District Energy Systems

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Executive Summary

The objectives in this section are 1) to provide an overview of the current district energy systems (DES) in Tompkins County, 2) to discuss the potential for future development of DES in the County, and 3) to identify the associated opportunities and challenges. We focus on two most relevant components in DES for the County, i.e., Combined Heat and Power (CHP) and Microgrid systems.

District energy systems centralize the production of energy services (i.e., heating or cooling or power) for a neighborhood, community, or cluster of buildings. DES can play an important role in improving energy system efficiency and resilience, by integrating renewable energy sources into the production of energy, vastly reducing greenhouse gas (GHG) emissions. Because the equipment is shared by the consumers, DES can potentially result in savings in space, thereby reducing construction, operations, and maintenance costs.

One frequently adopted component of a DES is CHP. CHP systems utilize exhaust heat from power generation to provide space or processing heating. Another component of a DES is a microgrid, which distribute the power locally within DES, and can serve as islands of reliability within the larger regional and national electricity grids, providing power in occurrences of natural disasters or power outages that impact the larger grids.

There are several existing CHP facilities located in the County, including the Cornell University campus, the Ithaca Area Waste Water Treatment Facility, and the South Hill Business Campus that is currently under construction. So far, Cornell University has the only microgrid system in the County.

We identified a number of potential sites for deploying DES in the future, including the urban core, business parks, and large institutional ratepayers. The deployment of DES can bring many benefits including: high energy efficiency, high energy reliability, reduced energy bills, and reduced GHG emissions. However, implementation faces several challenges, including the existing infrastructure limitations, the perspectives of policy makers, and needs of facility owners. As explained later in this chapter, the construction of DES requires significantly rebuilding existing infrastructure, and correspondingly large capital and time investments. Statewide, there are few incentives to incorporate microgrids in the current power grid system although the Public Service Commission's *Reforming the Energy Vision (REV)* contemplates policies and incentives to encourage microgrids and the State's current NY Prize microgrid competition grant awards are funding feasibility studies in Tompkins County and around New York State. At present, the lack of a favorable regulatory framework and relatively low electricity prices impinge on making progress. With current technology, the payback period of a new CHP system or a CHP-upgrading is still much longer than the typical business payback expectation, a barrier for the CHP implementation in commercial buildings.

1. Introduction

1.1 District Energy Systems

A District Energy System (DES) is a central system that provides essential energy services for a neighborhood or community. There are many different types of DES, given the various power generation methods (e.g., solar, geothermal, biomass, biogas or natural gas) and energy services (e.g., power, heating, and cooling) they provide. DES also consists of local distribution systems to deliver the energy services. Power can be distributed through a microgrid, and steam, hot water or chilled water piped underground to individual buildings for space heating, domestic hot water use and air conditioning.

1.2 CHP

A Combined Heat and Power system (CHP) is a single integrated system that generates electricity and heat (or cooling) simultaneously. CHP captures the “waste heat” during the production of electricity, for hot water, space heating, space cooling, or process heat for industrial applications.

As is shown in Figure 1, energy released by fuel combustion (or chemical conversion through a fuel cell) first drives turbines or reciprocating engines to generate electricity. Then the exhaust gas of engines and turbines is collected to heat water or generate steam for heating purpose. Sometimes the steam is used to drive absorption chillers for cooling purpose.

