Needs and Opportunities to Improve RHC Performance Metrics

Ground Source Heat Pumps: Challenges and Opportunities

J. Matthew Davis
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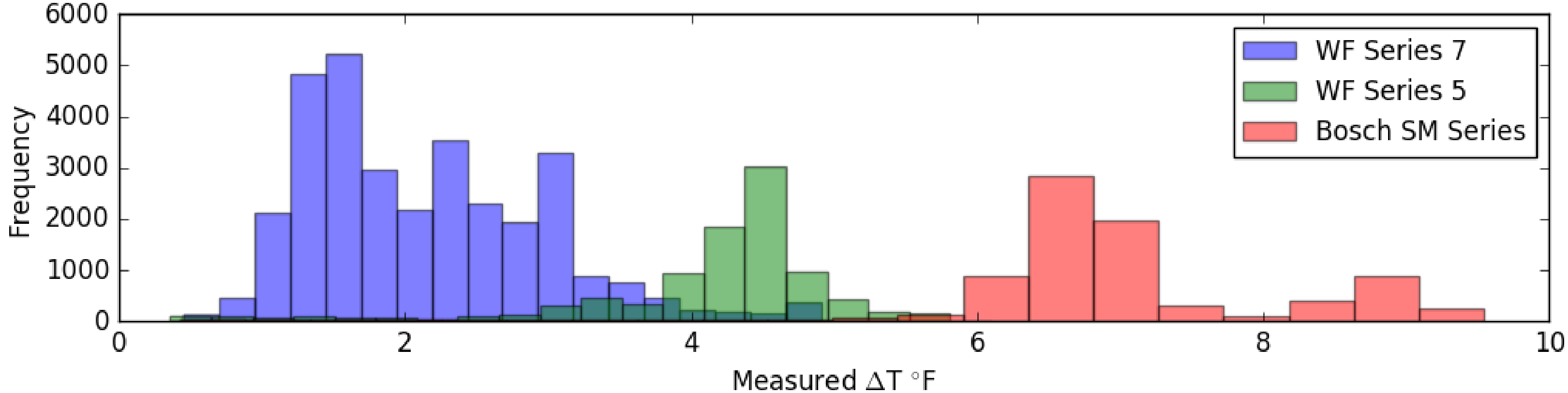
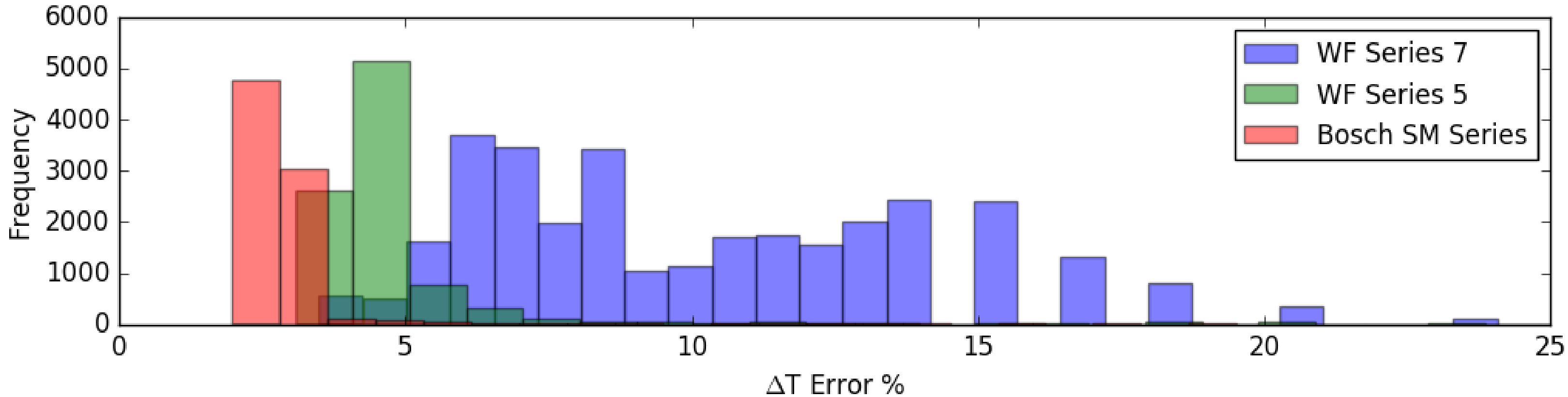
Ground Energy Support LLC

The problem with COP….

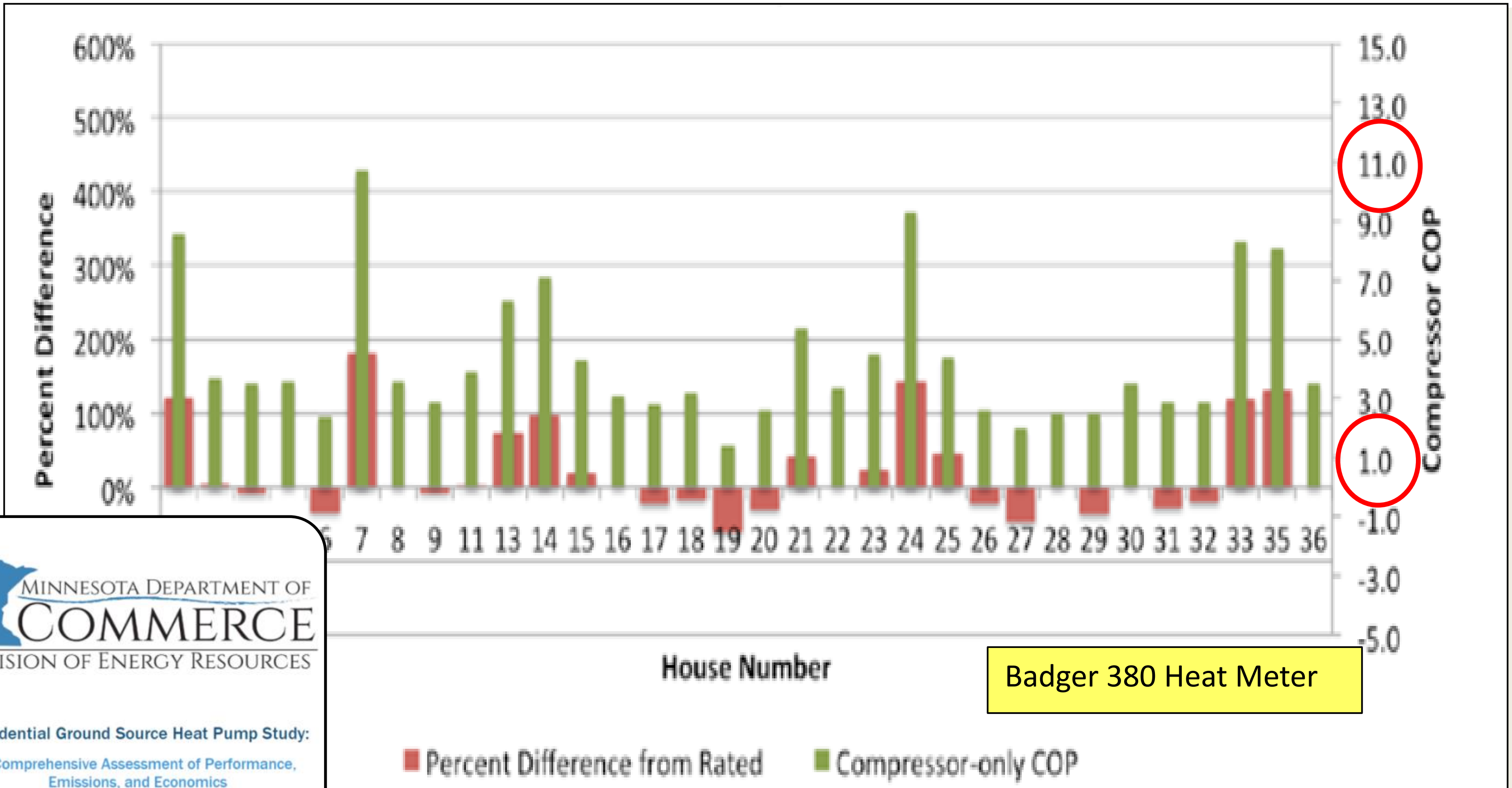
ΔT and corresponding error depends on:

heat pump equipment, system design, and installation





The problem with COP….



