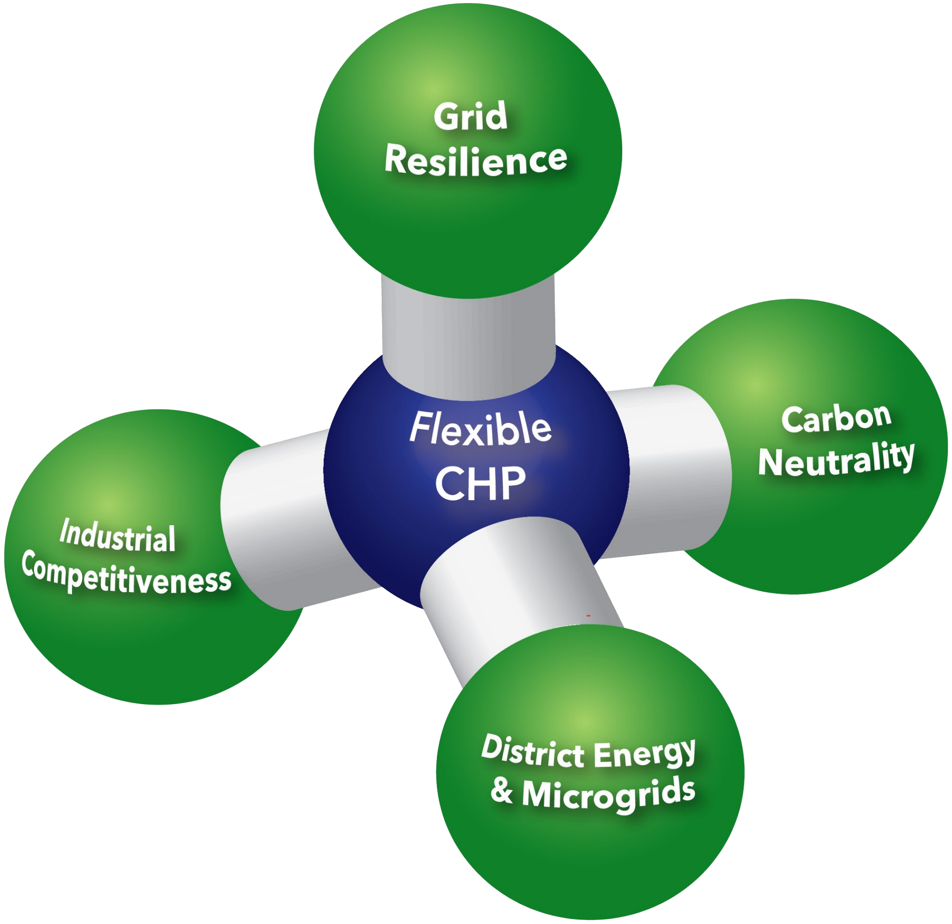
AMO Combined Heat and Power Workshop



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Advanced Manufacturing Office CHP Workshop

September 8-10, 2020

Bob Gemmer

CHP Technology Manager

September 8, 2020

CHP is an Integral Part of the AMO Program

AMO Work
FY20: $395M

R&D Projects
Fund R&D projects that propose innovative manufacturing processes and next-generation materials. Projects selected through merit-based process in response to AMO identified technical challenges. **FY20 = $151M**

R&D Consortia
Create an innovation ecosystem by bringing together hundreds of partners focused on a specific technical challenge. **FY20 = $199M**

Technical Assistance
Increase the adoption of advanced energy efficiency technologies and practices by assisting the manufacturing sector in establishing and achieving energy management goals through access to resources. **FY20 = $45M**

CHP R&D

CHP Deployment
- CHP TAPs
- CHP eCatalog
- Packaged CHP Accelerator
- CHP Market Resources

Why CHP Now?

CHP systems are becoming recognized as a critical component in the nation's energy infrastructure, providing greater energy security, reliability and serving as a resource during energy emergencies.

- They
  - Come in a variety of sizes, are fuel flexible, and can serve end-users in the manufacturing, commercial and institutional sectors.
  - Have proven effective during and after natural disasters.
  - Can provide important ancillary services and grid support
  - Can provide important services as an anchor in microgrids or district energy systems.

- What gaps or opportunities remain in AMO mission space?
  - Cost and efficiency improvements through improved materials and advanced system designs
  - Needed power electronics and prime mover improvements to enable seamless CHP system interaction with the grid
  - End user education and CHP implementation in underutilized markets
  - Fair and balanced policies to reduce implementation barriers

CHP Deployment Activities

Supporting deployment of CHP is part of the EERE/AMO mission to create and sustain American leadership in the transition to a strong and prosperous America powered by domestic, affordable, and secure energy for the industrial, manufacturing, federal, institutional, commercial and multifamily sectors. Key program components include:

- **CHP Technical Assistance Partnerships (CHP TAPs)**
- **eCatalog**
- **Packaged CHP Accelerator**
- **Deployment Program Resources**

We work with partners and stakeholders [multiplier effect]:

- Regional energy initiatives and alliances
- State Energy Offices/NASEO
- Utilities
- Nonprofits working on energy efficiency, CHP, and district energy
- Trade organizations for targeted markets (e.g., hospitals and hospitality industry) and professions (e.g., facility managers)
- Manufactures and suppliers of CHP systems
- End users (industrial and commercial & institutional), including large corporations with multiple facilities

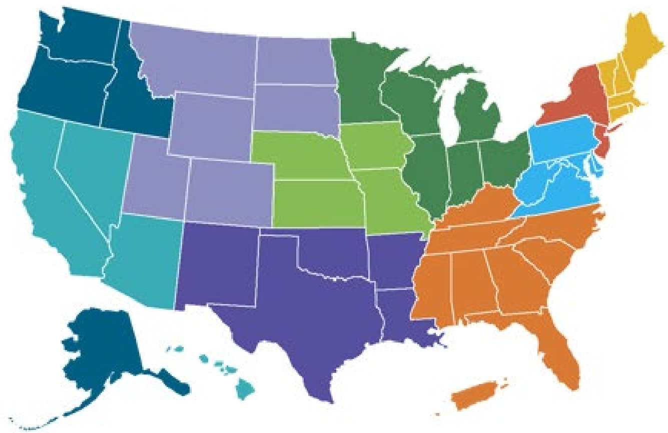
DOE CHP Technical Assistance Partnerships (CHP TAPs)

