Annual AEIC Load Research Conference

Is it On?

Impact of Duty Cycles on A/C Control Strategies

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What's Up?

- **Demand Response Programs are becoming more popular**
  - **Uncertainty in supply incentive to look for demand-side control options**
  - **Utilities no longer control supply in many states due to deregulation**
  - **Regulators, consumers concerned about shortages: no more "Californias"**
  - **Transmission constraints**

Old School

- **Traditional Direct A/C Load Control Programs: Operation**
  - **Pay customers a fee to allow control**
  - **Control 15 or more days per Summer**
  - **Typically one-way radio switches**
  - **Customers get $ BUT high free-rider %**
  - **No way to verify that switch is operational except for monitored sample**

Old School

- **Traditional Direct A/C Load Control Programs: Monitoring & Verification**
  - **Load impact hard to verify**
  - **Signal Propagation tests**
  - **Monitor a sample of sites**
    - **End use load recorders or loggers**
  - **Use surveys, load sample to estimate overrides, signal failures**
  - **Evaluation after the summer**
  - **Regulatory DSM Treatment**

New School

- Today's Typical A/C Load Control (Demand Response Programs)
  - Customers get a free thermostat and a small cash payment to allow control
  - Customers also get ability to access thermostat over the Internet
  - Control during critical periods (<10)
  - Two-way wireless switch built into thermostat – all can be monitored
  - Customer gets more → fewer free-riders

New School

- Today's Typical A/C Load Control (Demand Response Programs)
  - Monitoring via two-way communication
  - Overrides automatically tracked
  - Virtually 100% monitored
  - Database of run-time, other stats
    - Large databases permit segmentation
  - Evaluation day-after (once baseline established)
  - Utilities can use it as verifiable demand-side resource

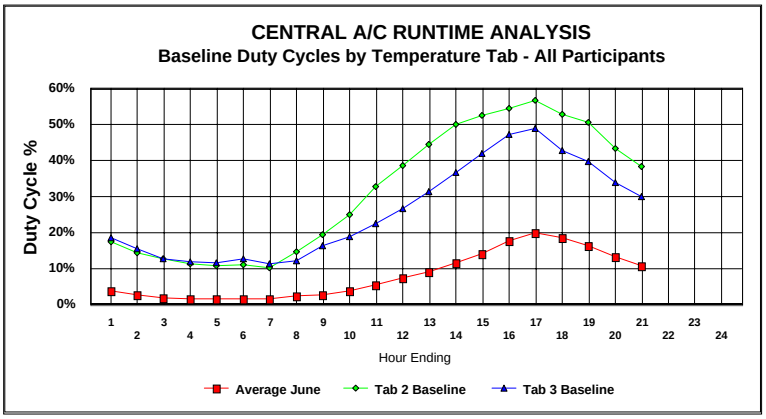
Monitoring & Evaluation

- Duty-cycle based analysis
  - TOU loggers
  - Smart thermostats
    - Carrier/Silicon, Cannon, Enernet (Wall)
    - Some store run-times
- Additional kW spot metering
  - Develop average connected kW to apply to duty cycle results
  - Confirm manufacturer nameplate

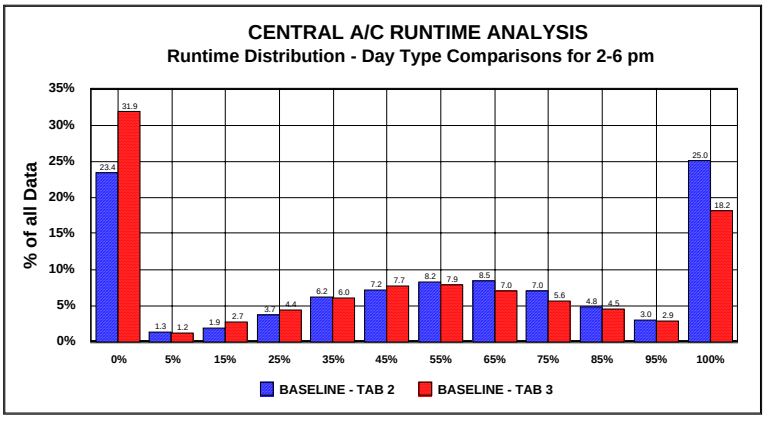
Why Duty Cycle Analysis?