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Residential Ground Source Heat Pump Study:

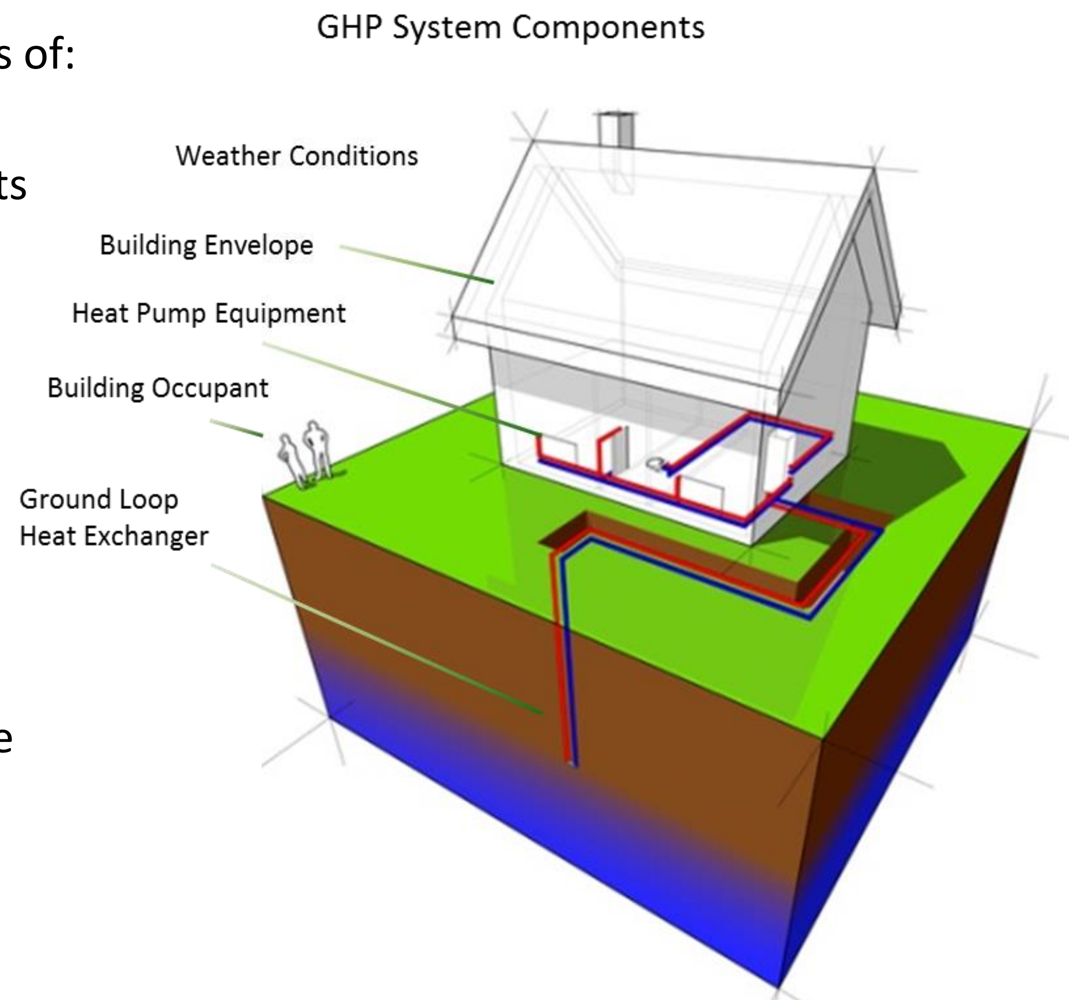
A Comprehensive Assessment of Performance, Emissions, and Economics

UNIVERSITY OF MINNESOTA
Driven to Discover℠

Rethink EM&V for Ground Source Heat Pump Systems

- Overreliance on 'COP'
  - Relies upon measurements of:

    q, ΔT, kW
- Consider all system components
  - Heat pump equipment
  - Ground loop
  - Building envelope
  - System design
  - User operation
  - Weather conditions
- Uncertainty and Risk
- Need quantitative performance metrics with risk attribution



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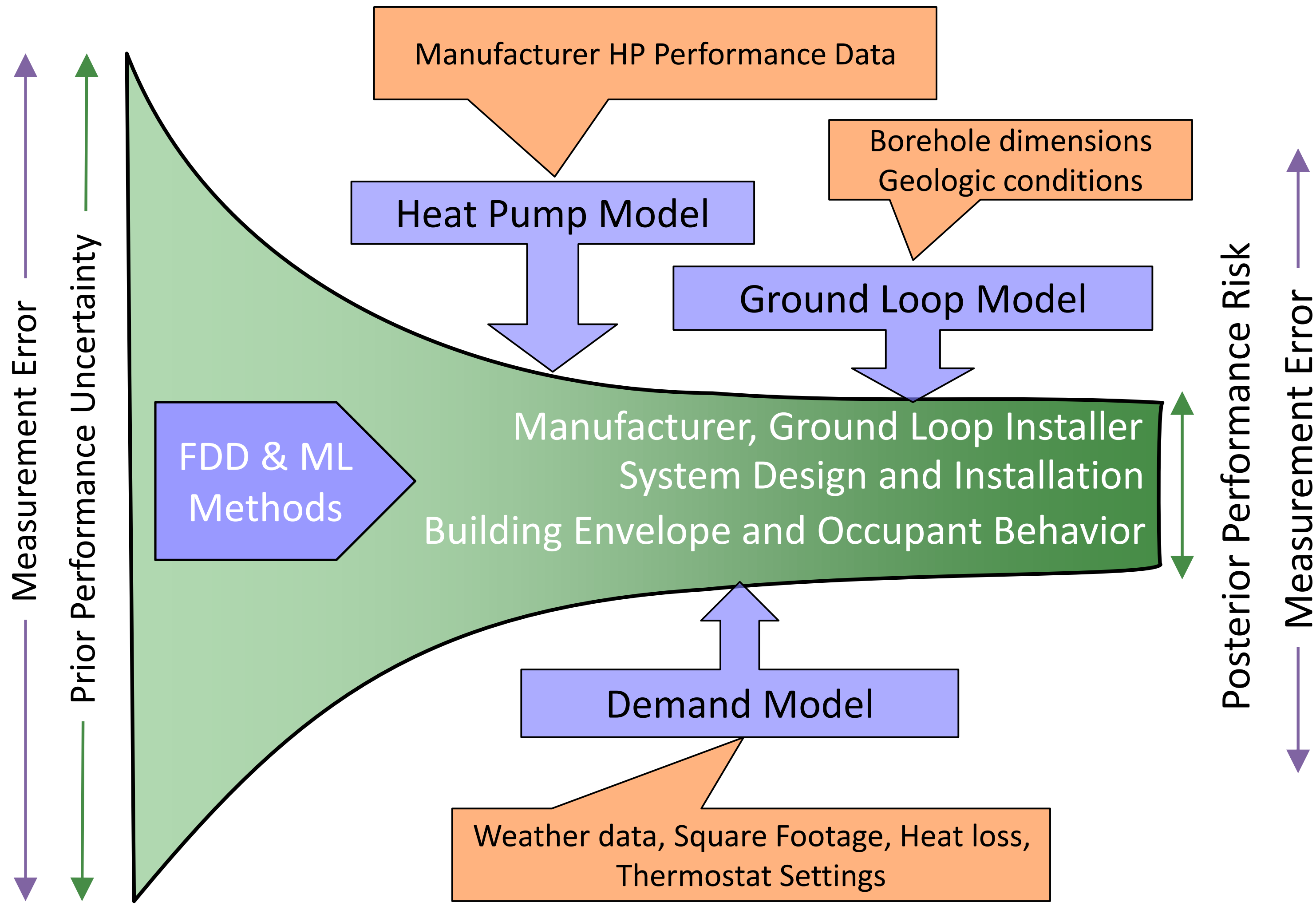
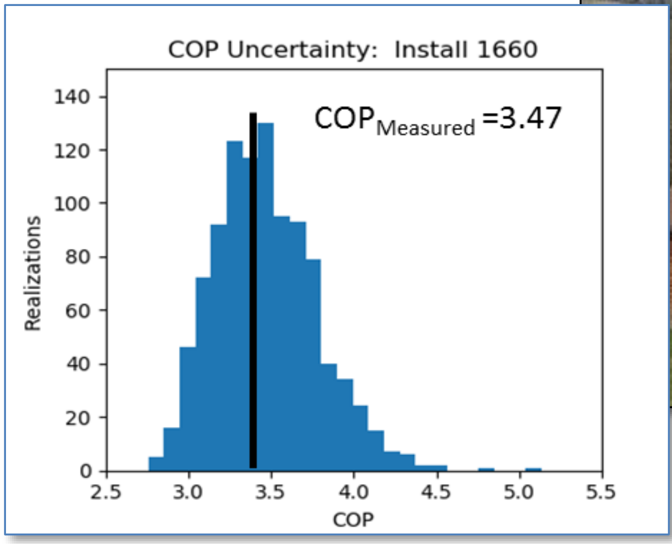
Conceptual Framework – the Hypothesis