Upper-West
CO, MT, ND, SD, UT, WY
www.uwchptap.org
Gavin Dillingham, Ph.D.
HARC
281-216-7147
gdillingham@harcresearch.og

Midwest
IL, IN, MI, MN, OH, WI
www.mwchptap.org
Cliff Haefke
University of Illinois at Chicago
312-355-3476
chaefke1@uic.edu

New England
CT, MA, ME, NH, RI, VT
www.nechptap.org
David Dvorak, Ph.D., P.E.
University of Maine
207-581-2338
dvorak@maine.edu

Northwest
AK, ID, OR, WA
www.nwchptap.org
David Van Holde, P.E.
Washington State University
360-956-2071
VanHoldeD@energy.wsu.edu



New York-New Jersey
NJ, NY
www.nynjchptap.org
Tom Bourgeois
Pace University
914-422-4013
tbourgeois@law.pace.edu

Western
AZ, CA, HI, NV
www.wchptap.org
Shawn Jones
Center for Sustainable Energy
858-633-8739
shawn.jones@energycenter.org

Mid-Atlantic
DC, DE, MD, PA, VA, WV
www.machptap.org
Jim Freihaut, Ph.D.
The Pennsylvania State University
814-863-0083
jdf11@psu.edu

Southcentral
AR, LA, NM, OK, TX
www.scchptap.org
Gavin Dillingham, Ph.D.
HARC
281-216-7147
gdillingham@harcresearch.org

Central
IA, KS, MO, NE
www.cchptap.org
Cliff Haefke
University of Illinois at Chicago
312-355-3476
chaefke1@uic.edu

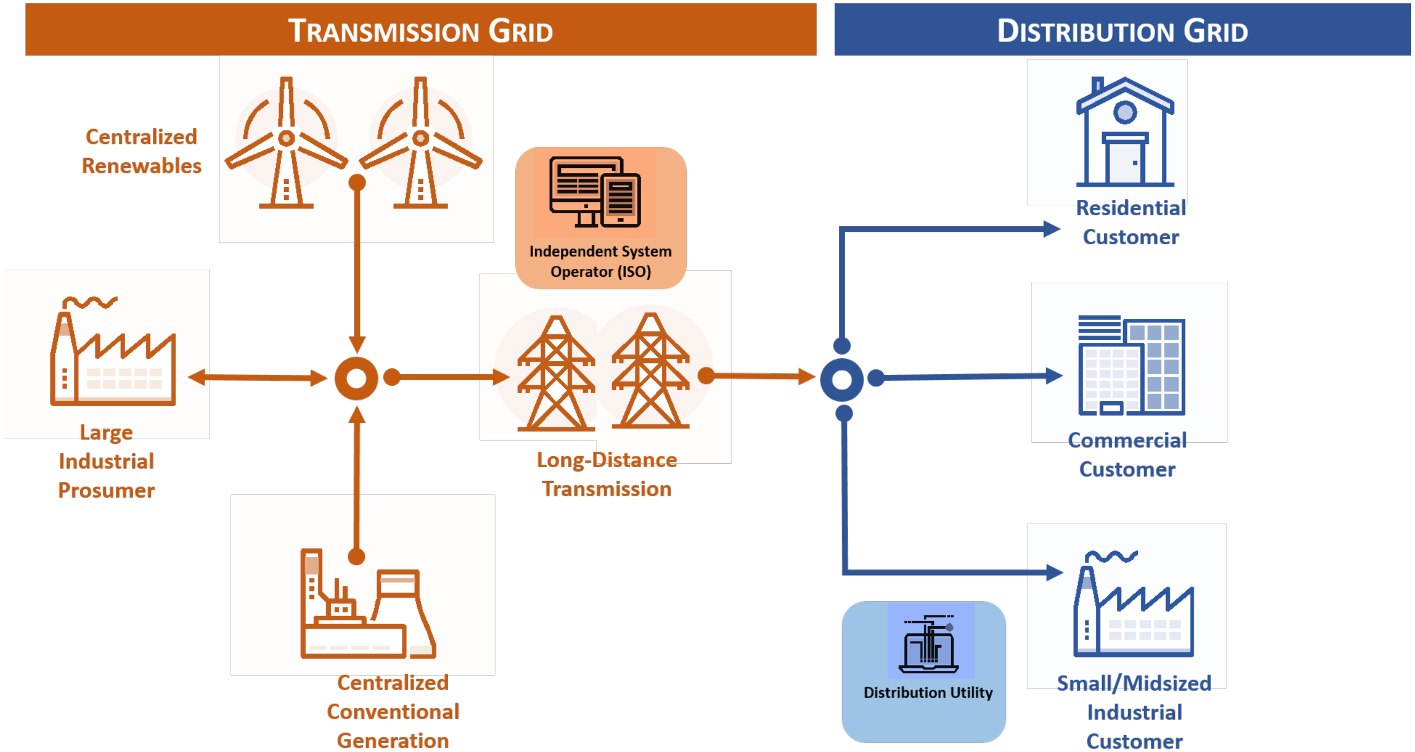
Southeast
AL, FL, GA, KY, MS, NC, PR, SC, TN, VI
www.sechptap.org
Isaac Panzarella, P.E.
North Carolina State University
919-515-0354
ipanzarella@ncsu.edu

CHP R&D Portfolio

The current CHP R&D project portfolio focuses on the development of technologies that address the technical and cost barriers to technology implementation:

- Providing support services to the modern electric grid, thereby providing an additional value stream to the CHP system owner
- Developing CHP systems that produce more power than heat, opening up opportunities in new manufacturing and commercial markets
- Improving the efficiency of CHP systems by developing new high temperature materials and component designs

