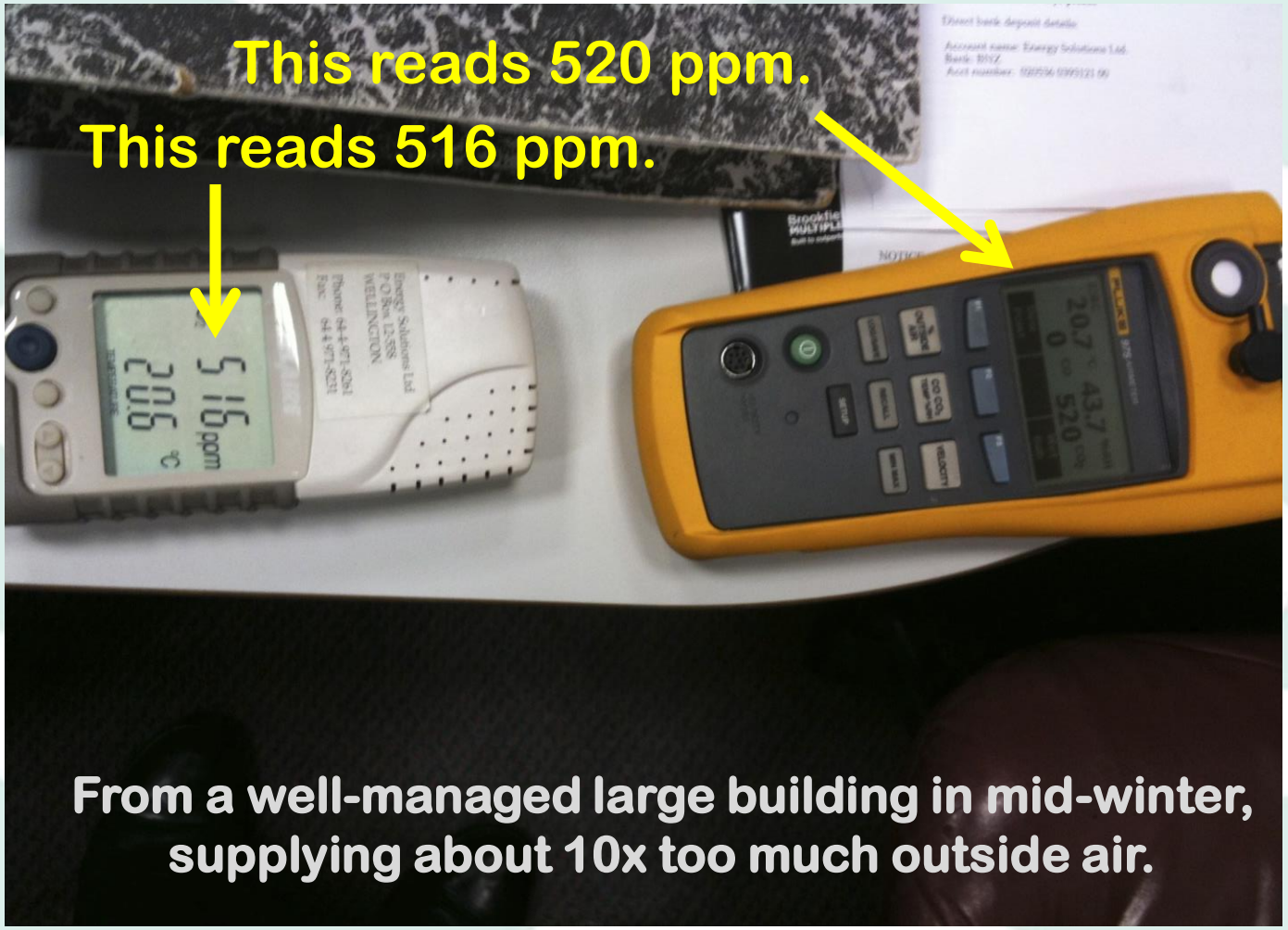
1. Savings opportunities abound

- There are many long lists of potential energy savings measures.
- Wulfinghoff manual lists over 400 generally cost-effective savings opportunities
- Most svgs come from a short list of measures
  - OA optimisation
  - Reducing supplied heating in summer
  - Reducing supplied cooling in winter

“Negative-cost” emission reductions



Ventilation control of OA



"Outside air control – the most cost-effective energy efficiency measure of all" - R. Bishop, EMANZ conference 2015

Savings Potential by End-Use

- Shown as cost effective in E Source analysis (1989-93)
  - Lighting 90%
  - Heating 90%
  - Cooling 90%
  - Appliances 75%
  - Motors 40%

Compared to new U.S. buildings, early 1990's

(IF - you do everything right the first time)

Savings opportunities (cont'd)

- Projects with paybacks under ½ year aren't normally done correctly.
  - Normally these are operational / control, and need proper commissioning to work right.
  - So, add commissioning cost to get up to ½ year SPB
- EUI / EnPI indicates svgs potential.
  - More complicated buildings -> higher EnPIs, but also more savings opportunities.

Unusual savings opportunities

- An electricity-intensive factory ignored their compressed air services.
  - Estimated savings = 1 GWh/yr at 0.5 yr SPB
- Transformers were 40+ years old, noisy and hot
  - Estimated as only ~95% efficient
  - New ones were 99+% efficient
  - Estimated savings = 3 GWh/yr @ 3yr SPB
  - One failed, with a 6 month replacement time.

2. Commissioning is necessary, cost-effective

- Energy commissioning is an investment, not an expense, necessary for project success.
- ESPECIALLY for low cost operational savings, too low a budget often compromises results.
- "Metering projects have a 90% failure rate"
- Some follow-up is NECESSARY to get projects to actually save energy.

Commissioning cost-effectiveness

- Lawrence Berkeley National Laboratory analysed ~100 US HVAC retro-commissioning projects
- **On average, 15% energy savings** (whole-building) were achieved from existing building commissioning
- Median "Payback": 0.7 years
- Non-energy benefits: $2.70/sq.m.

- Reference: The Cost-Effectiveness of Commercial Buildings Commissioning, Evan Mills, et.al., Lawrence Berkeley National Laboratory, November 2004.

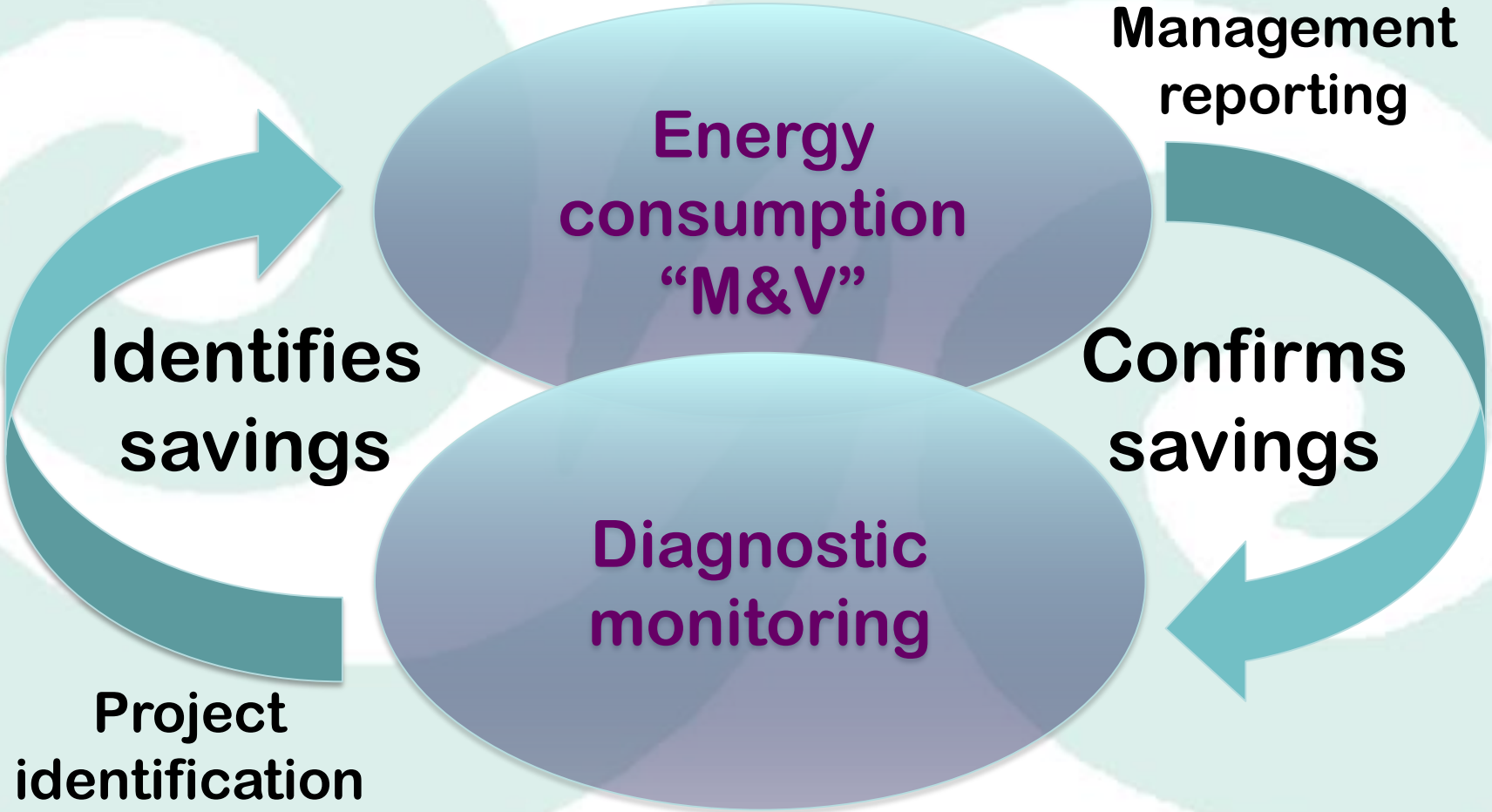
3. Energy analysis (M&V) is necessary, cost-effective

- The most important factor in improving energy performance is:

REGULAR ANALYSIS OF ENERGY DATA

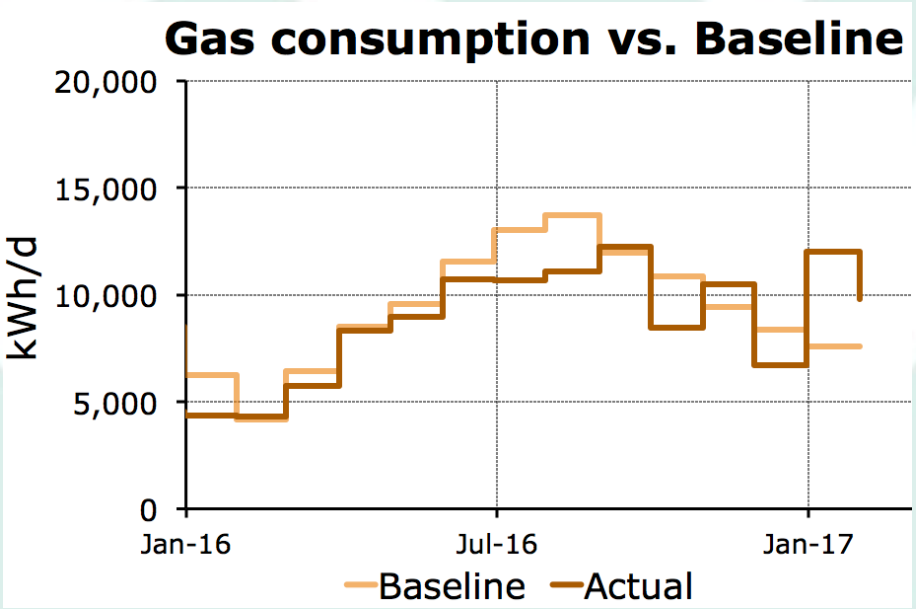
- Source: Eli Court (ClimateWorks Australia) at 2015 EMANZ conference.