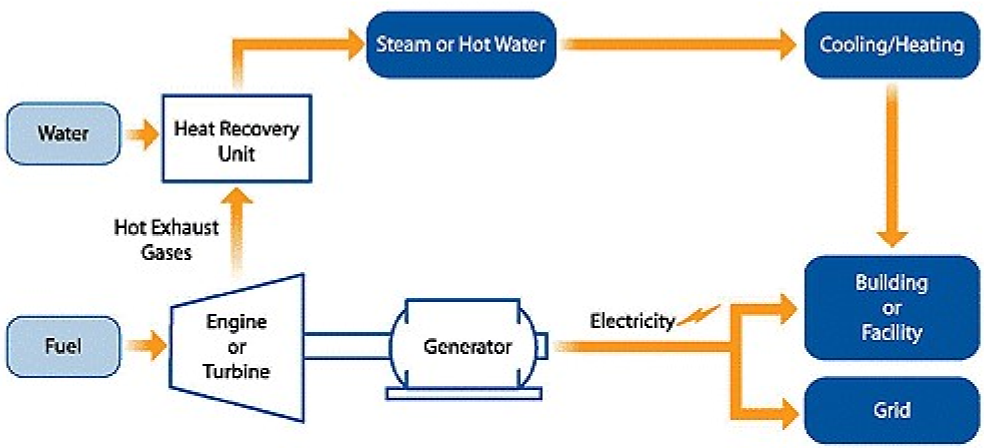

Figure 1. Combined Heat and Power System [20]

Due to the cascade use of waste energy, the energy conversion efficiency could reach as high as 95% with a well-designed scheme, compared to the maximum 40% efficiency that the latest coal technology (without waste heat utilization) could achieve [12]. Because of the high energy efficiency for the same energy demand, less fuel is consumed and greenhouse gas (GHG) emissions are also reduced.

Apart from high energy efficiency and low GHG emissions, CHP systems can also improve the energy system reliability. Working independently, CHP systems are not be affected by power grid failures and therefore reduce the impacts of power outages.

1.3 Microgrids

A microgrid is defined as a small, integrated energy system of interconnected loads and distributed energy resources (producing both electric and thermal energy), which can operate in parallel with the macrogrid or in an intentional island mode [1].

The schematic of the microgrid in Figure 2 shows the Distributed Energy Resources (DER) that can be aggregated to be meet regular demand, and different types of loads that operate within the macrogrid, or in island mode if possible. The microgrid generates power locally or consumes power from the macrogrid. The dependent loads can be separated by their reliability type into three categories: sensitive, adjustable, and sheddable. [2] Sensitive loads, as the name suggests, are the most critical and should always be supplied power. Adjustable loads can be controlled in a given power interval. Sheddable loads can be disconnected if enough power is not generated enough at a particular moment in time [3]. CHP is often the centerpiece of reliable, clean, and economic microgrids, but a CHP system can also operate without a microgrid, and vice versa.

Another distinct feature of a microgrid is that it uses a meshed distribution network instead of a radial network. An interconnected or meshed network is generally found in urban areas and has multiple connections to other points of power supply. The benefits include ease in identification and isolation of fault and high reliability. [13] A meshed network would be able to detect a fault in a bus segment and isolate that faulted section so that the system keeps operating without disabling the entire system.

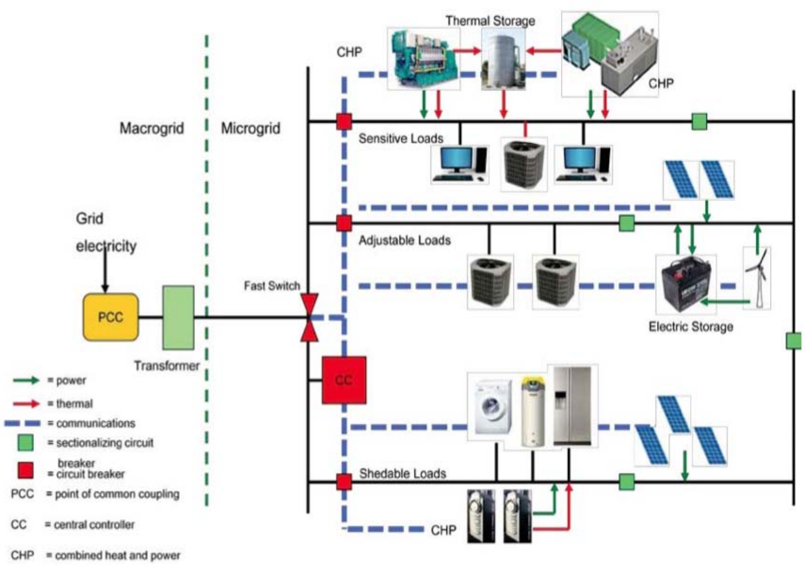

Figure 2. Microgrid schematic [2]

1.4 Potential Benefits of District Energy Systems

District systems with microgrid and CHP present multiple benefits. We list the major benefits in four categories: economic, reliability & power quality, environmental and security & safety.