Traditional Electricity Grid

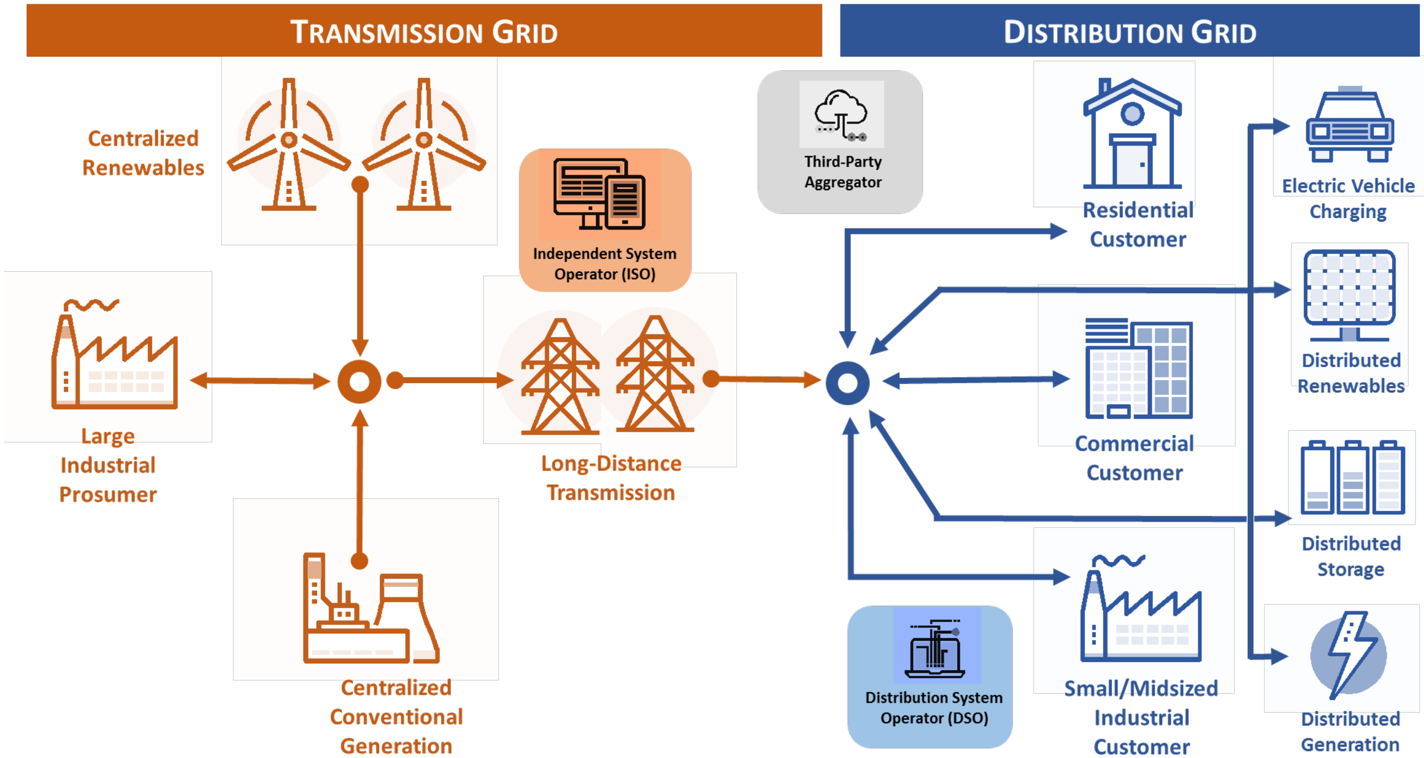


In the traditional power grid, electricity is produced by centralized power plants and moved to the customer over a long-distance transmission network

- Power flows are generally one-way (from generator to customer)
- Large industrial customers can export power, but small and midsized industrial customers do not provide services to the electric grid
- Generation and load are separated, and coordination between customers and load-serving entities is limited