Example Analysis:
Single Family Ranch House
Coos County NH

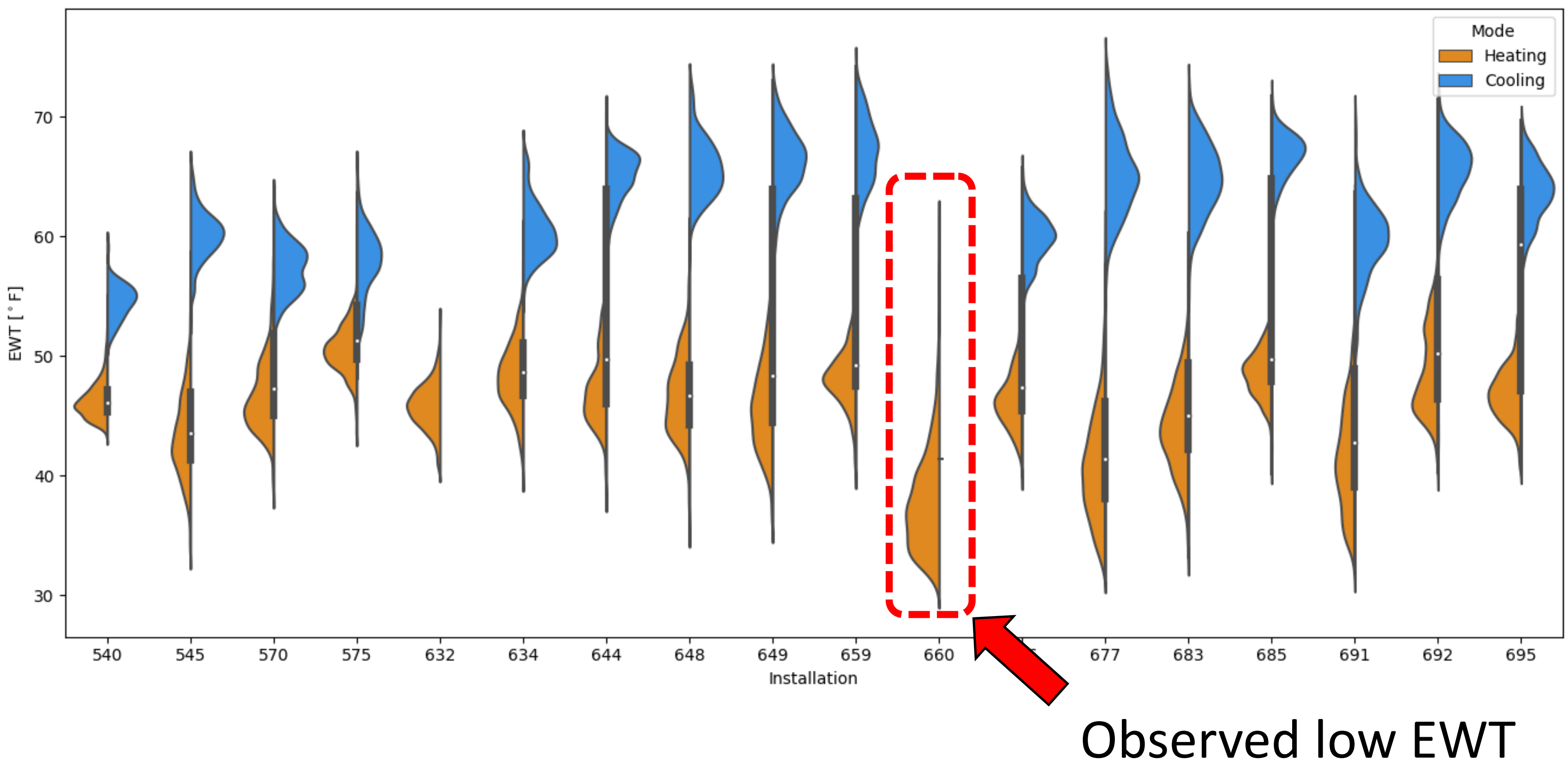


- COP appears to be below expected
- Potential factors:
  - Heat pump
  - Ground loop
  - Building
  - Occupant

Hourly Entering Water Temperature (EWT) for Heating and Cooling Modes

Selected GES installations

Calendar Year 2016



Heat Pump Model

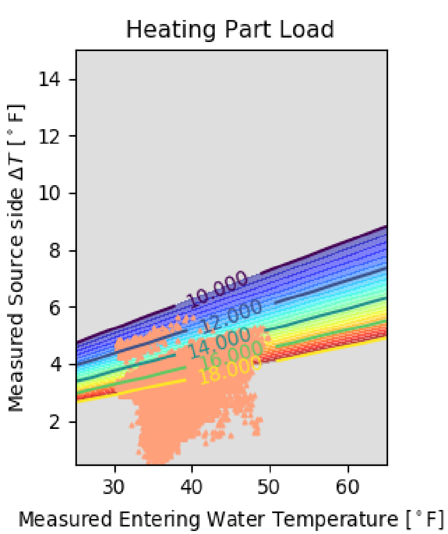
Section 6c: Model 036C Performance Data: 3.0 Ton, Part Load, 1050 CFM Cooling / 1050 CFM Heating

