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Advanced Analysis of Geothermal Heat Pump System Data

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Problem

• US Northeast relies heavily on fossil fuels for space and water heating.

• Geothermal heat pumps (GHP) have potential to provide an alternative source of clean renewable energy.

• Market penetration is limited by lack of confidence in technology among consumers, policy makers, and investors.

• $10 billion annual expenditures on fuel oil in Northeast.

Recognized Needs

• Objective, scalable, and actionable evaluation, measurement, and verification (EM&V) of actual systems.

• Quantify performance and risk with attention to each system component.

• Utilize readily available but imprecise information.

• Off-the-shelf heat meters are not a viable stand-alone solution.

The Problem with COP

• The Coefficient of Performance (COP) provides just a single metric of performance and is prone to large uncertainties.

CO\textsubscript{P} = \frac{\text{HE}}{\text{HR}} + 3.412 \cdot k_{Wc} \cdot \sigma = 60\%

• Results from recent studies using COP as primary performance metric illustrate the impact of measurement error:

Huelman et al (2016) completed a study for the Minnesota Department of Commerce. Use of budgetable 380 heat meter with Class III temperature sensors appears to have contributed to large uncertainties in measured COP.

The Uncertainty Model will be used to quantify uncertainty in performance metrics and conduct cost-benefit analysis on different measurement options with different accuracies.

Proposed Solution

• Apply methods of artificial intelligence (AI) and machine learning (ML) to synthesize multiple sources of data into “smart” GHP system meter.

• Provide Software as a Service to developers, utilities, policy makers to objectively assess performance of large numbers of GHP systems.

PROJECT SUMMARY

Advanced Energy Usage Northeast US

\begin{tabular}{|c|c|}
\hline
Space Heating & 55\% \\
Water Heating & 16\% \\
Space Cooling & 24\% \\
Refrigeration & 8\% \\
Other & 3\% \\
\hline
\end{tabular}

Preliminary Results

HEAT PUMP MODEL

The manufacturer performance data for heat pumps are translated into SQL database and used to assess whether heat pump operating conditions are within manufacturer specified ranges.

In the example to right, the source-side JT is plotted against the EWT to infer the ground loop flow rate. The UFs indicated by the red symbols suggest lower flow rates than expected.

Similar comparisons are made for observed and expected HE, HR, and kW.

GROUND LOOP MODEL

The Ground Loop Model will use heat pump operating data (EWT, LWT, HE, HR, WE) to infer effective thermal properties of the ground loop. Getchell (2017) implemented the models of Sutton et al. (2001) and Arnold-Girard (2011) to compute the thermal response for a range of subsurface conditions, including both the infinite and finite line source geometries as well as with and without groundwater flow.

The figure below shows a profile of steady state temperature distribution for the infinite (top) and finite (bottom) line source models and groundwater flow from left to right.

REFERENCES

