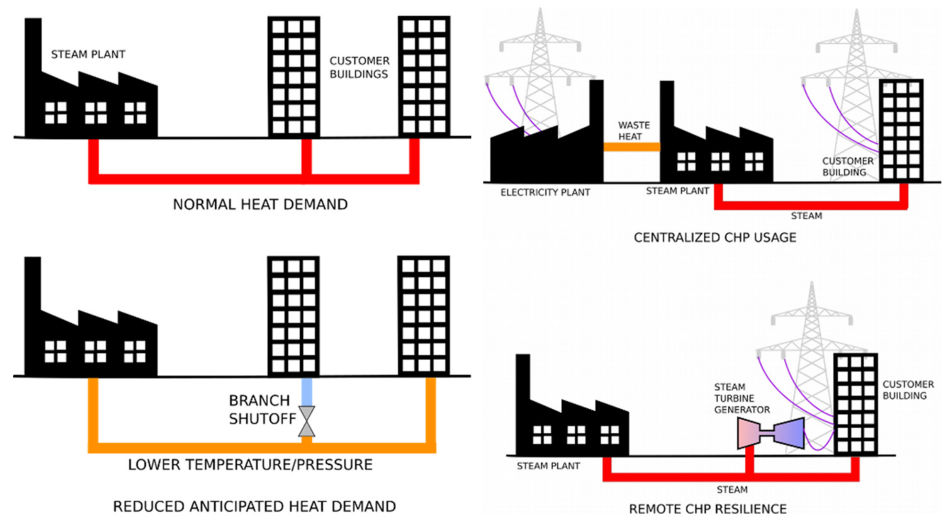
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY



Left: Simplified view of utility and customer configuration showing how energy transmission losses can be reduced by pressure, temperature, or flow reductions in district energy systems. Right: Simplified view of utility and customer configuration showing options for utilizing CHP systems to increase resilience of district energy systems. Optimizing energy production and use of CHP systems in district energy projects has historically been too complex to control. The controls developed in this project aim to overcome this limitation. *Diagram courtesy of Paragon Robotics, LLC.*

Advanced District Energy Controls for Improved Efficiency and Resilience

District energy systems efficiently provide thermal energy to multiple buildings and facilities through a network of shared infrastructure. Frequently, district energy systems are centered around combined heat and power (CHP) plants that generate electricity as well as heating and cooling to the local buildings. By providing both electricity and thermal energy from a single fuel source and central location, these systems use less fuel, decrease energy and operational costs, and reduce the need for heating and cooling equipment in individual buildings.

District energy systems are found throughout the world in areas such as denser downtowns, college campuses, military bases, and hospital complexes. These systems range in capacity and can utilize different fuel types and technologies. While district energy has been around for more than a century, these systems are not as common in the United States as in many other countries.

District energy systems face increasing inefficiencies as additional users and equipment are added to the system as they increase complexity and make optimization more difficult. Many district energy systems have parallel systems for producing utilities, allowing for shutting off parts of the system when demand is low and saving energy. As the number of users increases, identifying when these subsystems can be shut down to optimize performance becomes difficult, decreasing efficiency of the system.

The objective of this project is to improve district energy system efficiencies through development of a cost-effective, advanced district energy control system that can optimize equipment operation and identify opportunities to turn off less energy-efficient equipment when not needed. The system will utilize a new secure two-way metering and control architecture for transmitting usage and demand data along with an optimization algorithm developed for the project that identifies opportunities to reduce wasted energy based on the data collected.

Benefits to Our Industry and Our Nation

District energy systems are a complex mix of steam, cooling water, and electricity generating subsystems that interact and overlap with each other. Optimization of the energy and economics of these systems is difficult and becomes more complex as more users are added to the system. By incorporating an improved control system that optimizes energy, steam, and cooling water production for district energy systems, undelivered energy use (defined as energy used for electricity, steam, or cooling water generation that is not used by the clients) can be reduced by more than 20%.

Applications in Our Nation's Industry

A control system that can optimize energy production for district energy systems can reduce costs for users and make them more competitive in the marketplace. This improvement will further make these district energy systems more reliable as they have a lower energy demand. The control systems produced here are expected to be applicable to most district energy systems, allowing for significant energy efficiency improvements to be made across the country.

Project Description

This project aims to install a two-way control and metering architecture to improve energy efficiency and resilience of community-based district energy systems. This system will utilize a micro-auctioning control platform that treats all utility producers and users as individual economic agents and a genetic algorithm solver to simulate millions of possible outcomes, identifying the optimal operation mode based on system configuration and utility pricing.

The control platform will utilize data from a thermodynamic model developed on the project of all users in the system to perform these simulations. Significant real-time data will be required to monitor the performance of the system and a complex hardware and software topology will be necessary to collect this data from customers securely. Paragon Robotics will utilize its existing software that achieved Authority to Operate (ATO) under Risk Management Framework (RMF) requirements with the Air Force to create customized district energy interfaces for customers, providing the necessary link to securely receive usage data for the optimization algorithm as well as send usage and billing data to the customers.

Barriers

- Most district energy systems lack systems required for secure two-way control capabilities
- Complexity of system involving multiple energy types, producers, and users prevents use of conventional control systems

Pathways

This project consists of three phases. In the first phase, data was collected from a district energy provider and its customers to develop a thermodynamic and demand model. This model will be utilized to develop theoretical control optimizations that could reach energy efficiency improvement targets.

The second phase of the project focuses on developing and testing of the optimization control system for a district energy system. A small-scale testbed unit will be used to evaluate these algorithms. Designs and economic analysis for a CHP or energy storage addition to the project will be evaluated at this stage to determine if it is economically attractive to include in the final stage.

The final stage of the project will install the control system at three customer sites along with the CHP system. Control performance, system security, and overall energy efficiency will be evaluated to determine overall success of the project.

Milestones

This three-year project began in late 2020:

- Perform literature review and stakeholder survey on industry practices and energy demands (2021)
- Install sensors to develop dataset on user inputs and outputs for use in simulation model (2021)
- Develop and verify simulation modeling district energy system thermodynamics and economics (2021)
- Develop algorithm that can optimize energy production of district energy systems based on user demand (2022)
- Develop designs and economic analysis of using CHP or energy storage system for district energy systems (2022)
- Install developed control and CHP system on small-scale evaluation unit or production installation (2023)
- Validate ability of control system to improve energy efficiency and resilience of district energy systems (2023)

Technology Transition

The controls developed in this project are expected to significantly reduce lost energy for district energy systems with a cost-effective optimization system. The increased efficiency of the district energy systems will allow users to reduce costs and increase the ability of these businesses to compete in the market. These improved controls are expected to be rapidly commercialized by Paragon Robotics at the end of the project and are applicable to most district energy systems currently in use. The control algorithms and performance results will be published upon completion of the project along with results of the pricing and contract research and development for the optimized system. This will allow others to implement these new control systems in their own software/hardware systems, further enhancing efficiencies of district energy systems around the United States.

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