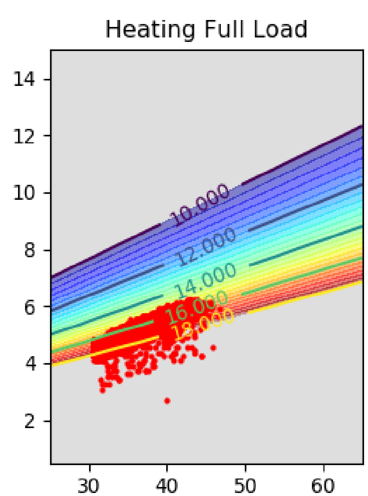
EWT	Flow	WPD		Heating							Cooling							
				Aiflow	HC	HE	LAT		COP	DH	Aiflow	TC	SC		HR		EER	DH
°F	GPM	PSI	FT	CFM	MBtuh	MBtuh	°F	kW	W/W	MBtuh	CFM	MBtuh	MBtuh	S/T	MBtuh	kW	Btuh/W	MBtuh
25	7.0	2.5	5.8	1050	17.3	11.9	85.3	1.58	3.21	2.3	Operation Not Recommended							
				950	16.8	11.2	86.4	1.63	3.02	2.2								
30	5.0	1.4	3.3	1050	18.6	13.2	86.4	1.59	3.43	2.5								
				950	18.1	12.5	87.6	1.65	3.21	2.4								
	6.0	1.9	4.4	1050	18.8	13.4	86.6	1.59	3.46	2.5								
				950	18.3	12.7	87.8	1.65	3.25	2.4								
	7.0	2.4	5.5	1050	18.8	13.4	86.6	1.59	3.46	2.5								
				950	18.3	12.7	87.8	1.65	3.25	2.4								
40	5.0	1.3	3.0	1050	22.0	16.5	89.4	1.62	3.98	2.9								
				950	21.4	15.7	90.9	1.68	3.73	2.9								
	6.0	1.7	3.9	1050	22.2	16.7	89.6	1.62	4.02	2.9								
				950	21.7	16.0	91.2	1.68	3.78	2.9								
	7.0	2.2	5.0	1050	22.4	16.9	89.8	1.62	4.05	2.9								
				950	21.8	16.1	91.2	1.68	3.80	3.1								
50	5.0	1.2	2.7	1050	25.5	19.9	92.5	1.65	4.53	3.4	1050	32.0	22.2	0.69	35.6	1.06	30.2	2.7
				950	24.8	19.0	94.2	1.71	4.25	3.3	950	30.8	20.7	0.67	34.5	1.07	28.8	2.5
	6.0	1.6	3.6	1050	25.7	20.1	92.7	1.65	4.56	3.4	1050	32.3	22.2	0.69	35.8	1.03	31.4	2.5
				950	25.0	19.2	94.4	1.71	4.28	3.3	950	31.2	20.7	0.66	34.8	1.05	29.7	2.3
	7.0	2.0	4.6	1050	25.9	20.3	92.8	1.65	4.60	3.4	1050	32.7	22.4	0.69	36.1	1.01	32.4	2.4
				950	25.2	19.4	94.6	1.71	4.32	3.3	950	31.5	20.9	0.66	35.0	1.03	30.6	2.2
60	5.0	1.1	2.5	1050	28.7	23.0	95.3	1.67	5.04	3.8	1050	30.2	21.4	0.71	34.3	1.21	25.0	3.2
				950	28.0	22.1	97.3	1.73	4.74	3.8	950	29.1	20.0	0.69	33.3	1.23	23.7	3.0
	6.0	1.5	3.4	1050	29.0	23.3	95.6	1.68	5.06	3.8	1050	30.5	21.5	0.70	34.5	1.18	25.8	3.0
				950	28.3	22.4	97.6	1.73	4.79	3.8	950	29.5	20.0	0.68	33.6	1.20	24.6	2.8
	7.0	1.9	4.3	1050	29.2	23.5	95.7	1.68	5.09	3.8	1050	30.9	21.6	0.70	34.9	1.16	26.6	2.9

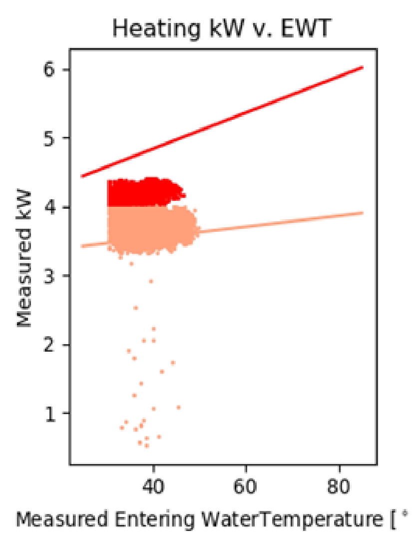
Database Structure | Browse Data | Edit Pragmas | Execute SQL

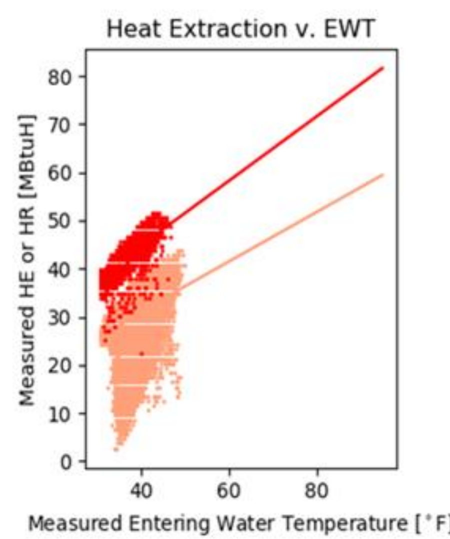
Table: Hydron_HXT_036_PL

	index	EWT [F]	Flow [GPM]	WPD [PSI]	Aiflow [CFM]	HC [Mbtuh]	HE [Mbtuh]	LAT [F]	HE kW	COP	DH [Mbtuh]	Aiflow [(
	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter
1	0	25.0	7.0	2.5	1050	17.3	11.9	85.3	1.58	3.21	2.3	NULL
2	1	25.0	7.0	NULL	950	16.8	11.2	86.4	1.63	3.02	2.2	NULL
3	2	30.0	5.0	1.4	1050	18.6	13.2	86.4	1.59	3.43	2.5	NULL
4	3	30.0	5.0	NULL	950	18.1	12.5	87.6	1.65	3.21	2.4	NULL
5	4	30.0	6.0	1.9	1050	18.8	13.4	86.6	1.59	3.46	2.5	NULL
6	5	30.0	6.0	NULL	950	18.3	12.7	87.8	1.65	3.25	2.4	NULL
7	6	30.0	7.0	2.4	1050	18.8	13.4	86.6	1.59	3.46	2.5	NULL
8	7	30.0	7.0	NULL	950	18.3	12.7	87.8	1.65	3.25	2.4	NULL
9	8	40.0	5.0	1.3	1050	22.0	16.5	89.4	1.62	3.98	2.9	NULL
10	9	40.0	5.0	NULL	950	21.4	15.7	90.9	1.68	3.73	2.9	NULL
11	10	40.0	6.0	1.7	1050	22.2	16.7	89.6	1.62	4.02	2.9	NULL
12	11	40.0	6.0	NULL	950	21.7	16.0	91.2	1.68	3.78	2.9	NULL
13	12	40.0	7.0	2.2	1050	22.4	16.9	89.8	1.62	4.05	2.9	NULL
14	13	40.0	7.0	NULL	950	21.8	16.1	91.2	1.68	3.8	3.1	NULL









