# Rooftop HVAC Field Monitoring Protocol & Annual Savings Estimation Methodology

## CEE Winter Meeting

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# NW Commercial Building Stock Assessment (CBSA) RTU counts-6th Power Plan

| AREABIN | Average of Count Package RTU Units | Average of Pack HVAC Tons | Faction of PNW Floor Area | Building Count | Fraction with RTU | RTU Count |
|---|---|---|---|---|---|---|
| 1. <5,000 | 1.9 | 4.7 | 10% | 89877 | 70% | 118,000.00 |
| 2. 5,000-20,000 | 4.3 | 5.5 | 23% | 57593 | 61% | 151,000.00 |
| 3. 20,000-50,000 | 8.8 | 9.0 | 19% | 15616 | 54% | 74,000.00 |
| 4. 50,000-100,000 | 16.1 | 27.5 | 15% | 5816 | 35% | 33,000.00 |
| 5. 100,000-500,000 | 19.7 | 14.1 | 28% | 4946 | 30% | 30,000.00 |
| 6. >500,000 | 5.5 | 5.2 | 4% | 175 | 5% | 100.00 |
| **Grand Total** | **8.9** | **7.0** | **100%** | **174023** | | **406,100.00** |

**51% floor area <50kSf**

**Est. RTU Population**

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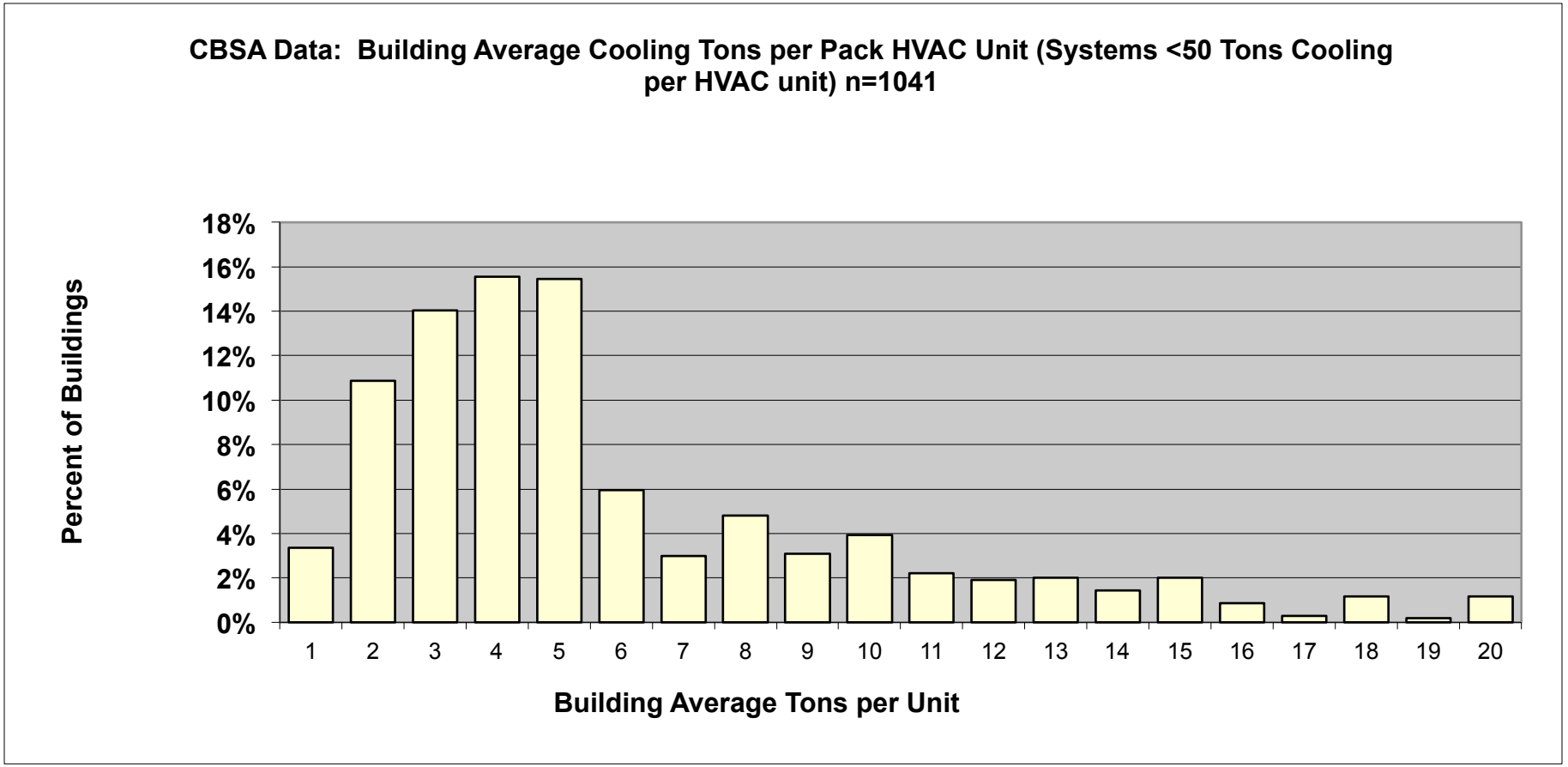
# % buildings, tons per RTU…




