Big data, applied to big buildings, to give big savings, on big energy bills

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PRESENTATION

Agenda

- BuildingIQ : From CSIRO to the market place
- The status-quo : heating, ventilation and air-conditioning (HVAC) operation in the big buildings industry
- Cloud-based Predictive Energy Optimization™: a paradigm-shifting technology
- Big data analytics and closed-loop real-time optimization : so much more than just predictive modeling

BUILDINGIQ : FROM CSIRO TO THE MARKET PLACE

BuildingIQ

- Energy efficiency optimization for large-scale buildings (office buildings, shopping centers, hospitals, casinos etc.),
- We achieve energy savings through optimized real-time control of temperature control loops within building,
- Technology developed by CSIRO’s energy flagship in Newcastle, Australia,
- Collaborative effort with the Argonne National Laboratory in the US,
- Founded in 2009,
- Venture-backed by industry heavyweights (including Siemens, Schneider Electric, Paladin Capital)
- Offices in Sydney, New York and Silicon Valley

Why bother with energy efficiency in large-scale buildings?

Economics :

- Approx. 30% of global energy consumption is due to large-scale commercial buildings,
- Massive energy bills (> $ 1 000 000) and current economic conditions (GFC) have been key drivers for innovative approaches towards energy efficiency,
- Global warming

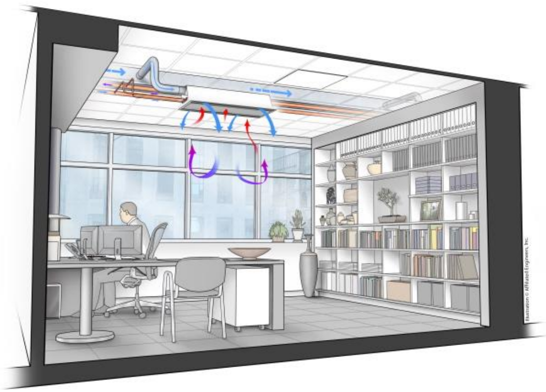
Status-quo HVAC technologies for temperature control :

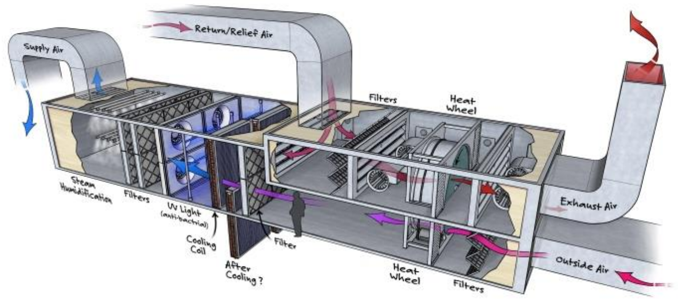
- Many localized and independent feedback loops across building acting on per-zone/per-room level,
- No global co-ordination at whole building level to optimize whole-building energy consumption/efficiency,
- Agnostic to real $$$-cost of energy. Time-Of-Use Tariffs? Peak Demand Management? Demand Response?
- Colossal waste of energy and of $$$
- It’s 2014, not 1984!