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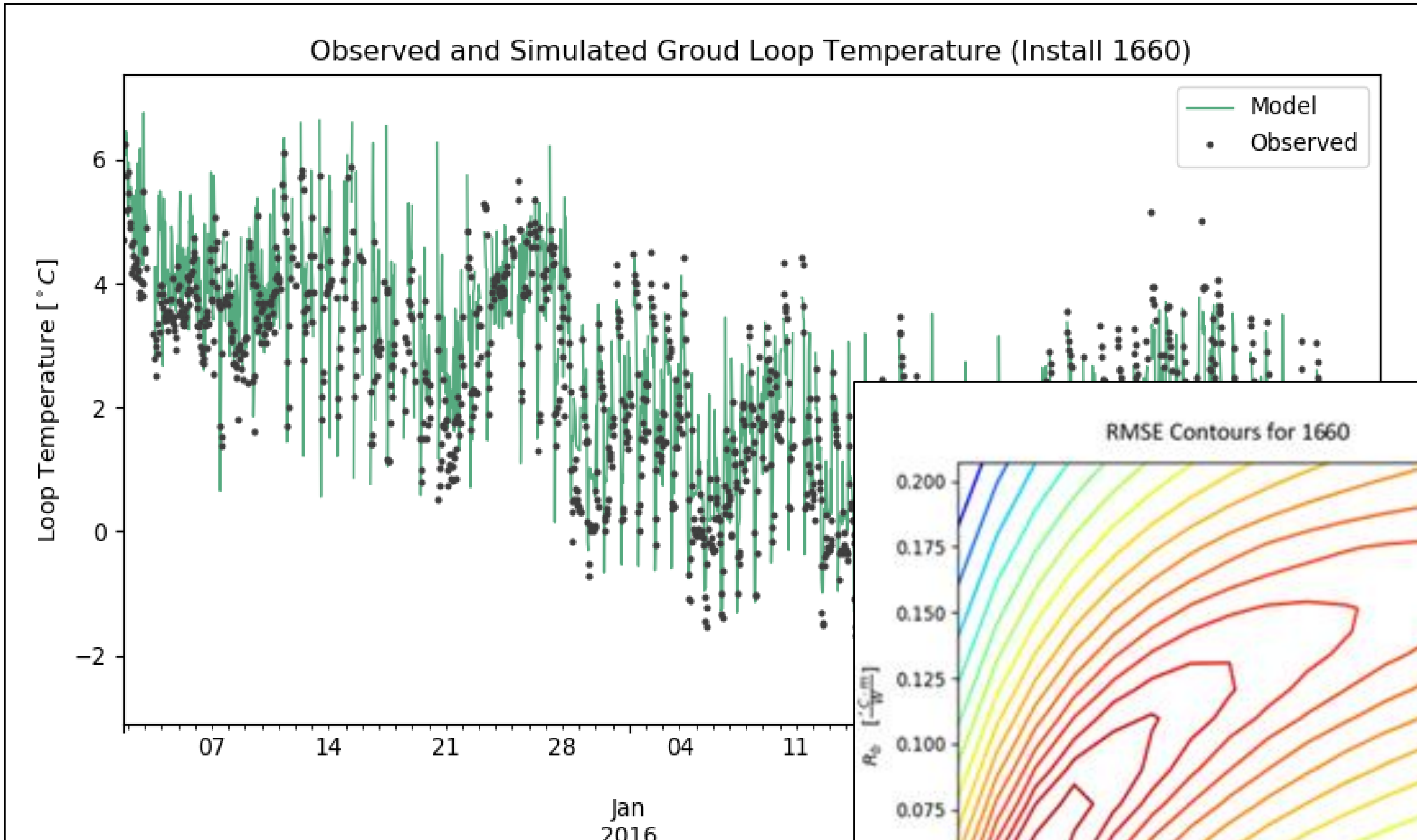
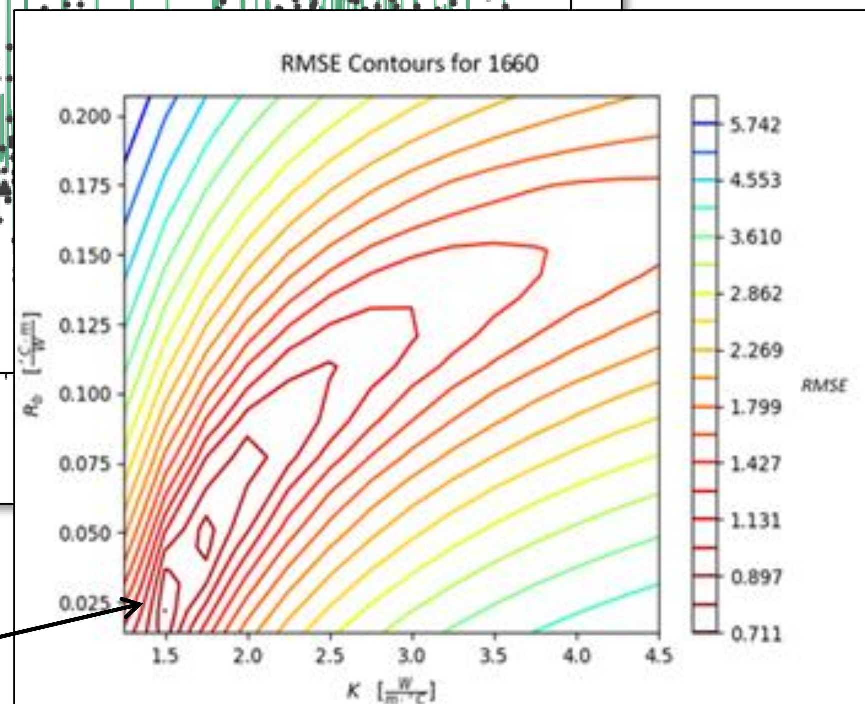
Ground Loop Model





Optimal parameters :