U.S. Department of Energy | Energy Efficiency & Renewable Energy

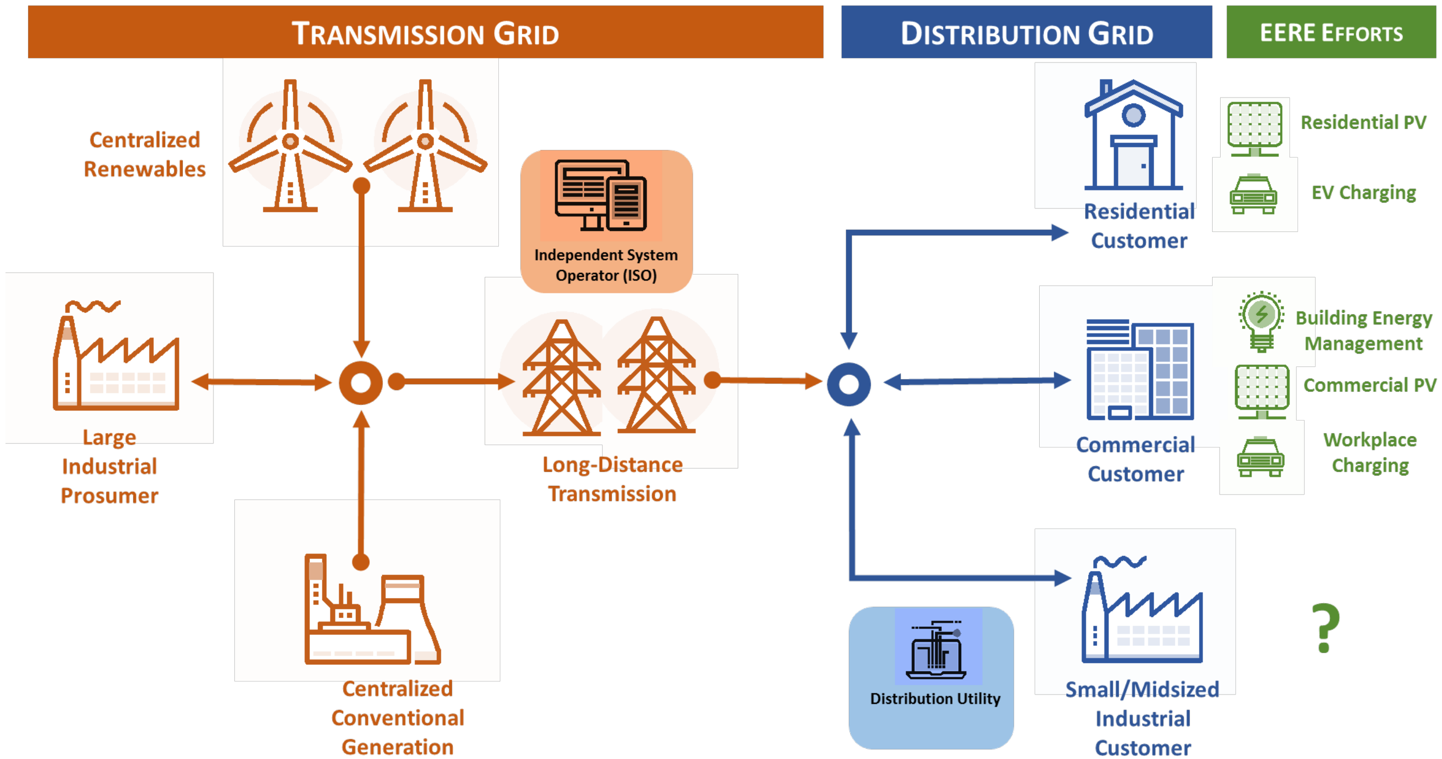
Evolving Electricity Grid



In the future, electricity will be produced by a variety of resources, including renewable distributed energy resources with variable production that can export power to the distribution system

- Power flows are bi-directional and managed by interconnected information and control systems
- Customers are “prosumers:” they consume electricity but also generate power to satisfy their own loads as well as to provide services to the grid (including energy to other customers)
- Generation and load are closely coordinated to optimize the performance of the system and reduce infrastructure costs

R&D Opportunity to address the role of Manufacturing

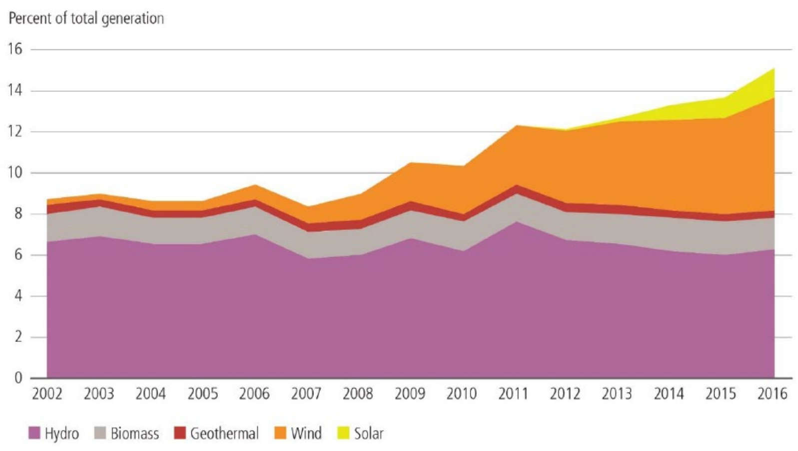


EERE has a variety of programs to integrate residential and commercial customers to tomorrow's distribution grid, but has not yet focused on small/midsized industrials

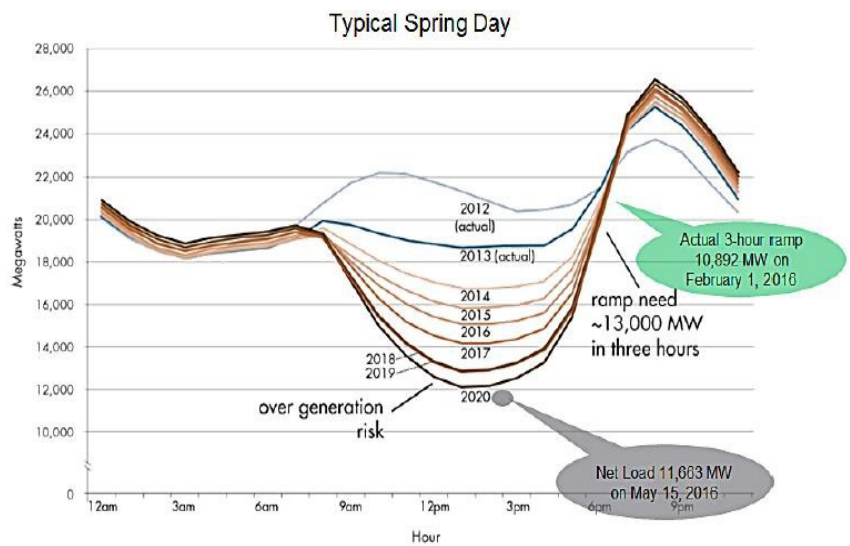
- Vehicles examples include a pathway for integration of vehicles with buildings, modeling and control software, and standard and interoperability systems research
- Buildings examples include data standardization to enable transactive services, hybrid inverter technology development, and load controls to support whole building response.
- Small/midsized industrials represent an important area of "white space" due to their substantial electric load (1-20MW) and familiarity with self-generation. But additional technologies are needed to integrate these generation resources to the grid.

Two Key Issues and Challenges as Grid Resources Evolve

- Non-dispatchable renewables (particularly wind and solar) are increasing rapidly on the U.S. grid.
- The rapid increase of renewables exacerbates the load changes at peak demand periods requiring additional fast-reacting grid resources.



