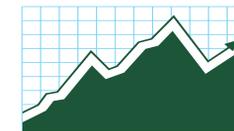




Measuring In-Field VRF Performance and Measurement Techniques

IEPEC Denver, October 2025

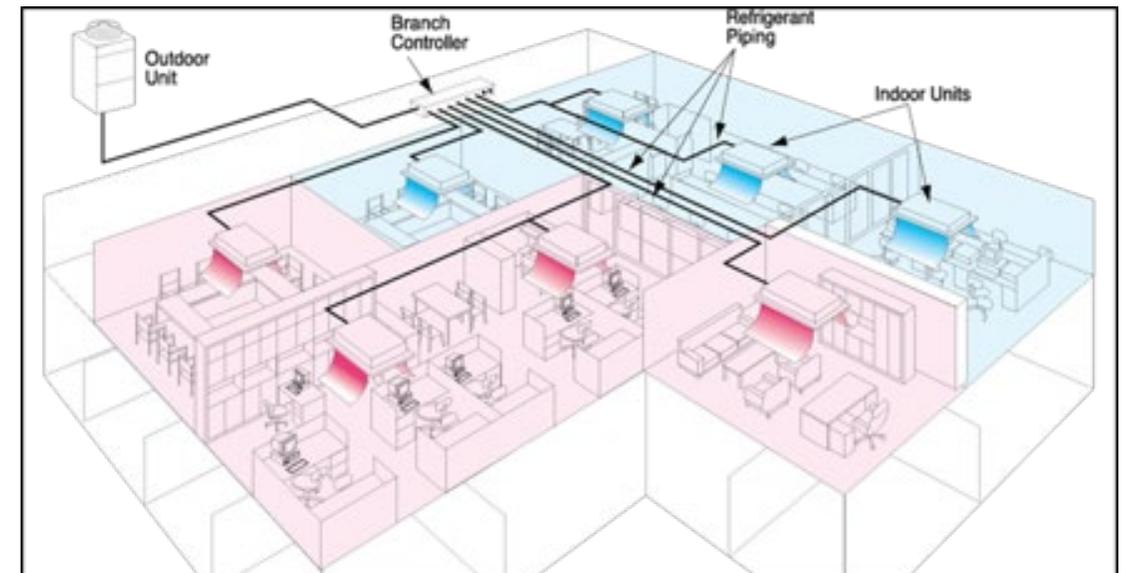
David Korn, Chris Zimbelman, Greg Goodyear,
Ridgeline Energy Analytics



RIDGELINE
energy analytics

Variable Refrigerant Flow (VRF)

- Variable refrigerant flow (VRF) is an HVAC technology that can provide both heating and cooling.
- VRF systems circulate refrigerant as the heat transfer medium. VRF systems generally include one or more air-source outdoor compressor units serving multiple indoor fan coil refrigerant evaporator units.
- DC inverters are added to the compressor to support variable motor speed and thus variable refrigerant flow rather than simply perform on/off operation.
- Systems selected with a heat recovery module have the added benefit of simultaneously heating and cooling from one condensing unit, transferring energy between zones.



Potential VRF Issues

- Headwinds forming – concern about volumetric toxicity of refrigerant – ASHRAE 15
 - VRF vs. heat pump – have larger amount of refrigerant that could be serving a head in a small space such as an office
- COP values uncertain
 - High rated COPs, but are they achieving that in the field?

Northeast Focused Studies

- **16 Sites with 37 VRFs**
- Goals varied a bit by study but overarching goals included:
 - Understand performance and level of use for VRFs
 - Measure consumption, estimate fossil fuel offset
 - Application of VRF systems in cold climates has grown in recent years, with increased interest in electrification solutions
 - To further increase market confidence, 3rd party validation of VRF system performance in cold climates was needed
- Approach:
 - Measure in-field energy consumption of VRFs
 - Energy consumption and performance
 - Refrigerant leakage

Study Limitations

Not a significant enough sample size to draw definitive conclusions of VRF technology