1.4.1 Economic

Direct

- Energy cost reductions
- Reduced purchases of electric generation, transmission & distribution services
- Reduced purchases of fuel for on-site thermal energy demand
- Reduced purchases of ancillary services
- Participation in demand response programs designed to decrease electricity consumption from on-peak to off-peak periods
- Provision of ancillary services to the national grid to support the transmission of electric power from seller to purchaser

Indirect

- Reduced electric Transmission and Distribution (T&D) losses
- Reduced electric T&D capacity investments
- Support for deployment of renewable generation [2]

1.4.2 Reliability & Power Quality

- Reduced power interruptions and enhanced power quality. Power quality refers to the reliability and quality of service. For example, when voltage deviates from specific quality standards, a high quality of service would not see much variation in the power output. Such events include voltage sags, harmonics, and spikes.
  - Voltage sags, typically called undervoltages, correspond to voltage levels that are reduced from the typical frequency (60 Hz) to last only from 0.5 to 30 Hz. These occurrences result from large momentary overload when large loads begin drawing power from the system. [2] This will especially affect sensitive loads, and disrupt their continuous operation.
  - Even though the US power system operates at 60 Hz, some equipment connected to the grid operates at other frequencies. This creates harmonics, increasing line losses and reducing equipment lifetimes.
  - Spikes, also called transients, are brief surges (in milliseconds) in voltages caused by the switching of large loads. This can damage the sensitive loads.

1.4.3 Environmental

- Reduced emissions of greenhouse gases and criteria pollutants. Microgrids can reduce the environmental impact of energy use by integrating technologies, such as CHP and renewables that are low-emission and increase the overall efficiency of the energy system.

1.4.4 Security & Safety

- Safe havens during power outages. During extended power outages, microgrids can provide public security and safety benefits. A community connected to the microgrid can serve as a refuge for others dependent on the national grid. In addition, reducing the reliance on the macrogrid as the unique source of power may render the national grid a less attractive target for terrorist attacks.

2. Current District Energy Systems in Tompkins County

Table 1. Existing CHP facilities in the Tompkins County

Facility Name	City	Prime Mover	Primary Fuel	Capacity
Cornell University	Ithaca	Combustion Turbine	Natural Gas	37 MW
Ithaca Area Wastewater Treatment Facility	Ithaca	Microturbine	Biogas	220 kW
South Hill Business Campus	Ithaca	Reciprocal Engine	Natural Gas	500 kW

2.1 Cornell University

Today Cornell University has over 21,000 undergraduate and graduate students and more than 11,000 faculty and staff. The University's main campus includes 150 buildings, covering 14 million square feet of space. Advanced research, done in the Cornell facilities, requires highly reliable electricity services. If energy were to be lost, for even short periods, research could be adversely affected, with severe financial consequences.

The University's 37 MW microgrid is powered by a dual-fuel combined heat and power (CHP) plant that can burn natural gas or diesel, plus 1 MW hydropower generator and a 2 MW solar installation. In addition, Cornell has a district cooling system, which uses Cayuga Lake as a heat exchanger [4]. Cornell's district energy system is estimated to reduce to 50,000 tons of CO_2 per year, 800 tons of SO_2 per year, and 250 tons of NO_x per year. [2]

2.2 Ithaca Area Wastewater Treatment Facility

The advantages of on-site CHP systems for wastewater treatment plants have become more apparent throughout the years. The appeal stems from: 1) the need for reliability during utility power outages and shortage, 2) the availability of free fuel compared to high fossil fuel prices, 3) the awareness of utilizing renewable resources, and 4) the government incentives available to fund the systems.