- Most control strategies restrict on-time to pre-set minutes/hour (e.g. 30)
- Units already below pre-set maximum (e.g. 50%) will have no impact
- A/C use is discretionary: hard to model:
  - Thermostat settings vary
  - Some units are off regardless of indoor temperature
  - Customer may not be home.. May leave unit on low or off

Typical CAC Average Duty Cycle



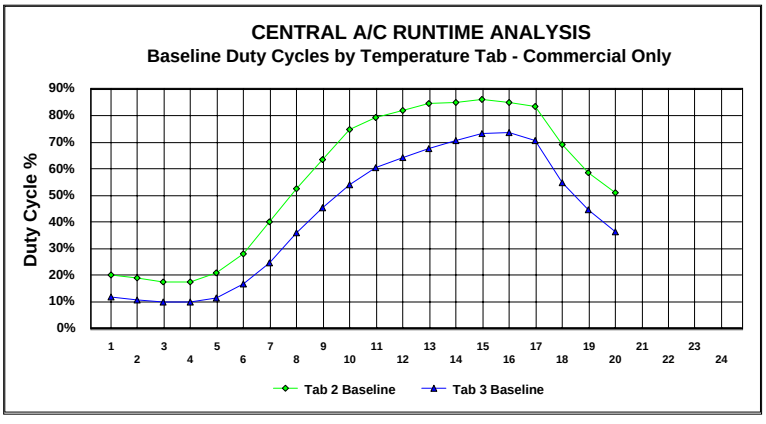
Typical CAC Duty Cycle Distribution



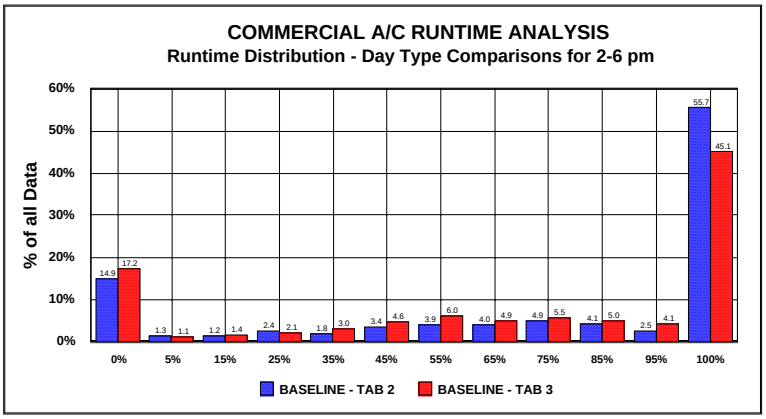
RESIDENTIAL CAC: IS IT ON?

- Can predict load impacts from baseline
- Average Duty Cycle on 86 deg. day (Tab 2) only 58%
  - Does 50% control get 8% impact? NO!
- Duty Cycle distribution analysis (Tab 2):
  - About 50% of units exceed 50% on-cycle
  - 25% of units at 100% on-cycle
  - Theoretical impact is 19% of connected kW
  - Overrides must be considered