64% of buildings <6 tons

79% of buildings <10 tons

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# PNW RTUs an aging fleet…

| Age category | | Under 5 tons | 5 to 10 tons | Over 10 tons |
|---|---|---|---|---|
| | | 44% | 36% | 20% |
| **0 to 4** | 17% | 30,000 | 24,000 | 14,000 |
| **5 to10** | 32% | 56,000 | 46,000 | 26,000 |
| **10 to 19** | 35% | 62,000 | 50,000 | 28,000 |
| **20+ years** | 16% | 28,000 | 23,000 | 13,000 |

**51% = 204,000 of the units have been on the roof for over a decade!**

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# RTU-DTU (Diagnostic Tune Up) Realities

- Simple controllers, low quality sensors, and primitive dampers insure minimal functionality in many units
- Economizer/OA adjustment: 54%
- Economizer not working at all: 35-67% [3 studies + Big Box report]
- Airflow/heat transfer problem: 22%
- T-stat/controls reset: 32%
- T-stat replace: 17%
- Outside air sensor problem: 22%
- Change over problem: 44%
- Minimum outside air too high: 20%
- Minimum outside air too low: 65%:

# Regional Technical Forum – RTF
# http://www.nwcouncil.org/energy/rtf/

Chartered by NWPCC & Bonneville Power Administration in 1999 to:

- Track progress toward the region's conservation and renewable resource goals
- Review cost and savings associated with new and existing energy efficiency and renewable resource measures
- Develop standardized measurement and verification protocols used to estimate efficiency and renewables savings
- Develop/review energy efficiency program specifications
- Established Rooftop Unit Working Group (RTUG) - 2006

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# RTF 2010 Funders

- Avista Utilities
- Bonneville Power Administration
- Clark County PUD
- Cowlitz PUD
- Energy Trust of Oregon
- Eugene (OR) Water and Electric Board
- Idaho Power
- Northwestern Energy
- PacifiCorp
- Puget Sound Energy
- Seattle City Light
- Snohomish County PUD
- Tacoma Power

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# RTF 2011 Budget Allocation

| Category | 2011 Budget | Percent |
|---|---|---|
| Standardization of Technical Analysis & Existing Measure Review | $660,000 | 47% |
| Review of New Measures, Specific Technologies, Identified High-Priority Measures & Unsolicited Proposals | $300,000 | 21% |
| Develop plan, funding and data warehouse for end-use load research | $100,000 | 7% |
| Website, Database support, Conservation Tracking | $30,000 | 2% |
| RTF Member Support, Contract Staff & Administration | $310,000 | 22% |
| **Total** | **$1,400,000** | **100%** |