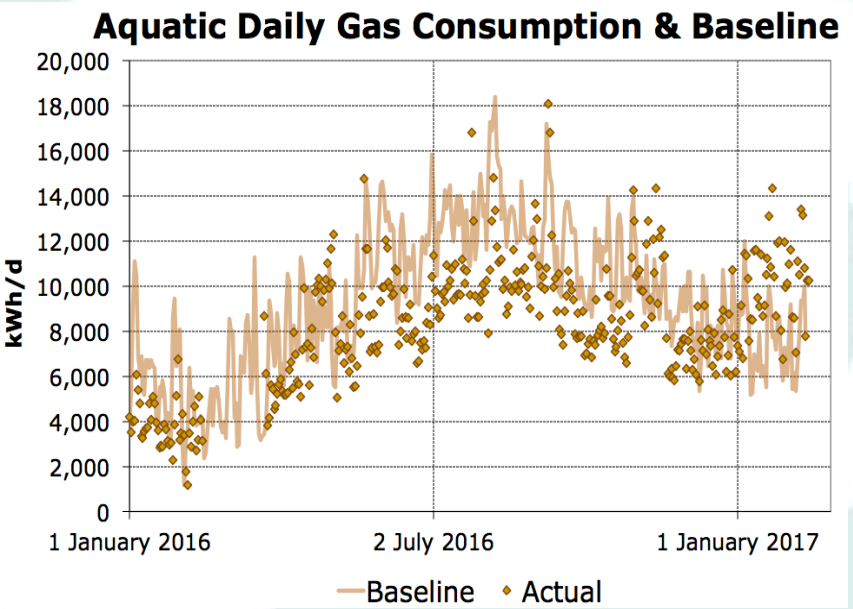
Two main components of energy analysis



4. Daily energy analysis is best

- Monthly analysis is simple, using invoice data.
- These two graphs show the same data.



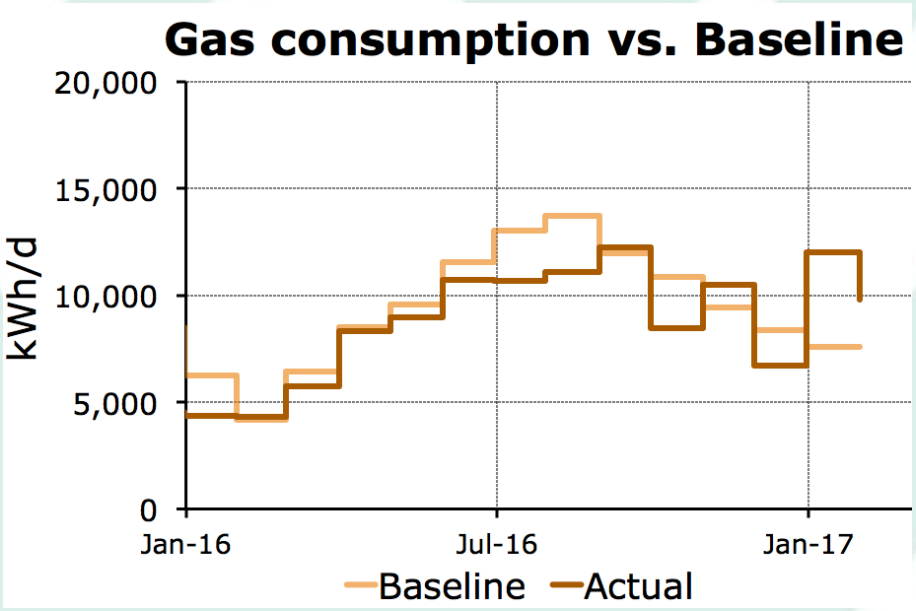


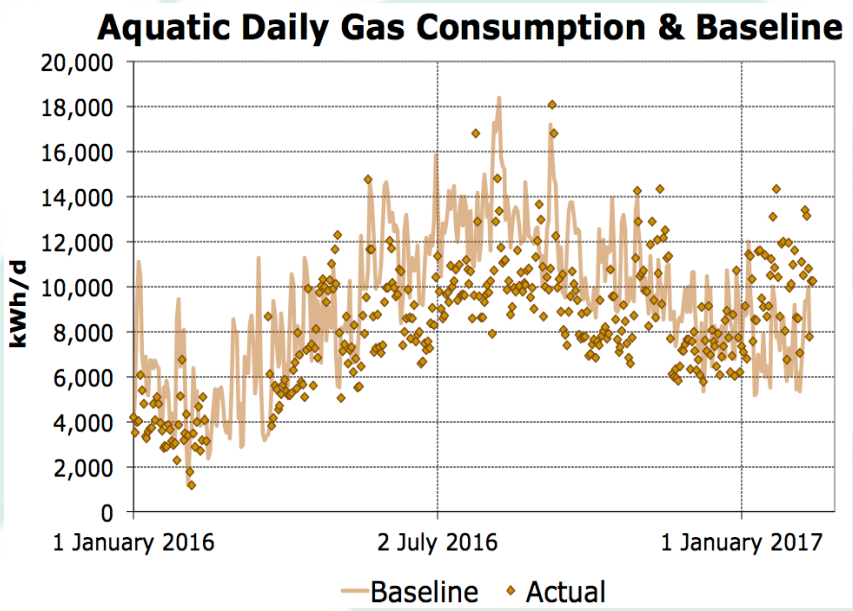
- Monthly is easier to read, at first glance.

Daily energy analysis advantage

When a problem occurs (as in Jan 2017)…

With monthly data/analysis only, the higher consumption may be just a one-off "glitch".

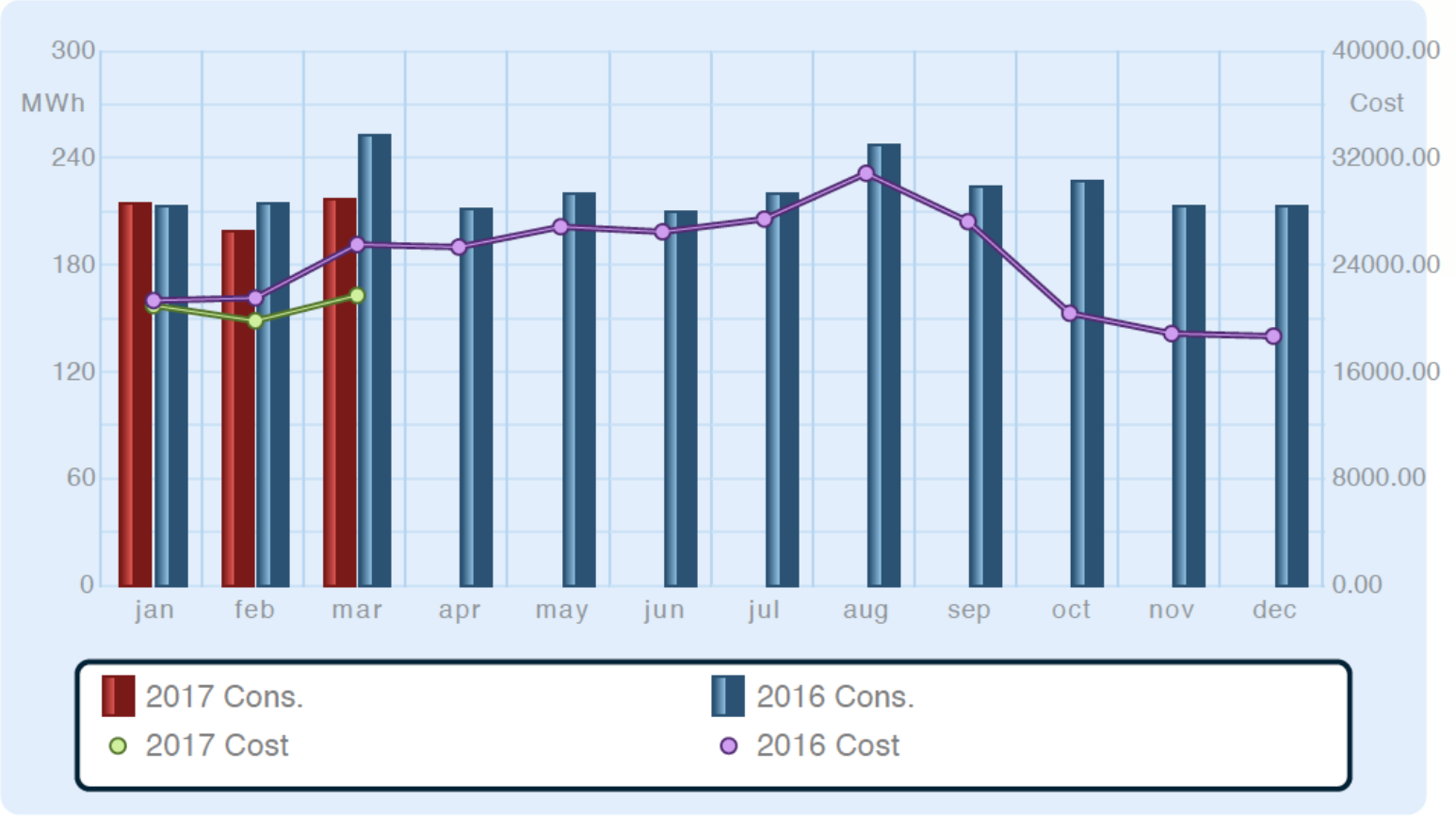




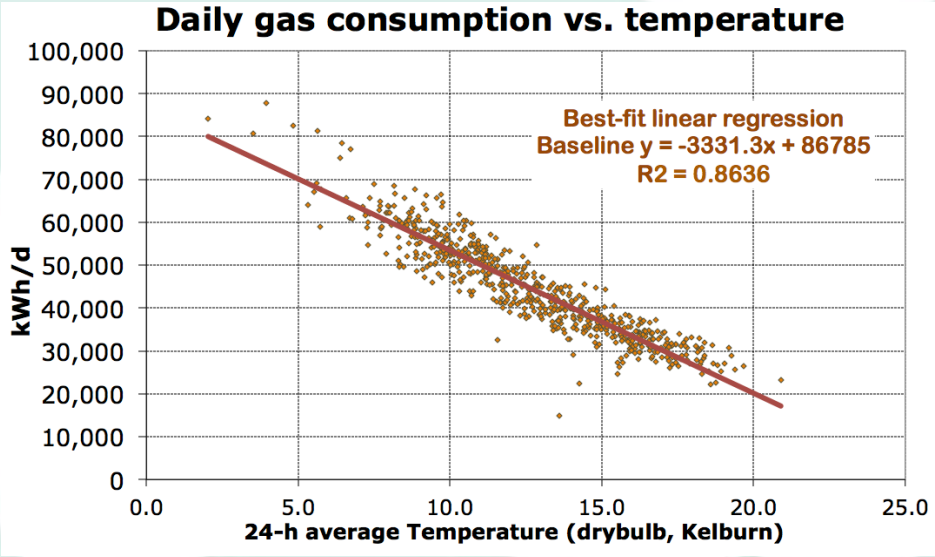
But daily analysis shows it's consistent, problem.

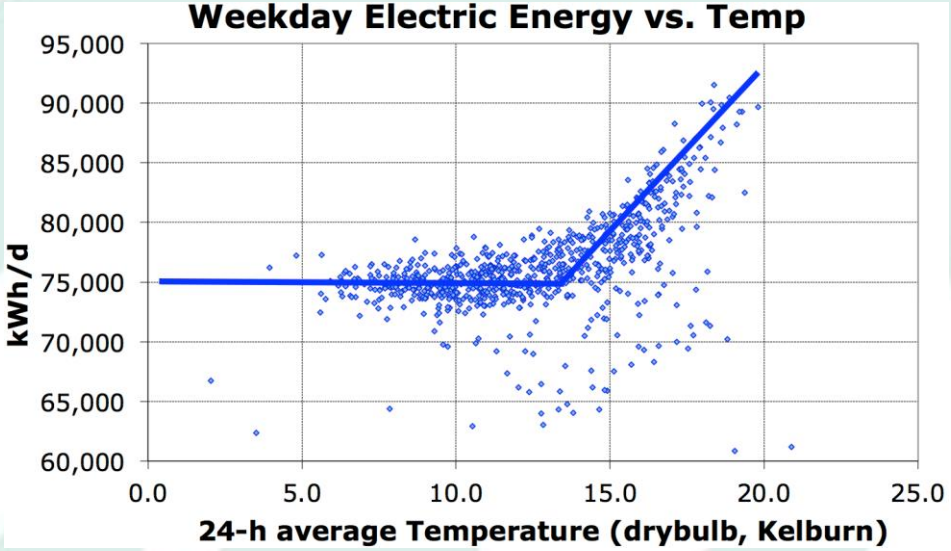
5. Temperature-adjusted baselines are best

- Most energy monitoring just shows this month's consumption vs. same month, previous year.