One study (26/36 total units) did not meter indoor loads, COPs are estimated

Even on sites with indoor units metered, data can be tricky

It is observational, educational, and directional

Initial Takeaways

VRFs are being used to offset fossil fuel use

Level of use and offset varies by building and building type

New construction – all electric buildings

Retrofit – may still maintain fossil system

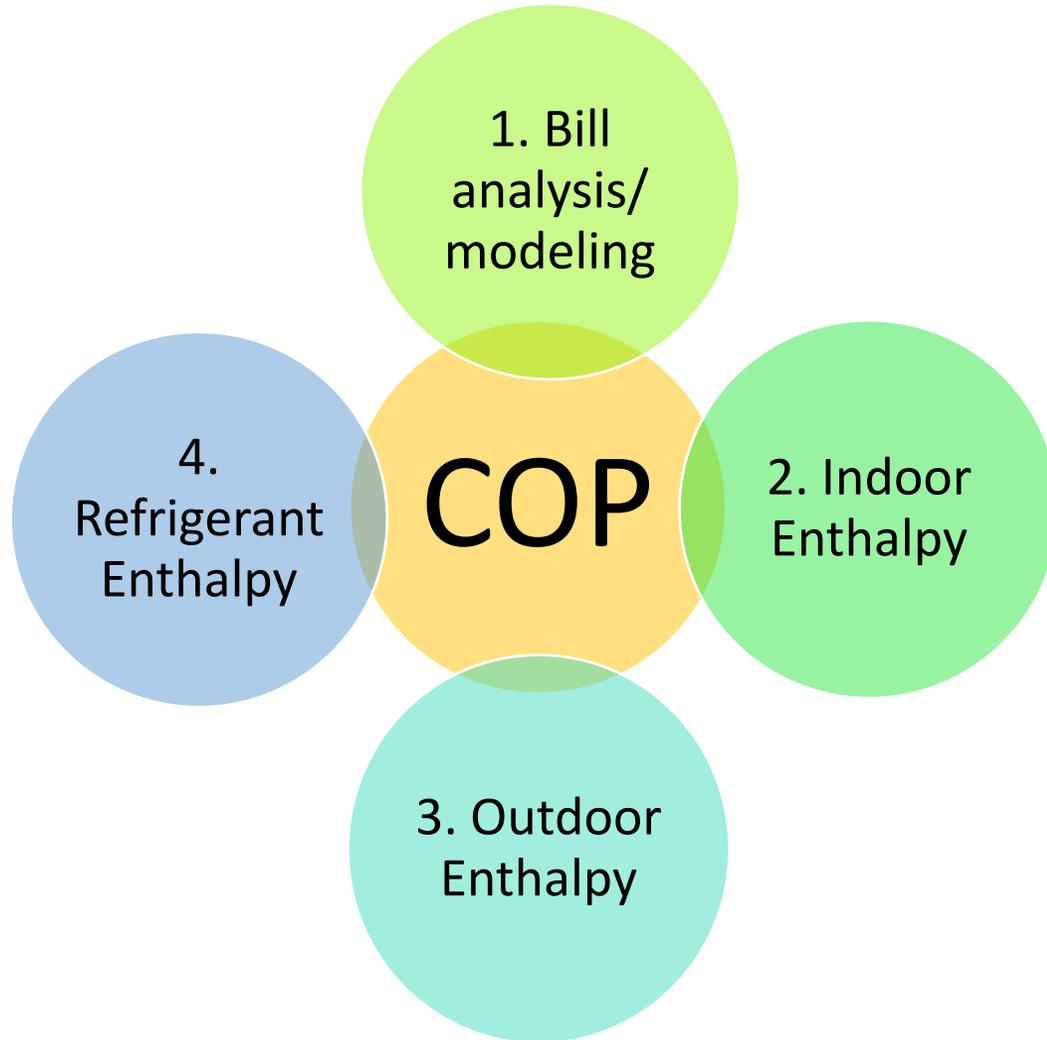
- Use varied significantly as well as COP

Normalized Consumption Values

Use Examples

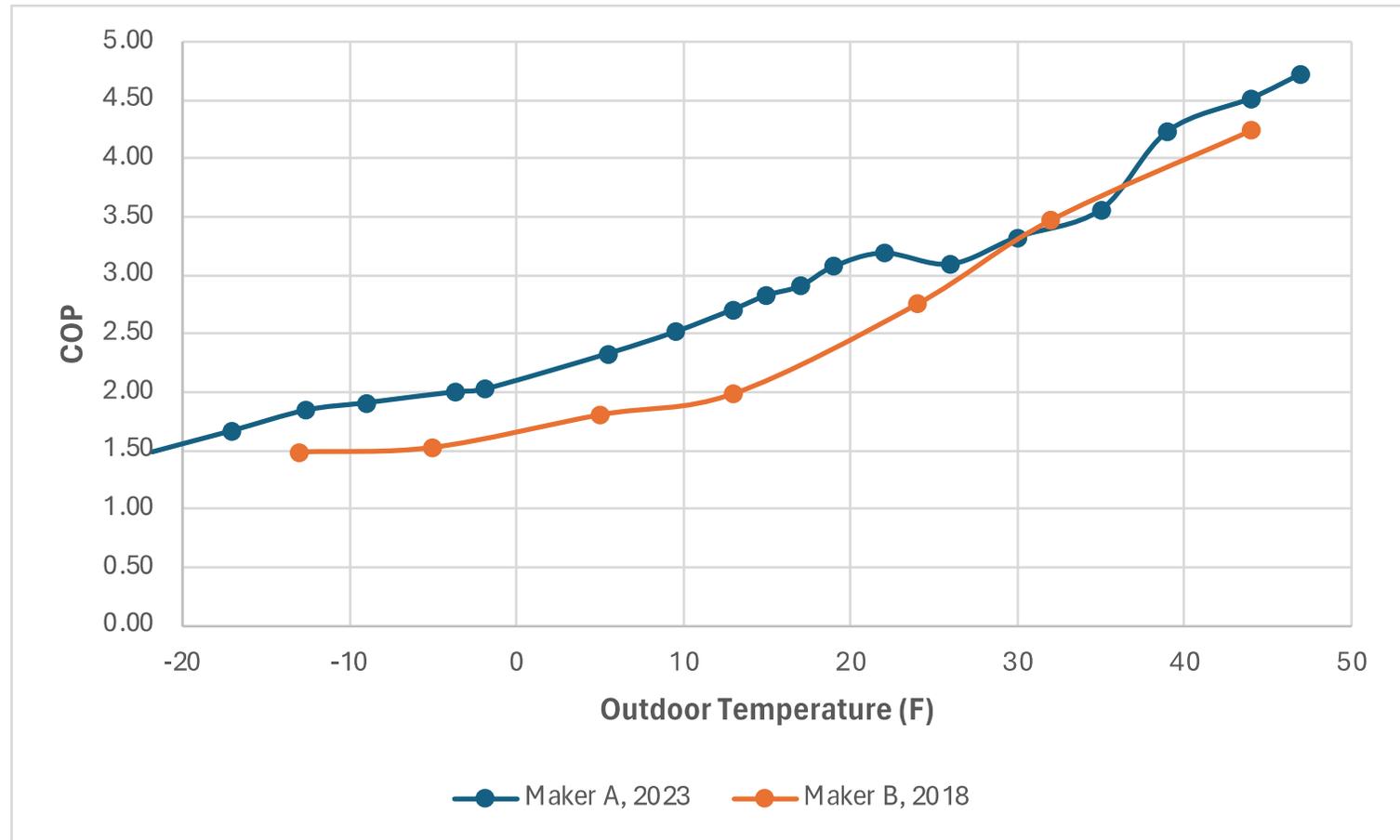
1. Heating and cooling – low cooling loads
2. Primarily cooling
3. Heating and cooling – also uses supplemental boiler for heating
4. Used for heating and cooling