Currently, the Ithaca Area Wastewater Treatment Facility, operating two 110-kW Caterpillar combined CHP systems, is able to generate 60 percent of its own energy (electricity and heating) by producing biogas. [5] The wastewater treatment plant harvests nutrients out of the water, in which a biological system absorbs nutrients and transforms them into a "bio-solid". The anaerobic digester uses this material to produces biogas. In the near future, the plant will start purifying the biogas for a lower carbon dioxide content, which would allow the fuel to be used for vehicles. Then, they would be able to sell the biogas. However, this market does not yet exist in Ithaca. If this possibility does present itself, the vehicles would have to be retrofitted to utilize purified biogas.

2.3 South Hill Business Campus

As of October 2014, a 500 kW(2-250 kW reciprocating engines) combined heat, cooling and power (CHCP) system with a 80 tonnes absorber is under construction for the office wing (~14% of the entire campus) at the South Hill Business Campus. The estimated cost of the project is $1.1 million, which is expected to reduce national grid purchases from 5,500,000 kWh to approximately 3,900,000 kWh annually. The savings during the first year are estimated to be 16,117 CO2e tonnes, equivalent to the emissions of 2,616 cars. [6] The South Hill Business Campus CHCP is the first project awarded incentives under the Tompkins County Industrial Development Agency Energy-Related Investment Policy.

3. Potential District Energy Systems in Tompkins County

3.1 The Commons

Energize Ithaca is proposing a District Energy-Combined Heat and Power (DECHP) microgrid in Ithaca, New York in order to increase energy efficiency, decrease energy costs and reduce greenhouse gas emissions. The size of the proposed project is a 12 MW grid to service 3.5 million square feet of building space in downtown Ithaca. [7] The DECHP system uses a centralized distribution system to provide heat and utilizes the waste heat for district heating. The system will generate electricity that will be available to the building owners and to tenants at a lower rate than from a utility. It is anticipated that the CHP system itself would be located in the Center Ithaca building and branch off to serve neighboring buildings.

3.2 Ithaca College

Currently, all of the Ithaca College buildings are heated by large, commercial-size boilers and cooled by chiller units that run water through a two-pipe piping system, meaning that only heated or chilled water can run through the pipes at any given time. For this reason, Ithaca College is interested in determining the feasibility of a central energy plant. The college’s peak electricity load is approximately 6 MW.

3.3 Dairy Farms

In Tompkins County, there are 63 dairy farms with an average area of 244 acres. [29] We estimate the total energy consumption with the amount of cows each farm owns. For New York State, the majority of dairy farms are medium sized, with around 200 cows. Assuming that a cow requires 1,000 kWh per year, a medium dairy farm will consume around 200,000 kWh energy in total per year [30].

In Tompkins County, in 2008, the agricultural sector emitted nearly 44,000 tonnes CO2e. Cornell Agricultural Extension Service can connect farmers with the appropriate technical assistance, to appropriately deploy systems such as CHP. All of this methane could be used to fuel generators and produce thermal energy, in turn reducing the emissions in the atmosphere.

3.4 Cornell Business and Technology Park

The Cornell Business & Technology Park is a property of Cornell University and is managed by Cornell University Real Estate Department. An area of 300 acres, serving 26 buildings, this is an attractive location for a microgrid. With over 90 companies residing in this park, a DES would offer energy savings and incorporate more renewables. Most importantly, it would offer energy security, and allow the companies operating at this Technology Park to maintain operations during blackouts. Additionally, Tompkins County operates several facilities in or adjacent to the park that provide critical community services and could benefit from the reliability and resilience provided by a microgrid.

An example of such a project in Upstate NY is Burrstone Energy Center, owned by Cogen, in Utica, NY, that delivers power to St. Luke’s Healthcare, St. Luke’s Nursing Home, and Utica College. The 3.6 MW CHP plant was a viable solution for all three of these neighboring institutions, since they all require a reliable energy source. [17] The biggest challenge for Cogen Power Technologies was obtaining approval from the NY Public Service Commission to deliver power to Utica College. However, since a CHP facility near the Cornell Business & Technology Park would generate the power, it would not need to cross the public road to obtain approval, making the implementation of Cornell Technology Park much easier.