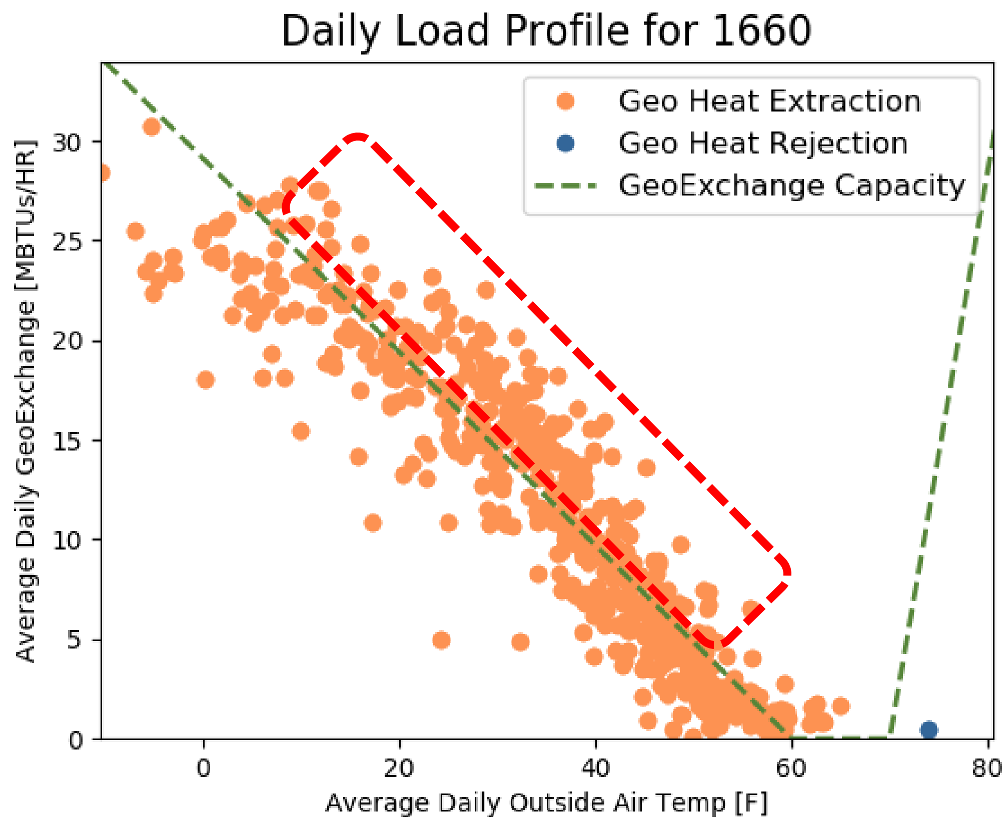
R_b = 0.025 Cm/W

K_T = 1.5 W/mC

Demand Model

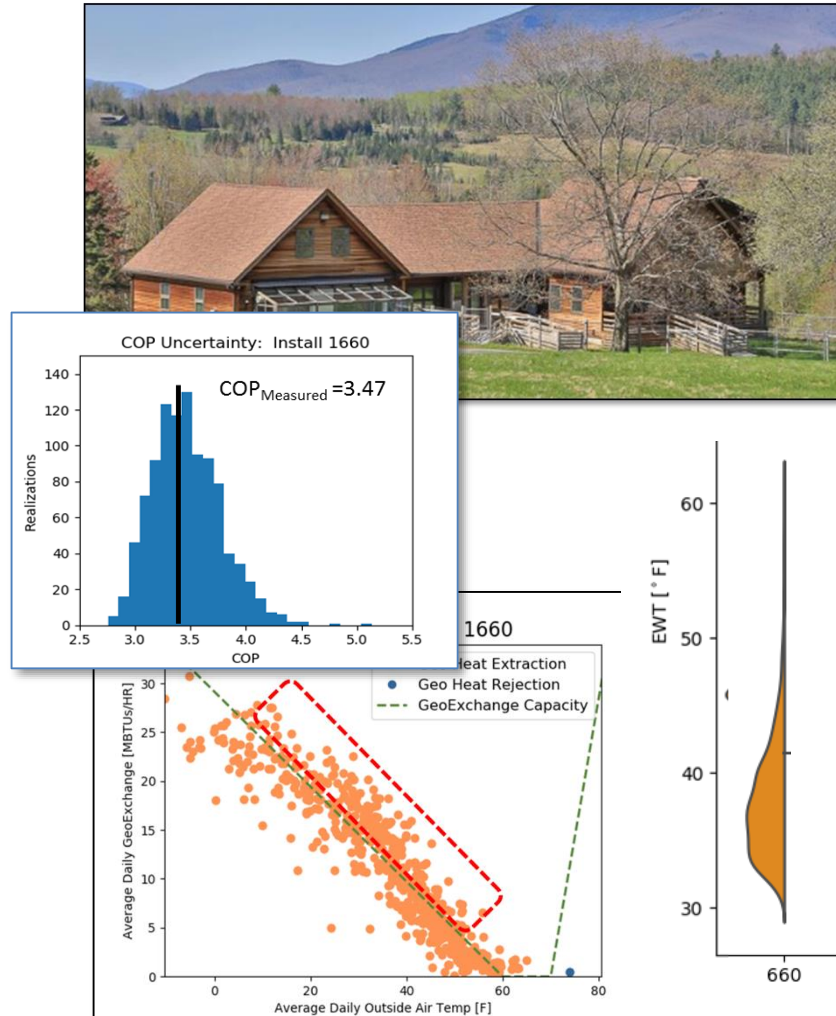
Demand on ground loop for heat appears to be greater than design.

No cooling enhances annual imbalance (NAGL).



Performance of Site 1660

- Heat pump
  - Operating within expected ranges
- Ground loop:
  - Lower than expected thermal K
  - Low borehole resistance (good)
- Demand
  - Homeowner does not use AC
  - Higher than expected heating load on ground loop



Challenges with Commercial GSHP Applications

- GES monitoring five commercial-scale buildings
  - Mixed Residential-Commercial Building (New)
    - Distributed heat pumps (10), large pumping penalty
  - Town Library (Retrofit)
    - Centralized heat pumps (2 10-ton units)
  - County Correctional Facility (New)
    - Centralized 'multi-stack' (12 10-ton units), intermingling of propane backup may be an issue
  - Multi-story climate-controlled self storage (New)
    - Distributed water-to-air heat pumps (9), highly efficient pumping, no back-up system.
  - Multi-unit (multistory) low-income housing (New)
    - Distributed water-to-air heat pumps (~40) make it difficult to quantify usage/savings.
- Highly variable design, installation, operation

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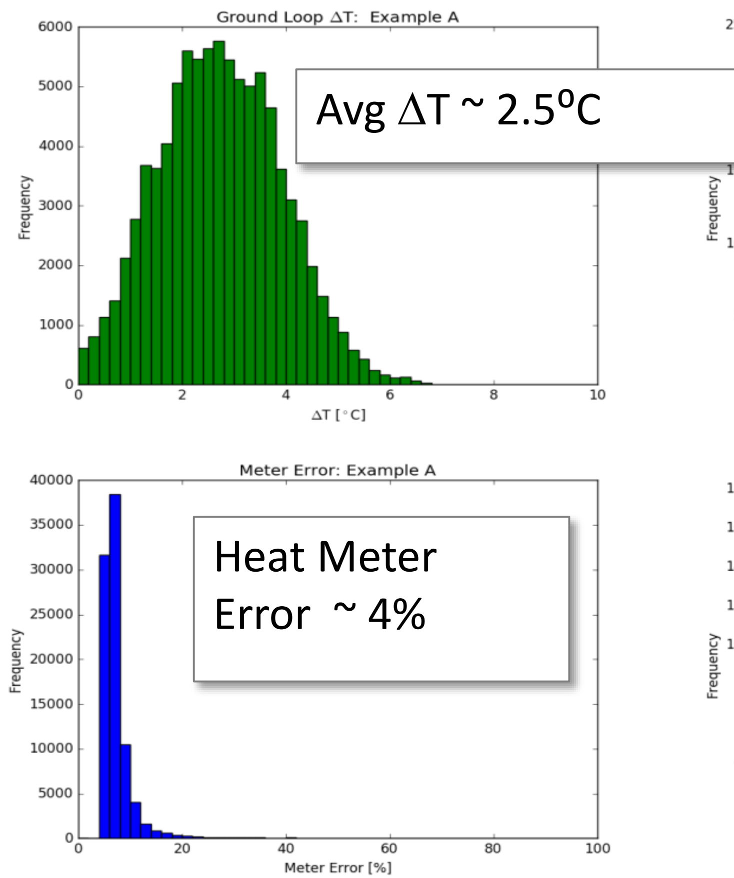
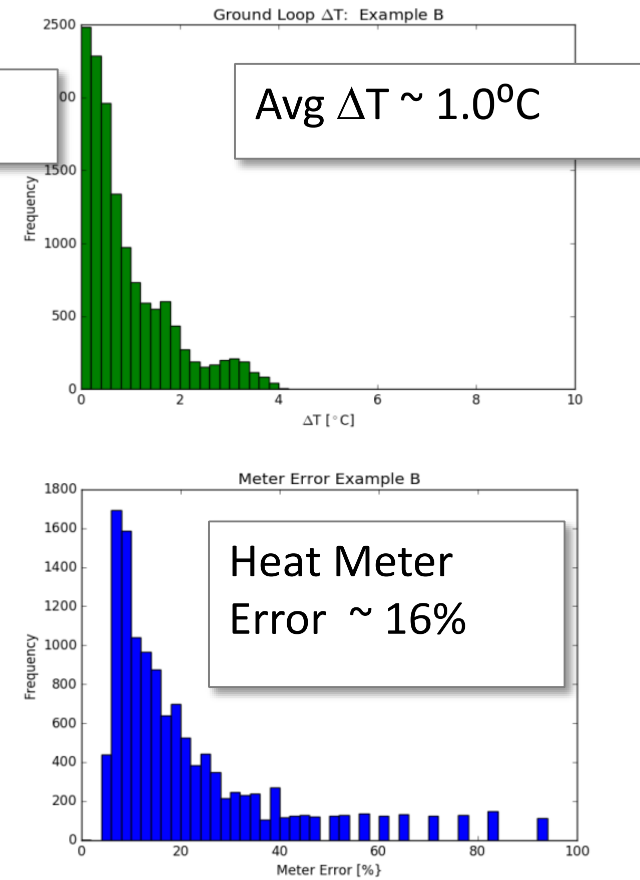
Challenges with Heat Meters in RTT systems

