Advanced District Energy Controls for Improved Efficiency and Resilience

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Presenters

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Project objectives

- Model, install, and verify a new, community-based DE demand and generation control system which reduces undelivered energy
- Install and verify the performance of either a centralized CHP/storage addition or remote CHP generation which can achieve < 10 year simple payback
- Demonstrate one or more feasible pricing/contract methodologies which could enable the control algorithms developed for objectives 1 and 2
- Demonstrate a new metering and control framework which can securely provide 2-way control, metering/billing analysis, and other communication between the utility and customer systems in order to enable objectives 1-3

Survey on energy efficiency

Survey Description

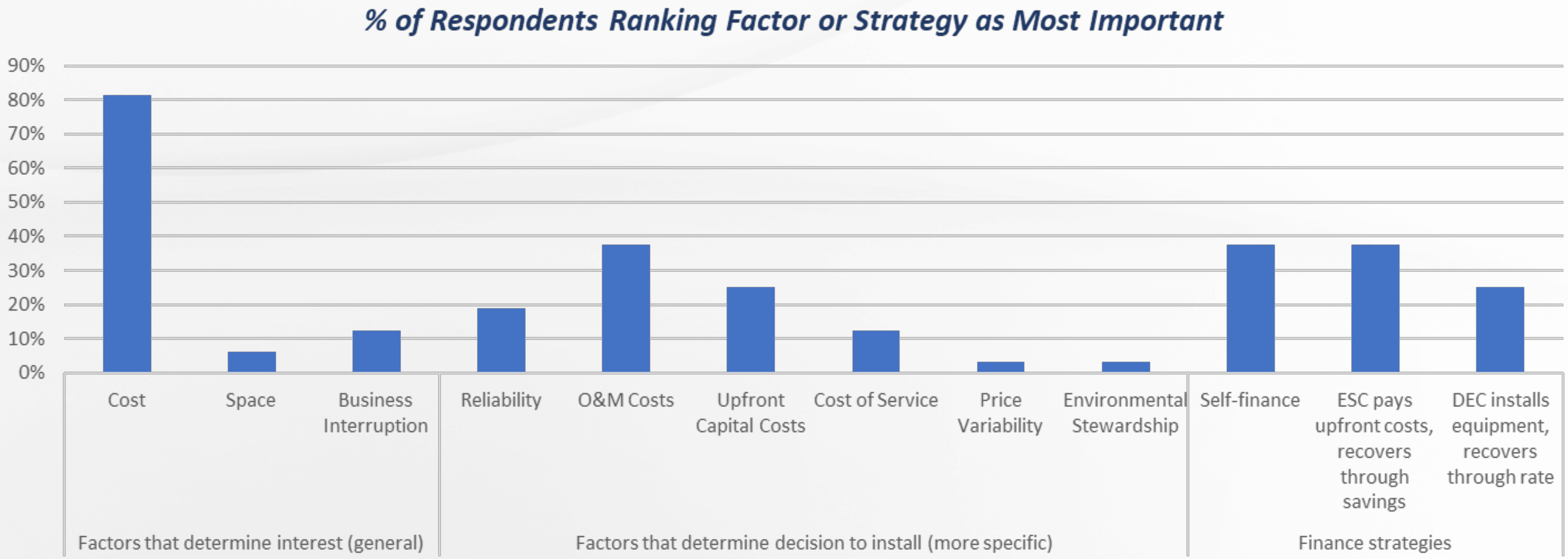
- Survey sent to approximately 40 end users on Cleveland Thermal's District Energy system.
  - 19 responses from 17 separate companies
  - Conducted 9/21 through 2/22 (before upturn in natural gas prices)
- Consisted of 36 questions about:
  - Understanding of energy efficiency for district energy systems
  - Prior efficiency work done
  - Interest in additional work
  - Best ways to pay for efficiency work
  - Price points for efficiency work
  - Interest in load management
  - Interest in carbon reduction strategies
  - Interest in microgrid adoption