RENEWABLE GENERATION AS A PERCENTAGE OF TOTAL U.S. ELECTRICITY GENERATION



CALIFORNIA'S "DUCK CURVE"

Impact of Flexible CHP Concept on the Grid: Modeling of the California Market

Objective:

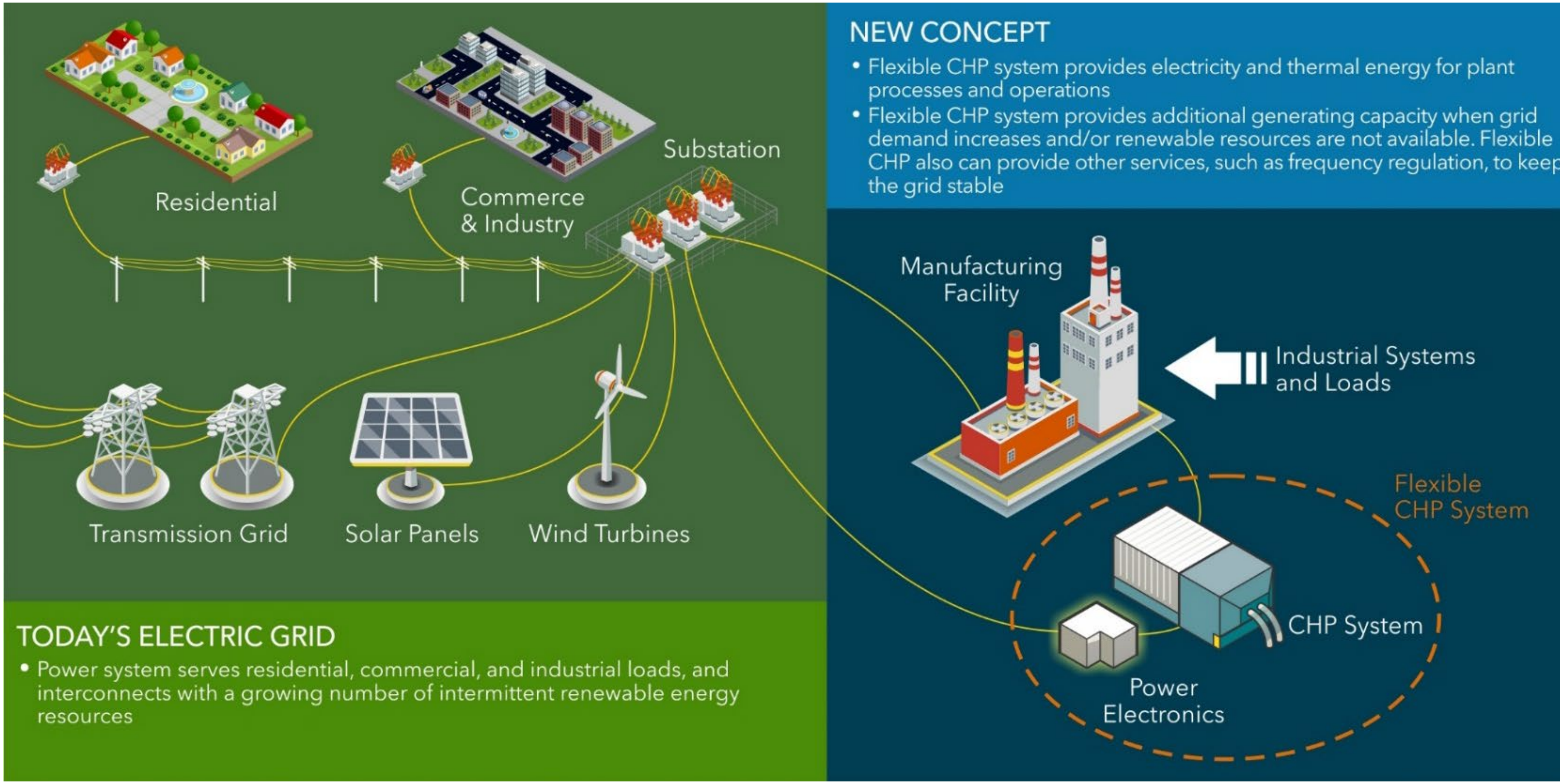
- Estimate value of added flexible CHP at California **industrial and institutional sites** due to increased revenue from grid services and lower CHP costs.

Three scenarios were modeled:

- *Baseline:* 33% renewables on grid, 3,400 MW existing CHP for site loads
- *Traditional CHP:* Serves site loads + 10% capacity for grid services <500 hr/yr
- *Advanced CHP:* Serves site loads + large flexible capacity for grid services
- *Combined Scenario:* Selects most profitable option (between traditional and advanced) at each site

Analysis Results to be presented by Mark Ruth

Flexible CHP Systems: Concept Basics



- Concept would improve grid reliability and resiliency, along with providing economic benefits to manufacturing facilities
- Technology advancements are needed to bring the concept to fruition

Current Flexible CHP R&D Portfolio (FY2018 FOA)

<u>Funding Opportunity Announcement Objective:</u> Research on enabling technologies for CHP systems (focusing on 1-20 MWe systems) that are specifically designed to provide cost-effective support to the electric grid

Area of Interest 1 – Power Electronics

- Research, develop, and test CHP components such as power electronics and control systems needed to enable the cost-effective use of new and existing CHP systems to provide support to the grid.
- 4 ongoing projects

Area of Interest 2 – Electricity Generation Components

- Research and develop the electricity generation components of a 1-20 MWe CHP system capable of two operating configurations—a baseload mode where it is running at half its rated capacity and is designed to perform in a conventional CHP manner, and a second, at full rated capacity, where it is designed to maximize its ability to support the electric grid.
- 3 ongoing projects

High Speed Medium Voltage CHP System with Advanced Grid Support

Photo credit Clemson University

Project Team

- Clemson University
- TECO-Westinghouse Motor Company

Timeline

- Project start: October 2018
- Project end: June 2021

Objective

- Develop and test a medium voltage modular control system architecture to enable flexible CHP systems with advanced grid support functionality

SiC-Based Modular Transformer-less MW-Scale Power Conditioning System and Control for Flexible CHP System

Project Team

- University of Tennessee, Knoxville
- Chattanooga Electric Power Board
- North Carolina State University
- General Electric
- Oak Ridge National Laboratory

Timeline

- Project start: October 2018
- Project end: December 2021

Objective

- Develop a silicon carbide based, modular, transformer-less, MW-scale, four-wire DC/AC power conditioning system converter and a corresponding control system for flexible CHP systems