What about their Performance (COP)?



- $COP = \frac{\text{energy benefit}}{\text{energy consumed}}$

Rated
Heating COP:
3-pipe



COP 1. Billing Analysis/Modeling

Retrofit fuel buildings

- Pre/ post analysis can provide an approximate COP but delivery timing and DHW can create difficulties

All electric buildings

- Works if the VRF provides all or a known and substantial portion of the building's heat and submetering is in place
- Heat loss model of known accuracy

Simplified Modeling Method for COP Estimate

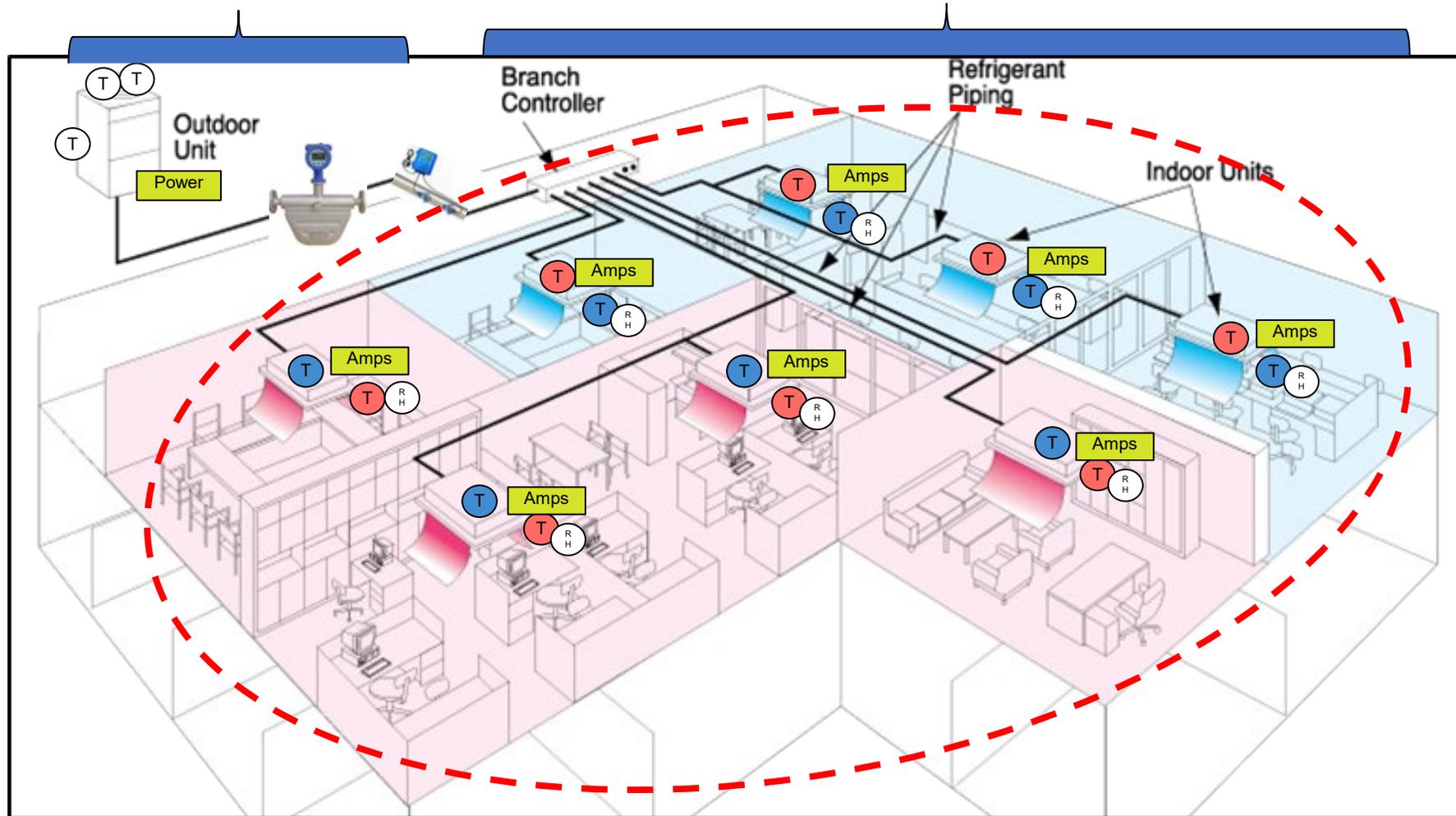
- COP is estimated by creating a building load profile starting with a fixed point
 - Electric consumption at 17 F (known)
 - Assume rated COP at 17 is accurate
 - Calculate building load and create curve using balance point from data