Customer Description

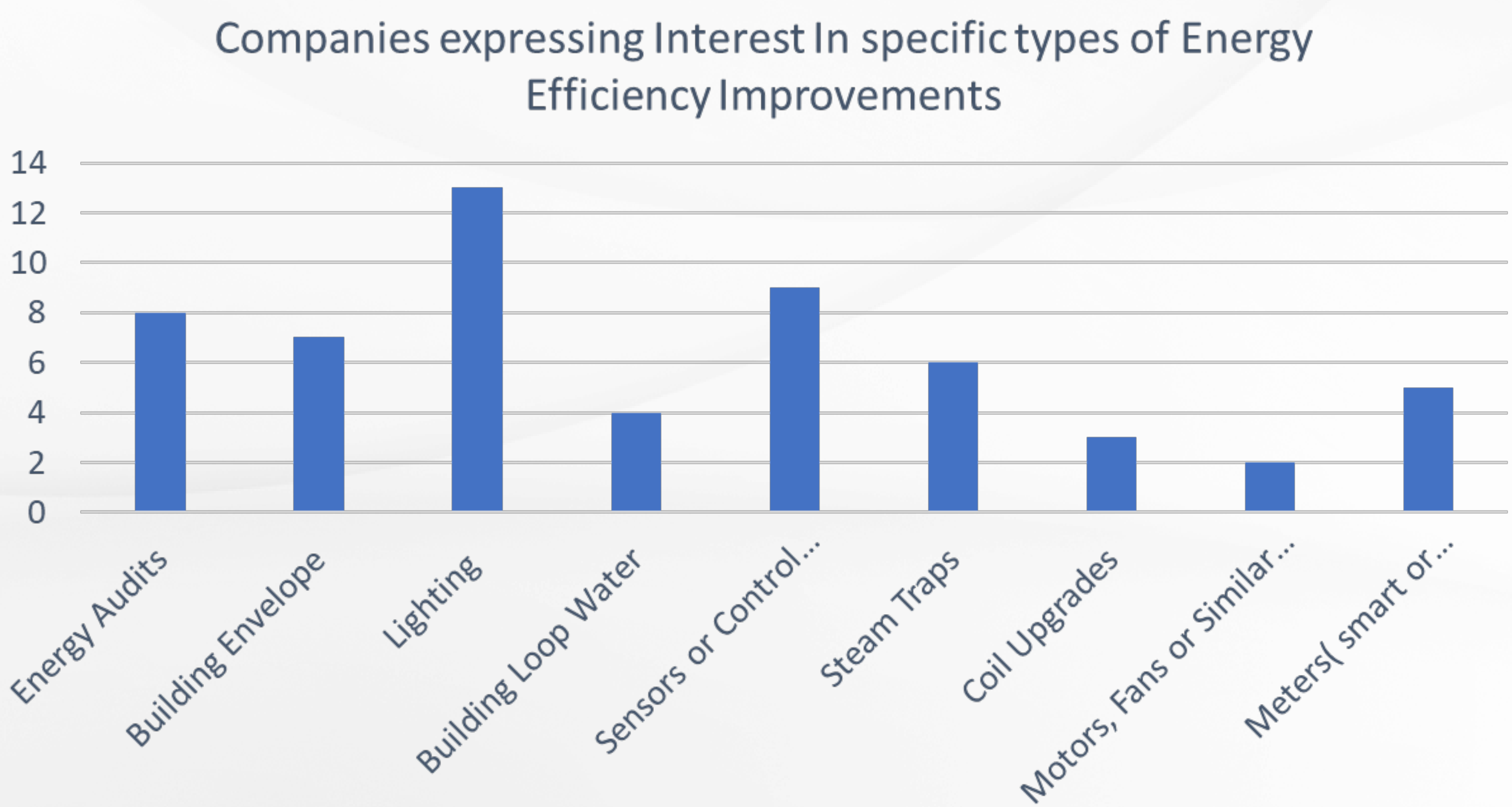
- All End Users are on system tariff with rates approved by the Public Utility Commission of Ohio
- Nature of end user business
  - Commercial, government, university, hospitality
- Size of facility served:
  - Smallest: 10,000 sq ft
  - Largest: 5 million sq ft
- Nature of use of load:
  - 15 building climate
  - 1 refrigeration
  - 1 equipment cooling
- Title or position of survey respondents
  - CEOs, CFOs, Utility Managers

Ranking factors and strategies

- Respondents ranked factors determining interest and decision to install efficiency improvements.
- Respondents ranked strategies for financing the installation of efficiency measures.



Interest in specific behind the meter improvements



Respondents (19) identified improvements that interested them from a list of potential strategies

Expected payback from energy efficiency investment

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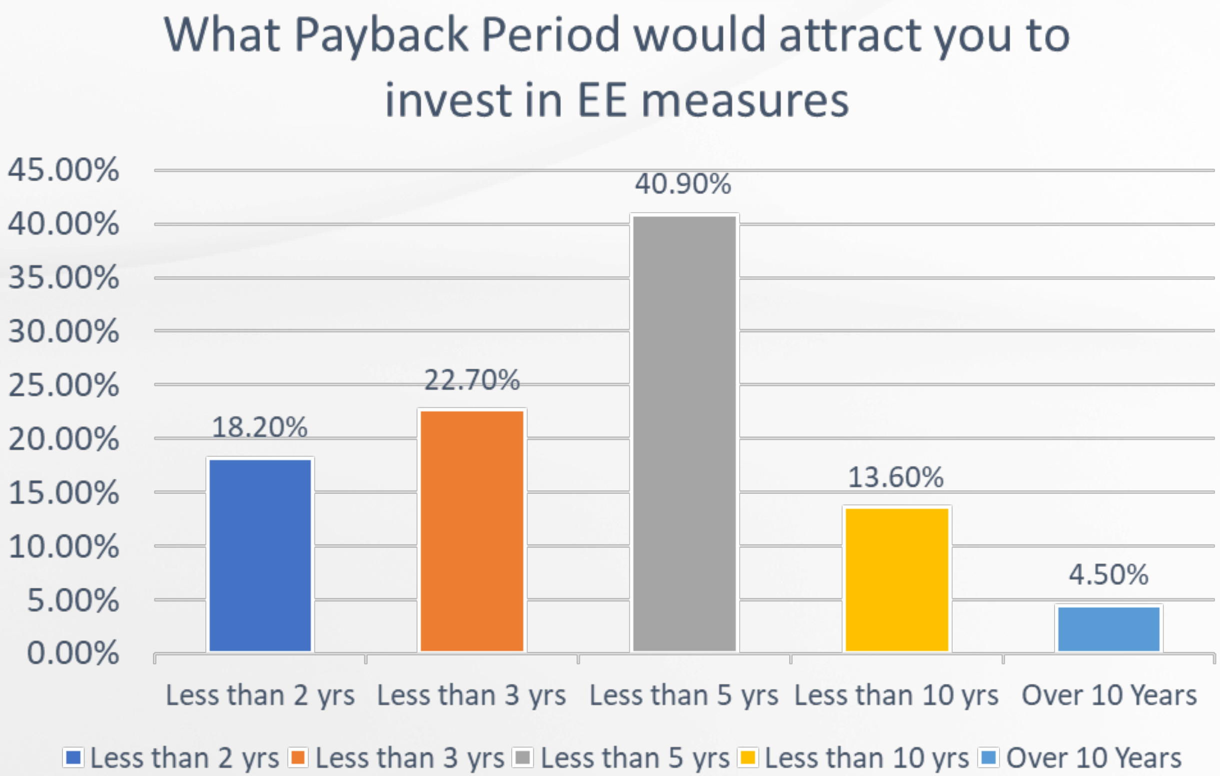
Over Half of Respondents Preferred Payback Periods of Less than Five Years for Energy Efficiency Investments

