Roadmap to Distributed Generation: Innovative Tools for CHP Adoption

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ABSTRACT

Combined heat and power is becoming an important strategy to help buildings reduce energy costs and increase resiliency while reducing greenhouse gas emissions system-wide. NYSERDA's CHP Acceleration Program assists New York customers with installing CHP by offering a catalog of vetted systems in the small to medium size range. The program's outreach contractor has been tasked with acquiring participants and assisting multifamily buildings, hospitals, nursing homes, and hotels with realizing CHP's benefits and navigating the complex installation process. Unlike other programs, which often include a variety of technologies, the CHP Acceleration Program provides an incentive for a single technology, which is only viable when significant coincident electric and heat loads are present.

To achieve widespread CHP adoption, the contractor has developed a comprehensive data-driven market assessment tool, based on building loads and geography, to identify NYC buildings that would make ideal candidates for CHP. The tool provides information on key decision-makers at those buildings to facilitate program outreach and includes a preliminary screening analysis that simulates the energy and economic impacts of CHP installations on building loads and operating costs. The tool allows the team to engage in targeted outreach and to quickly screen buildings for CHP potential taking into account n+1 configurations, energy prices, and other factors.

This paper describes the methodology on which the program tools are based and initial successes with their use through NYSERDA's program. It also describes how resiliency was incorporated into the overall outreach strategy to further drive participation in the incentive program.

Introduction

Combined heat and power (CHP), also known as cogeneration, is the use of a single fuel input to create multiple energy outputs. This technology is not inherently novel; in the 1880s the Pearl Street Station in lower Manhattan became the world's first CHP plant (Northeast CHP TAP). While the popularity of this solution for energy efficiency has varied since its first implementation over a hundred years ago, building owners and efficiency program administrators have recently renewed interest in utilizing CHP projects as a strategy for overall GHG emissions reductions, resiliency, and energy savings. There are however, still several technical and social barriers to CHP's widespread adoption that must be addressed if the technology is to be utilized to its full potential.

CHP Technology Overview

CHP presents the opportunity for efficiency through the production of two energy outputs from a single source of fuel. CHP plants consist of a few basic elements: the prime mover, electricity generator, the heat recovery system, and the control system. Most CHP plants consist of either a gas turbine or engine with heat recovery or a steam boiler with a steam turbine.

Benefits

By generating two energy outputs from a single fuel source CHP is often able to achieve efficiency over the traditional generation scenario. In a conventional generation framework a building receives power from the grid and uses another fuel (gas or perhaps oil) for a boiler. Due to transmission line losses and boiler efficiency, the conventional generation scenario is typically only 49% efficient (US DOE and US EPA). The use of a CHP system, however, could achieve the same energy outputs with less input – transmission losses are avoided and the waste heat from the on-site electric generation process can be used to offset fuel consumption of boilers and hot water heaters. Including both the heat recovered and the electricity produced, CHP systems can easily achieve 75% efficiency (US DOE and US EPA). Increased system efficiency is directly related to a reduction in GHG emissions.

In addition, CHP has the potential to result in significant energy cost savings. In certain markets, the low cost of natural gas and high cost of electricity make gas-fueled CHP systems lucrative for system operators. By using natural gas to generate electricity on-site *and* by using the waste heat for domestic hot water, absorption chillers, or other thermal uses, building owners and operators can use CHP to effectively reduce operating expenses at their facilities. This relationship between electricity and natural gas rates is known as the spark spread and, in places like New York City, it is favorable for CHP adoption.

In addition to the potential for energy and cost savings, installers can configure CHP systems to provide resiliency benefits to buildings. In the wake of increasing extreme weather events, on-site generation technologies like CHP can be assets for buildings that are seeking to increase tenant safety and reduce economic losses due to power outages. This need for reliable electricity and heating is especially important in New York, where ambient temperatures can be hazardous to vulnerable populations during both the summer and the winter months. CHP systems can support critical loads allowing occupants to shelter in place or evacuate successfully. Post Superstorm Sandy, this benefit has been a key selling point for buildings seeking to install CHP in the New York City region. CHP systems have the added benefit of being operational and achieving energy cost savings during normal operation, while typical back-up generators sit idle during non-emergency times. In addition, installing CHP on a widespread basis promotes grid reliability and can be an asset to utilities that have grid-constrained areas (ICF International).