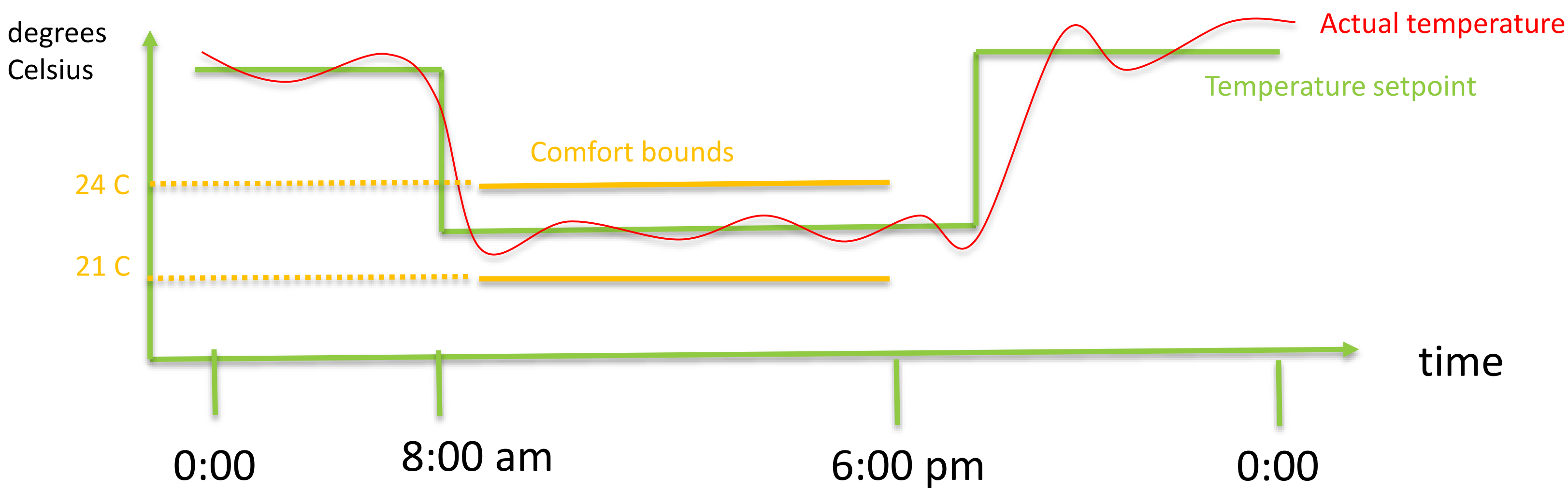
THE STATUS QUO

What's the problem with existing HVAC operations/technologies (1) ?

Problem 1 : Temperature control is static and scheduled independently for each zone/room, i.e. setpoint fixed throughout day and no coordination between zones/rooms







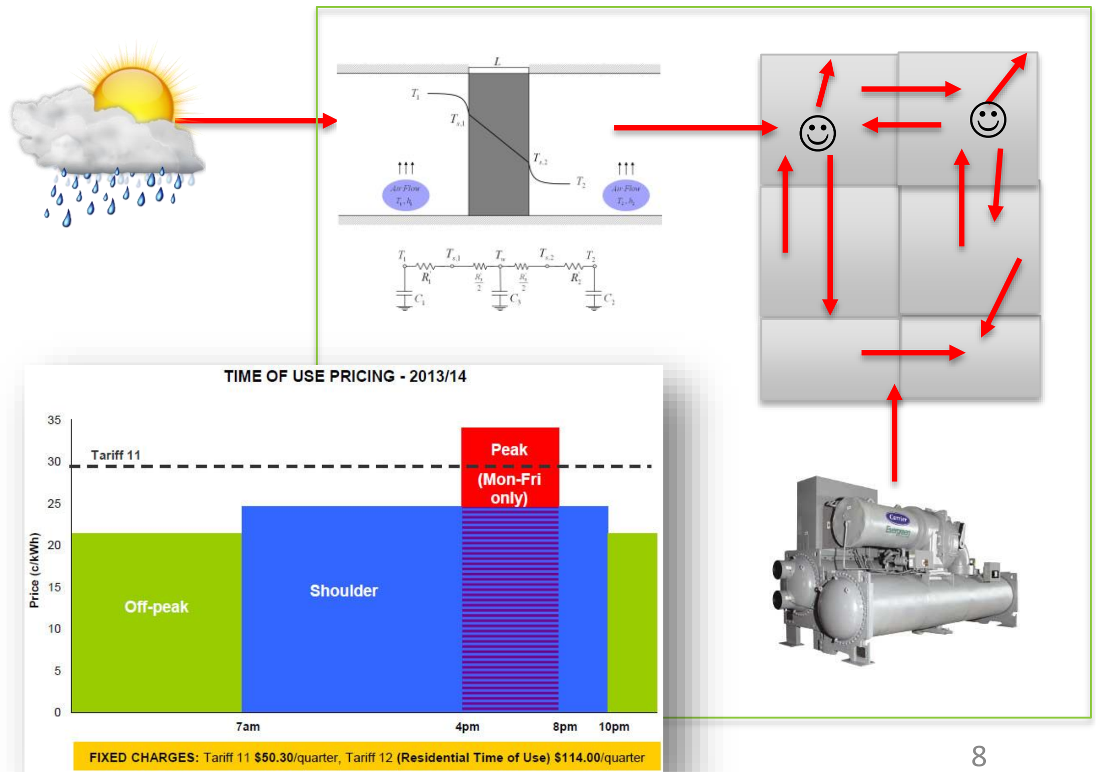
What's the problem with existing HVAC operations/technologies (2) ?

Problem 2: No global intelligence, co-ordination and energy market "awareness". No use/knowledge of underlying building physics, inter-zone coupling, time-of-use (TOU) energy $$$ cost etc

A building viewed in insolation (status quo) :

= heat/energy flow

Looking at things within the overall eco system :