18% of Respondents would consider paybacks of over 5 years

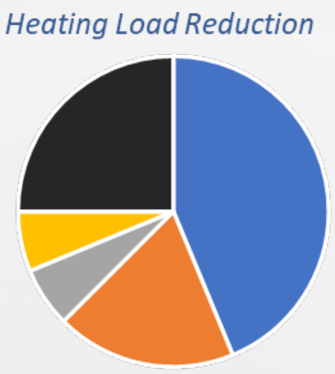


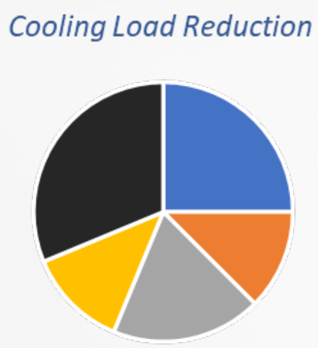
CLEVELAND STATE UNIVERSITY CORIX BRITE ENERGY INNOVATORS

Demand side management

Respondents were told about Demand Side Management and Demand Response and how programs like these can reduce costs:

- 44% were *not* familiar with Demand Side Management programs (including for electricity).
- 94% would likely participate in Demand Side Management if it could save them money.
- 40% have the ability to reduce **heating or cooling load** during peak demand events.
- Respondents were asked how much heating and cooling load they could reasonably reduce during a demand response event:



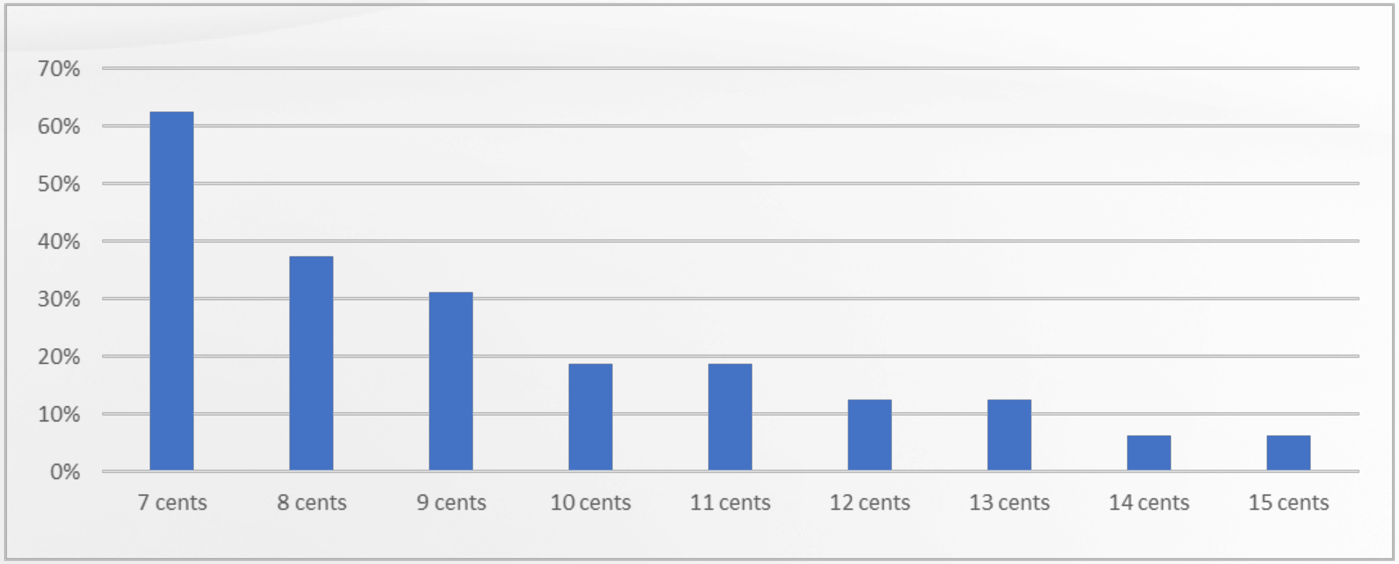


% of load that could be reduced: 1-10% | 10-20% | 20-30% | Greater than 30% | None

Microgrid opportunities

Respondents were told about how microgrids within a district energy footprint can deliver additional value for electrical and thermal loads.

- 62% were familiar with the design and operation of microgrids.
- 90% thought that microgrids could be useful to their company.
- Respondents were asked up to how much they would be willing to pay "all in" (in cents-per-kWh) for electricity within a microgrid that could deliver 99.999% uptime:



System efficiency analysis

System Limit

- Energy Production:
  - Sent-out steam produced by natural gas fired boiler
  - Electricity generated by steam
  - Cooling water produced by electric chillers
  - Cooling water produced by steam operated chiller
- Energy consumed:
  - Utility electricity
  - Steam turbine generated electricity

System Efficiency Definition

$$\eta_p = \frac{Q_{st,s} + Q_{st,CW} + Q_{CW} + E_{e,t}}{E_{NG} + E_e}$$

Energy system specification

Category	Steam	Chilled Water	Turbine
Capacity	350,000 lbs/hr (106.67 MW)	12,000 Tons (42 MW)	1 MW

Energy Category	Energy Production		Energy Source		Generation System Efficiency	Post-Generation Energy Losses	Total DE System Efficiency
	Annual MWH	%	Annual MWH	%		Annual MWH	
Steam Sendout	246.6	77%					
Electric Chiller Ton-hrs*	59.7	19%					
Chiller Steam Use	9.2	3%					
Turbines Output	4.0	1%					
Electricity			12.4	3%			
Natural Gas			358.3	97%			
Distribution Losses (12% of steam sendout assumed)						8.52	
Customer building system losses						358.33	

*MWH in chiller ton-hrs include the cooling energy produced by electricity-driven refrigeration equipment. Chill-water loss is neglected.