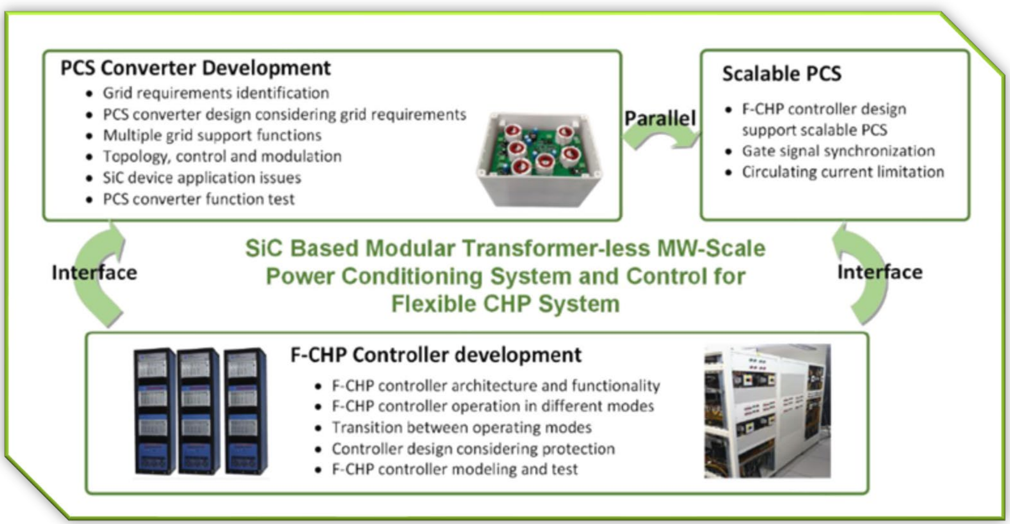


Image credit University of Tennessee

Project Overview: Virginia Tech

High-Efficiency Modular SiC-Based Power Converter for Flexible CHP Systems with Stability-Enhanced Grid Support Functions

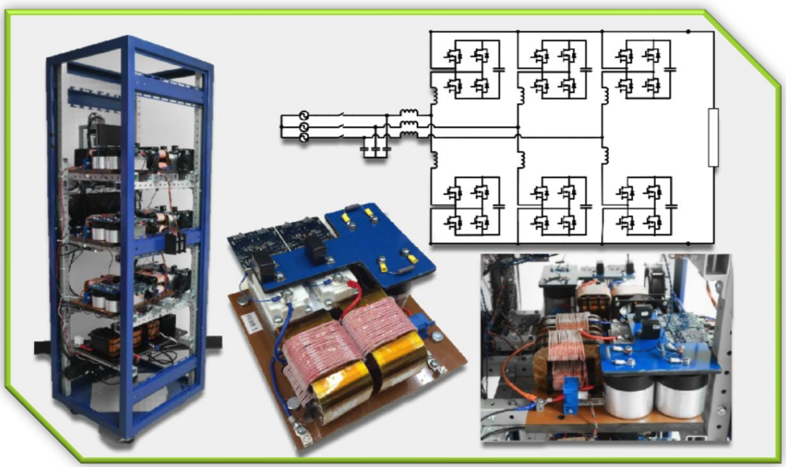


Image credit Virginia Tech

Project Team

- Virginia Tech
- Siemens Corporate Technology

Timeline

- Project start: January 2019
- Project end: December 2021

Objective

- Develop a modular, scalable power converter with stability-enhanced grid support functions that avoids the onset of dynamic interactions with the grid and other system components

Converter-Interfaced CHP Plant for Improved Grid Integration, Flexibility and Resiliency

GE Global Research GE Renewable Energy

nationalgrid

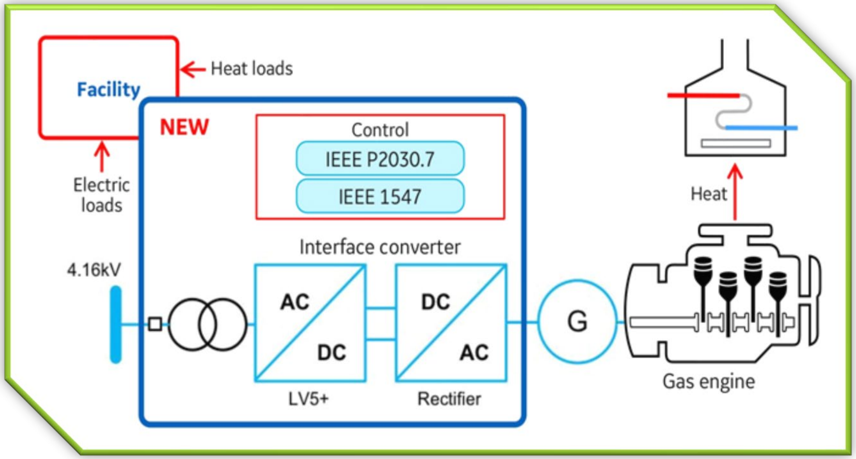


Image credit GE Research

Project Team

- GE Research
- GE Renewable
- National Grid

Timeline

- Project start: October 2018
- Project end: December 2020

Objective

- Develop a full-size grid interface converter and control solution to seamlessly interconnect small and mid-size CHP engines to the distribution grid

Modifications to Solar Titan 130 Combustion System for Efficient, High Turndown Operation

Photo credit Solar Turbines Inc.

