Disruptive tech experience: Surprises during monitoring

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Overview

- Purpose: generating *actual, verifiable* energy savings.
- Focus: what is cost-effective?
- This shows “lessons learned”.

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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.

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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.

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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

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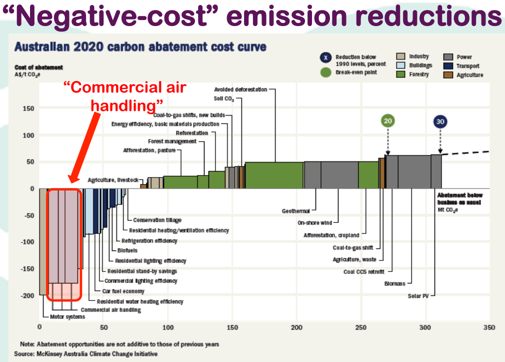
“Negative-cost” emission reductions



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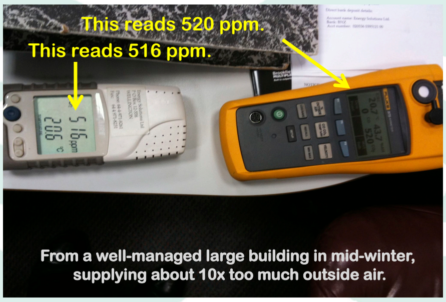
Ventilation control of OA



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

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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.

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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.

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2. Commissioning is necessary, cost-effective

- 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.

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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.

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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.

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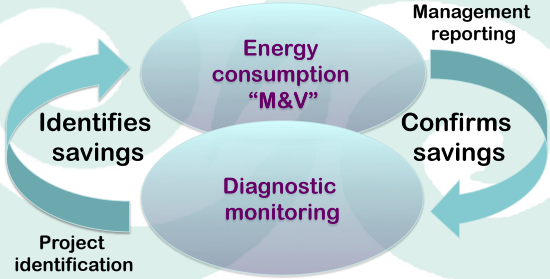
Two main components of energy analysis



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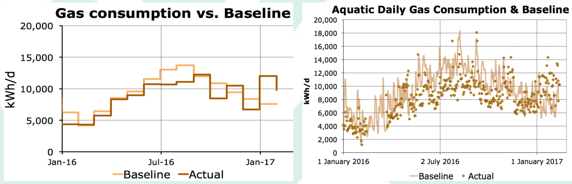
4. Daily energy analysis is best

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



- Monthly is easier to read, at first glance.

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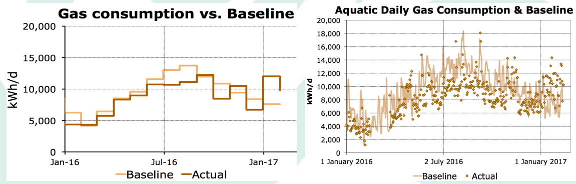
Daily energy analysis advantage

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.

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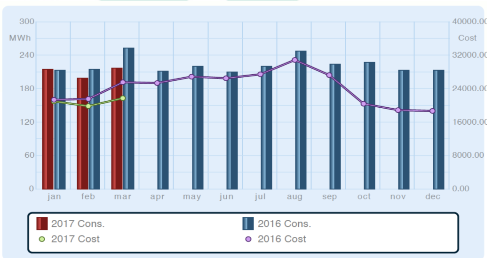
5. Temperature-adjusted baselines are best

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



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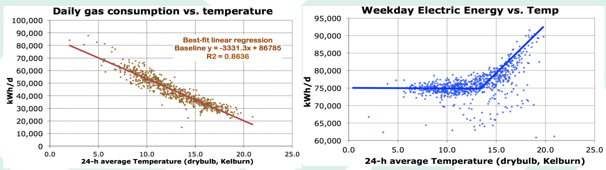
Temperature is the main driver of most buildings' energy consumption



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

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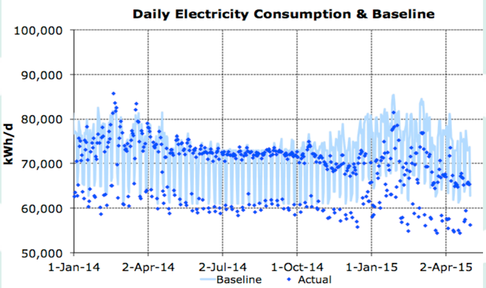
Temperature-adjusted baselines are



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

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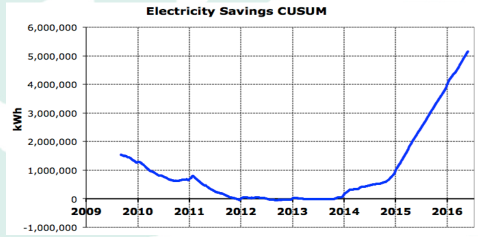
6. Best M&V metric: % savings

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



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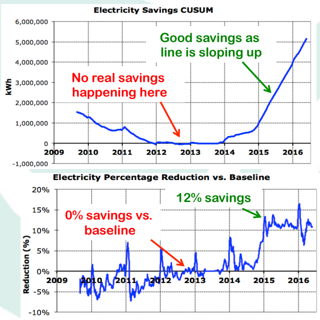
% savings is *slope* of CUSUM line



- CUSUM slope shows how fast savings are being achieved.
- % Savings = daily savings ÷ daily baseline
- Higher % savings means faster growing CUSUM.