Modified system efficiency definition

Energy Losses

- Distribution network – Piping system
- End users - Buildings and businesses

$$\eta_{sys} = \frac{(1 - f_d - f_b)(Q_{st,so} + Q_{steam,\,CW}) + Q_{CW} + E_{e,t}}{E_{NG} + E_e}$$

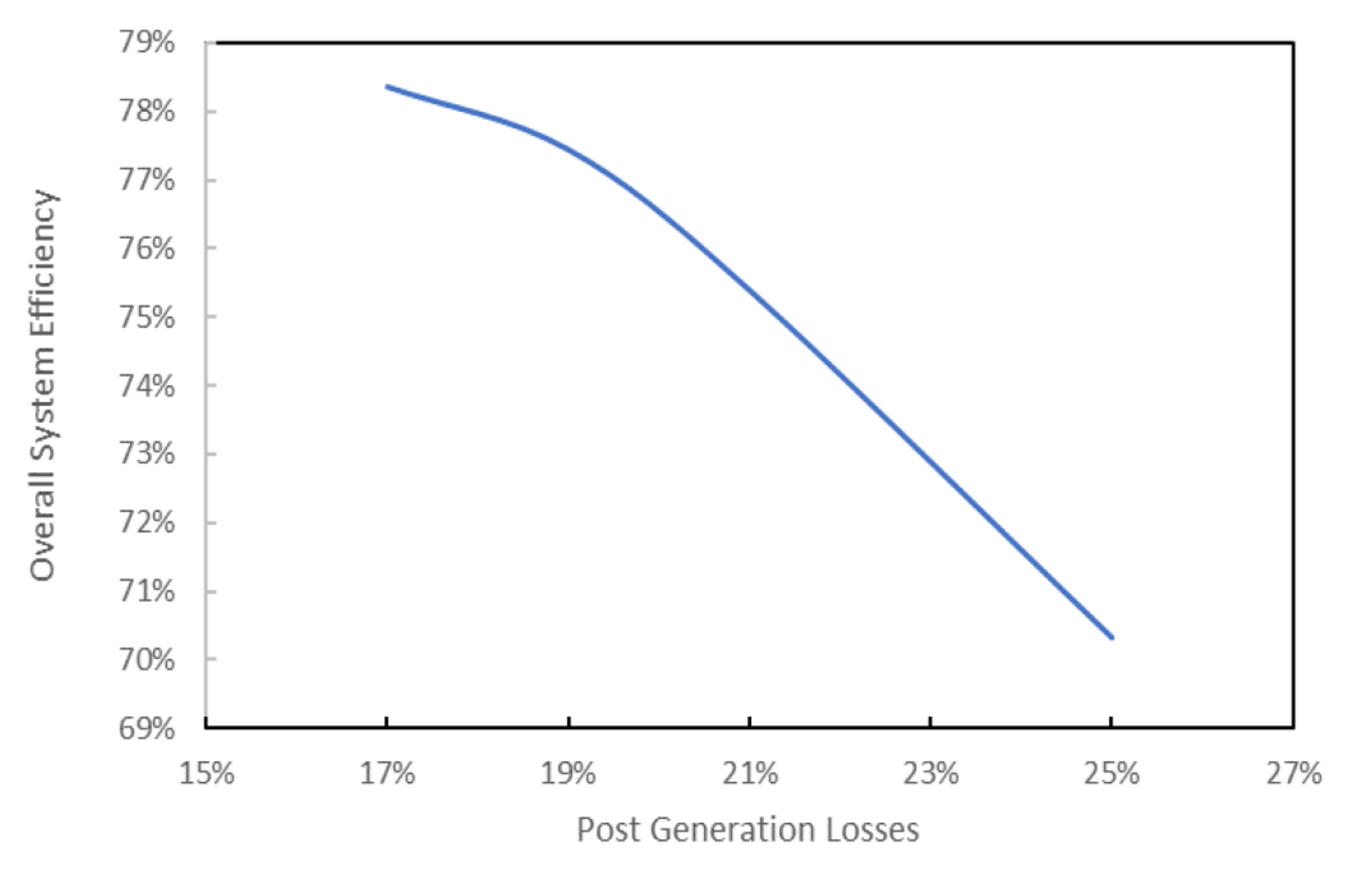
where,

$$f_d = \frac{m_{st}\,h_{st} - m_{so}\,h_{so} - \Sigma\,[m\;(\Delta\,p/\rho + \Delta\,V^2/2)]}{m_{st}\,h_{st}}$$

