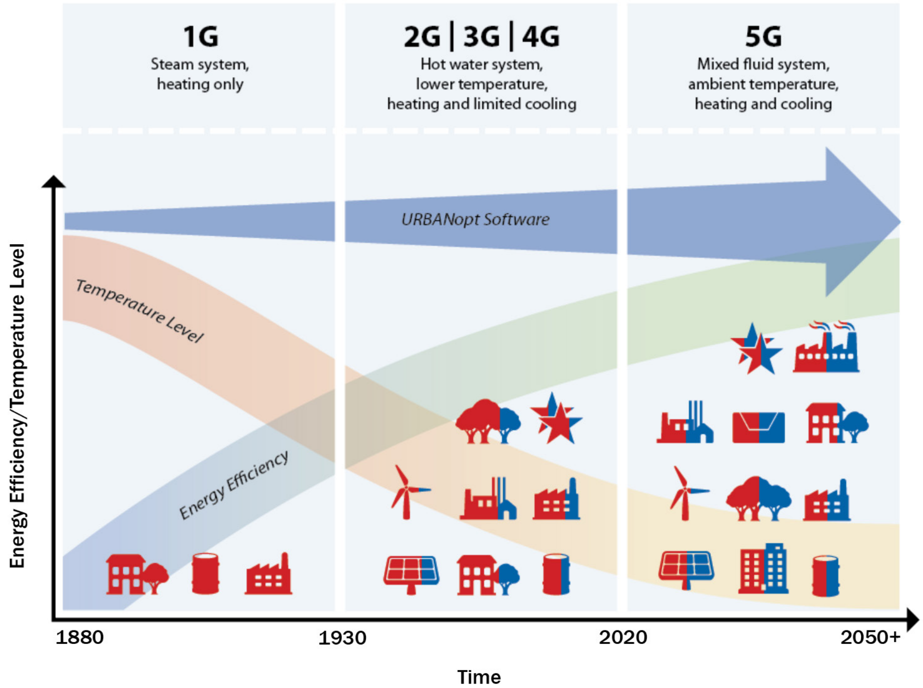
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Simulation-Based Design and Optimization of Waste Heat Recovery Systems



The Urban Renewable Building and Neighborhood Optimization (URBANopt) platform is helping more community development projects apply the latest technology for modern district energy systems that are able to utilize many diverse energy sources and technologies.

Diagram courtesy of National Renewable Energy Laboratory.

District energy systems efficiently provide thermal energy to multiple buildings and facilities through a network of shared infrastructure. Typically, 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 a 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 the inability to effectively model district energy systems. Typical design and engineering tools for buildings can optimize a single component, such as one isolated building, but they cannot identify an optimal solution for an overall system consisting of multiple connected buildings that utilize a district energy system.

The objective of this project is to address the current modeling limitations by developing a modeling platform that can quantify the value of a district energy system and its potential for waste heat recovery. The platform will evaluate and optimize district energy systems to better utilize low-temperature waste heat from nearby commercial and industrial buildings. The resulting platform will help project developers and engineers easily quantify the potential value and cost savings of community energy systems for producers, consumers, and prospective consumers of waste heat.

Benefits for Our Industry and Our Nation

Due to the limitations of current building energy modeling systems, developers face major obstacles in designing communities that incorporate district energy systems. As a result, developers tend to overlook systems that can connect CHP technologies and other distributed energy resources to local buildings. By capturing heat that is normally wasted and integrating renewable energy, these community developments can achieve up to 50% energy savings over conventional designs while improving energy affordability, increasing security, and enhancing resilience. 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

A model that can optimize the utilization of waste heat and renewable energy sources will increase the efficiency of district energy systems, which can improve business competitiveness and in turn grow the overall demand for waste heat recovery and district energy-related CHP systems. The added flexibility of these shared CHP and thermal energy systems is also expected to benefit grid profiles by lessening dependence on purchased electricity and redirecting excess heat produced by industrial and commercial activities to nearby buildings.

Advanced district energy systems that can utilize low-temperature heat sources will 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.

Project Description

This project will incorporate an integrated simulation method into the Urban Renewable Building and Neighborhood Optimization (URBANopt) platform to enable a detailed analysis of waste heat sources within a district of connected buildings. These advancements will be accomplished by combining an URBANopt software development kit (SDK) with the open-source Modelica programming language and the next generation Spawn of EnergyPlus, a building energy simulation program supported by the U.S. Department of Energy (DOE). The updated URBANopt platform will be capable of evaluating industrial processes and waste heat opportunities in conjunction with commercial and residential buildings.

Barriers

- Waste heat energy sources are typically not evaluated in connection to potential end users, namely buildings.
- District energy systems are typically not evaluated with integrated building design tools that are able to quantify the value of waste heat.

Pathways

One focus of this project is to leverage Spawn of EnergyPlus for building load calculations. Spawn combines the EnergyPlus building-envelope model with the flexibility of the Modelica programming language for thermal energy and control-system modeling. Spawn's refactored EnergyPlus building-envelope model introduces the ability to model multiple buildings and district systems together in one combined simulation while retaining much of the OpenStudio and EnergyPlus input format that is the basis for DOE's building energy modeling ecosystem. This, in combination with newly developed component models for district heating and cooling systems, will enable a next-generation integrated simulation technology.

In the final phase, the URBANopt SDK will be tested in real-world conditions for the design of a community development project that incorporates waste heat recovery. The project will be leveraging University of Colorado's Boulder Campus as a case study of the new software platform. The measured data acquired from field testing will be compared with the modeling approach and simulated data.

Milestones

This three-year project began in late 2018:

- Conduct stakeholder engagement by convening a technical advisory group to inform industry priorities and gap analysis (2019)
- Publicly release URBANopt SDK as an open-source software (2020)
- Develop enhancements to URBANopt SDK to incorporate next-generation simulation technology (2020)
- Develop district component models for integration into the Modelica Buildings Library (2020)
- Validate URBANopt's new simulation capability by comparing modeled results to actual measurements from a district energy project (2021)

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 forthcoming software analysis platform will help assess the value of district energy and waste heat recovery as well as its potential to provide benefits to both producers and consumers. Since this project will in part utilize EnergyPlus, an open-source building energy modeling engine, the increased modeling capabilities will quickly become available to the significant base of established EnergyPlus users. By increasing awareness and improving the business case, URBANopt can help facilitate the growth of these high-performance district energy systems resulting in cost savings, greater energy security, environmental and economic benefits, and more favorable grid profiles.

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