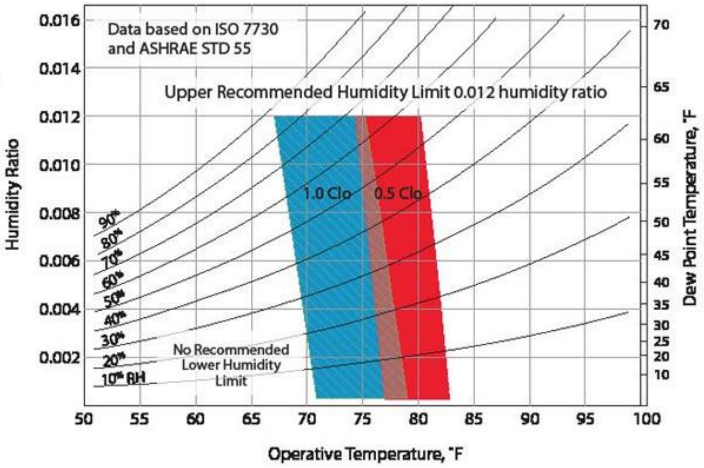


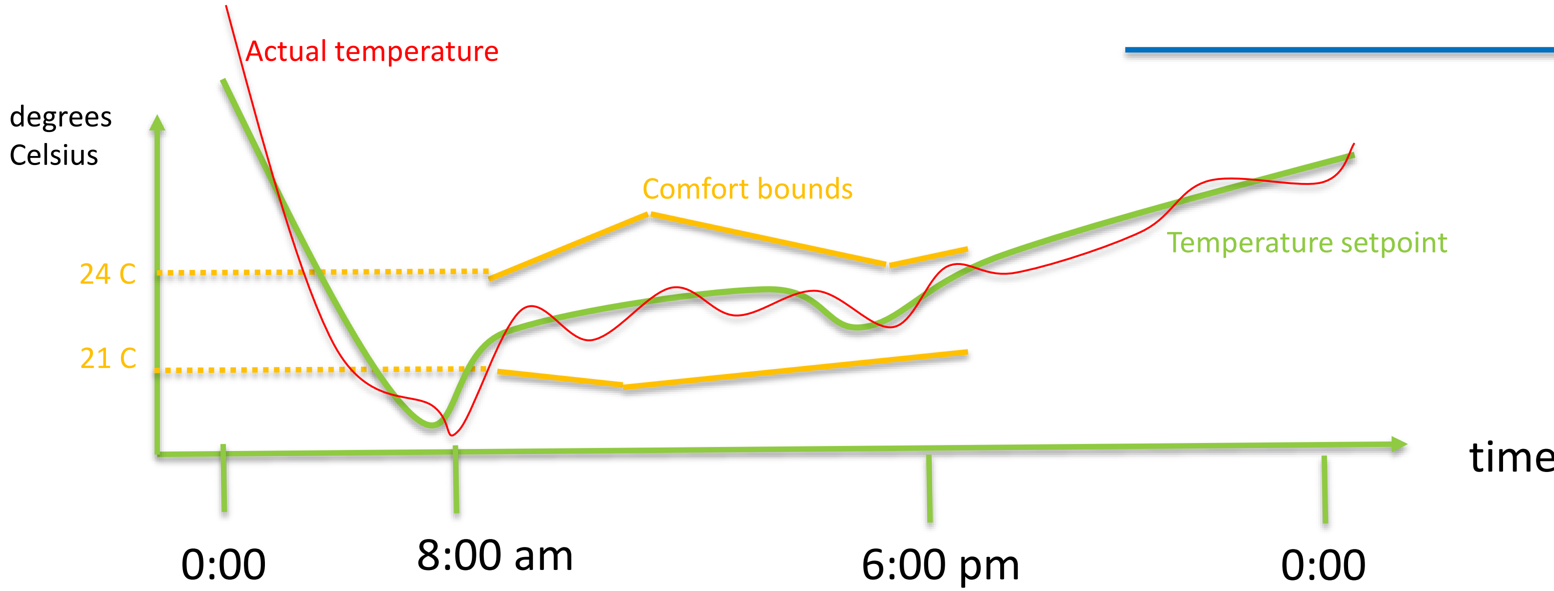
GOING BEYOND THE STATUS QUO : PREDICTIVE ENERGY OPTIMIZATION™

Going beyond the status quo (1) : the science behind comfort perception

- Setpoints and comfort bounds can be moved throughout the day without occupants noticing (psychrometric CSIRO/ASHRAE research)
- So got degrees of freedom (dof) to move temperatures around to optimize energy efficiency
- In huge buildings, a temperature movement in correct direction, by say 0.5 degree Celsius, can save massive amounts of energy!

ASHRAE chart:

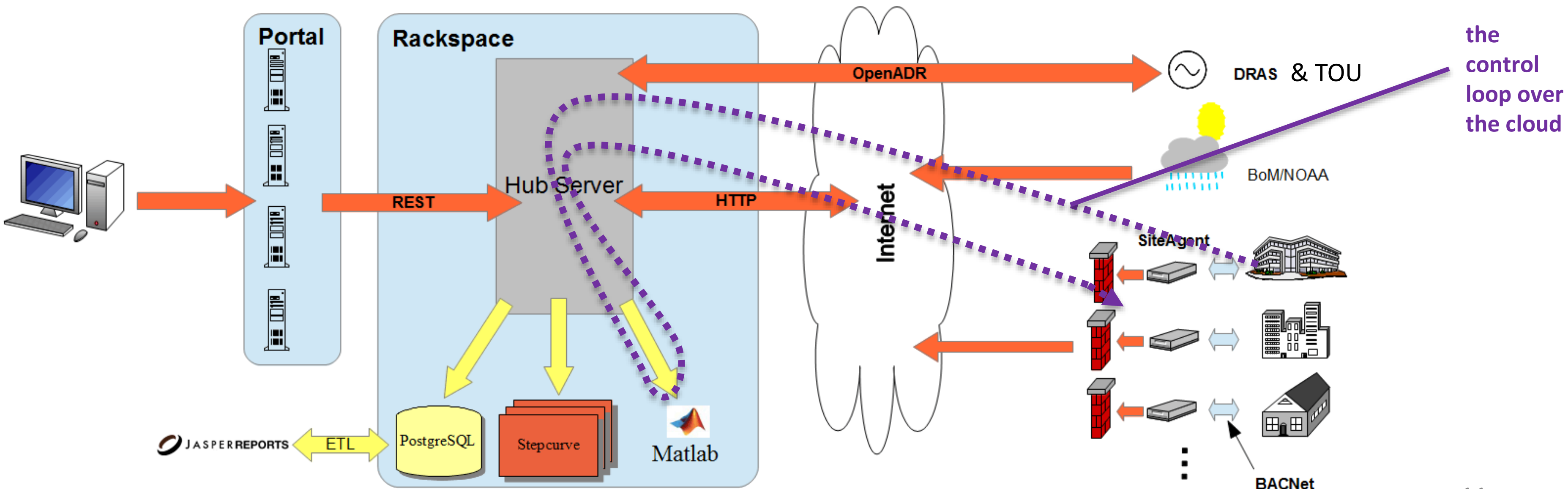




Going beyond the status quo (2) : the building within the wider energy- and information/data eco system

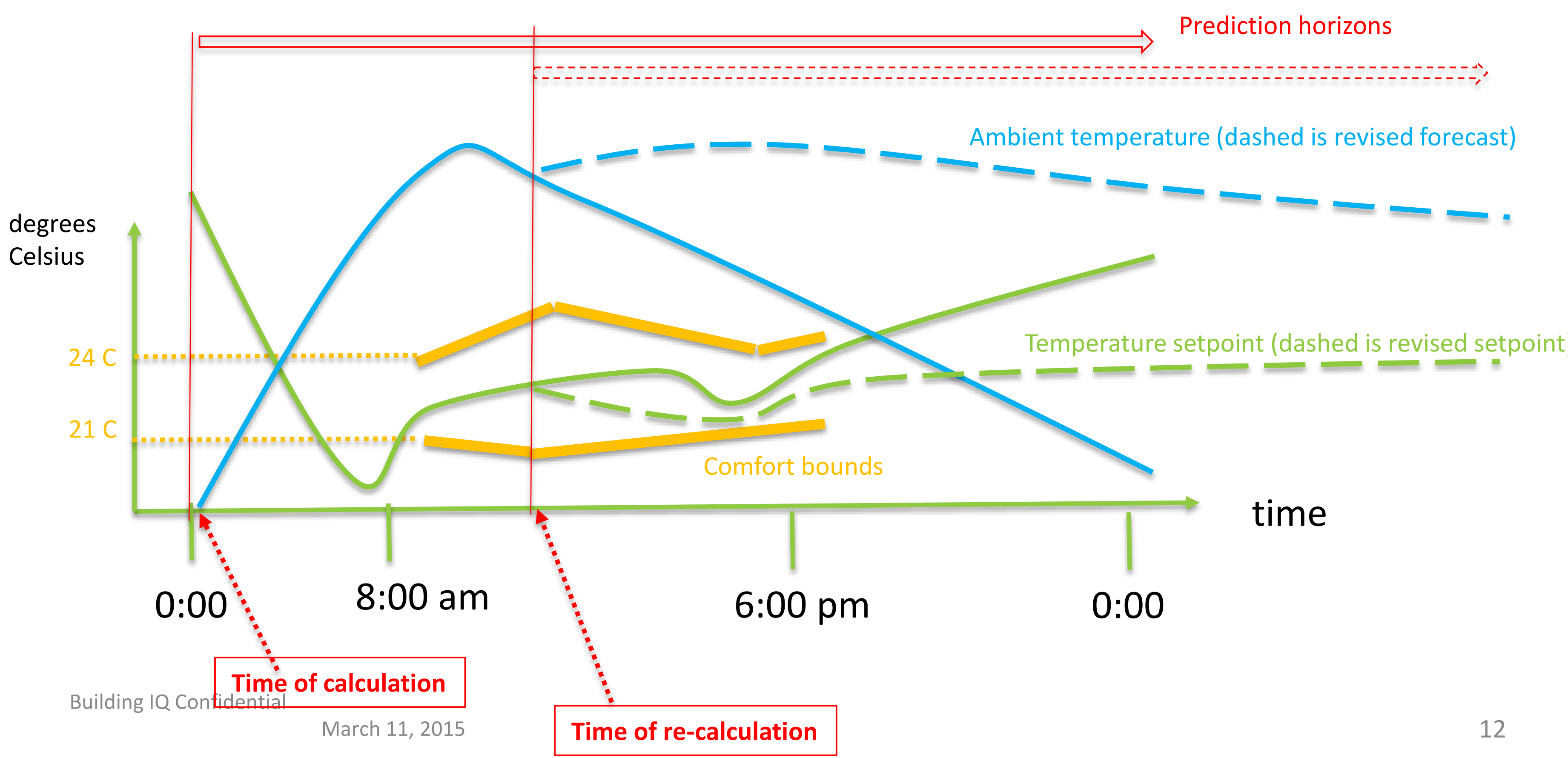
- The modern building does not "live" in insolation but is part of the wider information and energy market eco system
- We integrate and exploit big data to learn about each building's underlying physics (i.e. thermodynamic and power response)
- The physics is fed into <u>real-time and closed-loop optimization</u> algorithms that incorporate market cost of energy
- Billions of data points (power, internal temperatures for each zone, ambient temperatures, ambient humidity, building operation schedule etc.)
- Large-scale mathematical optimization within a cloud-based infrastructure