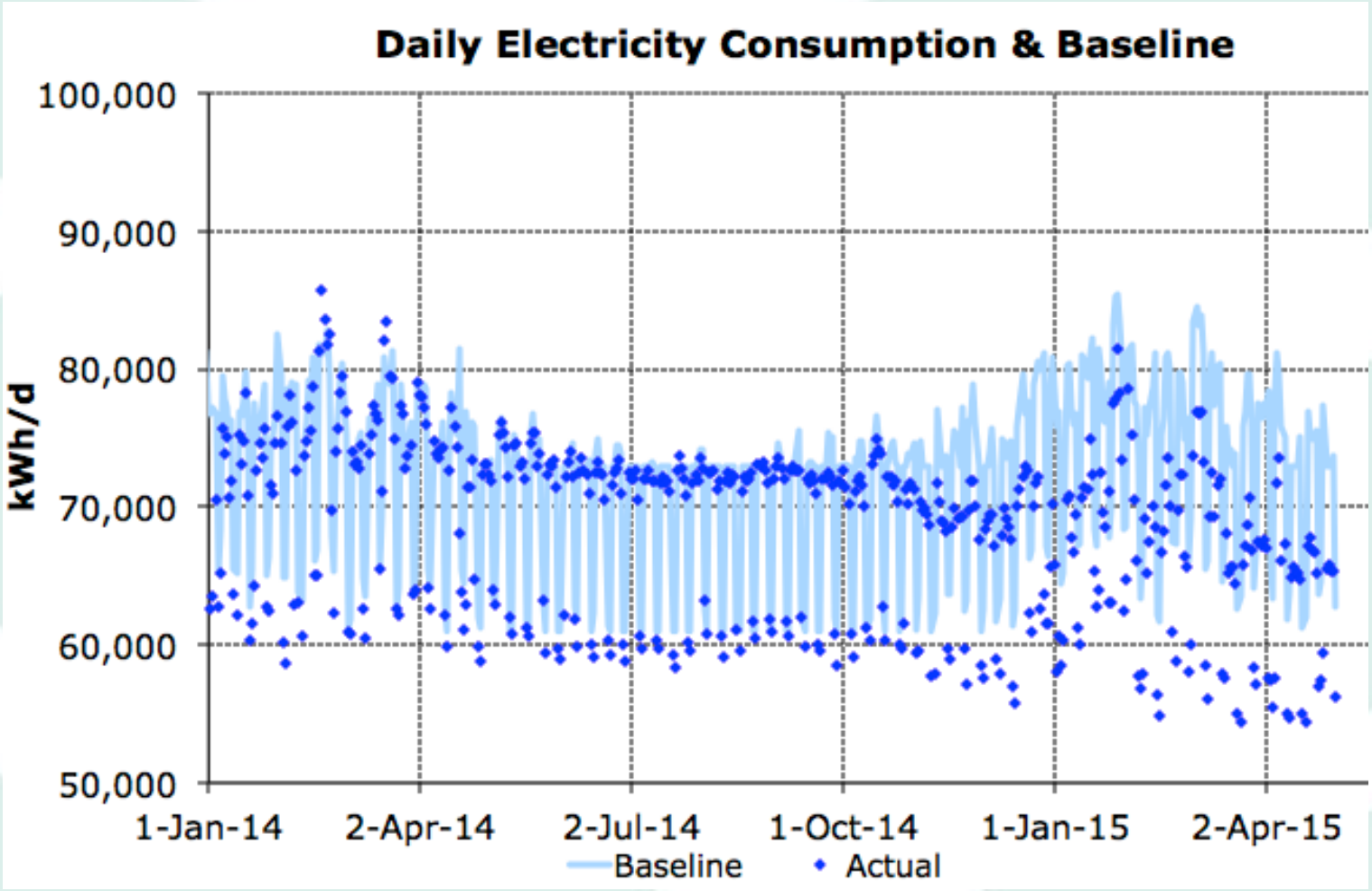
Temperature is the main driver of most buildings' energy consumption





- Gas (heating) and electricity (cooling) closely follow outdoor air temperature.
- For industrial facilities, production is generally a main driver of energy consumption.

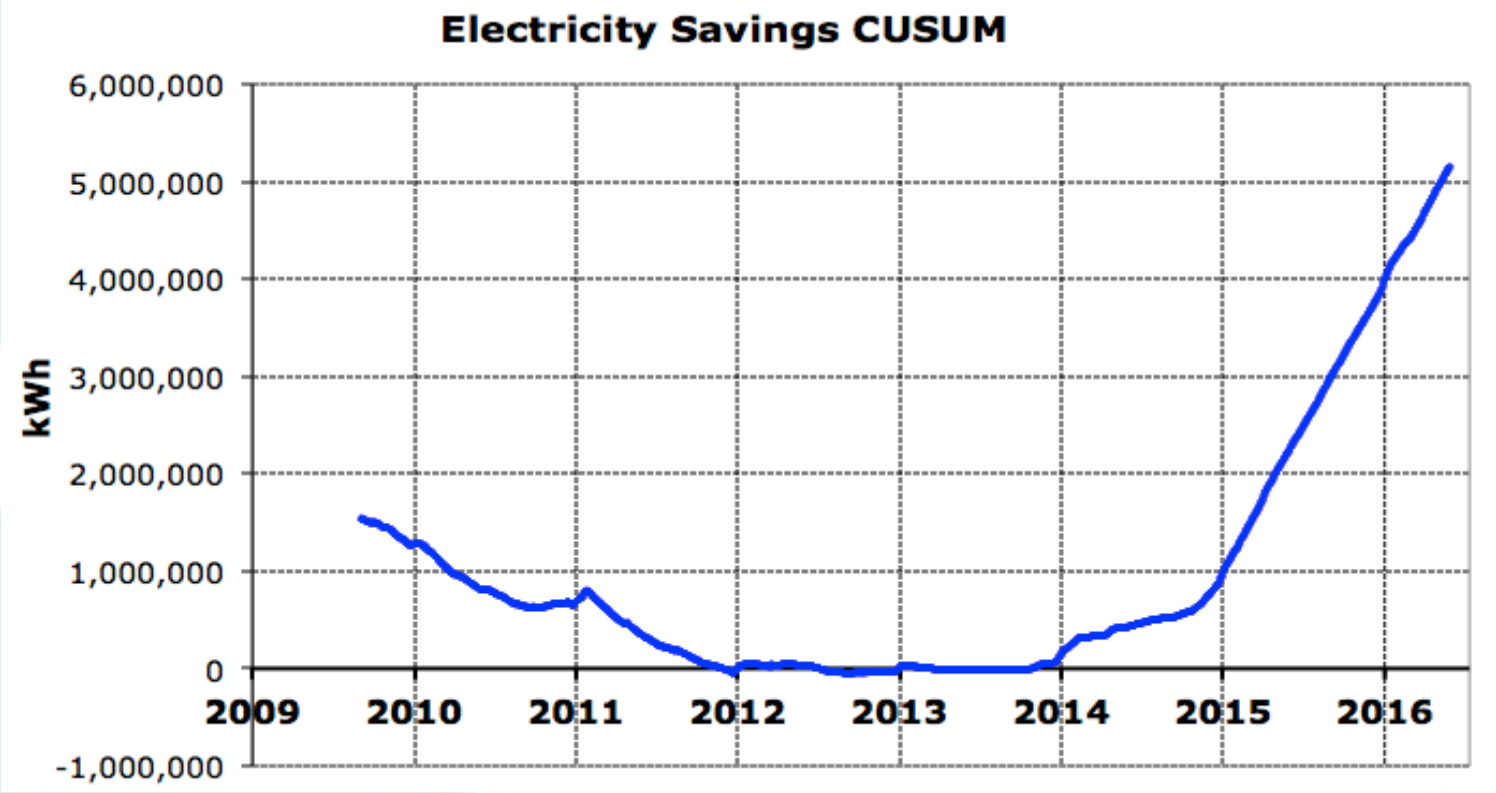
Temperature-adjusted baselines



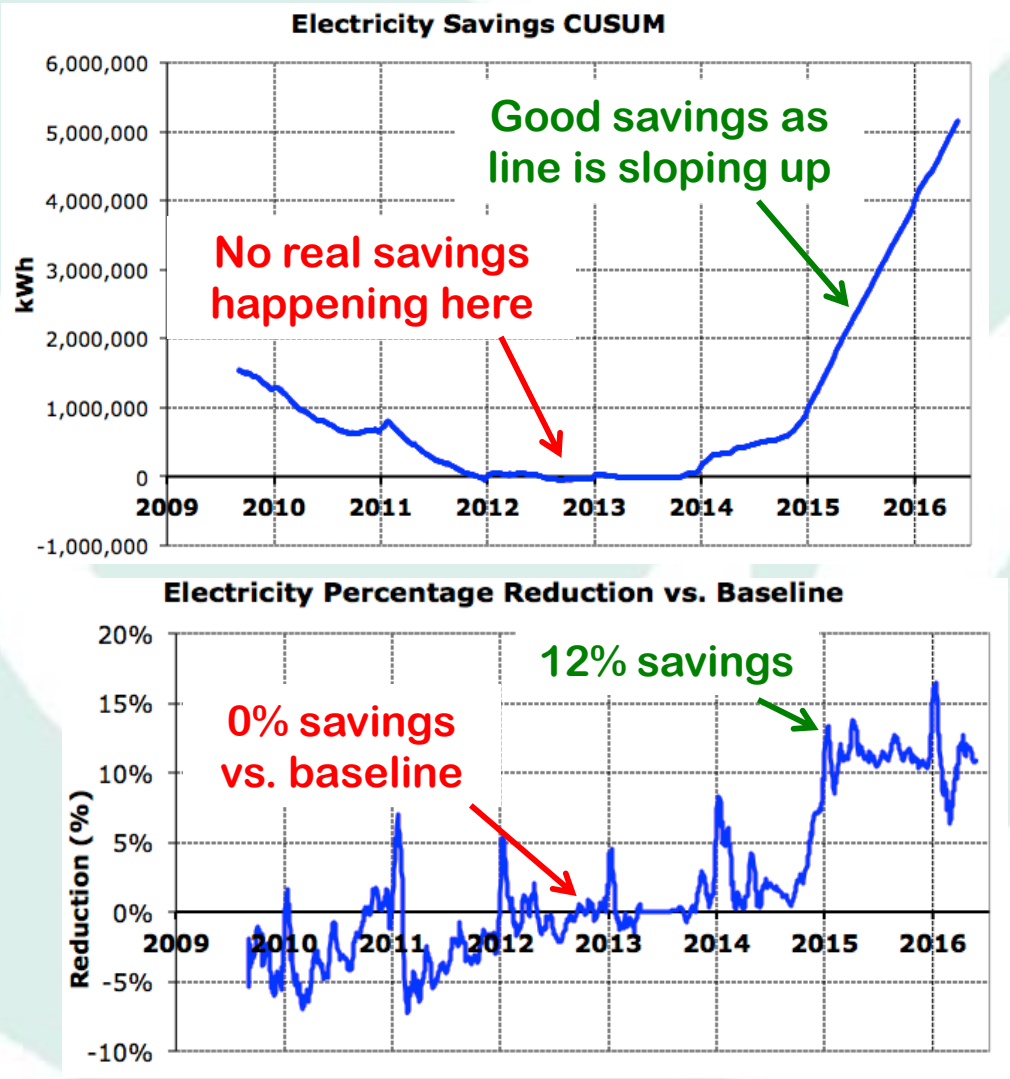
- Baseline can be adjusted each day (or month) for accurate savings calculations.

6. Best M&V metric: % savings

- Cumulative energy savings (vs. a baseline) are often reported as CUSUM.
- "The bottom line" in guaranteed savings projects.