Limitations

CHP's many potential financial, environmental, and resiliency benefits can diminish dramatically when the technology is used in the wrong application. One of the most common shortfalls of CHP implementation occurs when a facility lacks a thermal load, as this results in dramatically diminished energy savings and emissions reductions. This is true whether the system is controlled to dump heat or simply turn-down the combustion, as either of these control strategies result in an under-utilization of what is relatively costly CHP system capacity. Therefore, one of the key criteria for a successful application of CHP is that the facility must have year round and coincident needs for *both* electricity *and* heat. For most facilities, designing the CHP system to meet thermal needs (instead of electric needs) allows for the best project economics, as these loads tend to constrain their operation in non-industrial applications where thermal loads are relatively small.

There are also a range of practical and physical constraints to installing CHP systems. In many real estate markets, buildings often do not have the space to accommodate CHP systems. Based on frequent discussions with building owners and operators through this outreach effort, many of them would rather have more usable/rentable/sellable space than have a CHP system, especially in competitive real estate markets like New York City.

Maintenance costs can also be onerous for buildings that implement CHP. CHP engines require regular maintenance to operate successfully (and to provide persistent energy cost savings). These costs can be hefty and are often underestimated in preliminary economic analyses of the project. Perhaps even more importantly, CHP installations that are not maintained properly are often taken off-line before they are truly at the end of useful life (ERS and Itron).

Ultimately, these limitations create uncertainty for customers considering CHP systems, which in turn often results in dead ends for potential CHP projects.

NYSERDA’s CHP Program

The New York State Energy Research and Development Authority’s (NYSERDA) CHP Acceleration Program addresses persistent barriers to CHP adoption and operation. The goal of the program was to simplify the planning and implementation process and relieve some of the barriers to adoption of the technology, in addition to providing financial incentives to reduce first costs. The program features a catalog of eligible pre-packaged CHP systems and vendors vetted by NYSERDA. Each system in the catalog is associated with an established incentive, ranging from 1,200 to 1,500 dollars per kW of installed capacity.

NYSERDA’s pre-packaged approach helps to alleviate uncertainty over CHP plant component compatibility. By vetting prepackaged and pre-engineered systems, NYSERDA provides customers with the assurance that the components will work together. By requiring a single vendor be responsible for successful CHP installation and operation, the program effectively simplifies the communication chain for the customer, should any component fail. Additionally, the program requires that a customer engage in a 5-year maintenance agreement with the vendor who installs the system. By making this a program requirement NYSERDA was able to address the lack-of-maintenance issue and ensure persistence of savings.

To support NYSERDA’s mission to transform the market for CHP, educate potential buyers, and accelerate adoption of CHP on a widespread basis to achieve energy cost savings and grid reliability benefits and promote building resiliency, the program partnered with Con Edison to identify potential CHP targets in grid-constrained networks such as Con Edison’s Brownsville substation. CHP systems installed in this area benefit both the customer via energy cost savings and improved resiliency, as well as the utility via demand reduction during the substation’s peak periods.

Outreach and Technical Assistance

NYSERDA identified a lack of customer understanding of CHP technology as a barrier that needed to be overcome. Interviews with customers from NYSERDA’s CHP demonstration program conducted for the program’s impact evaluation identified that customers were in need of guidance in the project planning and initial start-up phases of the CHP installation (ERS and Itron). In order to assist customers in exploring CHP, NYSERDA hired an outreach and technical assistance contractor to guide customers through the process of learning about CHP, determining if their building is a good fit for the technology, analyzing preliminary feasibility, and connecting with the vendor and pre-approved systems. NYSERDA selected ERS as the outreach and technical assistance contractor.

ERS's main goals are to identify and engage interested customers (in New York State, but primarily in New York City and Westchester), provide technical assistance to assess if CHP could benefit their building, and guide them through the process of exploring CHP options. In order to engage customers, ERS has undertaken a multipronged approach which is supported by previous experience as outreach contractors for other energy efficiency incentive programs:

- Host and present at CHP seminars and installation tours.
- Approach industry allies, stakeholders, and trade groups in viable building sectors: multifamily, hospitals, nursing homes, and hotels.
- Make use of ERS's and NYSERDA's preexisting contacts from past energy efficiency program participation.
- Leverage publicly available data sets to target and identify potentially good candidates for CHP technology.