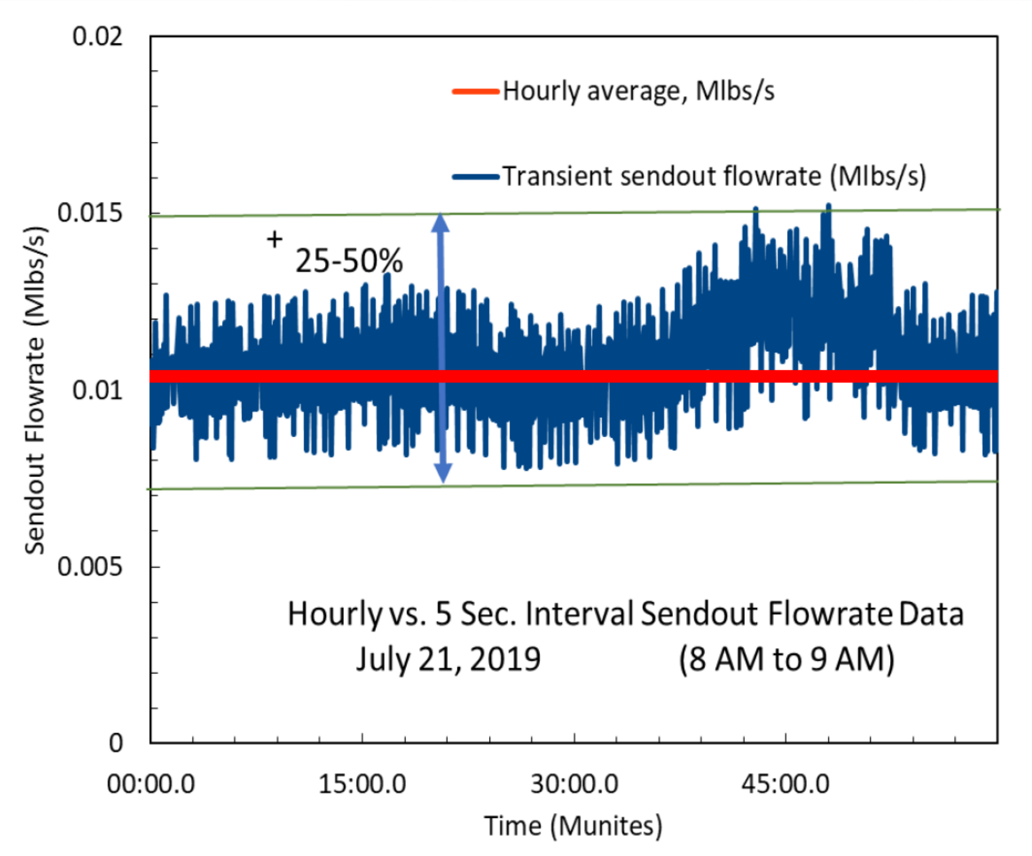
$$f_b = \frac{m_{so} - m_b}{m_{so}}$$

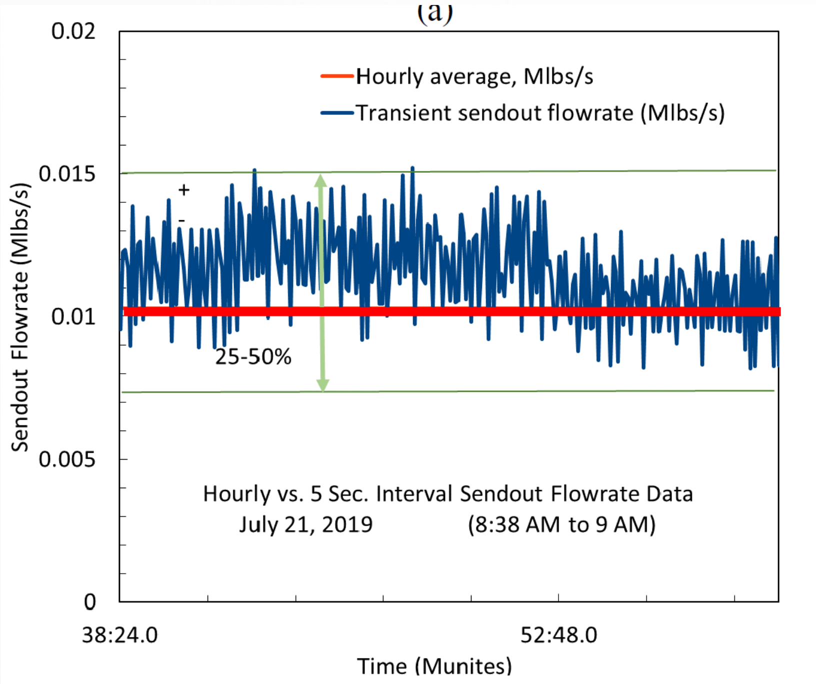
Assumption: *distribution loss for cooling water is neglected.*