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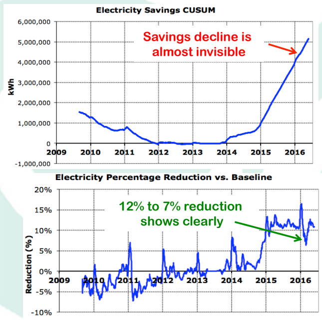
Advantages: visibility, diagnostics



- 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.

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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.

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Result of reasonableness checks

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

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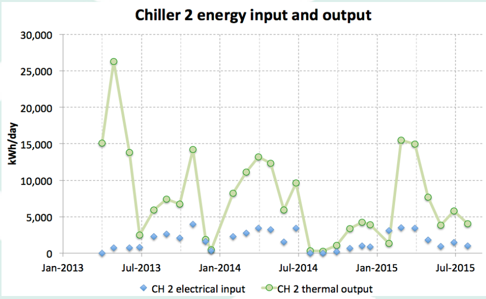
Reasonableness checks cont'd



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

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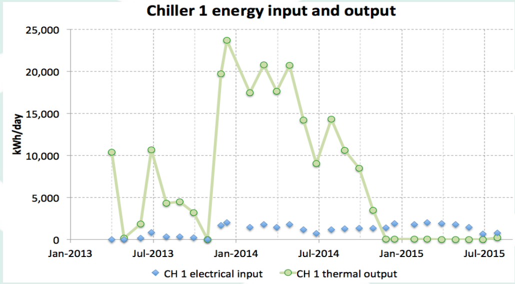
Reasonableness checks cont'd



Chiller thermal output = 20x electrical input: not OK

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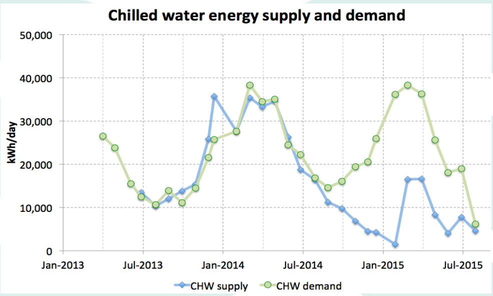
Reasonableness checks cont'd



Data after August 2014 does not match.

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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

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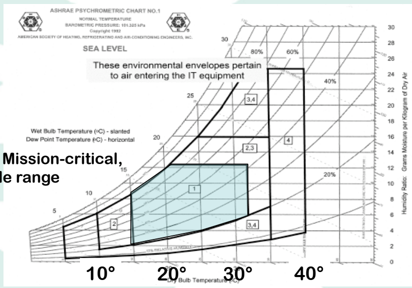
Computer servers are over-conditioned



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

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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?

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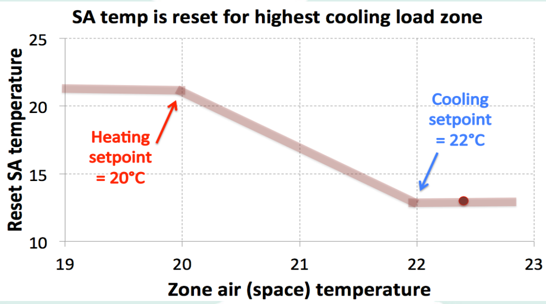
SA temperature reset - design



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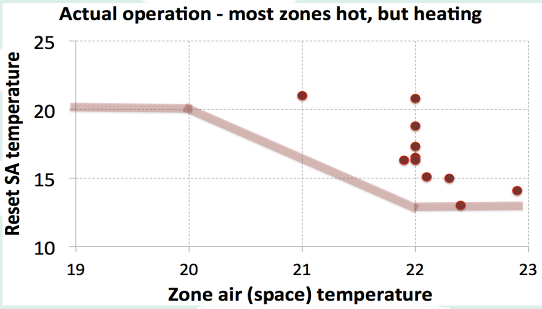
SA temperature reset - actual



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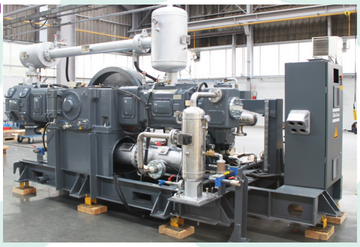
Opportunities at one factory

Air compressors drew 250 kW with factory at full production.