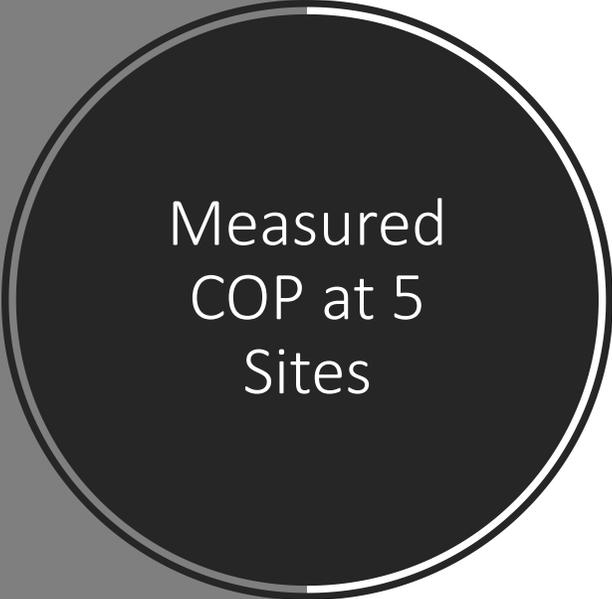
Estimated
COPs at 6
Sites

COP 2. Metering for Indoor Enthalpy Calculations

Up to 150 sensors deployed per site, powering meters is a challenge

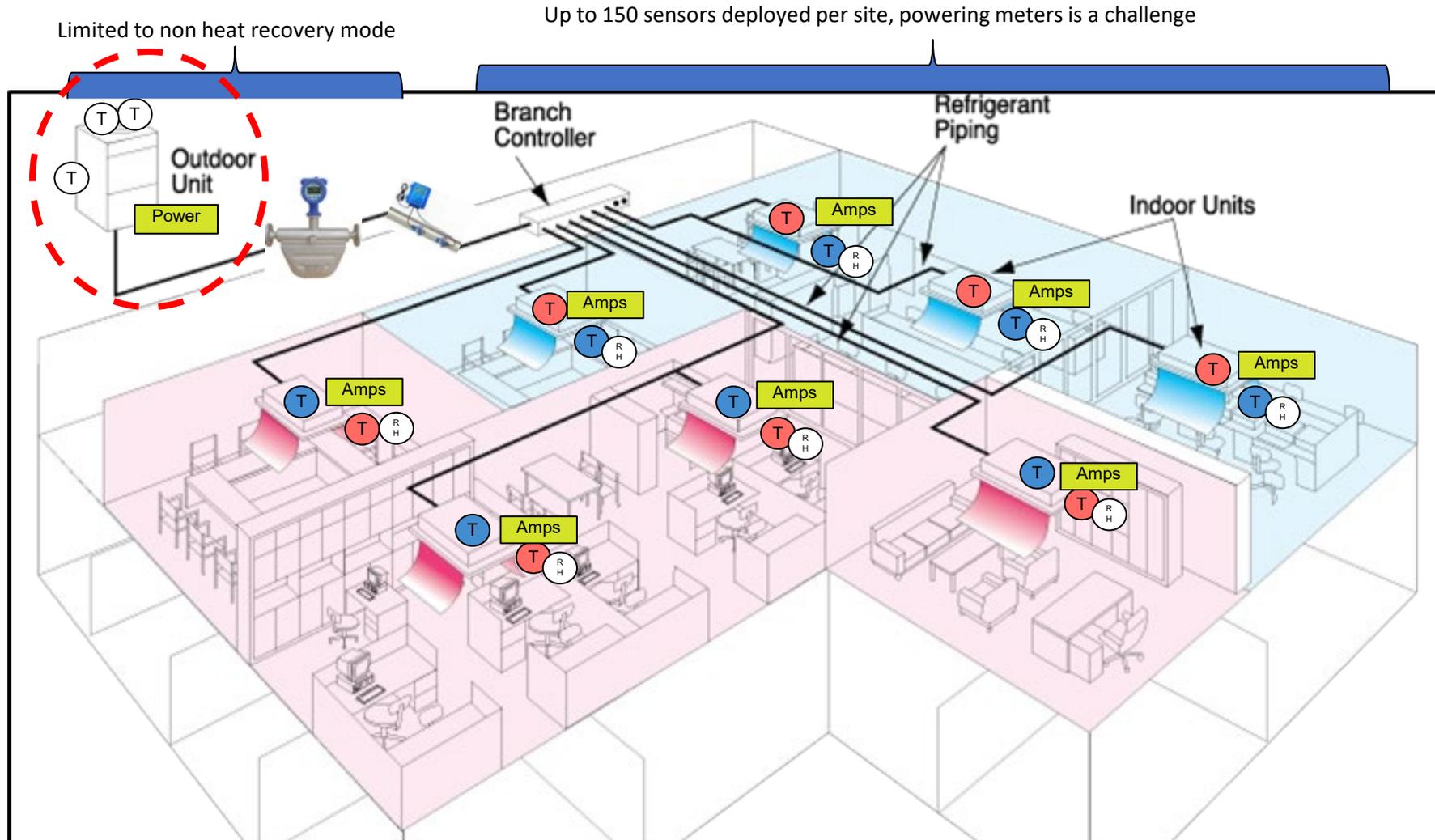


(Source: 2012 GSA VRF Systems Report / Mitsubishi)