# RTF Activities 2011

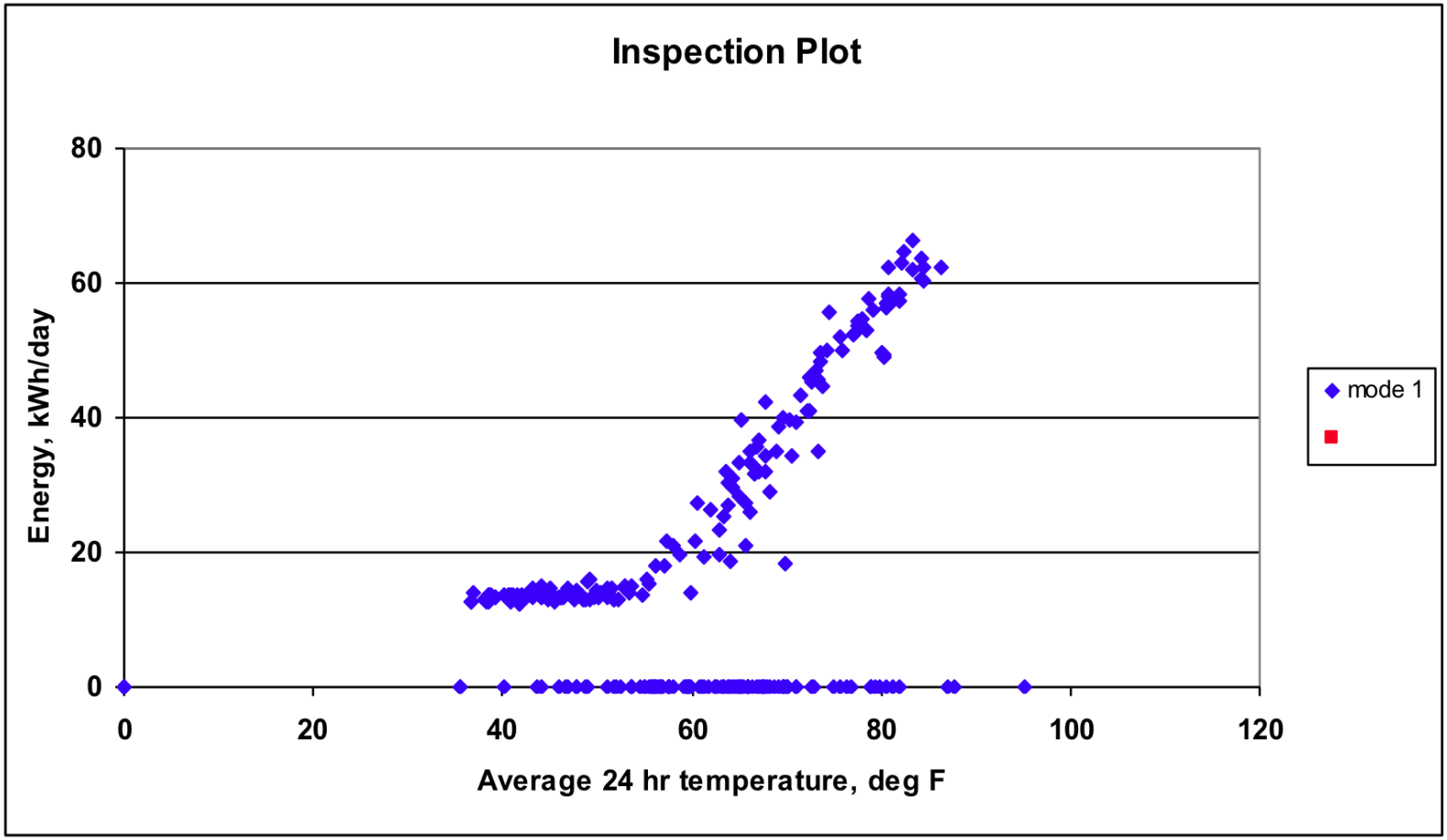
- Direct Use of Natural Gas
- Grocery Refrigeration
- Ground Source Heat Pump
- Information Technology Sector
- Operations
- Performance Tested Comfort Systems
- Residential Weatherization and Ventilation
- Rooftop Unit Work Group – Phase 4 Since 2006
- Small Commercial Weatherization
- Standardized M&V and Deemed Measure Protocols
- Small/Rural Utilities Efficiency Measures
- Variable Capacity Heat Pump with Bonneville Power Admin Leading
- Measure Life
- Fan VFD
- Whole building M&V