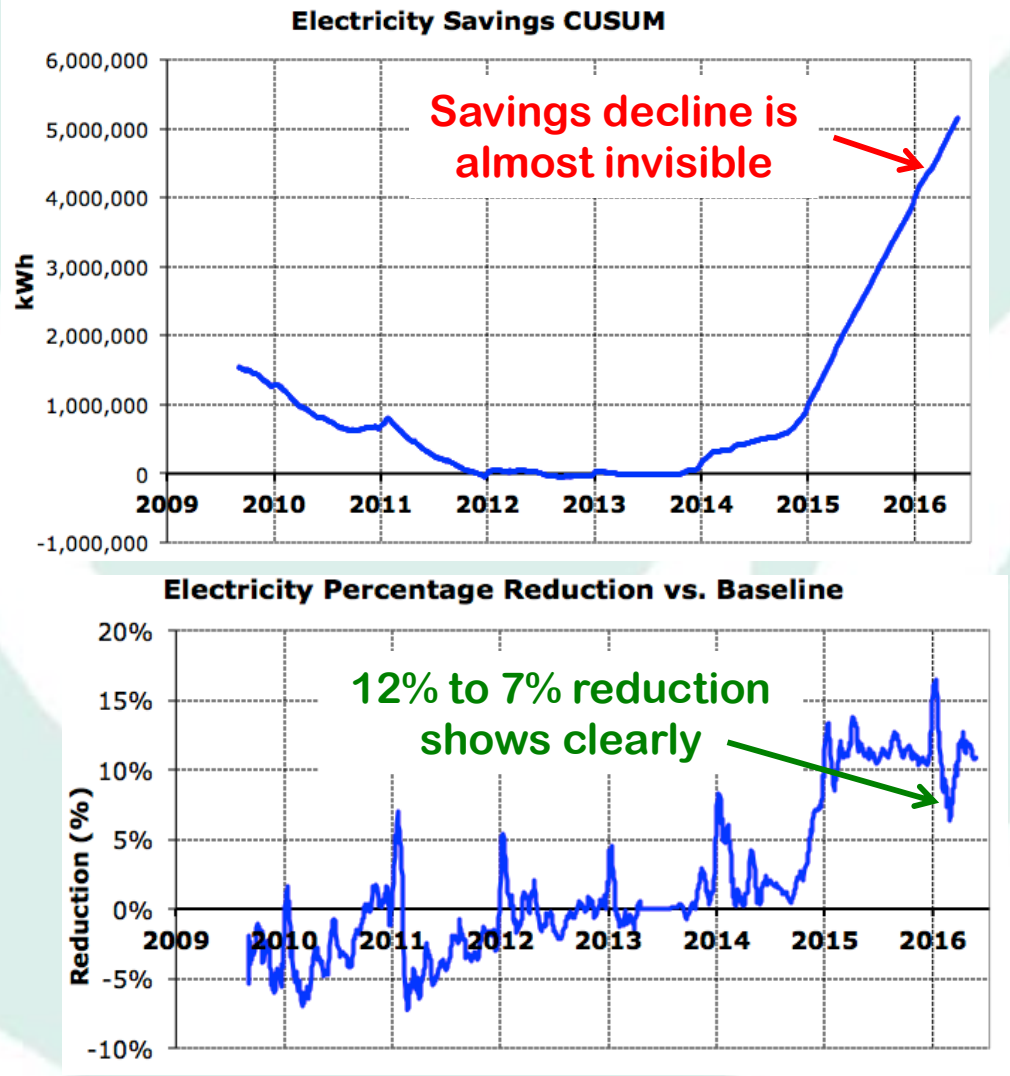
% savings is *slope* of CUSUM line



- CUSUM slope shows how fast savings are being achieved.
- % Savings =

  daily savings ÷ daily baseline
- Higher % savings means faster growing CUSUM.

Advantages: visibility, diagnostics



- Notice the problem in Feb. 2016. Almost invisible on CUSUM; clear in % reduction.
- % reduction allows higher resolution of performance changes
- Also means baselines don't need to be updated as often.

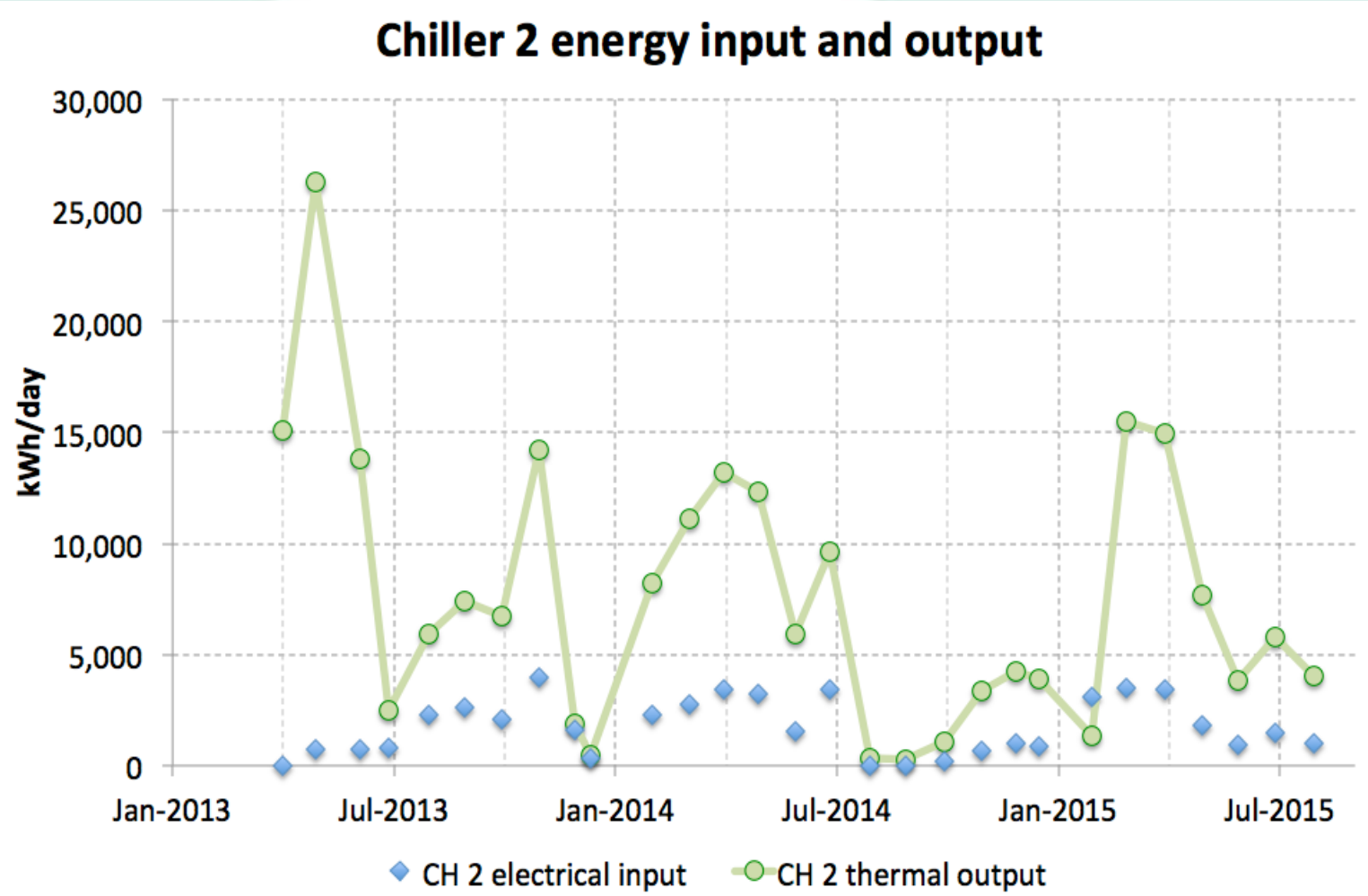
7. Don't assume meters are correct

- Energy audit of a large gas-heated commercial building showed EnPI of 10 kWh/m^2 yr.
- This seems much too low for a gas-heated building – most are in the range of 100 - 200.
- The building didn't appear to be super-efficient.
- So how could reasonableness be checked?
  - Observations of gas meter movement during boiler operation showed ACTUAL meter calibration.

Result of reasonableness checks

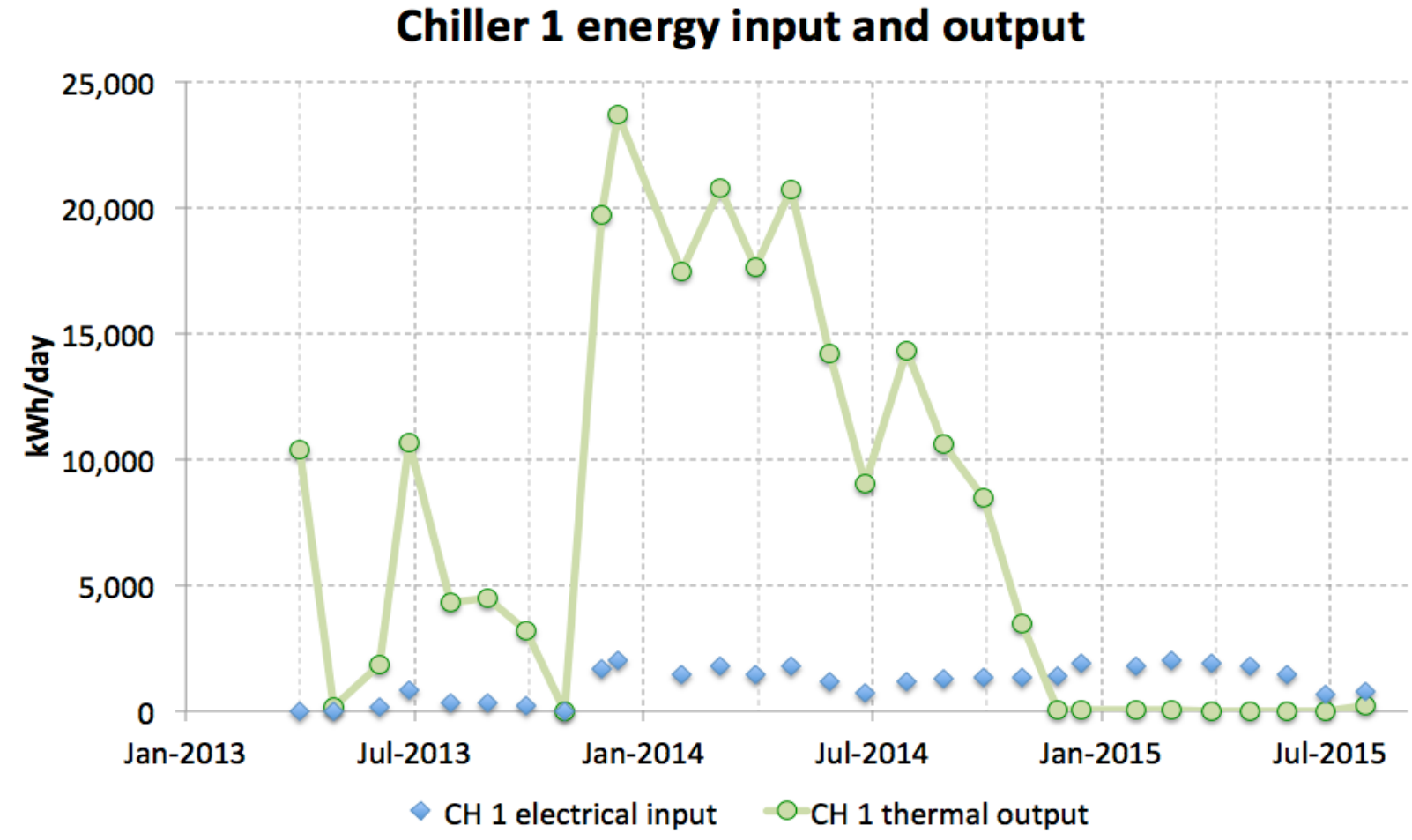
- Gas meter had been read 10x low for many years.
- Boiler size and elapsed gas meter readings proved this.