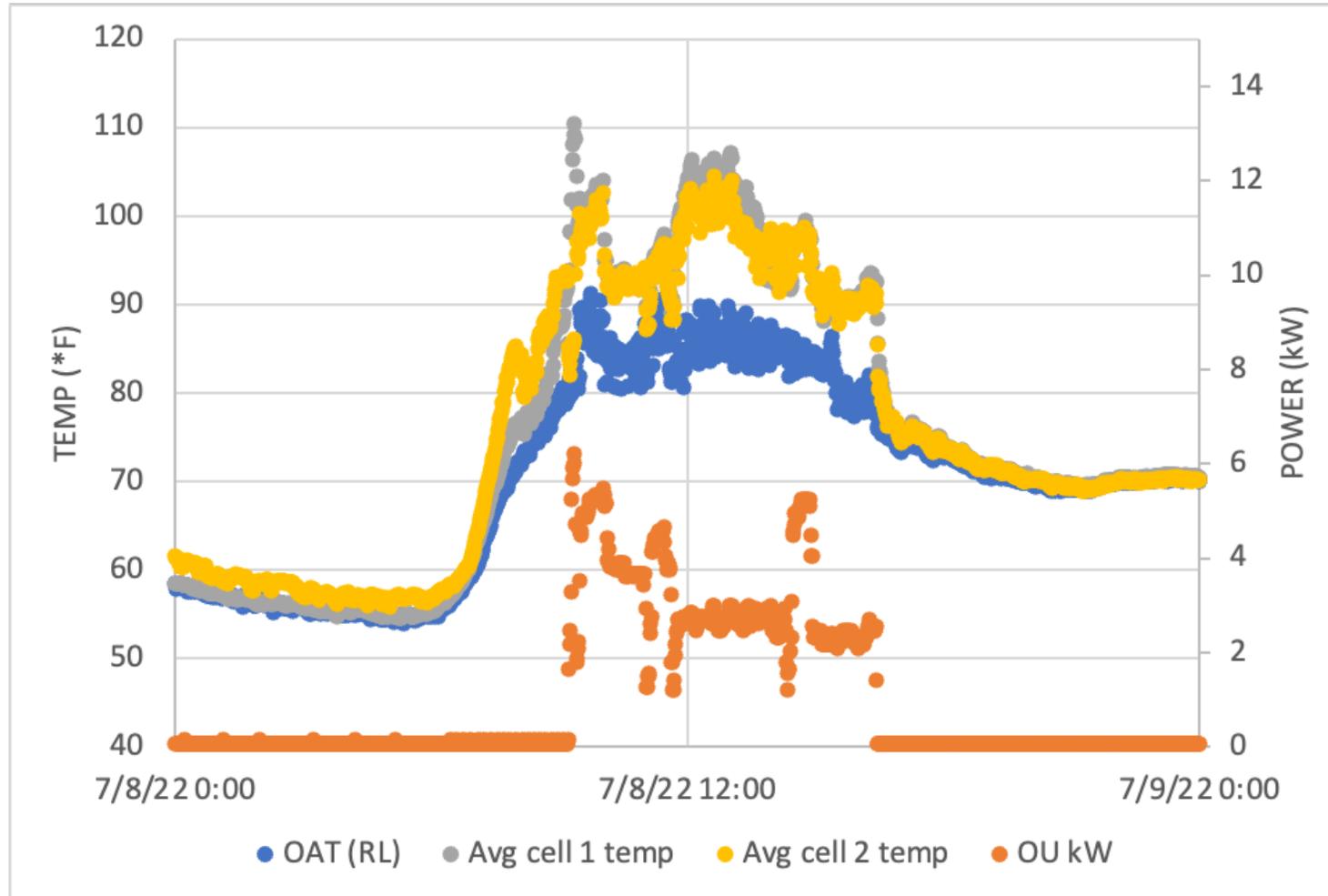
Measured
COP at 5
Sites

COP 3. Metering for Outdoor Enthalpy Calculations

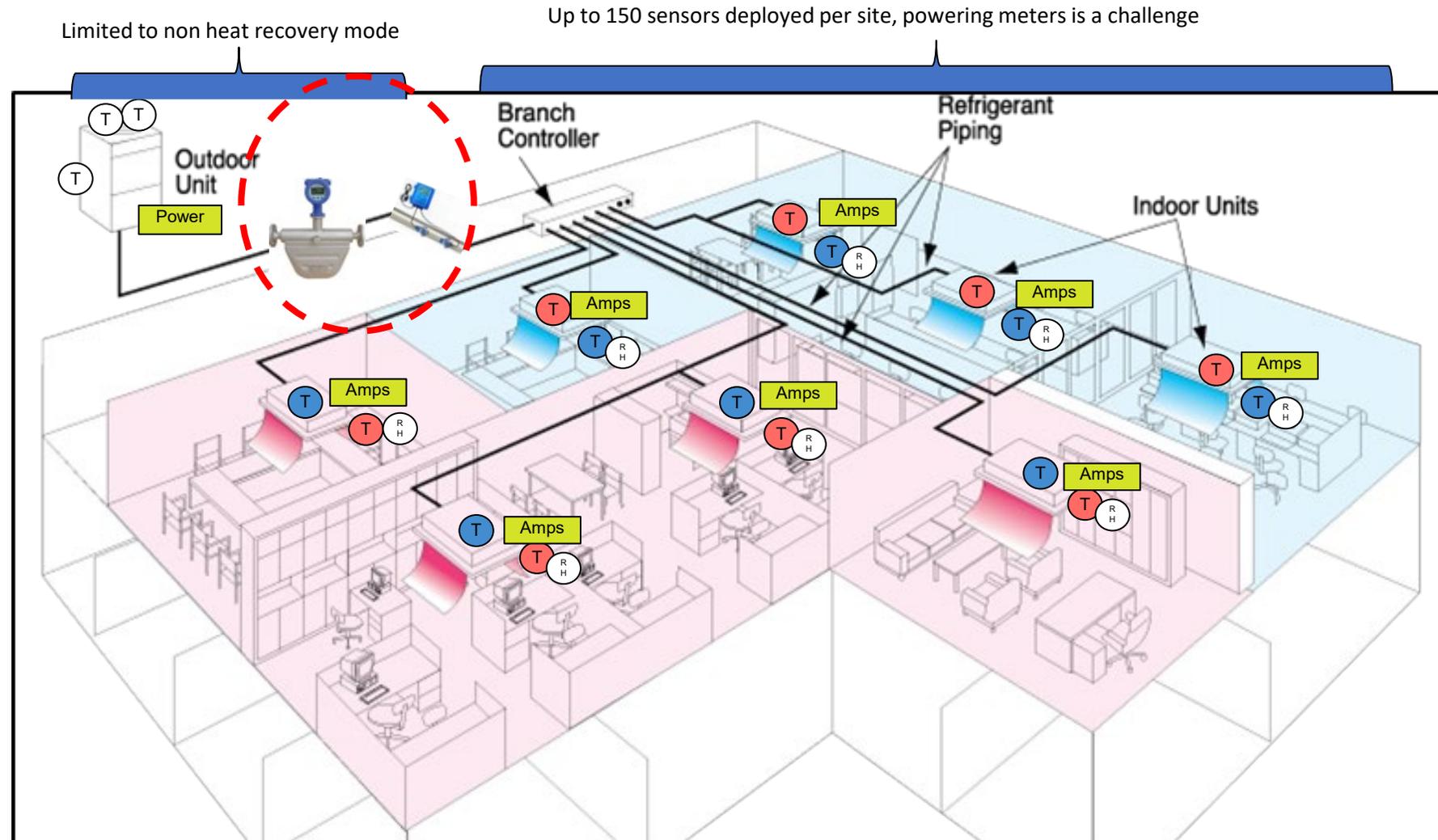


(Source: 2012 GSA VRF Systems Report / Mitsubishi)

COP 3. Outdoor Enthalpy Measurements



COP 4. Metering for Mass Flow Calculations



(Source: 2012 GSA VRF Systems Report / Mitsubishi)