Project Team

- Southwest Research Institute
- Solar Turbines Incorporated
- Electric Power Research Institute
- Georgia Institute of Technology
- University of California, Irvine

Timeline

- Project start: October 2018
- Project end: April 2021

Objective

- Develop new combustion system technologies to enable a gas turbine to maintain high efficiency and low emissions during high turndown operation, enhancing the ability of a CHP system to provide advanced grid services

Project Overview: ElectraTherm

Organic Rankine Cycle Integration and Optimization for High Efficiency CHP Genset Systems

ELECTRATHERM BY BITZER GROUP

INNIO

Susteon

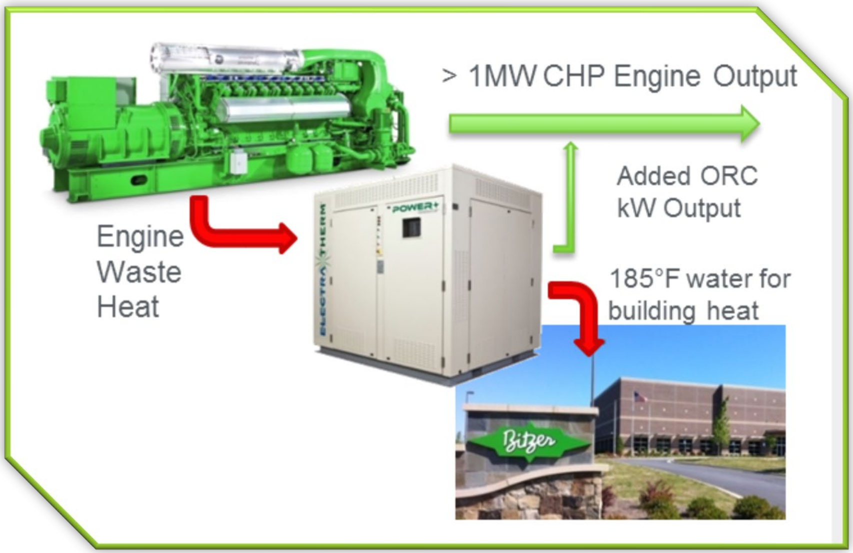


Image credit ElectraTherm

Project Team

- ElectraTherm
- Innio (Jenbacher Engines)
- Susteon Inc.

Timeline

- Project start: October 2018
- Project end: December 2021

Objective

- Enable a novel flexible CHP system concept by developing an Organic Rankine Cycle system that can be integrated with a reciprocating engine to achieve total CHP system efficiencies of 85% or more at both its rated electrical capacity and at 50% capacity

Development of Improved CHP Systems Utilizing Improved Gas Turbine and sCO2 Cycles Using Additive Manufacturing

SIEMENS OAK RIDGE National Laboratory

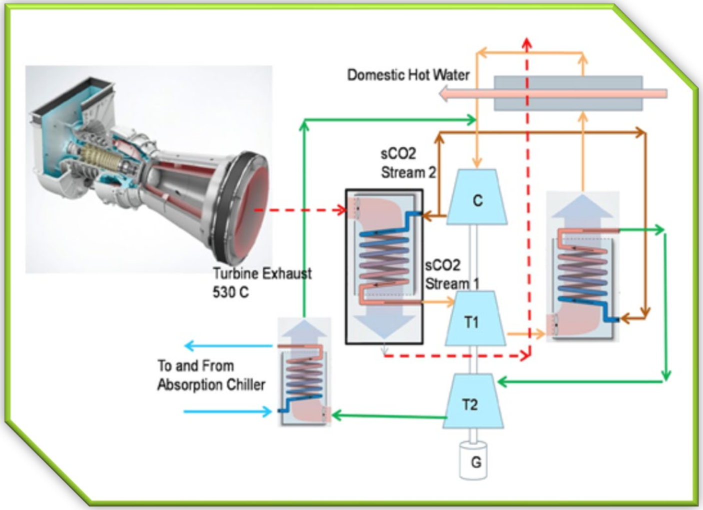


Image credit Siemens Corporation

Project Team

- Siemens Corporation
- Oak Ridge National Laboratory

Timeline

- Project start: October 2018
- Project end: September 2021

Objective

- Integrating a supercritical CO2 bottoming cycle with a 5.3 MW gas turbine to develop a CHP system that can transition rapidly between 50% and 100% load by engaging or bypassing the bottoming cycle while maintaining electrical system efficiency above 30% at all times

Turbocompression Cooling System for Ultra Low Temperature Waste Heat recovery

Project Team

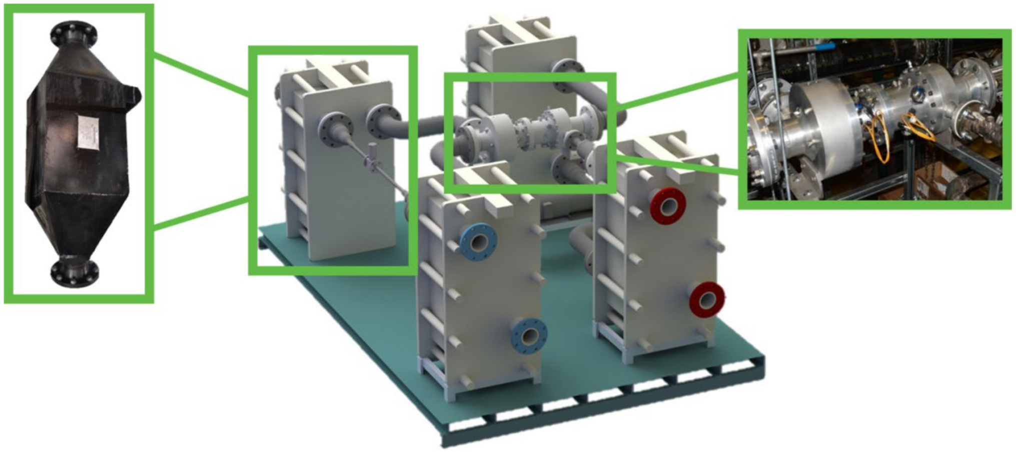
- Colorado State University
- Barber-Nichols, Inc.
- Modine Manufacturing Company

Timeline

- Project start: June 2018
- Project end: June 2021

Objective

- Develop a novel, low-cost turbo-compression cooling (TCC) system that utilizes low temperature waste heat available in industrial processes. The TCC system absorbs heat from the engine coolant of a diesel generator and consists of two different cycles that are coupled by a high efficiency turbo-compressor. The project goal is to achieve a competitive COP and cost while maintaining operation at a 10:1 turndown ratio.



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Current Connected, Flexible and Efficient Manufacturing Facilities and Energy Systems RD&D (FY2019 FOA)

Funding Opportunity Announcement Area of interest 3 Objective: A modernized electric power system will need to dynamically optimize distributed resources, rapidly detect and mitigate disturbances, and engage millions (if not billions) of intelligent devices. It must integrate diverse generation sources, demand response, and energy-efficiency resources, and enable consumers to manage their electricity use and participate in markets. Finally, it must provide strong protection against physical and cyber risks.