# RTU Proposed Field Monitoring Protocol

- Timing is critical: **4 weeks pre-metering May-Jun**

  **4 weeks post-metering Aug-Sept**
- 4 weeks minimum allows weekday and weekend data
- Regressions with hot weather 1st wk July through 1st wk August will bias annualized predictions due to limited cool weather with little or no economizer use
- True power measurement: 1 minute data allows hourly/daily analysis
- Outside air temperature at site or local NOAA weather station with TMY data [*$R^2$ 0.96 with 0.32degF higher at site]*
- Potentially inexpensive metering by using a *Dent Elite* logger in the breaker box to meter 2 units as well as local hourly data
- RTU supply air temperature measurement optional; not necessary for annual usage estimate, but useful for estimating minimum percent OSA

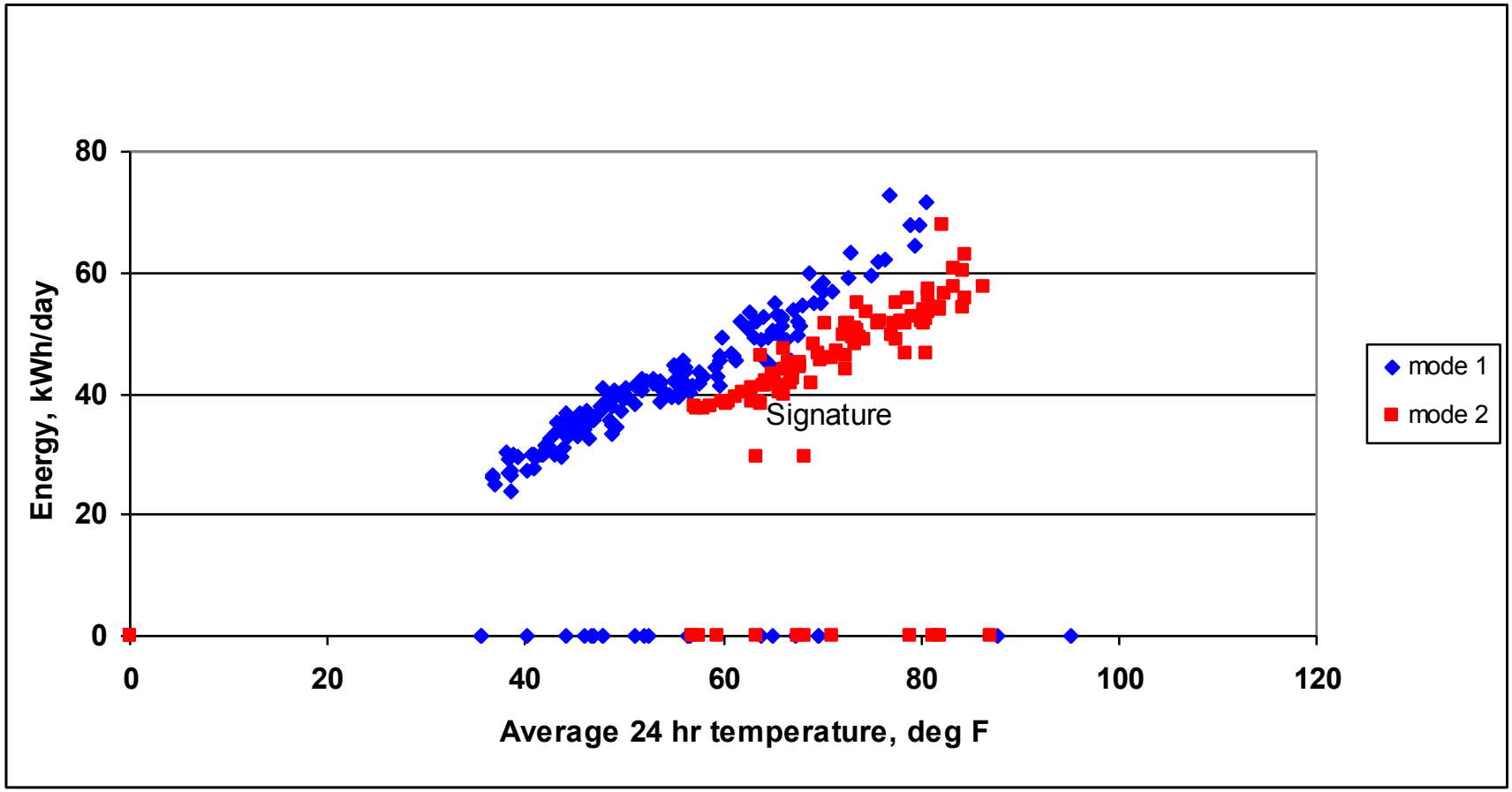
# Metered Data – Energy Signature




Pattern consists of the baseload kWh as the horizontal points [a timed fan in this case]