Reasonableness checks cont'd



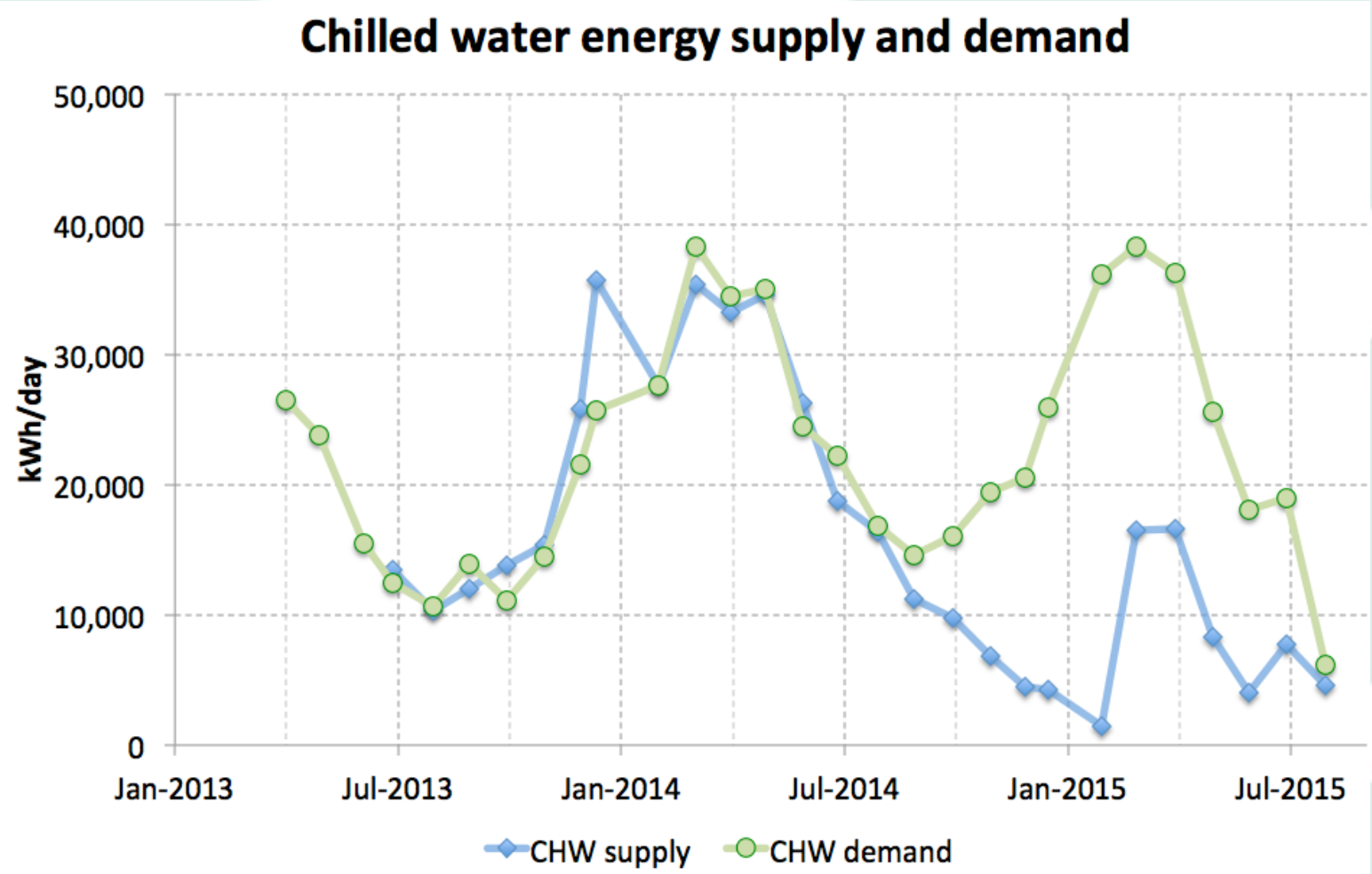
Chiller thermal output = 3-5x electrical input: OK

Reasonableness checks cont'd



Chiller thermal output = 20x electrical input: not OK

Reasonableness checks cont'd



Data after August 2014 does not match.

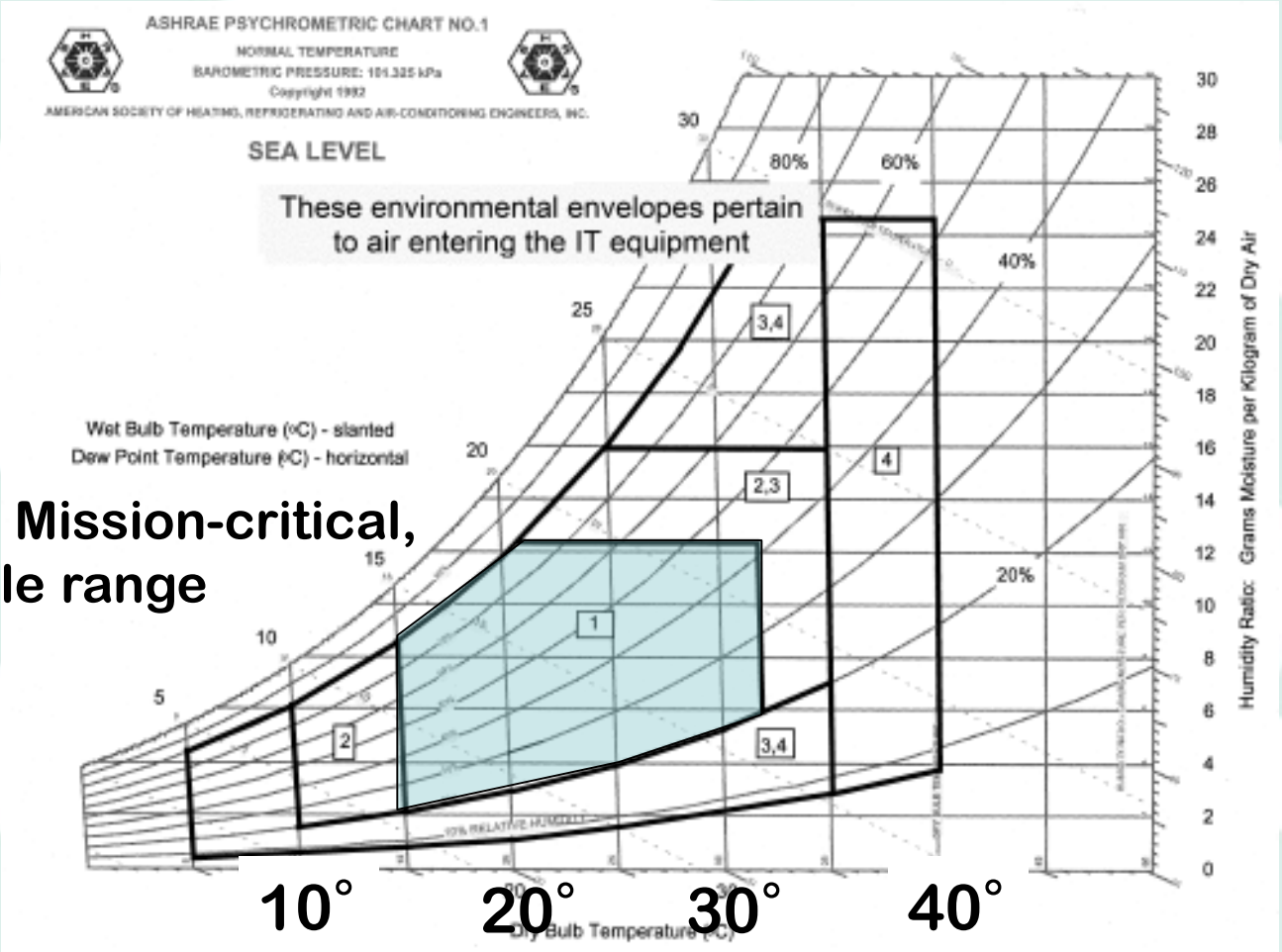
8. Don't assume controls are correct

These are IR photos of a modern commercial building in mid-summer, near cooling peak.

Normal: warm lights, cold SA grilles

Abnormal: some zones heating

Computer servers are over-conditioned



ASHRAE "Thermal Guidelines for Data Processing Environments, 2nd Edition, 2009

Process coolers often “fight” each other

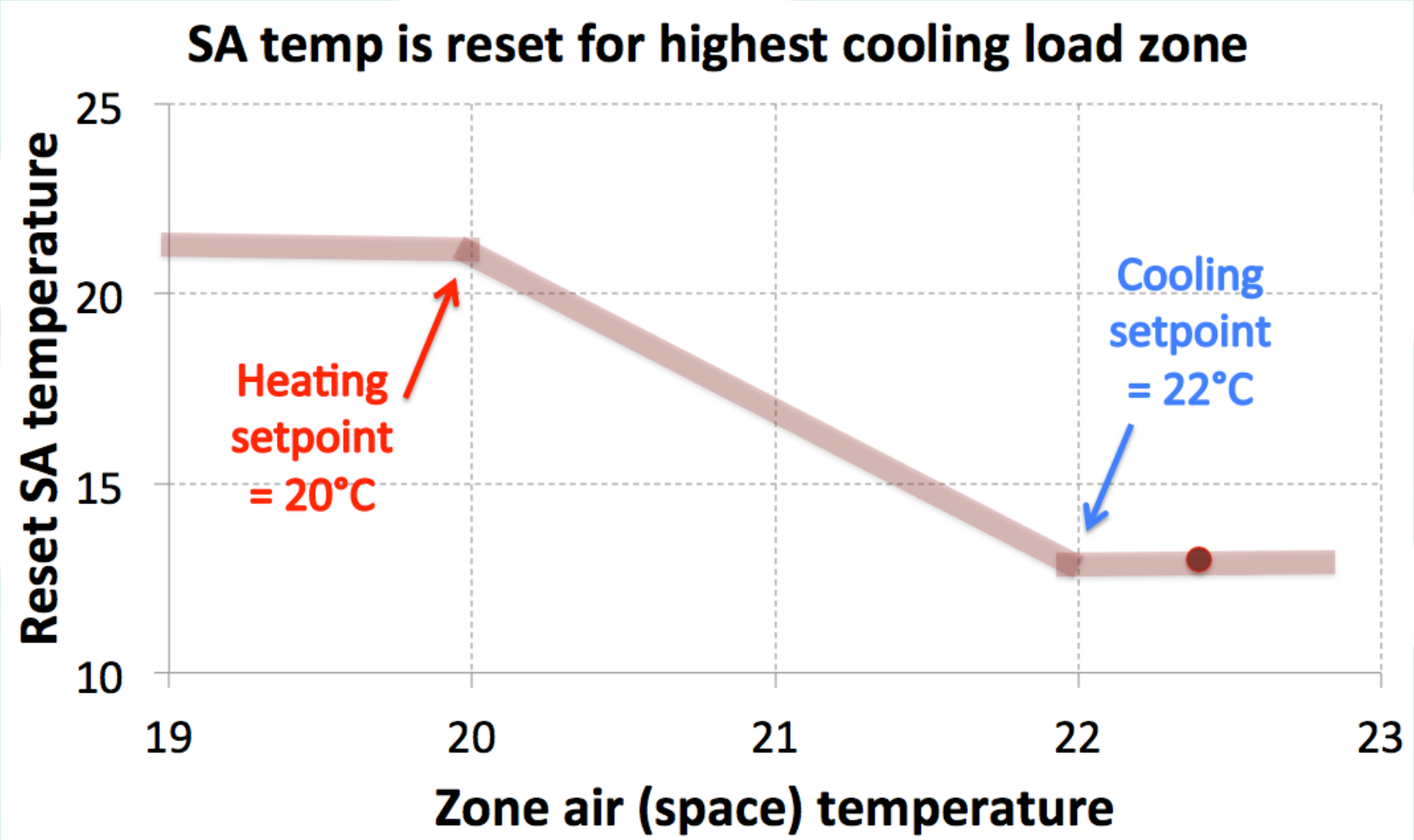
Multiple PCUs are normal.

Server room load is 100% sensible, so there should be no humidification or dehumidification.