Data Sources— Metering Methods

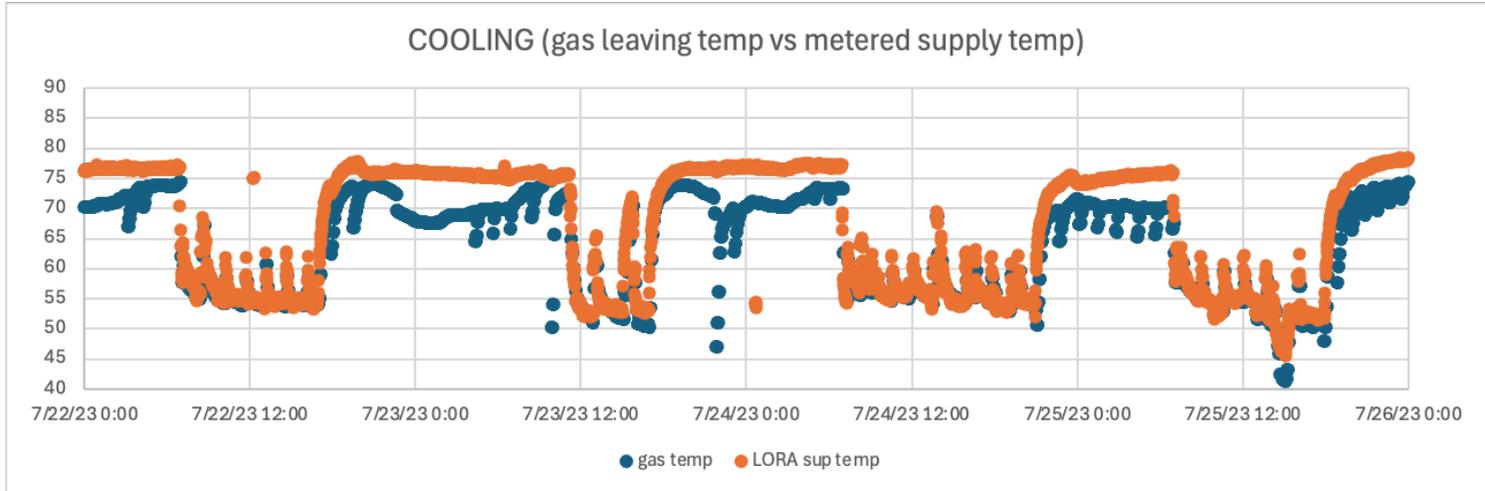
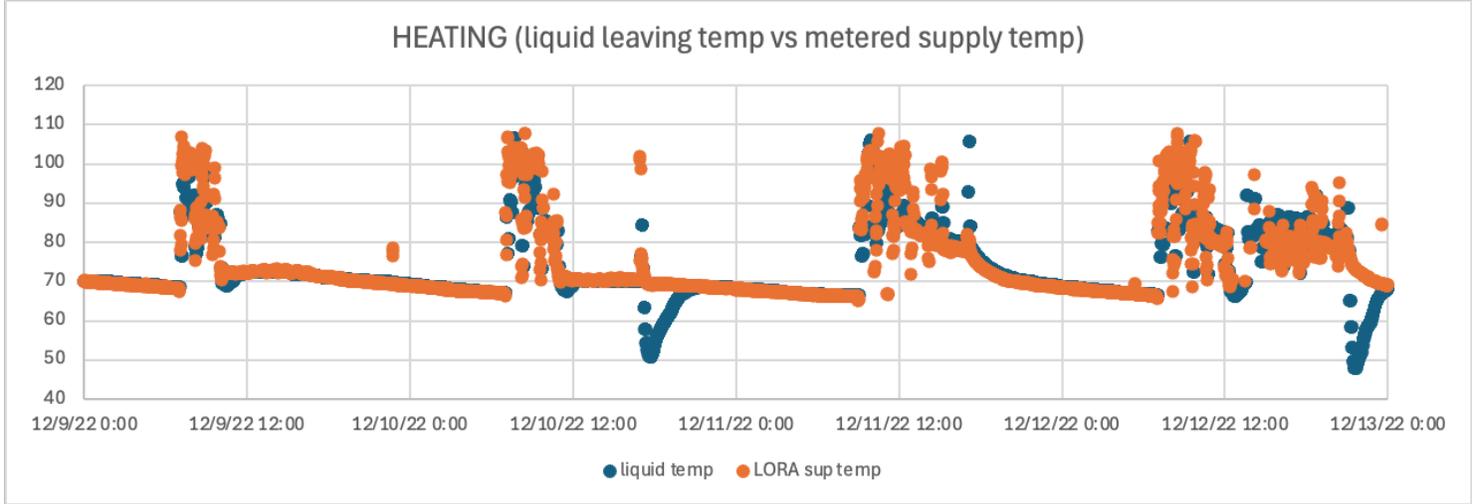
External metering systems

- Expensive, and labor intensive
- Calculations currently require data from power meters, mass flow meters and thermistors yielding potential multiple points of error or failure