3.5 Healthcare Facilities

Hospital buildings operate around-the-clock, 7 days a week and have relatively high energy loads for heating and hot water. According to the U.S. Department of Energy’s Hospital Energy Alliance, hospitals account for 8% of all of the energy consumed by commercial buildings in the U.S. They require guaranteed continuous power generation. For this reason, CHP is a great fit for hospitals. The CHP industry offers long-term energy services to hospitals, under which the hospital and the CHP provider share the energy cost savings over a 10 to 20 year period. For CHP to be economical, electricity and thermal energy needs to be utilized constantly. Hospitals represent some of the best examples in the marketplace today.

Cayuga Medical Center (CMC) has a thermal energy plant. Future expansion of this system could convert it to CHP. The peak electricity load for Cayuga Medical Center is ~2.2 MW. CMC completed the first phase of a CHP feasibility study in fall 2012 and conducted a technical study on assessing whether district heating for structures near the medical center could be incorporated into the system.

One example is the Cortland Memorial Hospital, in Cortland, NY, that has an islanded CHP system consisting of three 525 kW natural gas-fired reciprocating engines and three 190 kW diesel engines for backup. Another example of the success of CHP plants in hospitals is the Clifton Springs Hospital, in Clifton Springs, NY. First commissioned in 1994, the 425 kW plant has been on 24/7 operation ever since. The thermal output is used to heat the hospital and run a central absorption chiller of 300 tonnes. It offers over $190,000 of yearly energy savings, and 380 tonnes of CO_2 reduction per year. The reciprocating engines, used in both Clifton Spring Hospital and Cortland Memorial Hospital to generate CHP, have a low initial investment, are a mature technology and are relatively small in size. Even though they have high maintenance costs, maintenance can be provided by local service organizations. [31]

3.6 Retirement Communities

Kendal at Ithaca, a senior living community in Ithaca, owns 212 cottages of different sizes ranging from a studio to a two bedroom with den, a 36-room Enhanced Assisted Living Residence, and a 35-room Skilled Nursing Facility. Constant heat and electricity are also required for Kendal to provide reliable medical care and nursing services.

In Albany, NY, a CHP system has already been successfully installed in a retirement community: Avila. The 280,000 square feet Avila retirement community installed a 700 kW natural gas engine CHP Plant.

A different way to implement CHP systems for retirement communities is to cooperate with a power provider. The Green Hill retirement community in West Orange, New Jersey, provides an example: under the terms of the agreement, the power provider operates and owns the CHP system. The community, Green Hill, only needs to pay for the energy used by the facility at a guaranteed discounted rate. The contract lasts 15 years: the power provider receives a total revenue around $1,800,000 over the duration of the contract. The CHP system would offset 530 tonnes of carbon annually.

3.7 Hotels

Hotels and casinos have a number of characteristics that make them good targets for installing CHP systems. The facilities operate around the clock year-round; CHP is typically fitted to match the thermal demand of the hotel and usually provides 50% to 70% of a hotel's electricity needs. This approach maximizes both the efficiency and the return on investment for CHP. Hotels in the 100- to- 300 room size range can use small 60 to 250 kW CHP systems with reciprocating engines. [9] Larger hotels with central cooling systems can use larger CHP systems, 300 kW and greater.

The Doral Arrowwood Hotel in Rye Brook, NY receives its energy (electricity, heat, and hot water) from a 375 kW CHP system located at the resort, owned and operated by a company offering so-called on-site utility energy solution. On-site utility customers (e.g., The Doral Arrowwood Hotel) only pay for the energy produced by the system and receive a guaranteed discount rate on the price of the energy. All system capital, installation and operating expenses are paid by the company. This on-site utility energy solution allows the hotel to only pay for the energy they use and avoid all capital, installation and operating costs, in addition to maintenance and repair of the energy system.

Hotels in Tompkins County are usually small to medium-sized. Partnering with energy services companies for similar on-site utility solution can potentially avoid the additional costs, discussed above.