Onicon System 10 Heat Meter – One of the Best on the Market

Site A



Site B



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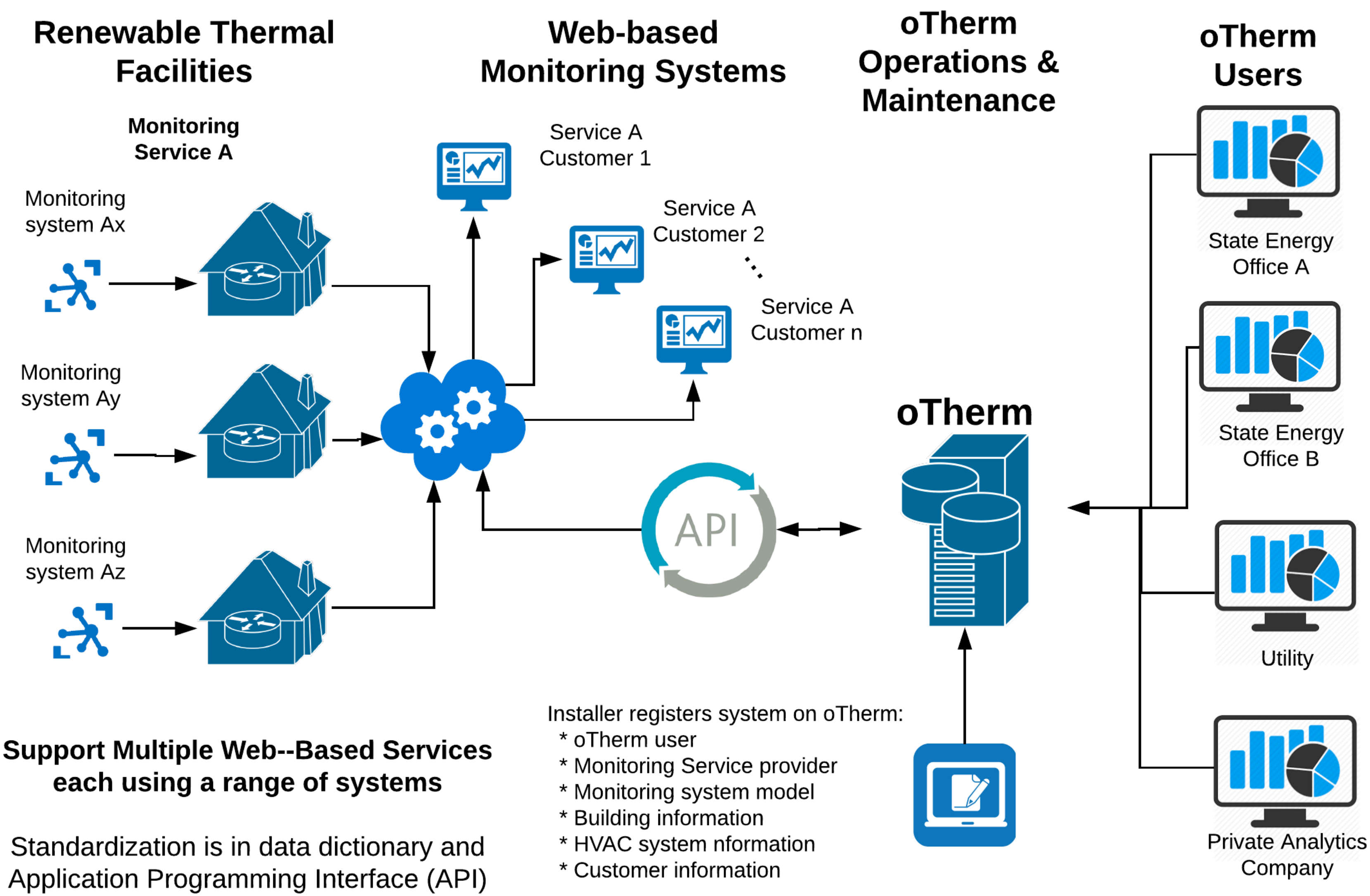
oTherm Initiative



oTherm Initiative

- Data models for RTTs, GSHP use case
- Consensus on best practices
- APIs to connect databases
- Build oTherm platform and launch

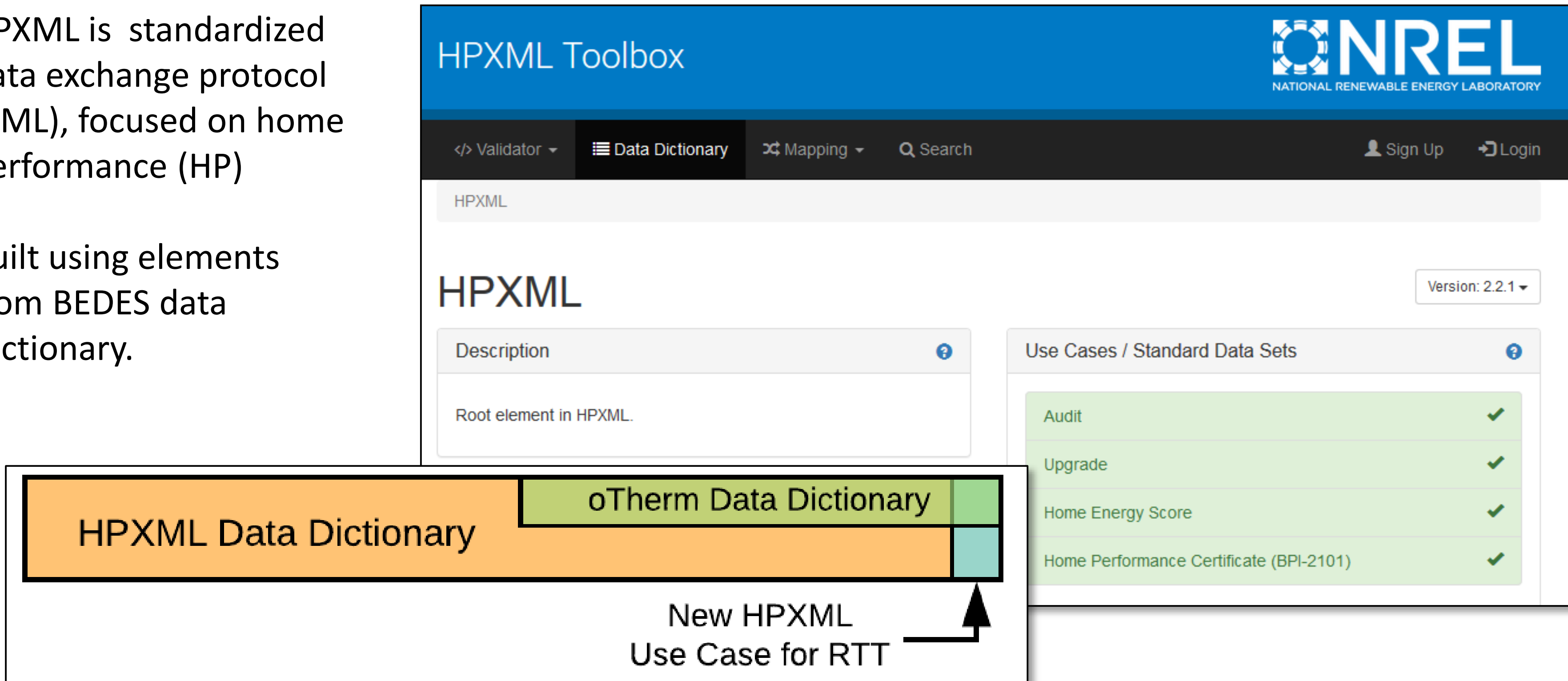
Conclusions

- Performance verification is needed to build confidence and demonstrate benefits.
- Efforts should focus on factors that are both measureable and provide insight.
- Small systems may more amenable to standardized approach.
- oTherm initiative is a community-driven effort standardize data dictionaries and aggregate data.

oTherm Initiative

HPXML is standardized data exchange protocol (XML), focused on home performance (HP)

Built using elements from BEDES data Dictionary.