<u>BuildingIQ's "cloud-based closed-loop real-time predictive optimal control" :</u>



Going beyond the status quo (3) : predictive energy optimization

- Update the optimal temperature setpoints "predictively" to maximally exploit changing weather conditions,
- Recalculates 24 hours forecast taking into account new forecast periodically
- Optimized cost function minimizes energy consumption and dollar cost, also maximizes occupant comfort
- Use "best-available" real-time information available at the time of re-calculation
- Planning and re-planning with new information (model predictive control)



Going beyond the status quo (4) : the science of predictive energy optimization

- Load-shift your use of cooling/heating when energy costs are low and when ambient temperature and humidity are low (basic thermodynamics; easier to reject heat into the ambient)
- Take thermal mass/drift/inertia into account (thermodynamic model of building thermal response)
- Optimize energy efficiency while ensuring occupant comfort (do not want to cause discomfort to occupants!)
- Multi-objective optimization!
- The “learning , controlling, re-learning” approach :

  1.) First we learn about building dynamics employing all available data

  2.) Once we have sufficient model stability, we go into active control

  3.) We continuously (i.e. nightly) re-fit our model with updated/new data

Matlab in the loop : how Matlab has helped accelerate our R&D and deployment

- Rapid algorithm development in Matlab
- Following Matlab features helped accelerate development :

  1.) Robust numerical algorithms (ODE-s etc)

  2.) Extensive visualization and analytics tools (DSP, stats, optimization, control)

  3.) Industry-robust and reliable mathematical optimization routines (needed for our large-scale real-time optimizations)

  4.) Good object orientation framework

  5.) Ability to interface with Java (with our backend and computationally-intensive routines)

  6.) Running Matlab in the cloud within production-level environment (i.e. don't have to translate all code into Java/C/C++, saves development time)