The sloping portion is increased temperature correlated to increased daily RTU energy

# Pre/Post-Service Signature

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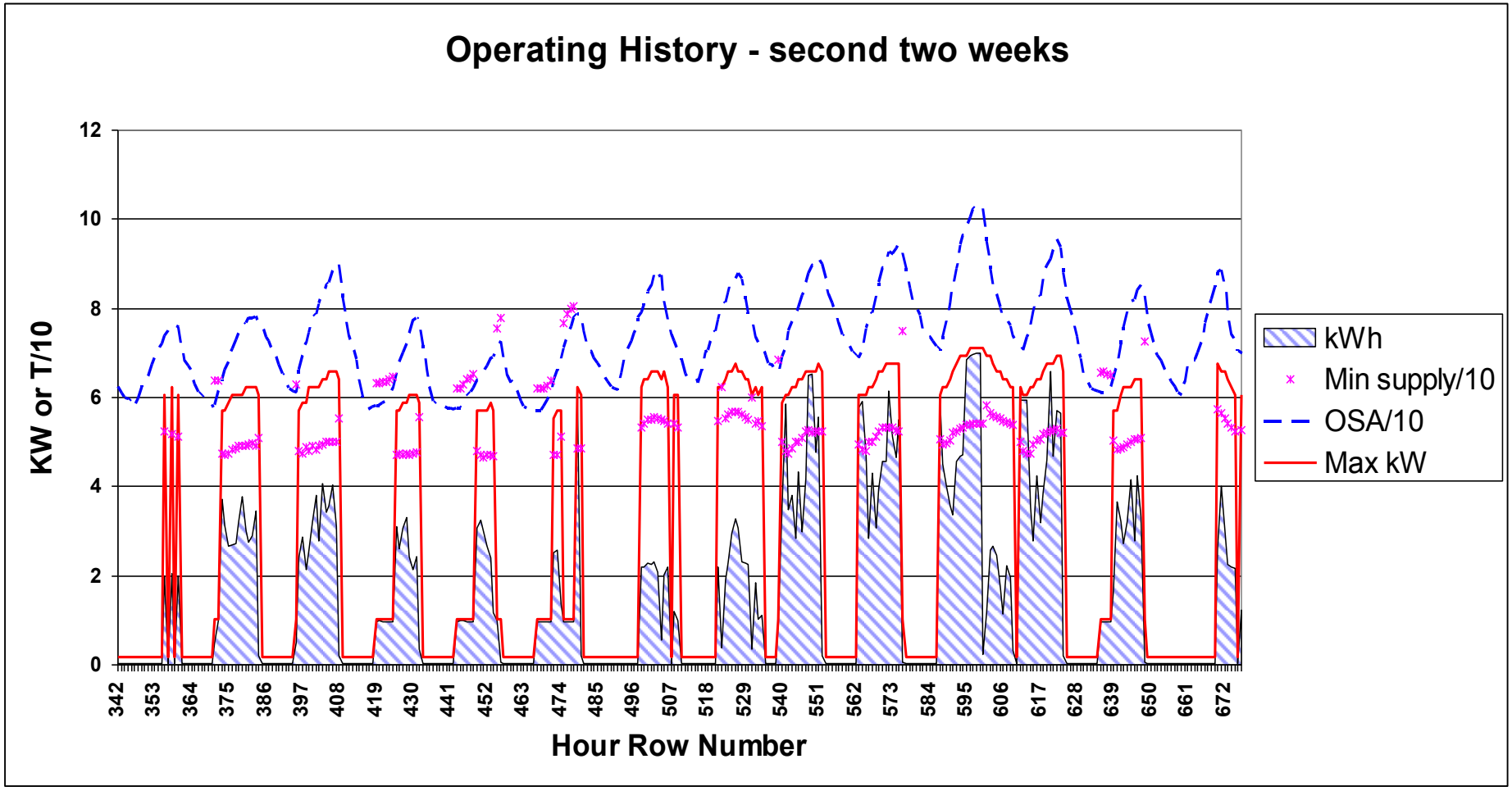
# Useful Diagnostic Data From Metering