Overall DE system efficiency



Boiler sendout





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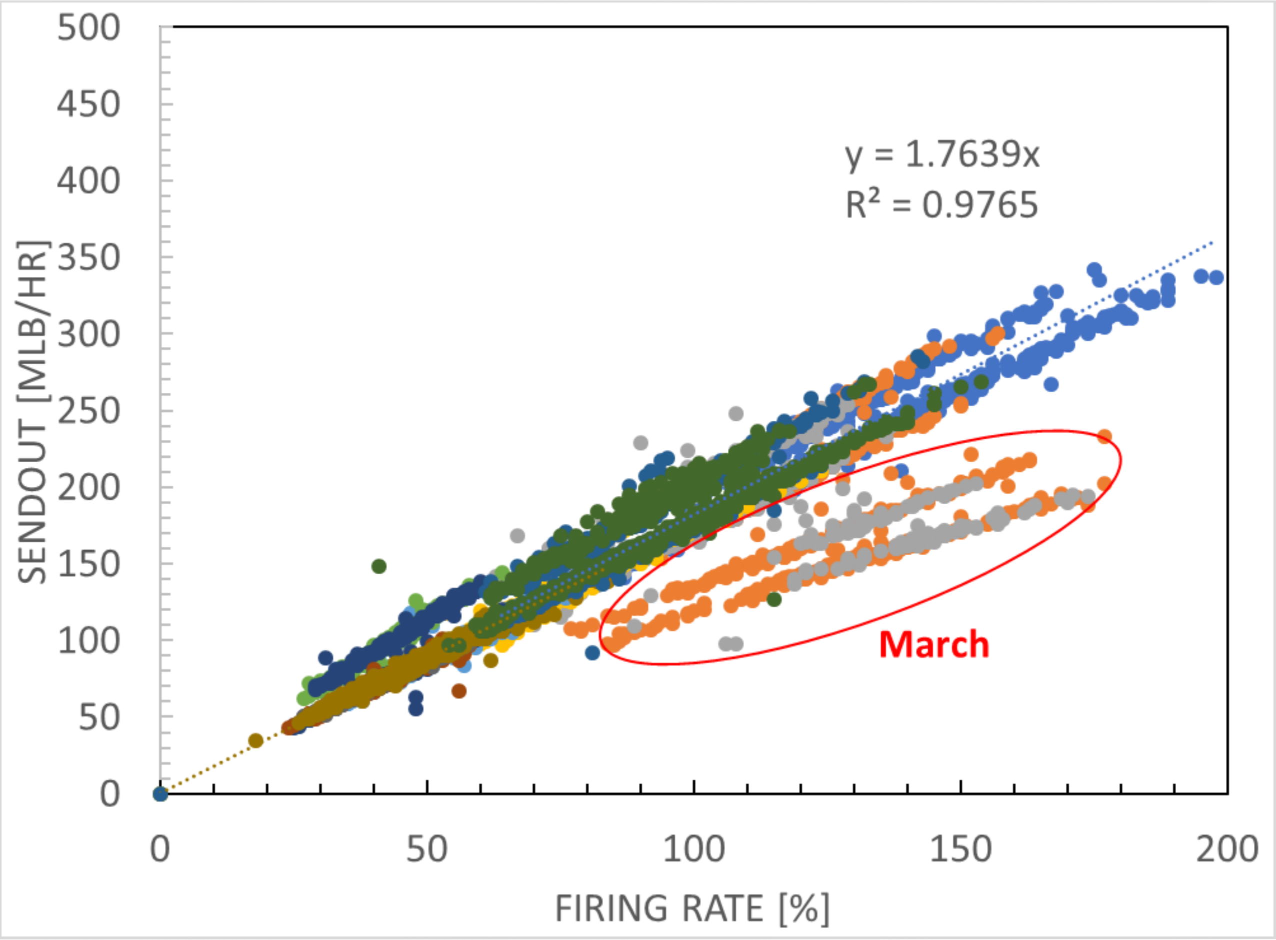