Lead Generation and Data Mining

One of NYSERDA's CHP program's primary objectives is to identify potential participants beyond the participant blend of previous programs, which typically revolve around large industrial and commercial facilities. Of particular interest is the application of CHP in the multifamily sector. ERS has developed a framework for extracting relevant information from private and public data sets on the building stock in New York to identify specific facilities that could support CHP, as well as to broadly characterize the region's potential for CHP.

In order to accomplish this, ERS utilized a combination of public and private data sets, including aggregated Local Law 84 reports, Dunn & Bradstreet, and CoStar. NYC Open Data, a publicly available data set of benchmarking reports which were mandated by Local Law 84 for facilities greater than 50,000 sq ft, was used as the primary data source to characterize the energy usage at the facilities while Dunn & Bradstreet and CoStar were used to determine qualitative characteristics, such as business type, and relevant contact information. (NYC Open Data)

Fundamentally, the methodology behind this lead generation framework involves the decomposition of total annual energy consumption data provided for approximately 30,000 buildings in the Local Law 84 benchmarking reports. This was accomplished to generate simulated 8,760 hourly electric and hot water loads using DOE Open EI profiles defined based on building type characterization. (Open EI & NYC Open Data) Using each of these building-specific simulated profiles, ERS established an appropriate CHP system size range using the number of hours above a given load level as the sizing criteria. This sizing system is based on the historical observation that the most successful systems fully utilize the electric and the steam or hot water outputs of the CHP system for many hours of the year. (ERS and Itron)

Given that this methodology was based on generalized facility profiles, it was important to test the validity of the analysis against historical CHP installations in the greater New York City region. Fortunately, NYSERDA has maintained an extensive and readily available set of records and an associated database of metering for systems installed through previous programs. ERS used this broad assortment of data to calibrate the lead generation model, ensuring that it was neither conservative nor generous in its assumed capacity for CHP. In addition to the generation of a filtered and prioritized lead list for direct outreach, this methodology allowed the outreach team to tailor the program's overall engagement strategy based on the geographic and characteristic trends observed. For example, ERS created several GIS maps of potential participants in the CHP program in order to determine geographic clusters as shown in Figure 1 below. These clusters have been instrumental in determining which regional events and expos are likely to provide the most effective opportunity to educate potential participants of the program