4. Opportunities and Challenges

4.1 Opportunities

DES are usually designed to improve energy efficiency and reduce energy consumption. Two major synergistic opportunities are energy system resilience and integration of renewable energy.

4.1.1 Resiliency

DES can potentially play a critical role in strengthening the energy systems resiliency in the County.

When Superstorm Sandy hit New York City in 2012, nearly $20 billion was lost in interrupted business activity. The microgrid of a residential building in Greenwich Village was able to maintain its power, water, and heat during the damaging storm and its aftermath. It was one of the few buildings that had lights on in the landscape of darkness after Con Edison cut power to almost one-third of Manhattan. The building's CHP system ran 24/7 for five days after the storm, maintaining operation of the central boilers, domestic water pumps, and elevator until power was restored [21].

Superstorm Sandy also revealed that the U.S. power delivery system is not designed to quickly recover from damaged power components. According to the PlaNYC "A Stronger, More Resilient New York" report, a single day without electricity can mean more than $1 billion in lost economic output for New York City [28]. Weather-related incidents remain the prime reason for power outages. The average outage duration in the U.S. is 120 minutes: 92 minutes per year in the Midwest and G14 minutes in the Northeast [11].

Because of their resiliency, microgrids and CHP systems are an excellent solution to optimize available generation and make power available to a larger area during sudden power outages. A microgrid can isolate itself via a utility branch circuit and coordinate generators in the area, instead of having each building operating independently of the grid and using backup generators. It creates a safe haven in the sense that it can sense loads and faulty conditions in order to reroute power to as many critical areas as possible given any situation.

Central Hudson Gas & Electric, a utility company, has proposed to build microgrids for resiliency, both in areas with critical facilities and in remote regions of its service territory [19]. The microgrids would be built and operated by the utility, and customers that are serviced by the microgrids would pay a fee on the utility bill.

A recent development is that New York governor Andrew Cuomo has put $40 million in a competition bolstering the state's post-Hurricane Sandy storm resilience with community microgrids [18]. This competition, named "NY Prize", is aimed at jumpstarting at least ten "independent, community-based electric distribution systems" across New York State. There are two Stage I winners in Tompkins County:

- **Village of Lansing** The project, submitted by Tompkins County, would ensure that the Ithaca-Tompkins Regional Airport and other local vital services would be able to continue operation in the event of a major power outage or other emergency. The proposed microgrid would include up to 3 MW of multiple biomass- or biogas-based combined heat and power units, at least one MW of solar arrays, and 450 kW of multiple energy storage systems. Several electric generators, as well as existing solar systems on three county buildings, would be integrated into the microgrid. The proposed microgrid would power Tompkins County Emergency Response (E-911) Center; Tompkins County Public Safety Building, including the Sheriff's office and County Jail; Tompkins County Health Department; and the Ithaca-Tompkins Regional Airport. Other facilities under consideration include a health care campus, a business and technology park, and the main Ithaca branch of the U. S. Post Office.
- **City of Ithaca** The city and nearby communities, which suffered storm damage during Tropical Storm Lee, have already committed to adding a biogas-to-power system at the local wastewater treatment center. The proposed microgrid would combine power from this system with existing back-up diesel power and proposed solar and combined heat and power systems. Users would include local schools, public works facilities, affordable housing, Ithaca College, the wastewater treatment center, possibly Cornell University, and other ratepayers.

4.1.2 Integration of Renewable Energy

"High-penetration renewable-based microgrids" represent the future opportunity as Tompkins County moves to substantially reduce greenhouse gas emissions. Microgrids of this kind incorporate renewable generation, energy efficiency, demand response, and energy storage that provide the benefits to owners, ratepayers, and utilities.

The California Energy Commission has started experimenting with "high-penetration renewable-based microgrids," defined as projects that can incorporate "high amounts (up to 100%) of renewable energy to meet the facility/community load while avoiding adverse grid impacts, through the use of a microgrid controller/energy management system." [22] While microgrids of this kind are much rarer, they represent a large part of the coming market opportunity in microgrids.