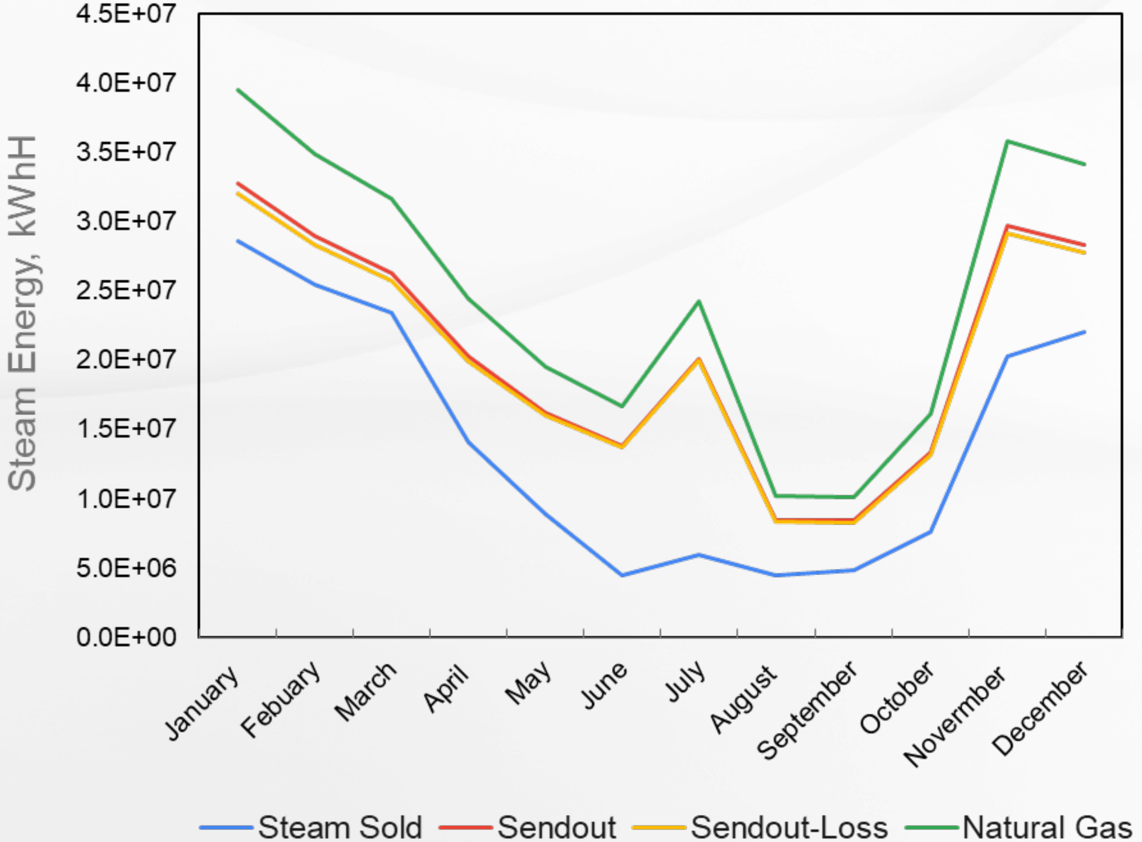
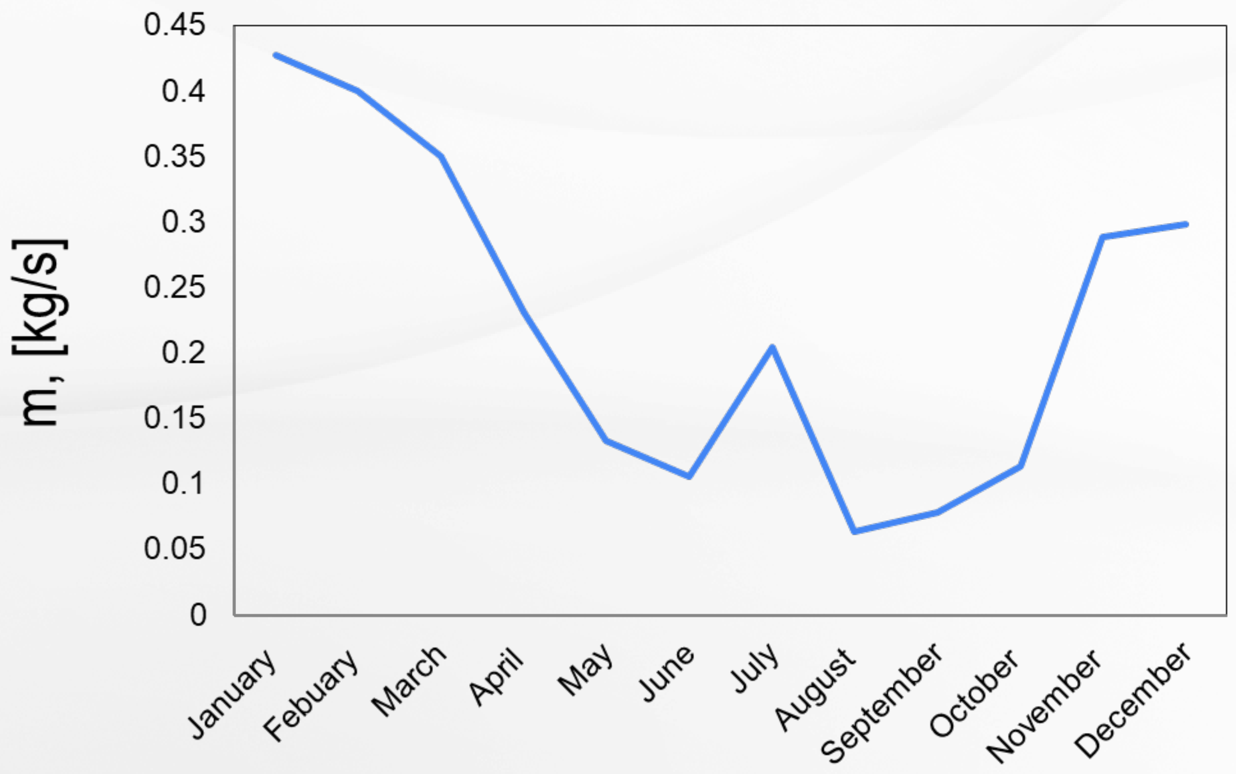
Sendout rate vs flowrate



