U.S. DEPARTMENT OF
ENERGY

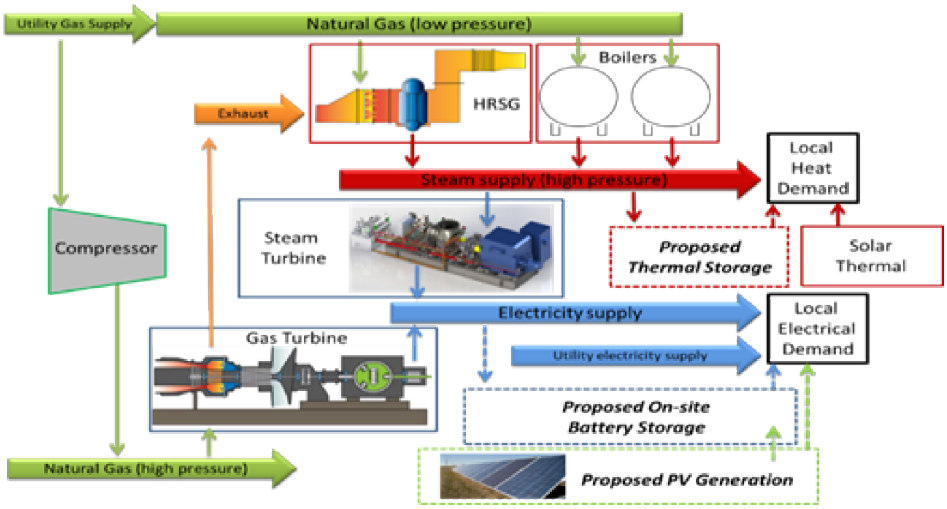
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Urban Combined Heat and Power with Integrated Renewables and Energy Storage

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.

One constraint to the growth of these systems in the United States is that many non-traditional CHP plants and small district energy systems improve one component or piece of equipment at a time without conducting a system-wide analysis. This project will investigate the entire system and analyze the operation of the components collectively. The goal of this project is to determine how to effectively integrate and enhance electricity generation and energy storage components of an urban district energy system. This project will model measures that improve CHP plant efficiency, increase backup power capacity, and diversify district energy system energy technology portfolios. The project will also explore enhancement of district energy system reliability in maintaining a daily generation-load balance and resilience during emergencies.



Schematic of the energy flows to end usage of The George Washington University (GWU) district energy system. The existing modeled components have solid borders and the additional modeled components have dotted borders. Capability to evaluate onsite battery and thermal storage as well as photovoltaic generation will be added to improve efficiency and resiliency. *Diagram courtesy of GWU.*

Benefits to Our Industry and Our Nation

The resiliency and reliability characteristics of CHP have motivated greater deployment of CHP and resilient CHP-based microgrids. However, solutions which balance distributed CHP systems' output and consumption of both electricity and heat at high efficiency are still lacking. Existing efforts propose and apply miscellaneous designs and solutions for domestic CHP applications. Energy storage buffers offer a cost-effective, adaptive solution to managing the inherent differences between supply and demand.

A national push exists to understand the performance metrics of CHP systems. The modeling technology will quantify the value of the resiliency, reliability, and security benefits that an integrated, urban district energy system provides. District energy projects also have the potential to provide significant energy efficiency and financial benefits to participating industrial facilities. Additionally, onsite electricity generation and increased thermal storage potential can be used to balance energy sources and sinks to attain a more grid-friendly profile for the facilities.

Applications in Our Nation's Industry

Advanced district energy systems that integrate a diverse portfolio of CHP, renewables, and energy storage systems capture the benefits of diverse, shared infrastructure to create more sustainable and resilient communities and help the United States more rapidly meet its energy goals.

Facilities and organizations that would benefit most from a CHP-based district energy system, such as manufacturing facilities, universities, and hospitals, currently lack a clear mechanism for measuring the value of resiliency benefits and integrating that value into their investment decision-making activities. This project will combine

real-world data with computational models to create a decision support tool for real-time management of a district energy system with inputs from CHP and renewable energy sources.

Project Description

This project will evaluate an urban district energy system with a CHP plant, solar thermal heating, rooftop photovoltaic generation, and battery and thermal storage. The project will demonstrate how incorporating a diverse generation and storage portfolio allows an urban district energy system to improve its efficiency by at least 50% and increase its backup power by at least 40% with a return on investment of 10 years or less. The improvement will be evaluated against the baseline operations for two urban district energy systems: a synthetic district energy system and The George Washington University (GWU) district energy system. The project will provide tools for the design, analysis, and implementation of next generation district energy systems.

Barriers

- Communications from multiple disparate systems need to be synchronized and interpreted dynamically for the Energy Management System (EMS).
- District energy systems with integrated renewables and energy and thermal storage are not well understood and have little operational data.

Pathways

The proposed project has four areas of focus. The first area of focus will be to design and apply an EMS platform embedded with a suite of control mechanisms and mechanisms for online tracking of reliability and resilience performance metrics. The EMS will leverage an existing computational model of the GWU CHP plant, but it will be expanded to include battery and thermal storage technologies.

The second area of focus will be to create specifications for energy storage technologies. Team members will use a multi-objective optimization algorithm to determine optimal allocation of electric battery storage units. The objective functions will be metrics of reliability, resilience indicators, and benefit-to-cost ratio.

The third area of focus will be to perform testbed demonstrations to validate the generation and storage technology and determine field implementation feasibility and specifications. Several test and use cases will be simulated, modeling different failures and scenarios (weather or cyber-driven events with different severity levels). These test and use cases will help validate the situational awareness, reliability, and resilience of the GWU and proposed district energy systems.

The fourth area of focus will be to develop a techno-economic framework for district energy systems with diverse technology portfolios, including CHP, PV generation, as well as battery and thermal energy storage. The techno-economic framework will be used to analyze the cost-effectiveness, security, and resiliency changes in district energy systems with integrated renewable generation and storage.

Milestones

This three-year project began in late 2020 and will deliver the following:

- Integrated EMS that yields projections of system operation and efficiency for synthetic and GWU district energy system cases evaluated under baseline and emergency scenarios (2021)
- Report on specifications, sizing, and siting for energy storage technologies (2022)
- Validation of generation and storage technology for synthetic and GWU district energy systems under test and use cases with performance metrics reported (2022)
- Evaluation of reliability, resilience, and vulnerability, as well as capital cost and return on investment, of the GWU district energy system with renewable generation and storage (2023)

Technology Transition

Advanced district energy systems with CHP offer a promising pathway toward a more resilient and energy efficient future for many communities and industrial facilities in the United States. The data generated from this project and resulting computational models will be available to developers and investors who wish to see how different systems operate, perform, and provide reliability/resiliency benefits. Making the GWU district energy system more resilient will also serve the surrounding community because the campus will become a central hub with electricity and water resources in the event of emergencies.

Project Partners

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DOE/EE-2677 • January 2023