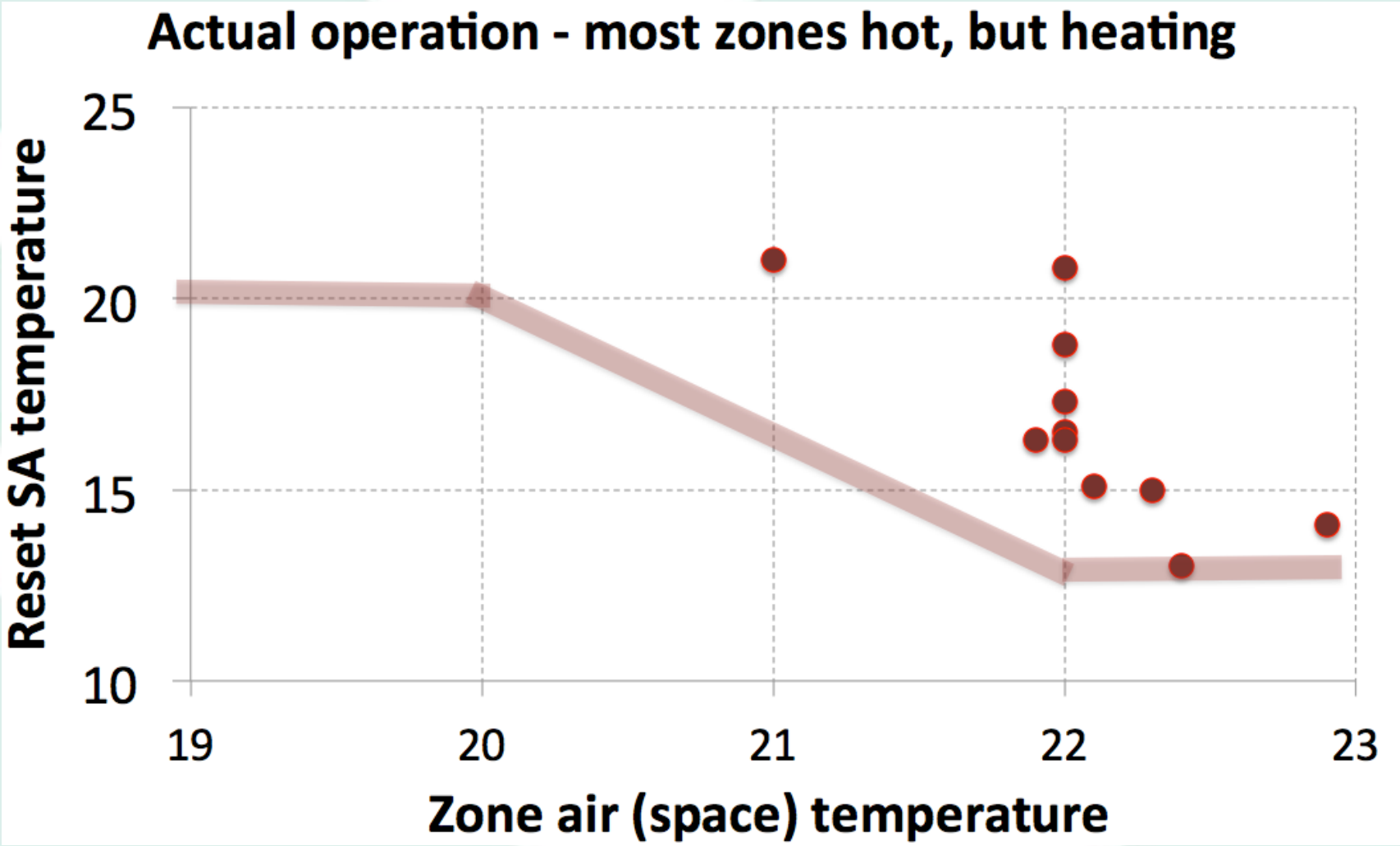
If there is, what is the moisture load?

Are PCU control sensors consistent?

SA temperature reset - design



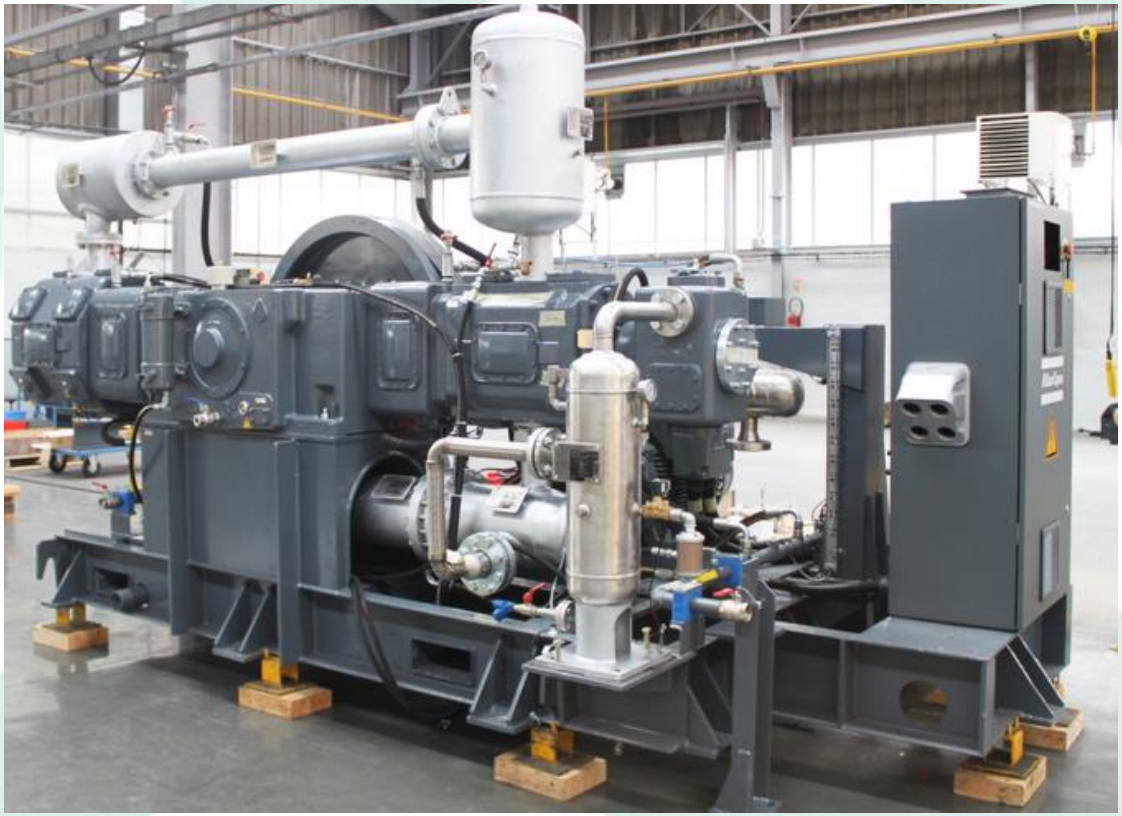
SA temperature reset - actual



Opportunities at one factory

Air compressors drew 250 kW with factory at full production.

With factory closed, still drew 200 kW (for air leaks).



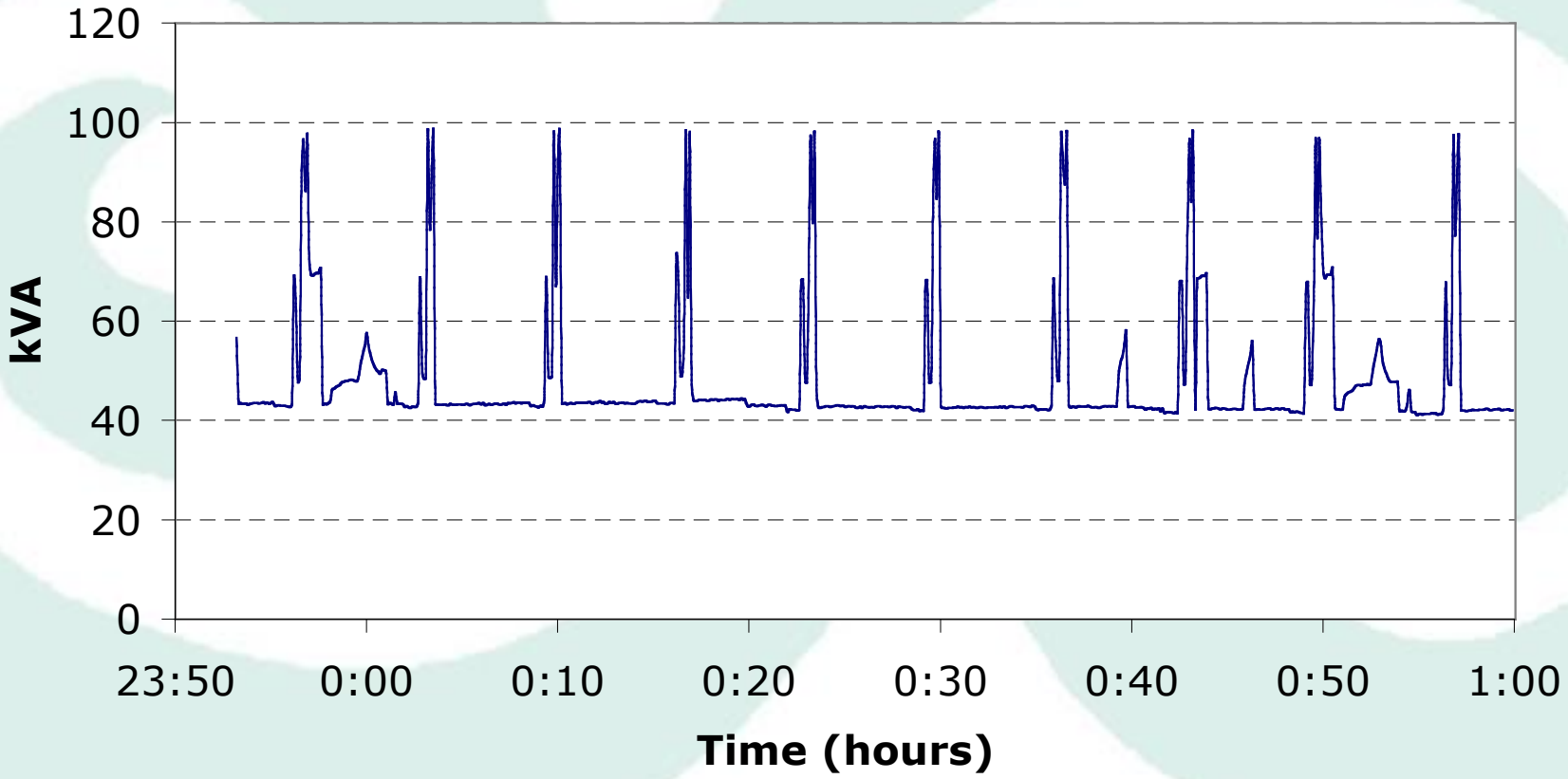
Opportunities at same factory

- 2 MW boiler had flue temperature measured = 435° C.
- Design stack efficiency = 89%
- Measured stack efficiency = 73%.
- Gas consumption: $2.8 million/year.
- Inefficiency cost = $500,000/yr.