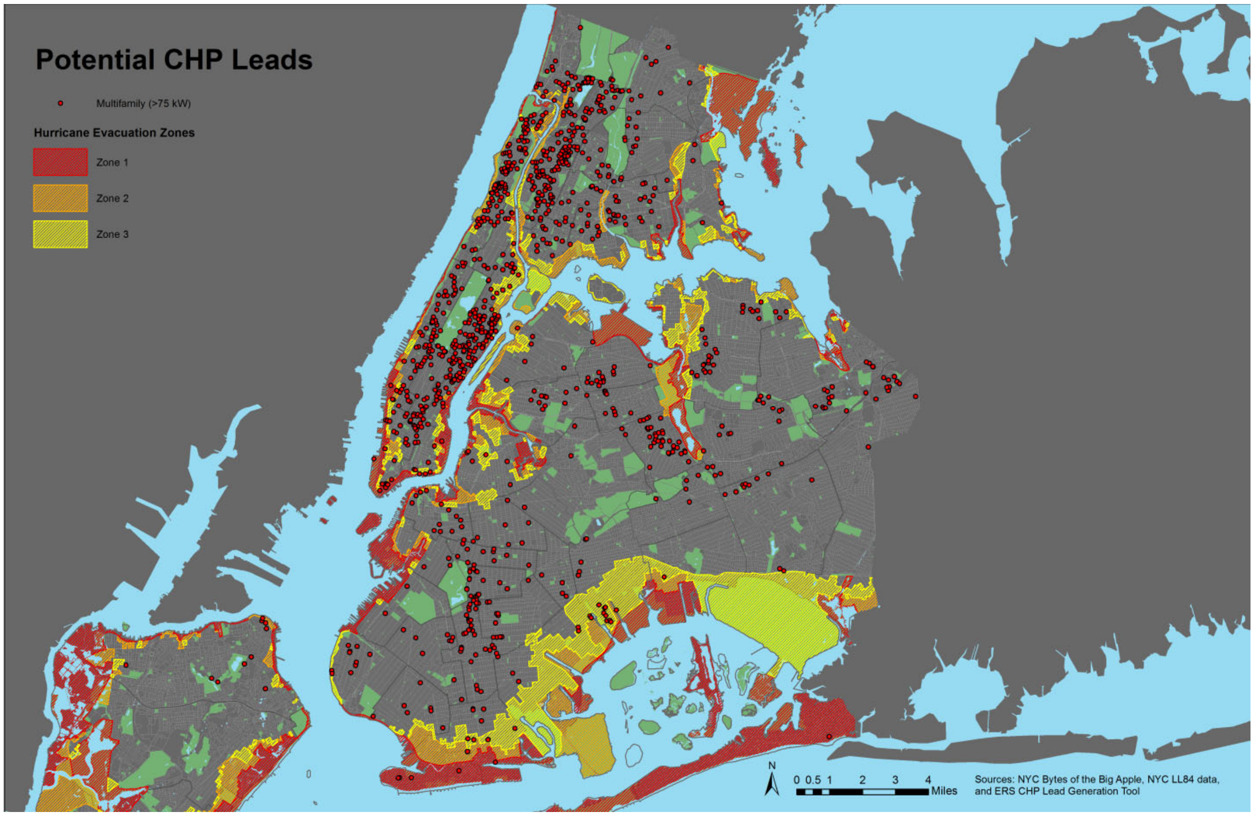

Figure 1. GIS mapping of potential multifamily participants in the CHP Program (NYC Bytes of the Big Apple, NYC LL84 data, and ERS CHP Lead Generation Tool)

Participant Screening and Assistance

In addition to identifying opportunities for CHP implementation throughout New York, ERS also developed a framework to provide technical support at the individual participant scale. As an unbiased representative of NYSERDA, ERS provides technical guidance for potential participants, including a site-level preliminary assessment of potential for CHP, educational engagement on the available technologies, and assistance navigating the bid procurement and selection process. In order to accomplish all of these tasks, ERS developed and utilized innovative load modeling and CHP system simulation software.

Requiring nothing more than monthly utility consumption records and a basic qualitative description of the facility and its end uses, the CHP system simulation is able to characterize the hourly electric and hot water or steam loads that can effectively be offset by the CHP system. This methodology requires a combination of empirical and physics-based simulations to accurately deconstruct monthly consumption records into approximated hourly loads. This methodology is similar to the methodology used in the lead generation task, with the added benefit of greater resolution building consumption data. By observing consumption at a monthly, rather than an annual resolution, the tool is able to isolate and distinguish the space heating and domestic hot water components of the facility's hot water usage, which are applied to distinct hourly load profiles. Once the electricity and thermal loads at the facility have been accurately modeled, the tool simultaneously simulates an assortment of user-defined CHP system sizes and configurations using a physics-based approach. This is achieved using an iterative numerical simulation method to match the modeled hourly loads with the electric and thermal output of the simulated CHP system, resulting in an accurate assessment of CHP system operation, energy and demand savings, and GHG impacts. Table 1 provides a description of the site-specific inputs parameters required for the preliminary screening and simulation.

Table 1. Summary of preliminary screening simulation facility parameters

Input	Description
Summary of utility bills including starting and end dates, kWh consumption, peak kW, and fuel consumption for each billing period.	This information is used to create a correlation between energy consumption and ambient temperatures using historical weather data over the elapsed periods.
Building type (Multifamily, Office, Hospital, etc.)	Each building type is associated with distinct electricity and DHW hourly load profiles provided by DOE Open EI
Baseload, cold-weather, and warm-weather electric and thermal load accessibility factor	The approximated accessibility factor is used to adjust the electric and thermal consumption represented in the utility bills based on the loads that can actually be met by the proposed CHP system. For example, a facility's existing natural gas bills may include consumption for direct-fired air handling units. This consumption could not be displaced by a CHP system, and should be omitted from the analysis.
Electricity, demand, and fuel/steam rates	Utility rates are used to determine the costs and savings associated with the additional gas consumption, electricity generation, and peak demand reduction due to the installation of a CHP system.

Similar to the lead generation effort, ERS effectively leveraged previous evaluation results to further refine and calibrate the preliminary screening model. This was accomplished by comparing the outputs of the simulation tool with actual records of CHP system operation at a variety of facilities, spanning multiple geographic regions and business types.