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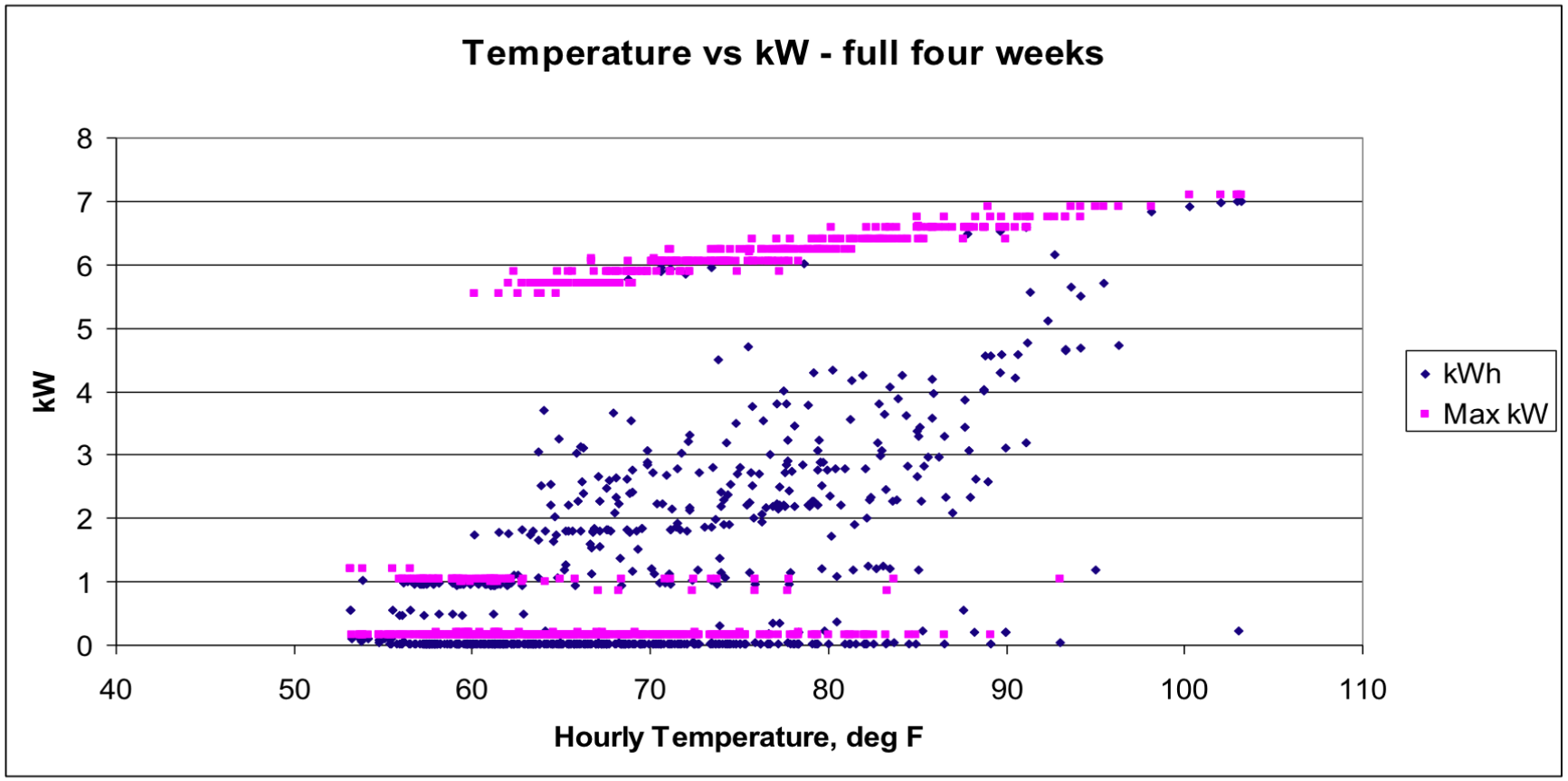
# Economizer Operation
# Minimum OSA