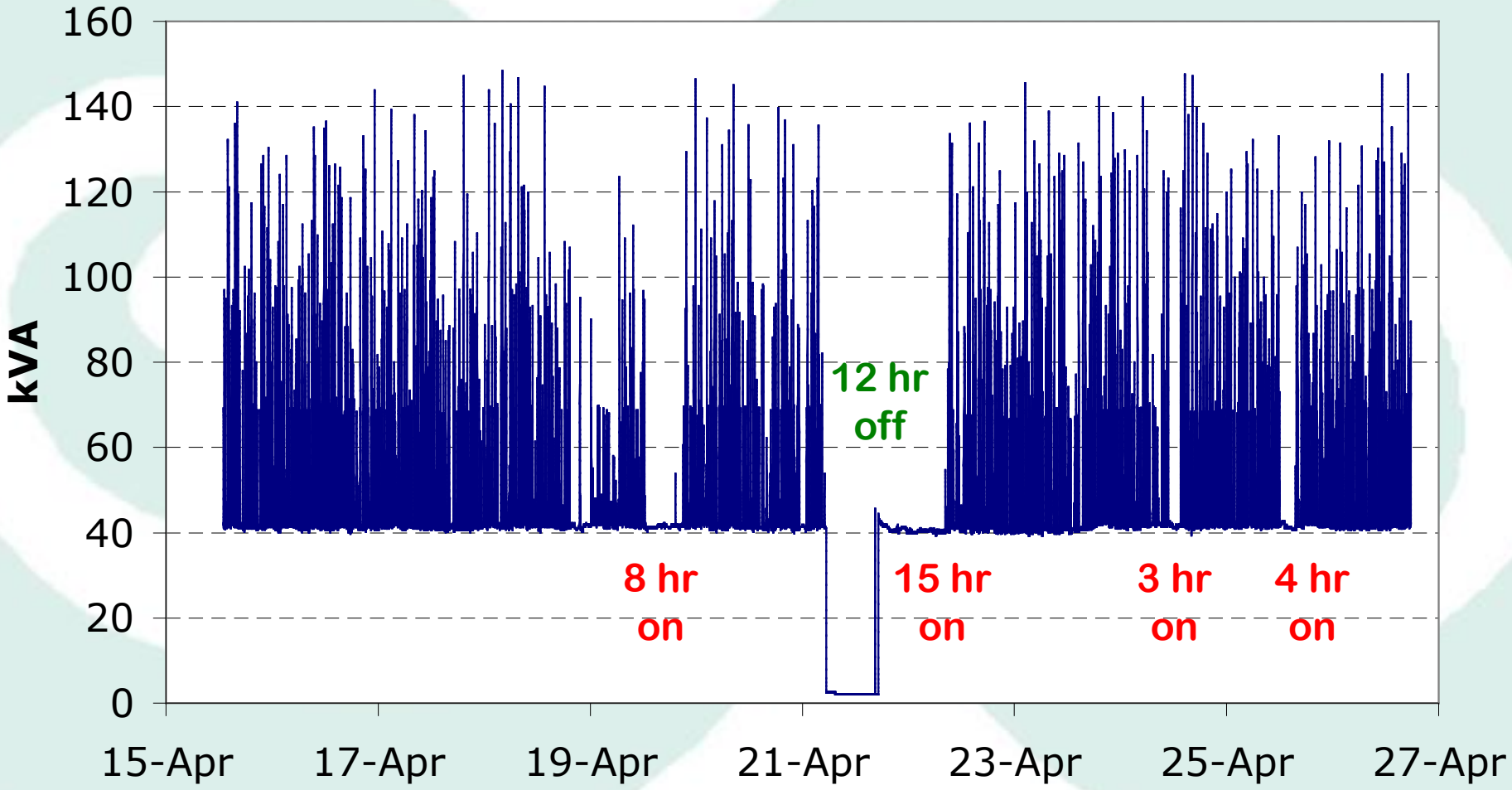
Opportunities at same factory

- Hydraulic presses used ten 90 kW oil pumps.
- Maximum press load was 90 – 200 kW.
- Control was by using one or two pumps as required, per press cycle.
- The lead pump was rotated through each cycle.
- All pumps kept running in “bypass” when not required by the press.
- Cooling towers needed to dissipate heat in oil.

Pump motor power time series
(6 second data)



Longer time series of pump motor power



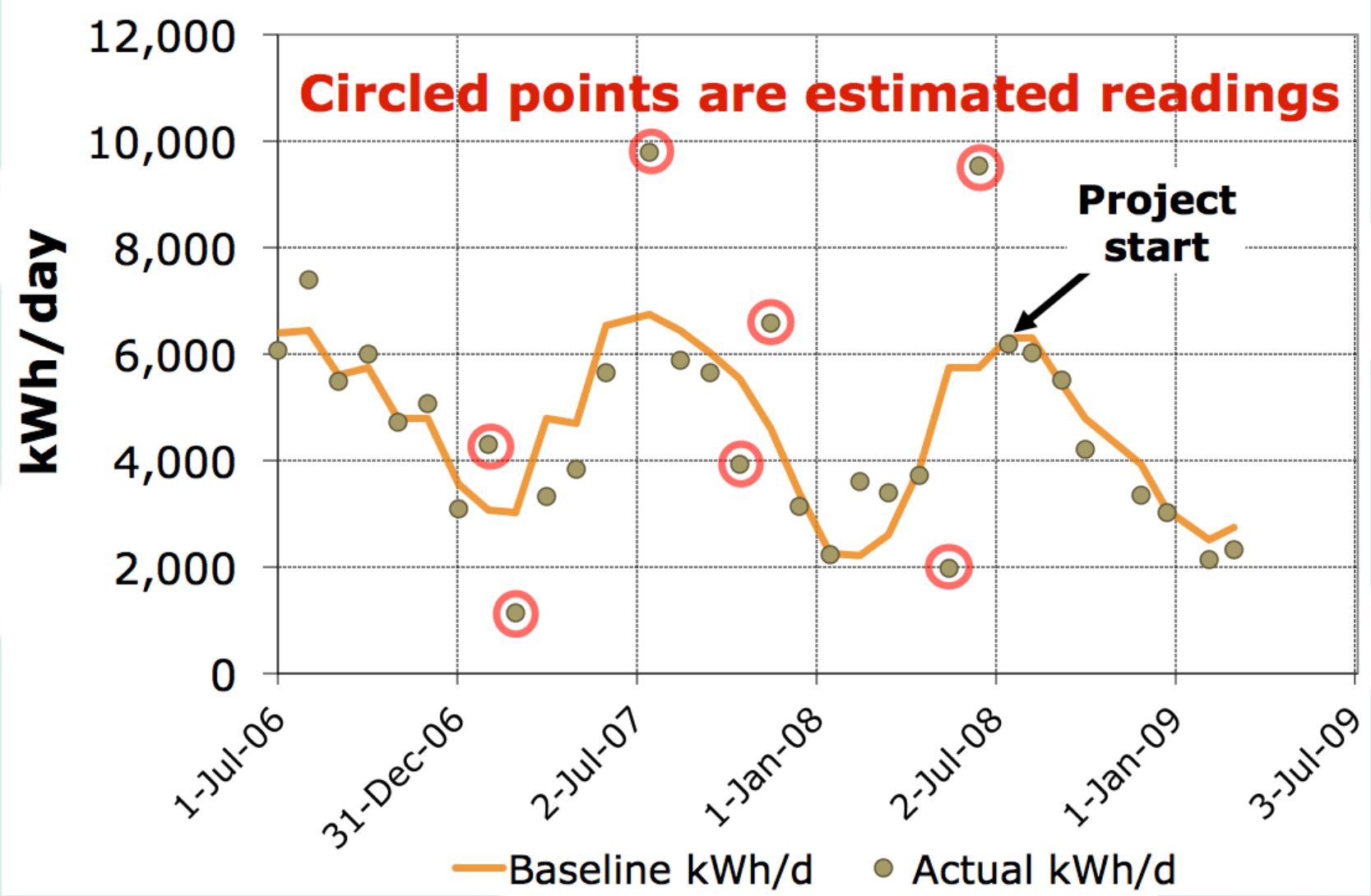
9. More metering is worth it

- During a major renovation, a large pulp mill installed compressed air and steam flow meters costing over $1 million.
- Value engineering would have blocked them, as there were no “proven benefits”.
- They immediately showed energy savings opportunities worth over $1 million/year.
- Engineering manager said they expected to identify at least $1 million/year of additional savings for “many years to come”.

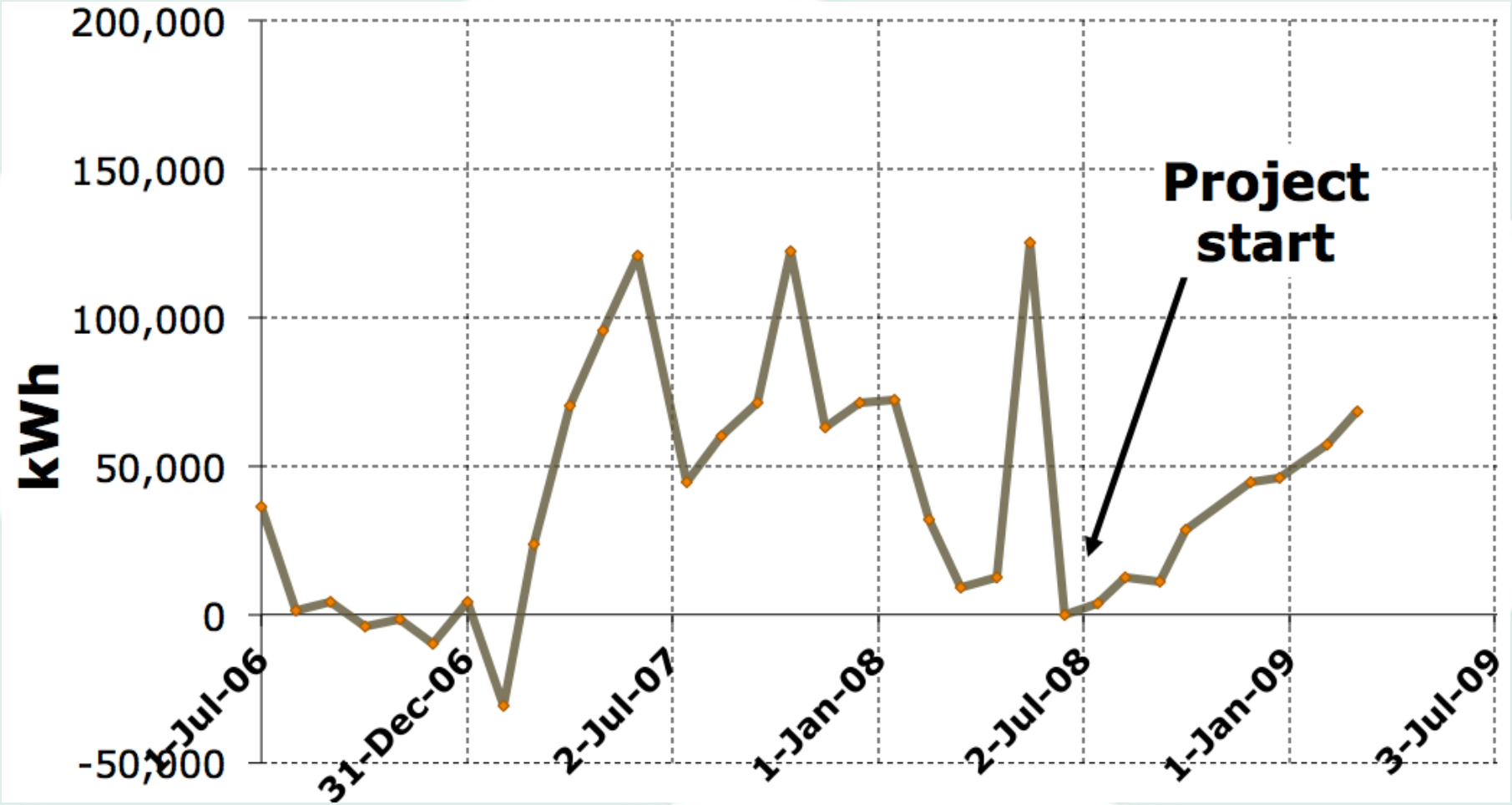
Metering to achieve savings

- On a guaranteed savings project, gas savings were much less than expected.
- Cumulative savings for first nine months were less than the variability from estimated reads.
- A TOU gas meter solved the problem, by showing patterns of gas consumption.
- When the high summer gas use at 04:30 was shown, contractors immediately knew why.