Perhaps the single greatest benefit of the simulation tool is that it facilitates discussion and engages potential program participants. By varying several input parameters such as system control strategy, prime mover technology, utility rate structure, thermal storage capacity, and maintenance contracts, the outreach staff can easily demonstrate the implications of a number of subtle design and purchasing decisions. This ability provides the participant with a degree of comfort around the technology, which is one of the primary objectives of the outreach contract. One such example of a visual aid used to facilitate engagement with the customer is shown in Figure 2 below, which demonstrates the relationship between the simulated system electric generation capacity and anticipated payback period.

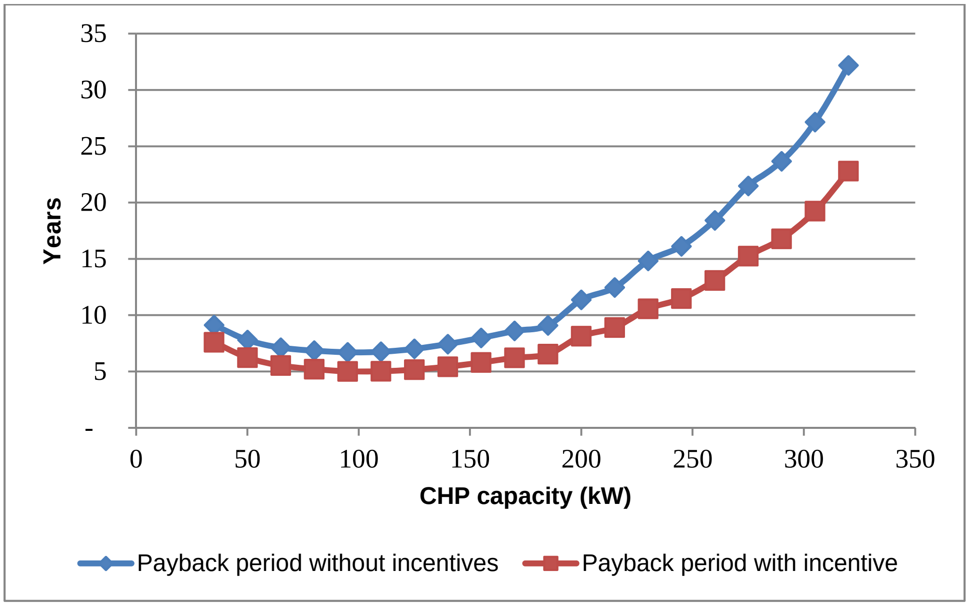

Figure 2. Sample relationship between CHP system capacity and payback period (ERS)

While the above sample figure provides useful approximations for the financial feasibility of various CHP systems, payback period alone is an inadequate metric to engage potential customers and drive participation for the program. ERS has also tailored the simulation outputs to illustrate the effect of CHP systems on grid and customer resiliency, including anticipated reductions in peak demand, system operating hours, efficiency, etc.

In addition to the targeted engagement of potential participants, ERS's technical outreach efforts provide necessary support for non-technical customers as they navigate the complex decisions associated with installing such a system. This is especially important when considering resiliency, as a simple metric such as minimizing payback period can often miss the subtle benefits of alternative designs. Of particular interest is the number of CHP units at an installation. Installing more units is generally more expensive, however results in significantly greater reliability which is an important criteria for resiliency in extreme conditions. For example, if a site installs two 50kW units, the likelihood of both failing simultaneously is very low. On the contrary, if a single 100kW unit were installed any equipment failure would result in a complete loss of generation capacity. This reliability is especially important if the CHP system is to be installed in critical infrastructure, such as hospitals or other medical facilities.

Preliminary Results and Conclusions

As the program is presently ongoing, there is some difficulty in assessing the impact of these efforts on program participation and performance. While the program's impacts have not yet been evaluated, there are several indicators that the engagement methodology is effective at increasing program performance and ensuring effective installations.

Table 2 below shows a summary of the applications received by program year, clearly demonstrating an increase in activity after ERS began working with NYSERDA on the CHP acceleration program in 2015.