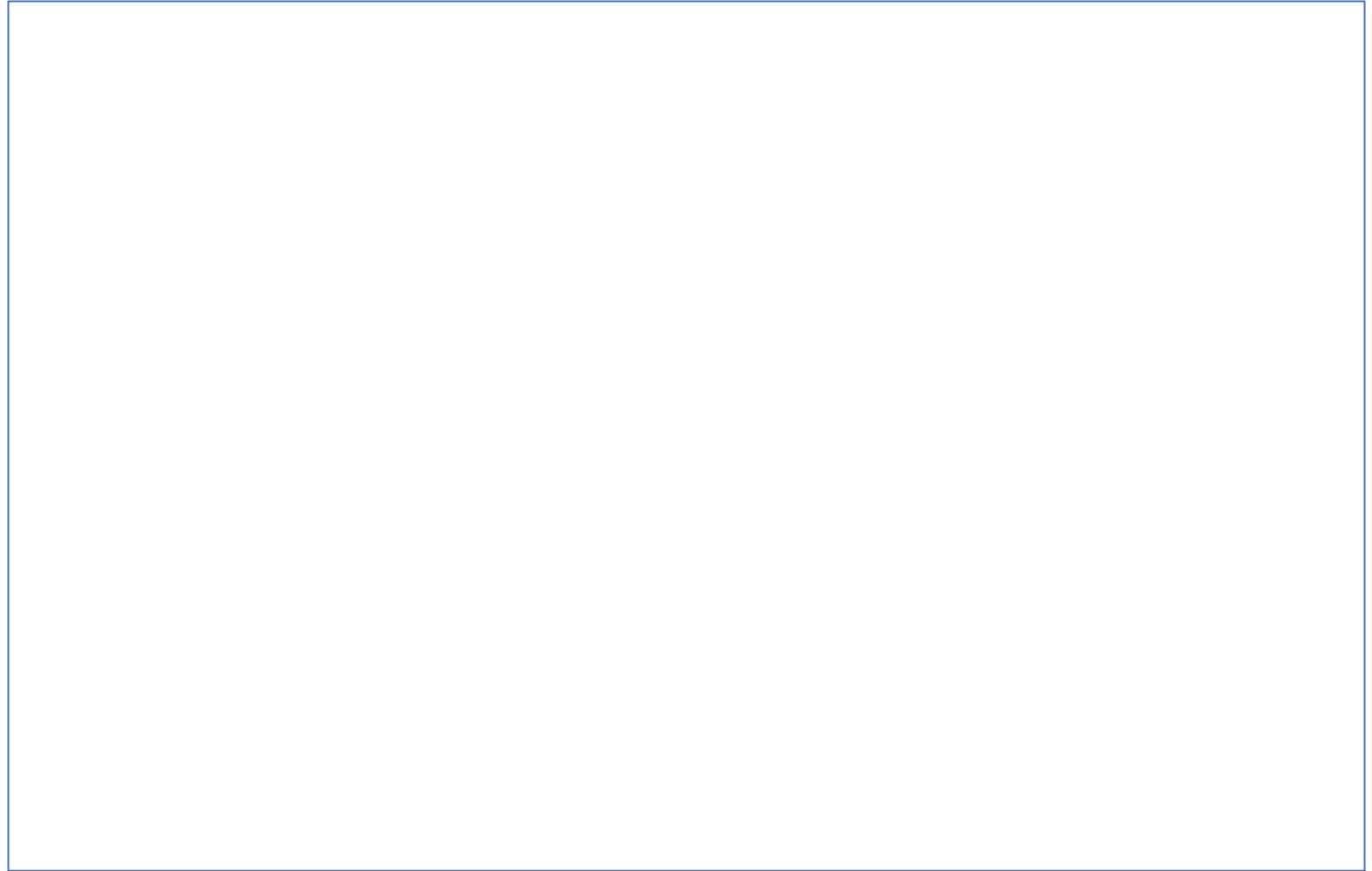
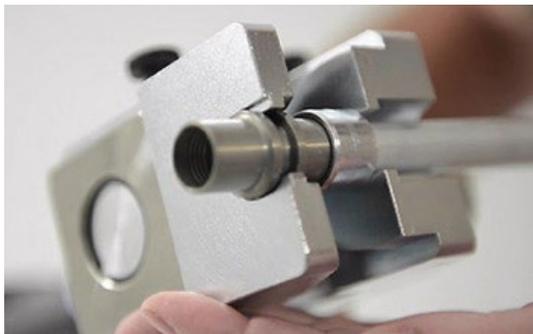
DAS systems

- Some elements require post processing by manufacturer
- Intended for short term metering and need to be downloaded regularly to avoid outages
- Good potential tool for long term metering if sensor gaps are filled
 - Gaps: FCU airflow, FCU supply and return humidity, true power, outdoor exhaust temperature

Leaving Coil Vs. Measured Air Temperatures



Refrigerant Leakage



Hypothetical Carbon Balance—2% Leakage vs. Oil



Leakage
Review of 5
Sites

Findings

- Adding third-party retrofit meters is challenging
 - Systems have complex operating parameters and numerous indoor units.
 - Requires many meters and possibly wireless infrastructure
 - Onboard manufacturer DAS' are evolving quickly and provide a promising method for cost-effectively measuring performance
- VRF Performance varied between heating and cooling.
 - **Heating:** Systems can deliver COPs that range from 2 to 4
 - **Cooling:** COPs in the 4 to 5 range are achievable by some systems
- Low COP performance could be from oversized units.
 - Consistent with manufacturer feedback.
 - Could be that same issue is causing lower cooling COPs because northeast cooling loads are relatively low
- Did not see chronic, unexplained leakage. These studies found episodic leakage (e.g., at installation) but not chronic leakage.
- Challenges include having site managers and contractors sufficiently knowledgeable to design, install, control and operate the systems.
 - Manufacturers have a role in making the systems easier to use, reducing training pressure on site owners and contractors



Questions?

What was
metered