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



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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.

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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.

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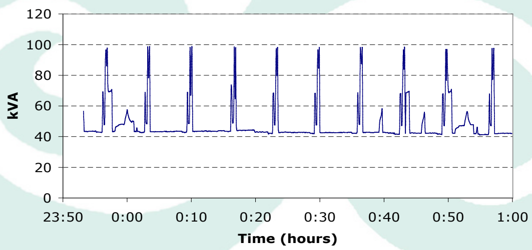
Pump motor power time series (6 second data)



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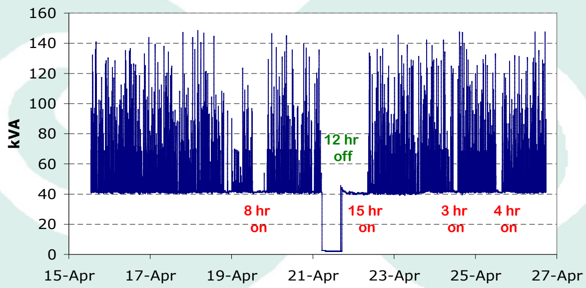
Longer time series of pump motor power



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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”.

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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.

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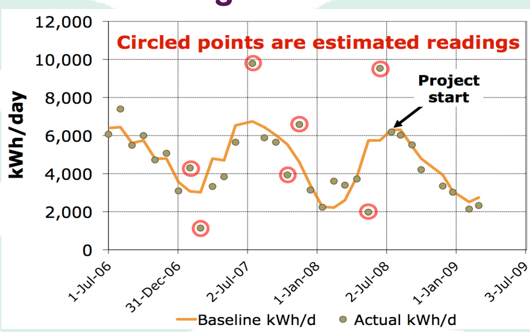
Gas savings were too low



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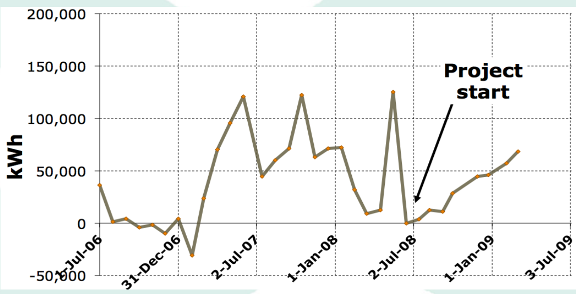
CUSUM was less than variability



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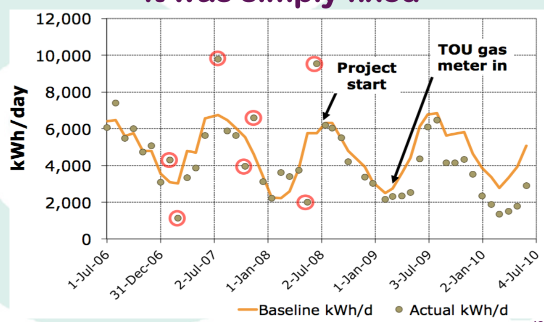
TOU gas meter showed problem, and it was simply fixed



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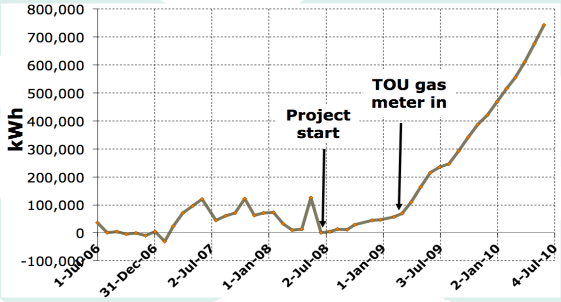
Now CUSUM looks respectable



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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".

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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.

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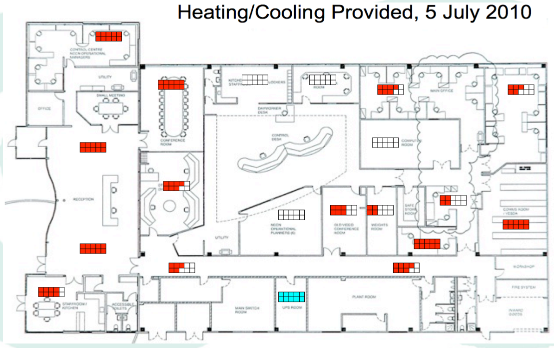
Heating/Cooling Provided, 5 July 2010



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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 draw ~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 consistently drew 85W.
- 35W integral ballast CFLs drew 31W.
- LED lamps have apparently not been independently monitored yet.

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SUMMARY

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

Adequate energy metering

Commissioning of metering

Commissioning of controls

M&V of energy consumption

- These normally give a "one-year payback".

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