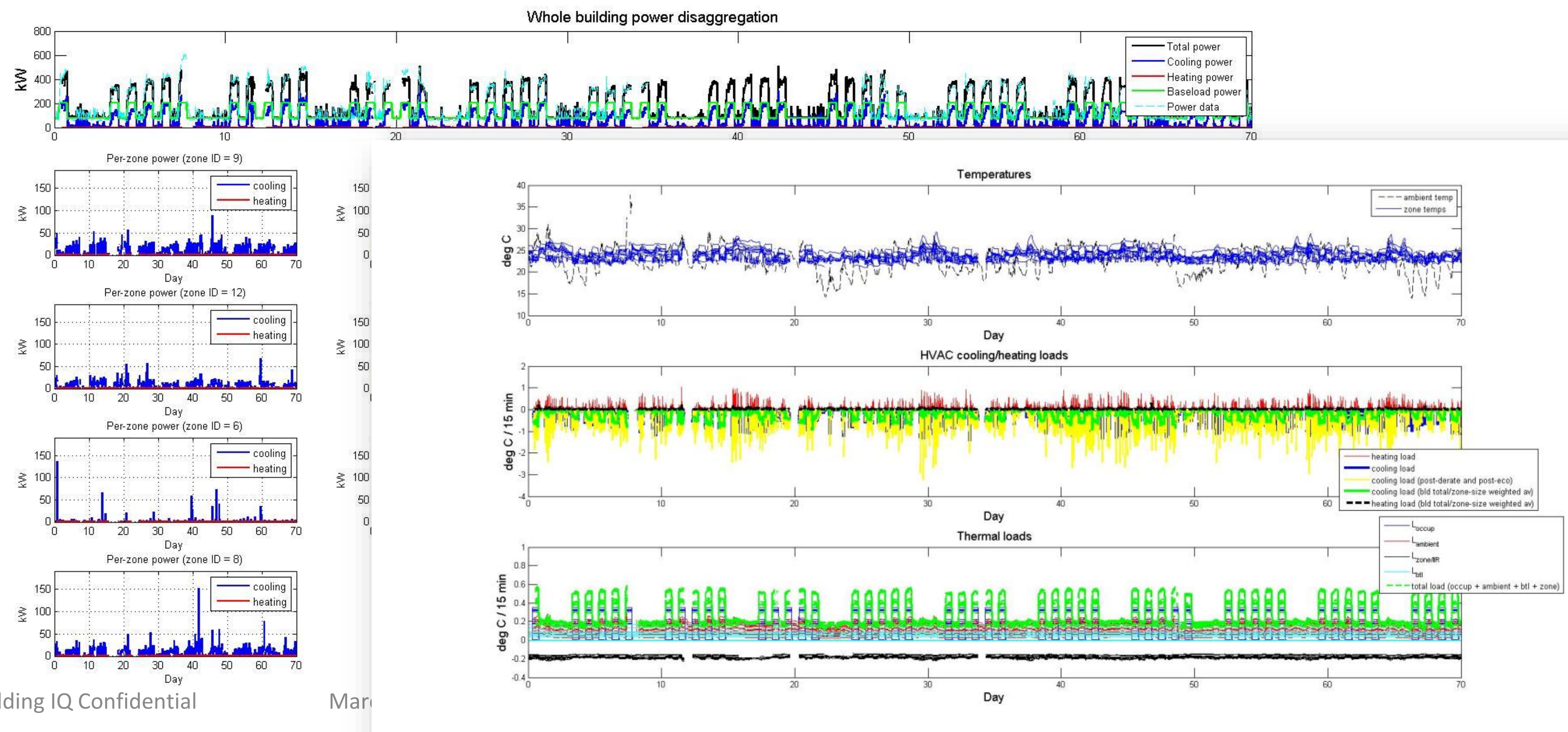
  7.) Unit testing framework (huge codebase, needs discipline!)

- Matlab enabled us to rapidly translate our prototypes into production-level algorithms that can deal reliably with real-world noise/uncertainty

BIG DATA ANALYTICS AND CLOSED LOOP REAL-TIME OPTIMIZATION : SO MUCH MORE THAN JUST PREDICTIVE MODELING

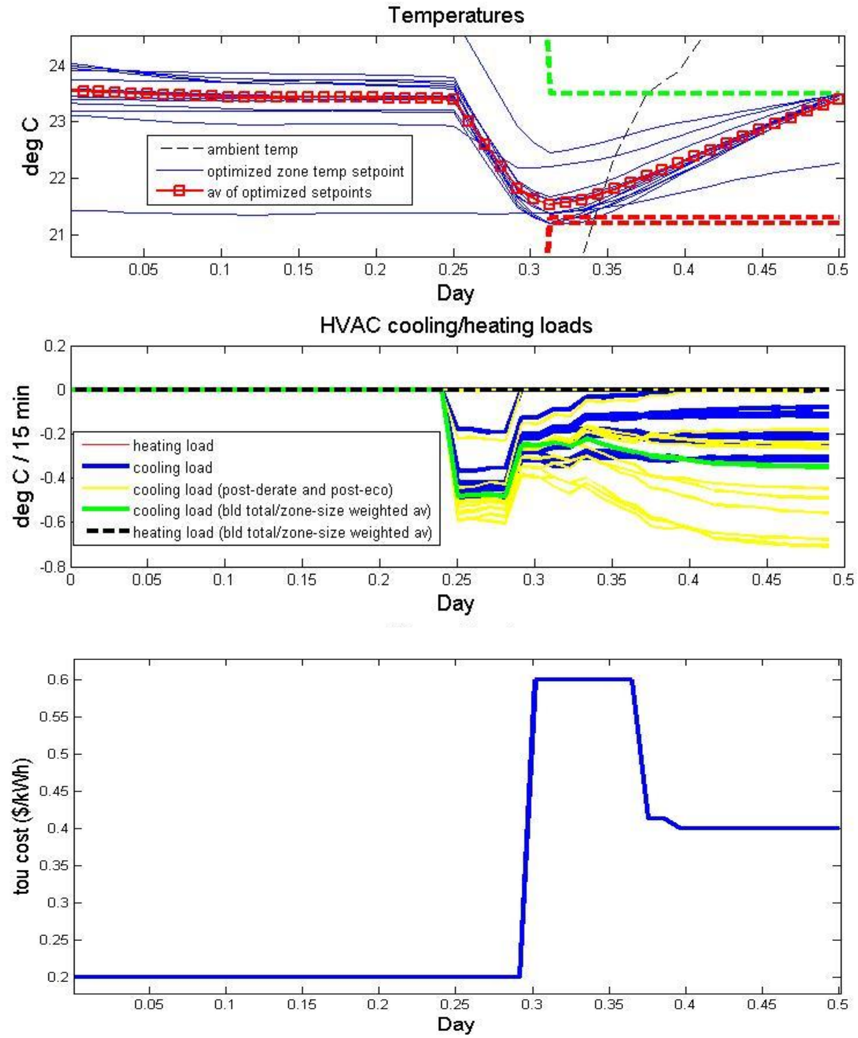
The power of big data (1) : Deep analytics of building thermal and power dynamics