Area of Interest 3.1: Medium-Voltage Power Conditioning Systems to Enable Grid-Dispatchable and Resilient Manufacturing Facilities

- 3 ongoing projects

Area of interest 3.2: High Power to Heat Ratio, High Efficiency Combined Heat and Power (CHP)

- 3 ongoing projects

Area of interest 3.3: Verification and Validation of CHP and District Energy

- 5 ongoing projects

Advanced Turbine Airfoils for Efficient CHP Systems

Project Team

- National Energy Technology Laboratory
- Oak Ridge National Laboratory

Timeline

- Project start: 2019
- Project end: 2022

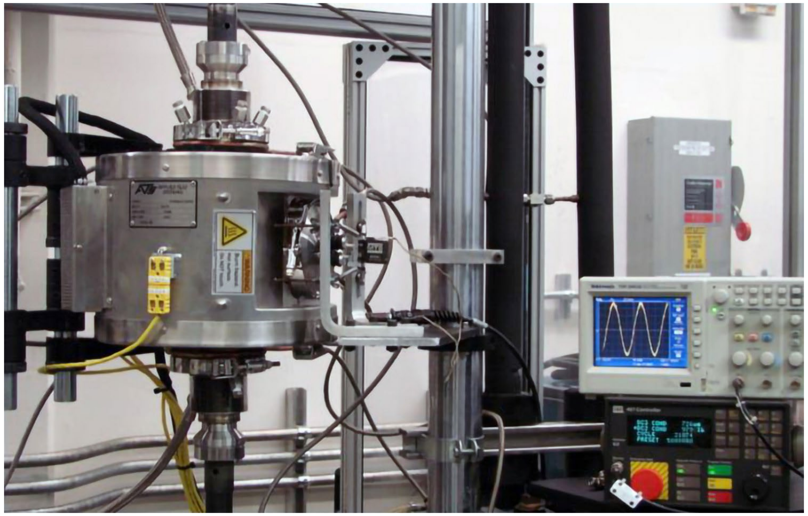
Objective

- Evaluate how a combination of new materials, additive manufacturing technologies, and airfoil cooling design can raise the efficiency of turbines used in CHP systems by demonstrating how to increase the turbine firing temperature by 100°C compared to a 2015 baseline; economic benefits from these efficiency gains in CHP systems that use turbines smaller than 20 MW will also be estimated.

High Performance, High Temperature Materials to Enable High Efficiency Power Generation

Project Team

- Oak Ridge National Laboratory
- Argonne National Laboratory
- Capstone Turbine Corporation
- Siemens Corporation
- Solar Turbines
- Tennessee Technological University

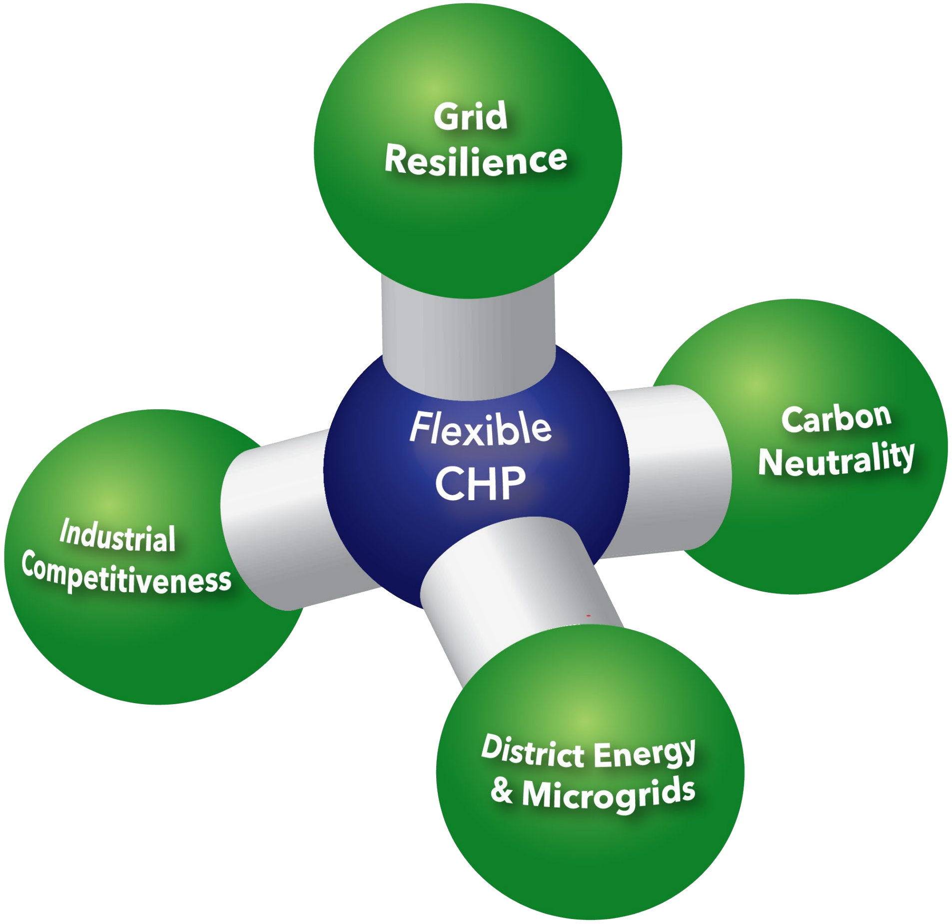


Timeline

- Project start: 2019
- Project end: 2022

Objective

- Evaluate advanced materials and develop lifetime modeling tools to enable a greater than 100°C increase in gas turbine inlet temperature compared to a 2015 baseline and improve the durability and reduce maintenance costs of high temperature components in current CHP systems. The targeted components include heat exchangers, combustion liners, and hot corrosion-resistant coatings for disk applications.


Grid Resilience
Flexible CHP
Carbon Neutrality
Industrial Competitiveness
District Energy & Microgrids