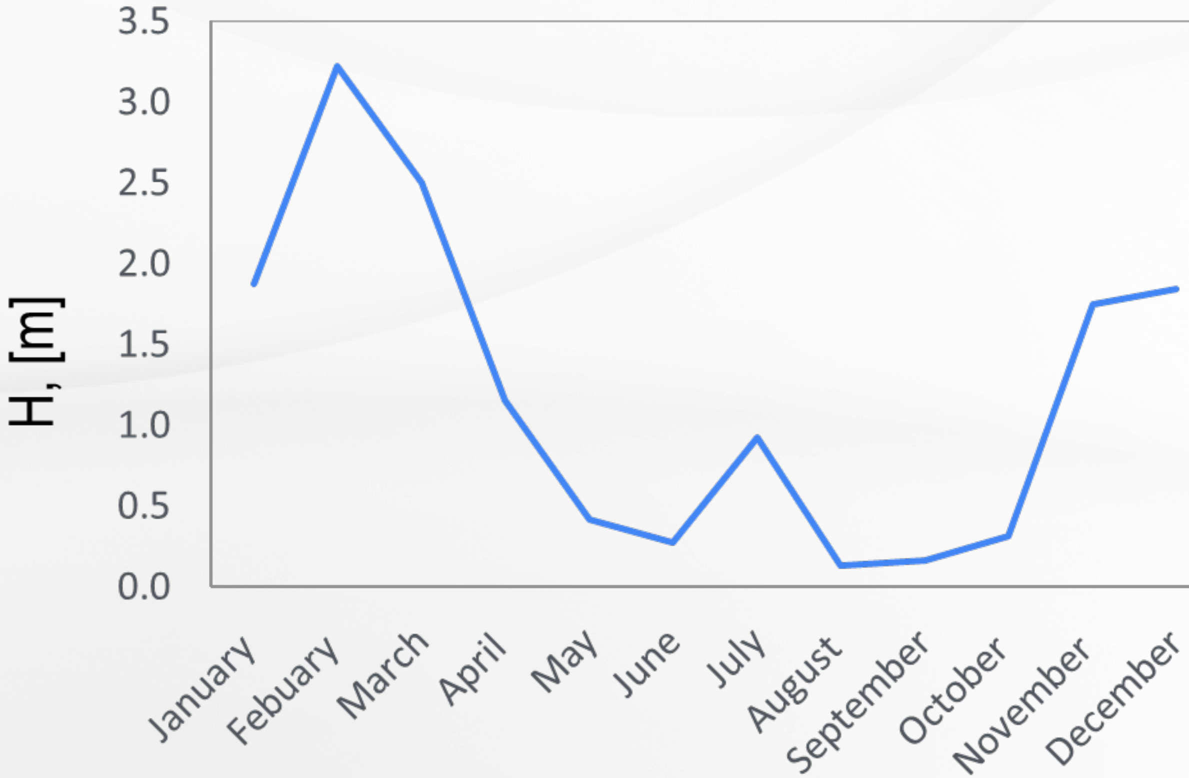
Steam energy breakdown



Monthly averaged sendout

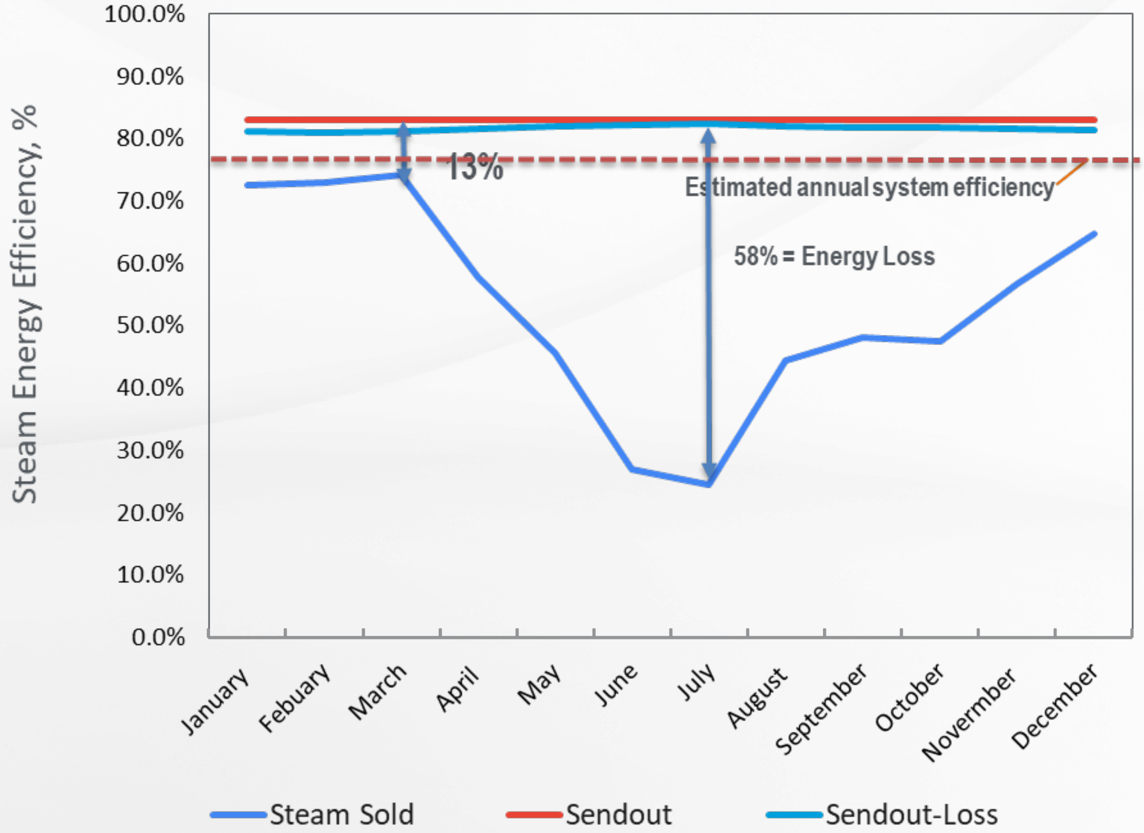


Pipeline mechanical losses*



*From the Sendout Point to One End-User Building

Steam energy efficiency



Analysis summary

- The above discussions provide preliminary analysis of energy efficiency improvement potential at a system-level, district energy system.
- Between 13% to 58% of energy loss were found. In addition to the heat loss through piping, loss due to flow discharge in traps and leaks could be the causes.
- Modeling work, based on the thermal energy balance, and field data acquisition are in progress to develop a sensor and data acquisition system that can provide a cost-effective feedback for an intelligent control system.
- Future work includes building HVAC and total energy load analysis, integrated energy production, distribution and end-user system modeling.

Distribution and load instrumentation

- LTE-M cellular for all instrumentation
- Typically connecting to either basic condensate meters (with either built-in pulse output, or using pulse converter), or to full pressure+flowrate meters already installed
- The goal is to ensure value of any additional equipment added to the existing system

Primary focus for improvements

- Generation-side is typically well instrumented, as boiler and chilled water controls require lots of sensors
- Steam trap and other underground (manhole) sensors on the distribution system are prohibitively expense to maintain
- Focus is on real-time flow rate (typically condensate flow rate) and optional pressure sensing at some customer sites
- Integrate real-time data from entire network, and use AI analysis against the system model to look for discrepancies, and make suggestions to operators for them
- Demonstrating additional renewable, CHP, or microgrid equipment in budget period 3

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