4.1.3 Cooperation with on-site utility providing companies

A new way to carry out CHP implementation is to cooperate with an energy provider. As is discussed in the retirement community and hotel sections, the energy provider is responsible for the system design, construction, operation and maintenance. The customer only pays for the amount of energy that it uses. This form of cooperation provides multiple benefits to private facility owners and small communities:

- All capital investments for system installation, operation and maintenance are borne by others;
- The system is installed and operated by experienced professionals, which brings more reliability and is also more time-efficient;

- The community does not need to hire their own professionals for implementation;
- A discount rate for electricity and thermal demand is guaranteed;
- The overall energy reliability is improved;
- The total GHG emissions are reduced.

4.1.4 Job Creation

Microgrids are built and operated on site. Therefore, local construction, maintenance, and operating staff will need to be employed. This would help keep wages and income within the local community by reducing the money spent on energy imported from outside the community.

4.1.5 NYSERDA CHP Incentives

It is important to note that NYSERDA offers incentives for CHP development under their "The Combined Heat and Power Performance Program." This provides further benefits to Tompkins County residents who wish to install CHP energy systems.

Additional Incentives are available for CHP Systems with an aggregate nameplate greater than 1.3 MW that provide summer on-peak demand reduction. These incentives are performance-based, determined annually over a two-year measurement and verification process period. Performance correspond to the summer-peak demand reduction (kW), energy generation (kWh), and fuel conversion efficiency (FCE) achieved by the CHP System [27].

4.1.6 Energy Smart Community in Ithaca

Iberdrola USA, the parent company of New York Electric and Gas (NYSEG), has selected the Ithaca region as the host location for the Energy Smart Community primarily due to its ongoing interest and proactive approach to energy and sustainability initiatives. Iberdrola USA quoted comprehensive energy and sustainability plans established by Tompkins County, the City of Ithaca, the Town of Ithaca and Cornell University, aligned with Reforming Energy Vision (REV) principles, as the key factor for this selection. The Energy Smart Community will enable Ithaca and Tompkins County to make significant strides toward their energy and sustainability goals. Leaders from these institutions and organizations have engaged with the Company and act as partners in the Energy Smart Community. It is hoped that development of the Energy Smart Community will greatly facilitate the implementations of microgrids and other district energy systems.

4.2 Challenges

4.2.1 Physical Barriers

Relatively constant heating, cooling and electricity demand is a main limiting factor for CHP implementation. For most CHP systems, the electricity/heat ratio is adjusted twice a year (before winter and summer). If the energy demand is not stable, the CHP system might be working either overloaded or underloaded. Both situation will sacrifice the system efficiency to a great extent.

For single buildings to install CHP systems, the energy demand needs to be both stable and large enough. Generally speaking, buildings with an annual energy bill over $500,000 dollars can consider installing a CHP system.

For district systems with CHP, there are more limiting factors. All the buildings in the district need to be connected by an independent electricity grid (microgrid) and steam pipes. The distance between buildings should not be too large, because a great percentage of heat could be lost in the pipelines. A sparse district, therefore, cannot expect a high energy efficiency from CHP. In addition, the cost of installing the pipes makes proximity advantageous.
Generally, four pipes will be needed for a CHP system: two for heating cycle and two for cooling cycle. The cost of local infrastructure has to be taken into consideration, as the construction could be both costly and time-consuming.

4.2.2 Economical and Regulatory Barriers

Economically, factors such as relatively low electric and natural gas prices and relatively high capital investment pose challenges for district systems to achieve cost savings even with improved efficiency and reduced energy consumption. The payback period of current CHP projects, usually around 10 years, is considered to be too long for many institutions.

Regulatory wise, legal boundaries and existing regulations would define many CHP/microgrid projects as public utilities subject to the full burden of Public Service Commission statutes, regulations, and rules. Due to the complexity of this regulatory environment, simply trying to negotiate the regulatory requirements is beyond the capability of most local governments and project developers.

Acknowledgement

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