Table 2. Summary of program applications

Date range	Quantity of received applications	Total generator capacity (MW)
1/1/2013 – 12/31/2013	15	2.61
1/1/2014 – 12/31/2014	29	6.09
1/1/2015 – 12/31/2015	19	3.24
1/1/2016 – 5/1/2015	65	18.04[1]

Given the long lead times for project development, it is difficult to directly attribute increased applications and installations to ERS's outreach efforts. ERS's internal project tracking database shows that the pipeline of potential projects is growing steadily. Figure 3 shows the growth in actively engaged CHP opportunities since September 2015.

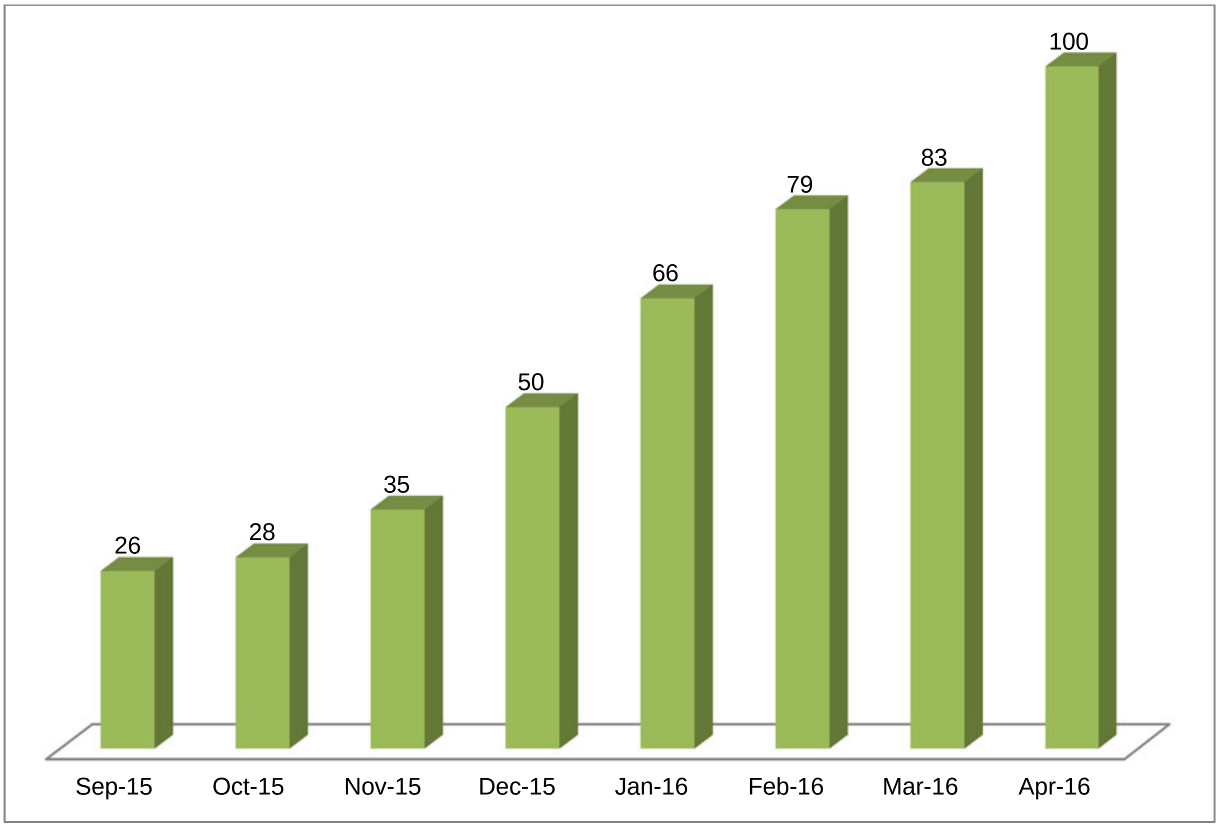

Figure 3. Cumulative active CHP opportunities by month (ERS)

[1] This increase in participation can be partially attributed to NYSERDA's collaboration with Con Edison in 2016, resulting in an increased incentive within the territory served by the Brownsville substation in Brooklyn and Queens.

In addition, the potential capacity of the pipeline of possible CHP projects that ERS has offered technical assistance on has also grown. Figure 4 shows a steady increase in the pipeline of CHP capacity.