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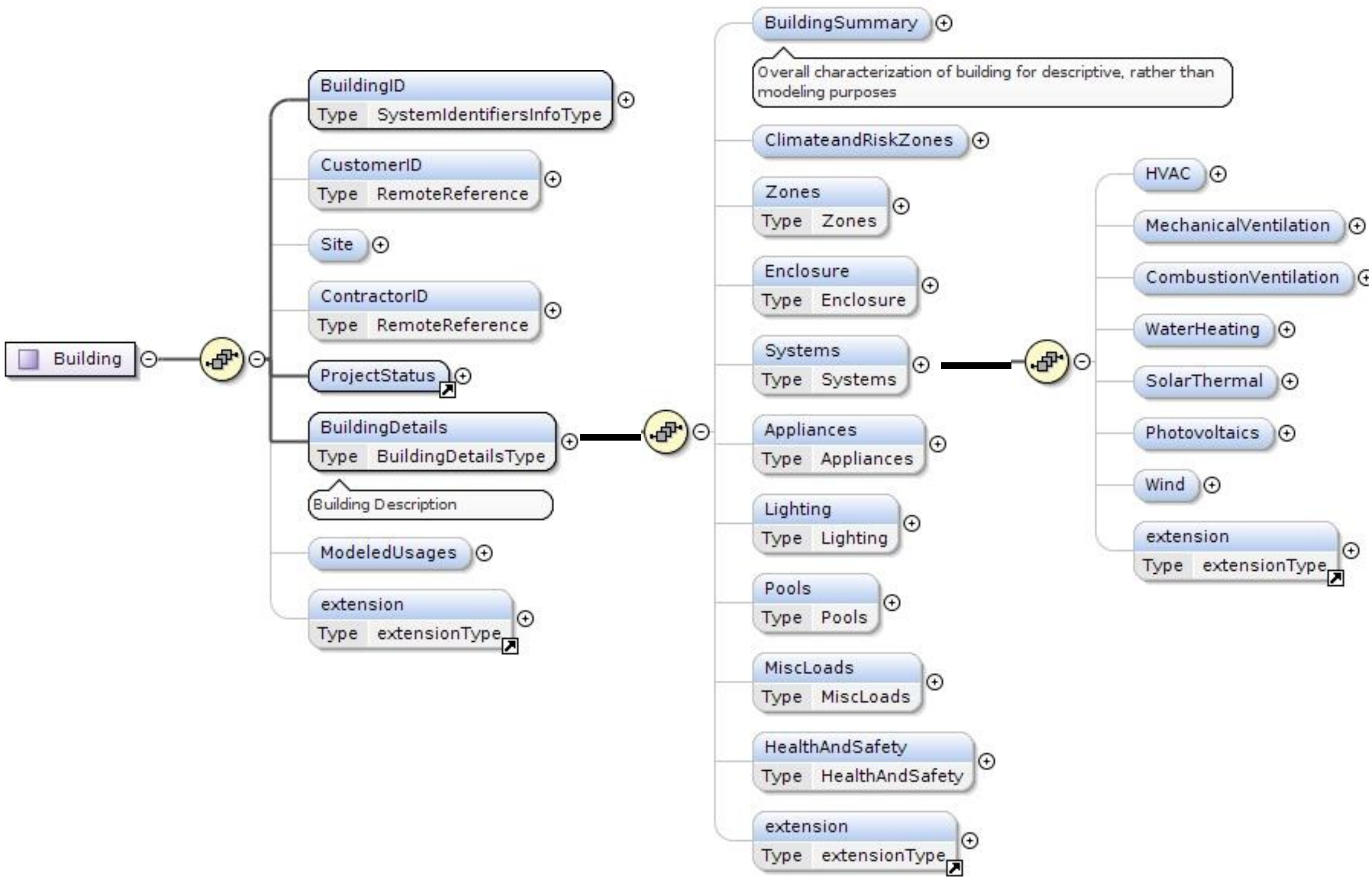
oTherm Initiative



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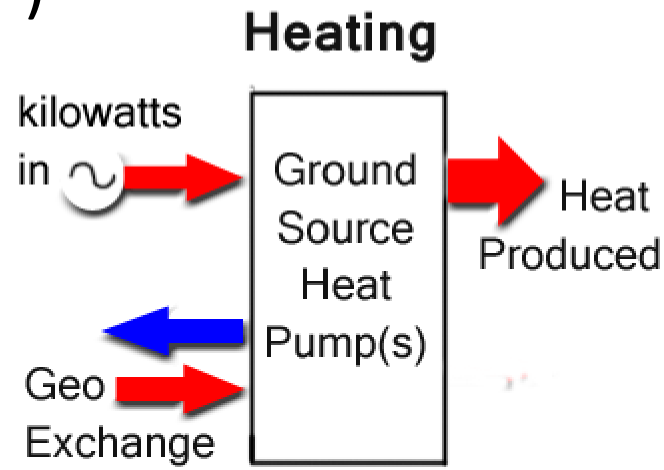
University of New Hampshire

The Coefficient of Performance (COP)

$$\text{COP} = \frac{\text{HE} + 3412 \cdot \text{kW}_{\text{in}}}{3412 \cdot \text{kW}_{\text{in}}}$$

$$\text{HE} = c \cdot Q_f \cdot \; [T_{in} - T_{out}]$$

$$\text{HE} = c \cdot Q_f \cdot \Delta T$$



Sources of Error when calculating COP

- Temperature (ΔT)
- Ground loop flowrate (Q_f)

} GeoExchange (HE)

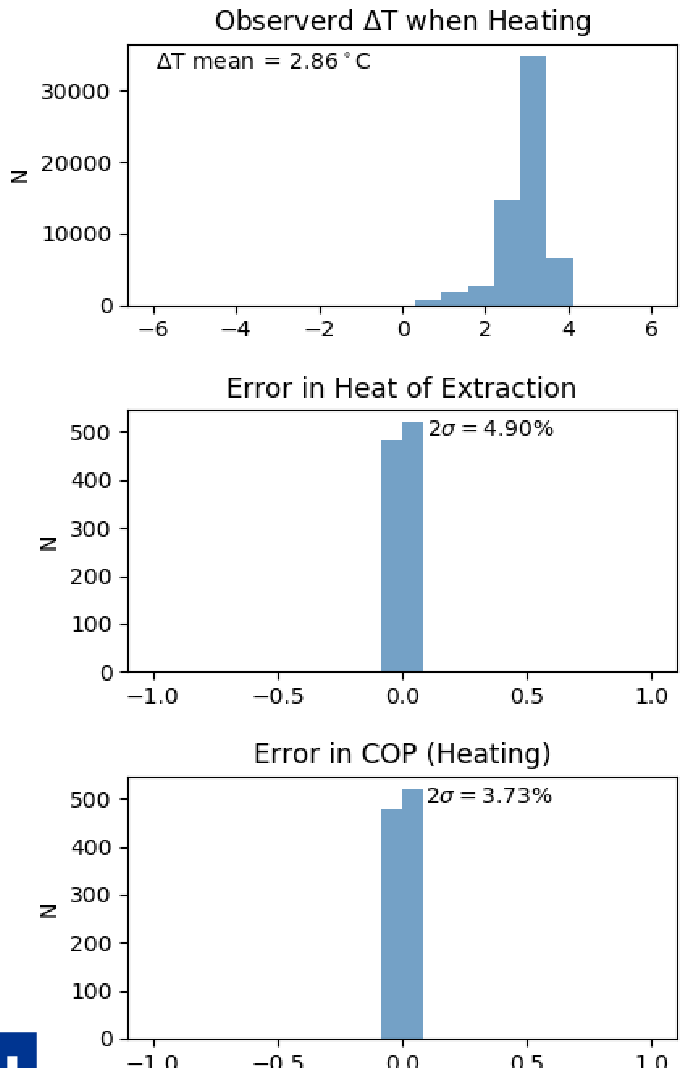
- kW (compressor and electric auxiliary)
- kW (circulating pumps, fans)

Measurement Error Model

Propagation of Sensor Errors

$N_{obs} = 74923 \quad N_{real} = 1000$

$\sigma_T = 0.05\ [^\circ C] \quad \sigma_Q = 0.04\ [gpm] : kW_{err} = 0.5\%$



$N_{obs} = 8659 \quad N_{real} = 1000$

$\sigma_T = 0.25\ [^\circ C] \quad \sigma_Q = 1.0\ [gpm] : kW_{err} = 10.0\%$