**Peak kW vs. temperature is very distinct**

**Unit likely oversized and never maxes out**

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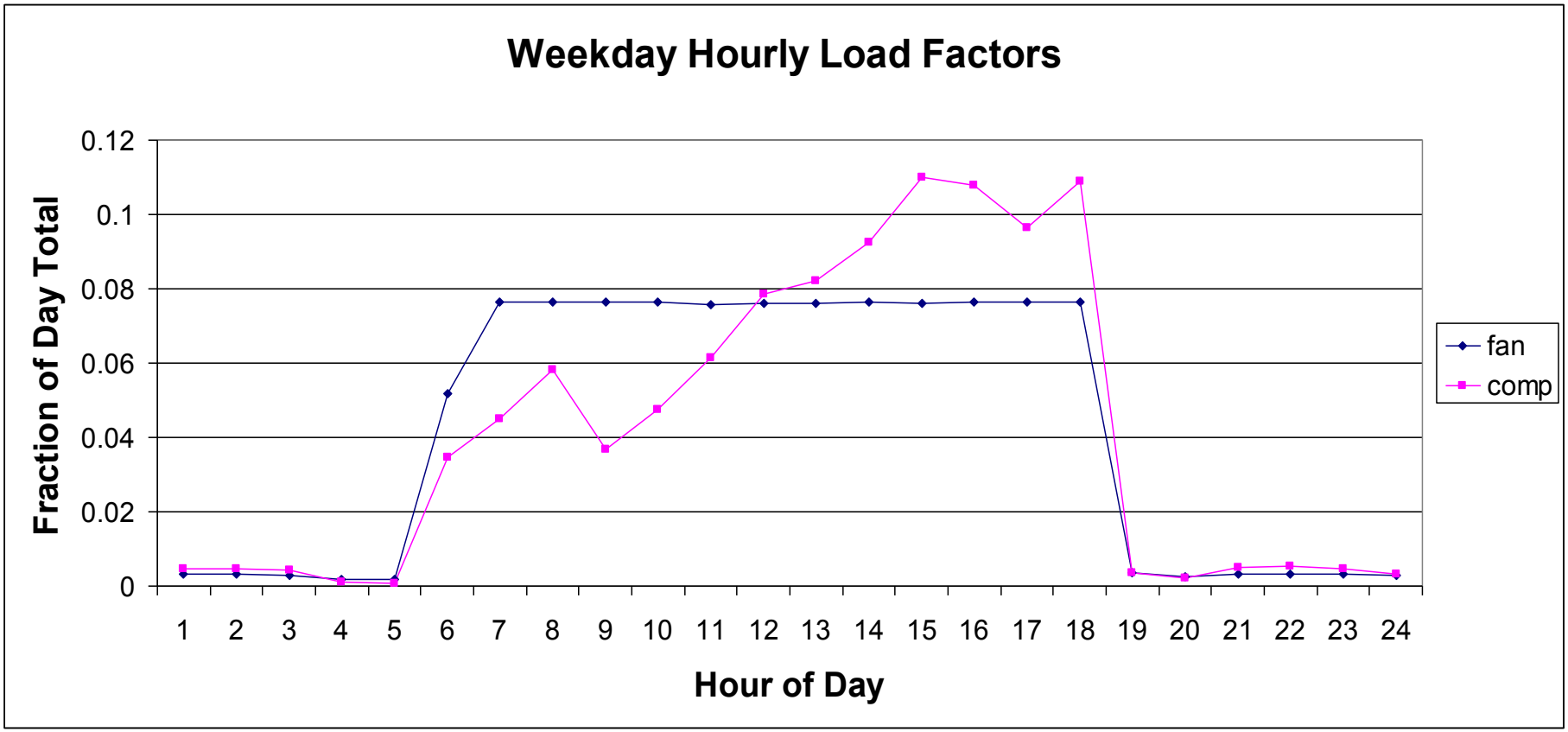
# Hourly Data Modeled by Deriving Hourly Load Factors

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# Sample Size
# Program Savings Evaluation

- 20% precision with 80% confidence
- Sample sizes of about 60 can detect program savings as small as 10%

| Number of Units | Sample Size |
|---|---|
| 100 | 55 |
| 500 | 60 |
| 1,000 | 60 |