- We exploit the power of big data to learn about the thermal and power dynamics of each building
- Billions of data points pulled over the cloud to create the thermal/power models that are subsequently used in our closed-loop optimization strategies,
- Some serious mathematical machinery powered some serious cloud-based computing
- Powered by Matlab's robust optimization routines embedded within our cloud-based infrastructure



The power of big data (2) : big data predictive optimization, so much more than just predictive modeling

- It's nice to have deep-level analytics to build a thermal/power model (previous slide), but how to use this information?
- We employ predictive optimization (i.e. optimal control) to compute the optimal setpoints
- We re-calculate/revise predictions to take into account changing weather information,
- This is prediction + closed-loop control in real-time with hundreds of decision variables
- Maximizes HVAC use when tariffs are low (low energy costs) and when heating/cooling is easier to achieve (low ambient temperature and humidity) subject to thermal mass/inertia effects
- In the end it's all just a game : i.e. we optimize building operation subject to the goal of energy efficiency, and subject to the laws of thermodynamics and any system-level constraints



The power of big data (3) : Real-time predictive control in action

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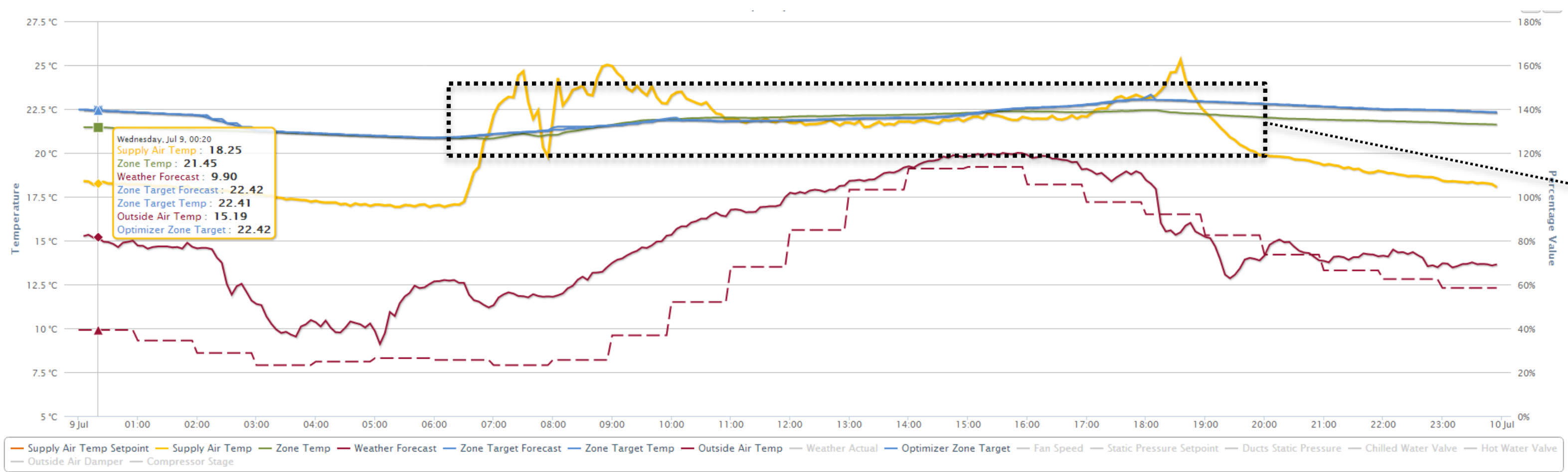
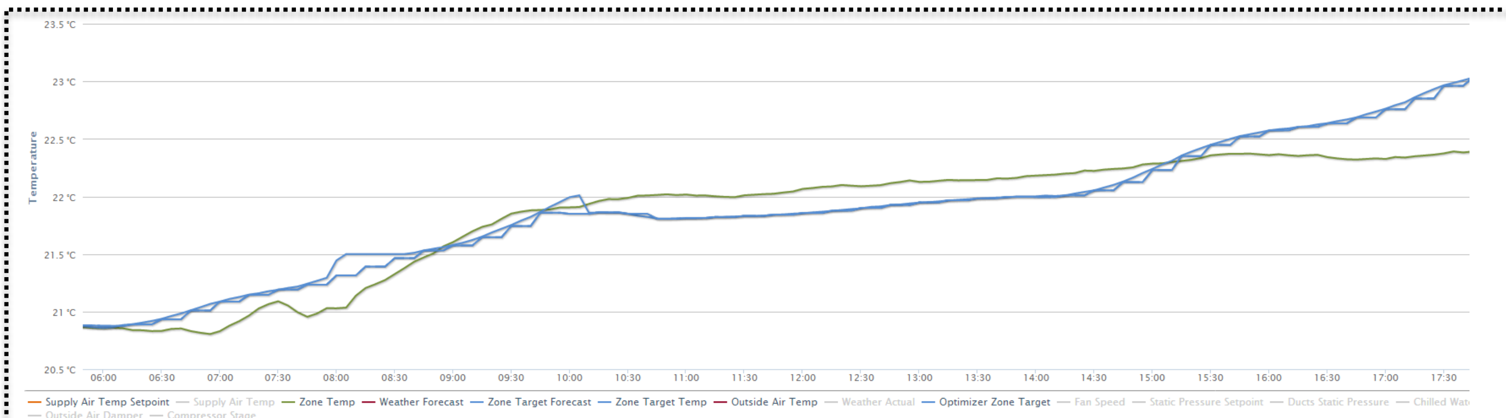
An optimized run over a 24 hour period:

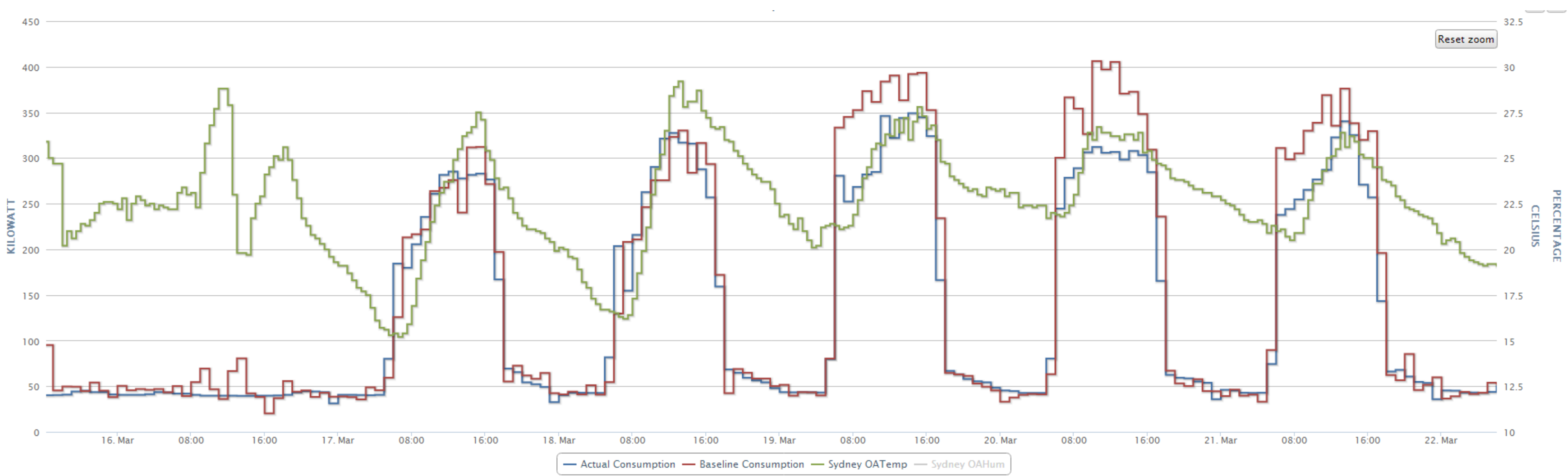


A BuildingIQ-optimized control setpoint being tracked by the zone temperature :



The power of big data (4) : savings maketh the man

- Generally we achieve 10-25% savings on total energy cost
- HVAC consumption is generally approx. 40% of total energy cost, so we can reduce HVAC energy consumption by half!
- How do we evaluate savings?
- We use a separate mathematical model to “baseline” the building power consumption when we’re not in control :



- The baseline model accounts for the effects of ambient temperature and humidity (enthalpy!) on total energy consumption

Conclusion

- Technology successfully deployed and saving on buildings in the US and in Australia
- Repeatable savings and proven results
- Employing big data, scientific principles, deep mathematics, large-scale mathematical optimization, and cloud-based distributed computing
- Achieve 10-25% savings on total energy bills; so if your bill is $1,000,000, how much would you save?
- A success story both in Australia and in the US