Typical Commercial CAC



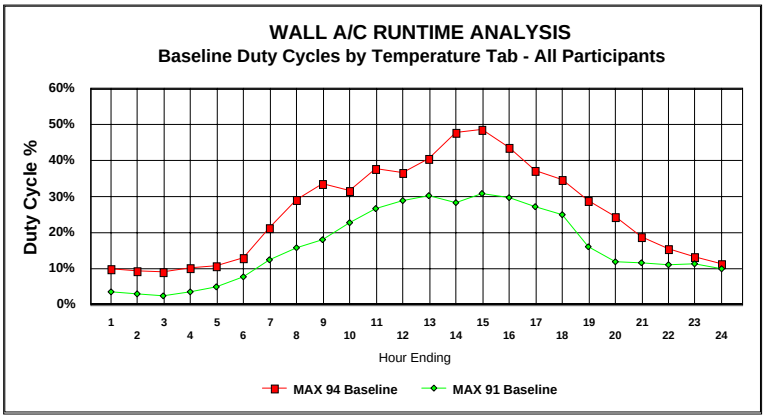
Typical Commercial CAC



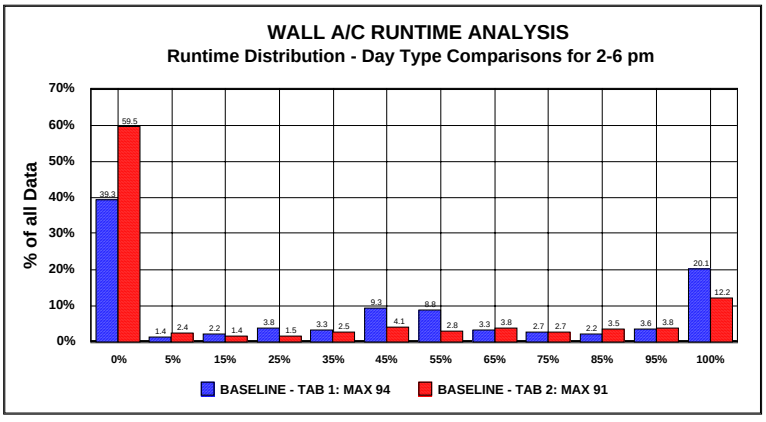
Typical Wall A/C Units

- **Only Residential Units Studied**
- **Wall A/C defined as large through-wall units serving Living Room/Den**
- **Average size app. 18,000 BTU**
- **More discretionary than Central A/C**
  - **Lower average duty cycle**
  - **Higher percentage off**

Typical Wall A/C units



Typical Wall A/C units



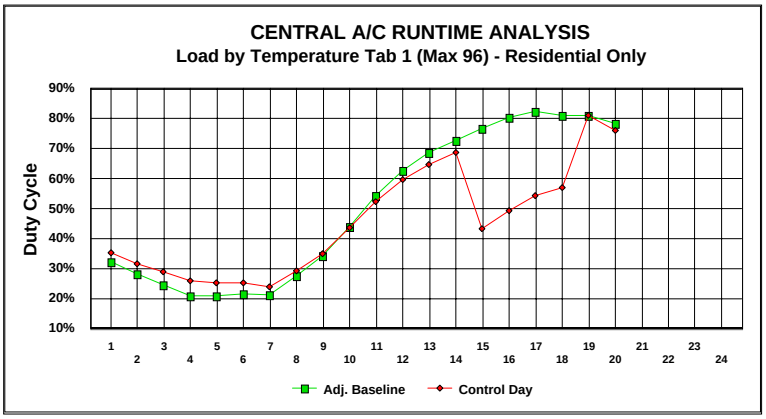
Load Impact Calculation

- Several methods applicable to duty cycle analysis
  - Comparison Day (Temperature tabs):
    - Compare Control Days to Baseline days with comparable weather
    - Dependent on having comparable days
    - Many demand response programs control on all the hottest days – no baseline!
    - Can adjust baseline (each interval) by ratio of CDD, max 100%