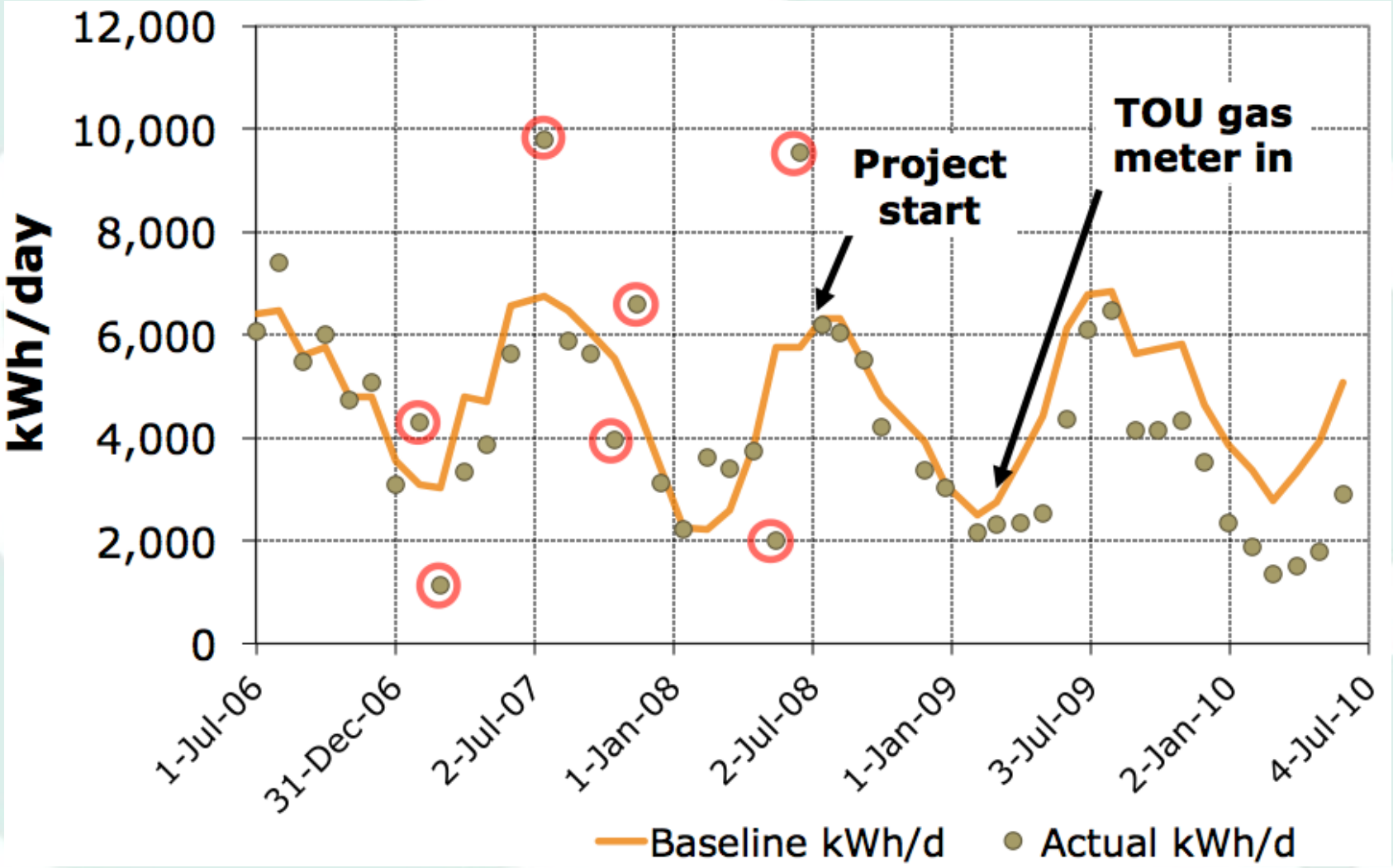
Gas savings were too low



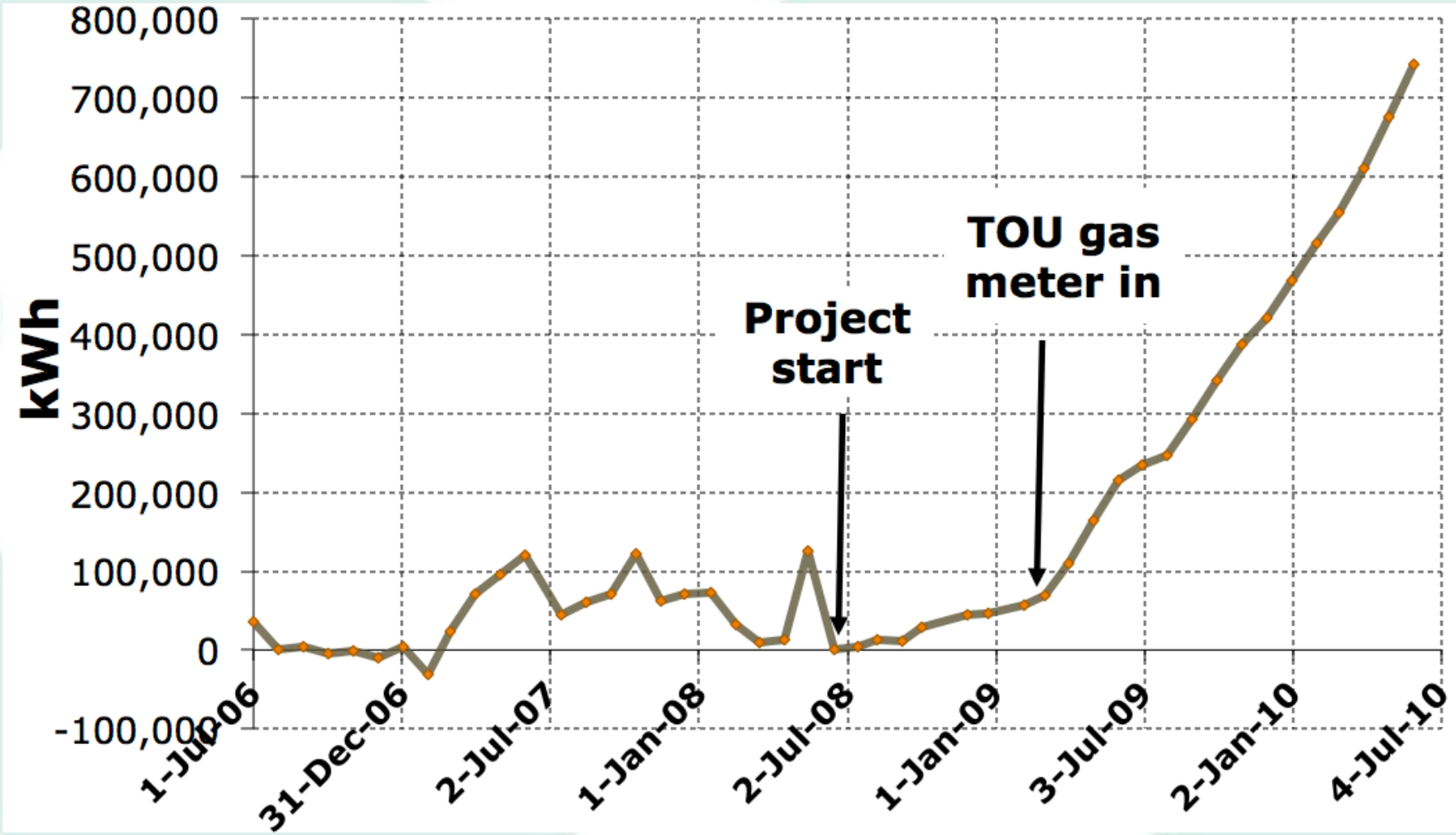
CUSUM was less than variability



TOU gas meter showed problem, and it was simply fixed



Now CUSUM looks respectable



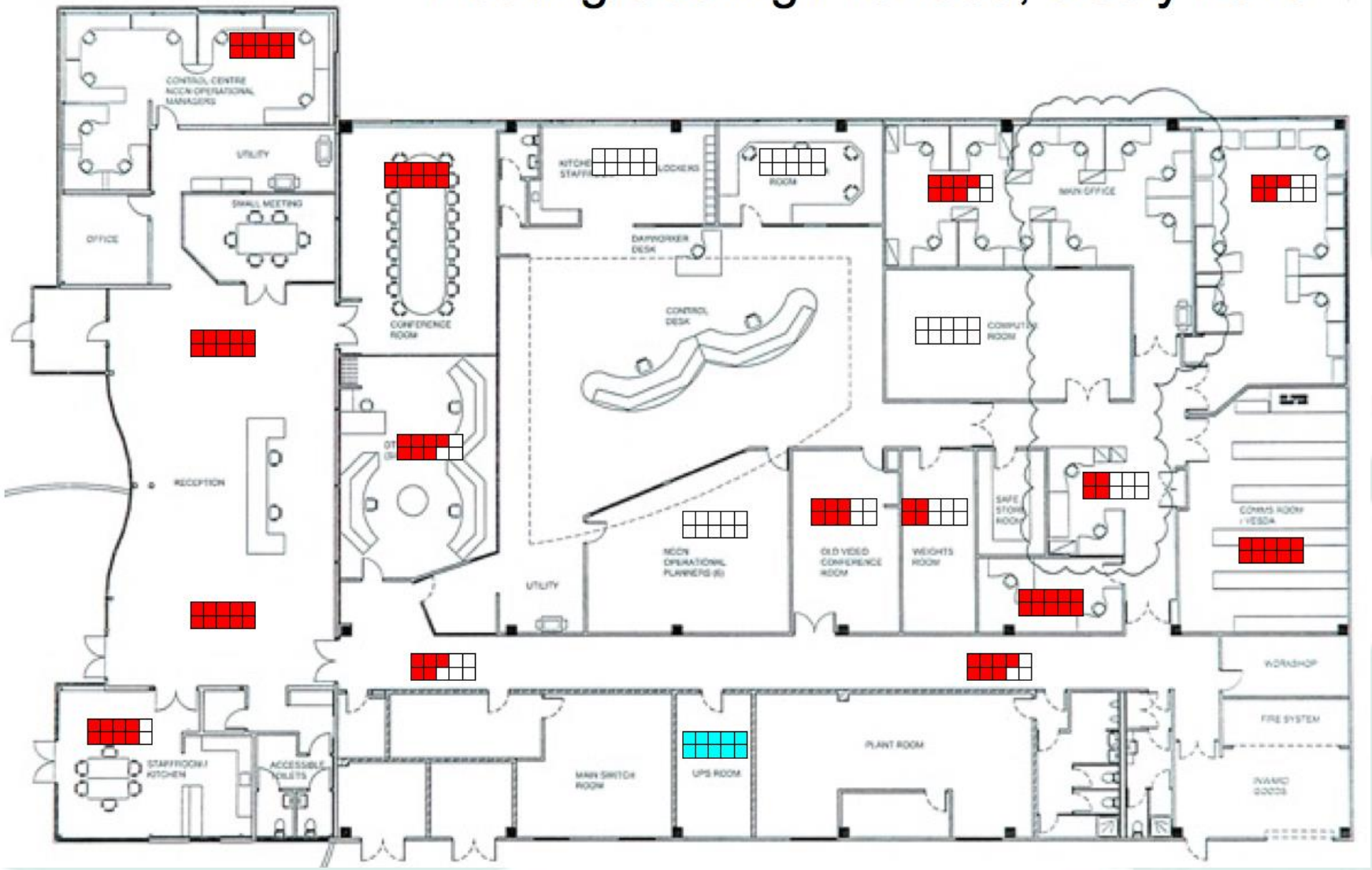
10. Most HVAC problems are hidden

- Heating / cooling fighting is common.
- Continuous commissioning (CCx) is said to be the "most cost-effective energy savings measure" (Dan Turner, Loan Star Director)
- Most CCx savings are from reducing heating in summer, and reducing cooling in winter.
- And that's mostly about commissioning the minimum OA damper position and the operation of the "fresh air economiser".

Comfort problems indicate potential savings

- Example building: always too cold in winter.
- Testing showed very high ventilation rates.
- This turned out to be economiser cooling.
- One zone had a high cooling load, called heating on everywhere else.
- Many engineers and BMS techs were on site, but couldn't identify the problem.
- One graphic diagram made it clear.

Heating/Cooling Provided, 5 July 2010



Lighting power is not consistent

- Multiple, unpublished studies of measured lamp power show actual lighting electric power consumption is different than design.
- Tubular fluorescent lamps power was measured ~20% higher than their rated power (from unpublished BEES analysis 2009).
- The range (per luminaire) was -20% to + 60%.
- This is better than in 1994, when 300+ fluorescent luminaires were measured, averaging 30% higher than rated (with wider range).
- 75W incandescent lamps were measured as 85W.
- 35W integral ballast CFLs were measured as 31W.
- LED lamps have apparently not been independently monitored yet.

SUMMARY

To achieve *actual, verifiable* energy savings you need:

Adequate energy metering

Commissioning of metering

Commissioning of controls

M&V of energy consumption

- Metering, M&V and commissioning are an *investment*, not an expense.
- They normally give a "one-year payback".