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# PNW RTU Data Processing

- 1-minute data is examined automatically to find the fan only power and the maximum power level in each hour
- 1-minute data aggregated to hourly averages for graphic presentation
- Hourly averages aggregated to daily averages of power and outside air temperatures, including the associated day type designator(weekday/weekend)
- The daily average data is the basis of the weekday and weekend energy signatures
- Must have separate weekday and weekend signatures

# Overall Findings

- RTUs have a steady enough pattern that their in field energy use can be metered and modeled
- It is important to model at least two operating regimes: weekdays and weekends
- On an annual basis, fan power is the dominant RTU end-use in the PNW, up to 2/3's
- In-situ metering can be used to verify models and to explore savings options

# PNW RTU Research Results Database

http://www.nwcouncil.org/energy/rtf/subcommittees/rtug/2009_rooftop/Default.aspx

## Site Summary

- Site ID
- RTU ID
- Weather data
- Annual kWh pre-service
- Annual kWh post-service
- Compressor stages
- Compressor max duty (fraction of full load)
- Economizer (y/n)
- Monitoring level

## Pre- and Post- Service Summary

- Fan kW
- Fan duty (fraction of full load)
- Baseload kWh/day
- Balance point temp
- Slope kWh/day/degF
- Demand stages 1&2 kW
- Compressor trigger degF

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# RTF Next Steps

- RTF initial review of field measurement protocol and annualized savings calculator on Feb 14, 2012; potential final review March RTF meeting (check website for date)

- When adopted, utilities operating RTU maintenance programs can book kWh savings in accordance with regionally deemed protocol

# ANSI/ASHRAE/ACCA 180 Quality Maintenance Standard

**REFRIGERATION CONTROL PANEL**
•Sequence test all controls
•Calibrate and clean controllers and safety controls
•Check setpoint of controls and limits

**ELECTRICAL DISCONNECT**
•Inspect contacts
•loose connections
•Check for proper operation

**ECONOMIZER**
- Replace sensor
- Correct set points
- Check blades

**REFRIGERANT AND REFRIGERATION COMPRESSOR**
•Check crankcase heater operations, refrigerant and oil leaks, refrigerant charge and oil level and condition
•Perform acid test10
•Observe bearing and operating surface temps
•Measure vibration

**FILTER SECTION**
• Replace media as required

**FRESH AIR, RETURN, AND EXHAUST AIR DAMPERS**
•Check for unrestricted and proper operation and close-off
•Lubricate bearings as required

**COOLING COIL**
• Inspect and clean as required
• Check condition of finned surfaces and straighten if bent
• Check for corrosion and leaks

**CONDENSER COIL**
•Clean finned surfaces

**CONDENSER FAN/MOTOR**
•Perform vibration test
•Lubricate bearings
•Examine motor mount resiliency
•Check motor insulation resistance

**BURNER SECTION**
•Perform combustion and draft tests
•Inspect and clean nozzles
•Inspect, clean and lube burner fan (gun type burners)
•Test safety controls

**RETURN AIR FAN/MOTOR & SUPPLY FAN/MOTOR**
•Perform vibration test
•Lubricate more bearings
•Check motor insulation resistance
•Examine motor mount resiliency.
•Lubricate bearings and check for end play, excessive bearing temp and wear
•Check blower and clean dirt accumulation
•Check condition of drive couplings and belts
•Check for alignment, balance, security to shaft
•Check rotation

# CEE Recommendations

- Detailed Comm HVAC Committee review of the final PNW field protocol and calculator
- Promote ANSI/ASHRAE/ACCA 180 Quality Maintenance Standard as a minimum required utility service program approach
- Review technician credentialing and address knowledge gaps such as the economizer and air flow measurement
- Review Honeywell Economizer Savings Estimator (other similar tools?) for use as customer educational/sales collateral
- Review advanced controls/VSD including review of DCV work in other building use/types beyond kitchens; PNW Premium Ventilation project applied nationally
- Review new RTU controller products including Honeywell JADE (W7220)
- New RTU products including VRF (already on CEE agenda), air to water HP, radiant heat/cool, combos with heat recovery for DHW; DOE/CBEA High Performance RTU: Daikin-McQuay *Rebel*

# > Thanks <

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