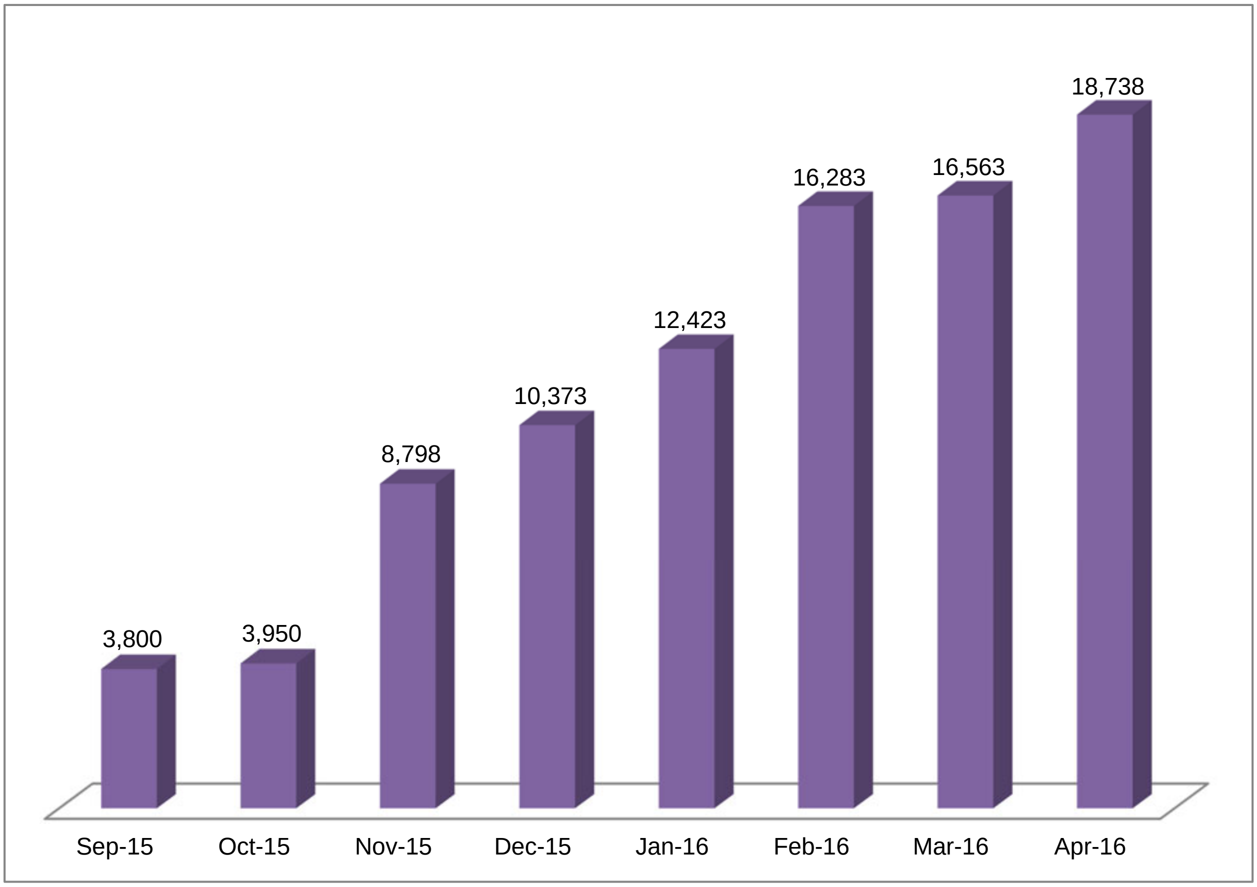

Figure 4. Cumulative CHP kW pipeline by month (ERS)

Also, the opportunities that ERS provides technical assistance on have moved steadily through the phases of program development. While many CHP opportunities are in the preliminary prospecting stages, many have moved on to detailed feasibility studies or even the bid solicitation and selection process. Figure 5 shows the breakdown of potential CHP opportunities by stage since September 2015.