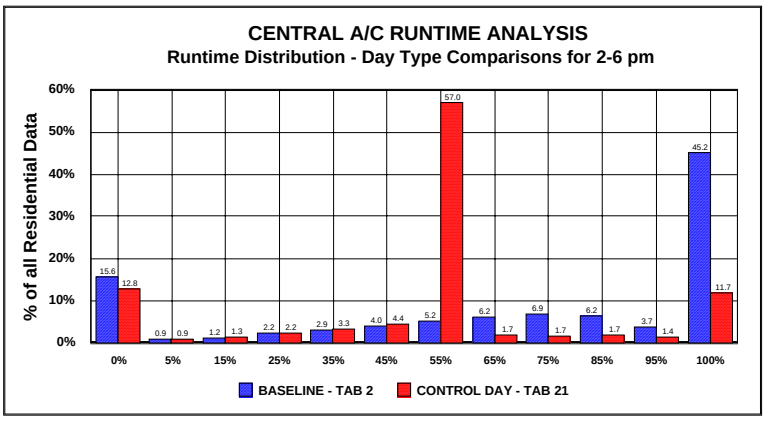
Load Impact Calculation

- Methods applicable to duty cycle analysis
  - Create Model of Duty Cycle distribution
    - Duty Cycle distribution a function of weather: plug in control day weather in baseline model to predict baseline, then subtract actual control day
    - Requires extensive database to ensure model validity

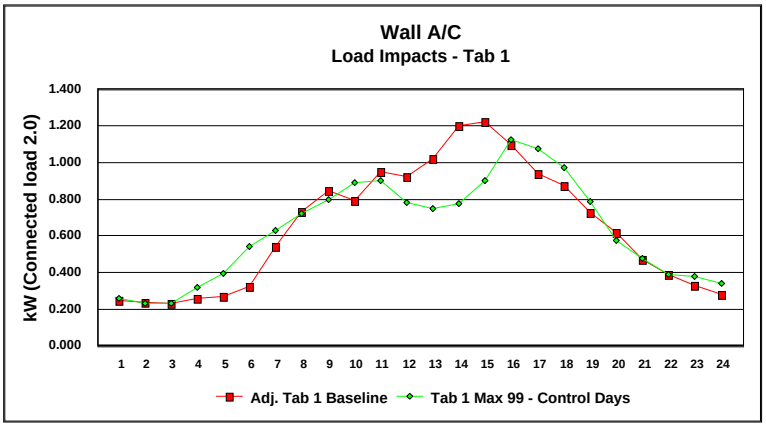
Load Impact Analysis



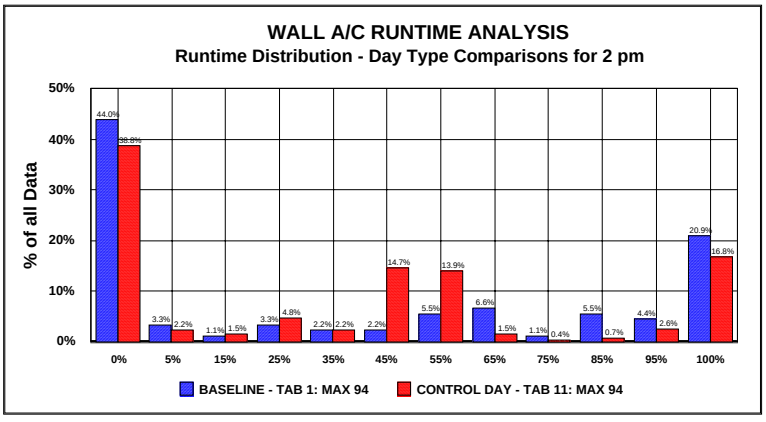
Load Impact Analysis



Load Impact Analysis



Load Impact Analysis



Load Impact Analysis

- What happens if no Control Days?
  - Create “shadow” interval duty cycles for sets of baseline days (temp. tabs)
  - Apply control strategy (e.g. 50% off) by modifying all intervals to max out at pre-set value
  - Subtract simulated control day from baseline to produce impacts
  - Apply estimate of overrides

Load Impact Analysis

- What happens if Baseline is poor?
  - Can happen if all hottest days are control days
  - Extrapolate model of duty cycle distribution
    - Exclude zeros from adjustment
    - Max out at 100%
    - Beg for more baseline days!

CONCLUSIONS

- **Duty Cycle models are the best approach for load impact analysis**
  - **Inherently simpler to understand**
  - **Provide flexibility since you can more accurately adjust for weather**
  - **Accounts for both shut-off units and max'd out units**
  - **Can identify overrides**