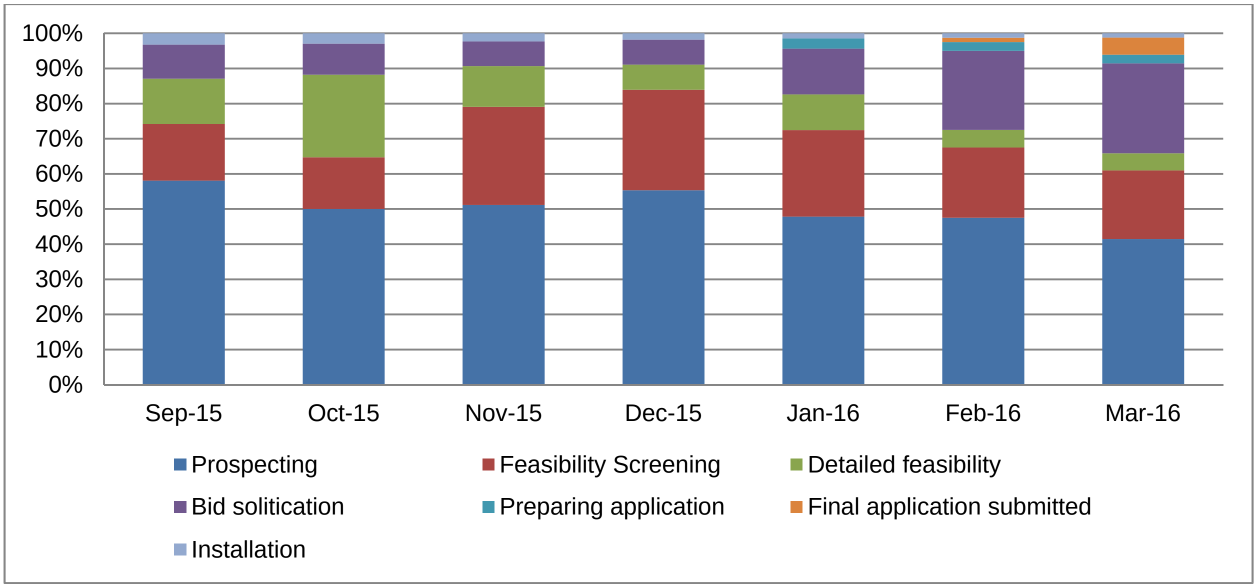

Figure 5. Cumulative CHP opportunities by stage (ERS)

ERS's internal tracking data shows an increase in interested customers with viable opportunities. In addition, the potential kW of CHP capacity being actively explored has increased. Finally, ERS's outreach efforts have increased the number of potential CHP projects that have moved to the vendor bid solicitation and selection process.

While the increase in program participation is indicative of successful program outreach, this is only one of the goals of the outreach effort. The other primary goal of the program, that installed systems are reliable and appropriate for the facility, cannot be quantitatively assessed until the program undergoes a comprehensive impact evaluation at which point metrics such as annual energy savings, system life, annual operating hour, etc. can be assessed and compared to previous program cycles. ERS has, however, acquired consistent qualitative feedback from participants that the technical engagement has been instrumental in effective bid procurement and system selection.

References

ERS and Itron. 2015. *Distributed Generation-Combined Heat and Power Impact Evaluation Report (2001 – June 2011).* Prepared for: NYSERDA. https://www.nyserda.ny.gov/-/media/Files/Publications/PPSER/Program-Evaluation/2015ContractorReports/2015-Distributed-Genertation-CHP-Impact-Evaluation-Final.pdf.

ICF International. 2013. *Combined Head and Power: Enabling Resilient Energy Infrastructure for Critical Facilities.* Prepared for: Oak Ridge National Laboratory. eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf

Northeast CHP Technical Assistance Partnerships (TAP). *History of CHP Development in the U.S.* northeastchptap.org/chp-history

NYC Open Data. *Energy and Water Data Disclosure for Local Law 84 (LL84)*. data.cityofnewyork.us/Environment/Energy-and-Water-Data-Disclosure-for-Local-Law-84-/rgfe-8y2z

Office of Energy Efficiency & Renewable Energy. 2013. *Commercial and Residential Hourly Load Profiles for all TMY3 Locations in the United States.* Open EI en.openei.org/datasets/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states

Saba, A., B. Howard, M. Gerrard, V. Modi. 2013. *The Opportunities for and Hurdles to Combined Heat and Power in New York City.* Columbia University. academiccommons.columbia.edu/download/fedora_content/download/ac:178487/CONTENT/CHP.Saba_.Paper_.pdf.

US Department of Energy (DOE) and US Environmental Protection Agency (EPA). 2012. *Combined Heat and Power: A Clean Energy Solution.* http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf