

## **DRAFT for Review Do Not Publish**

### **US DOE Packaged Combined Heat and Power eCatalog**

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#### **ABSTRACT**

As part of its Combined Heat and Power (CHP) program, the U.S. Department of Energy is developing a packaged Combined Heat and Power (CHP) web-based catalog (CHP eCatalog) of US DOE-recognized packaged CHP systems. These packaged CHP systems are targeted at unit sizes of 10 MW or below. The eCatalog offers significant opportunity for new CHP installations in markets with significant technical potential such as small and medium sized commercial, institutional and industrial facilities. The eCatalog is designed to decrease installation barriers, lower risk, and reduce project costs and installation times by:

- a. Improving the market penetration of CHP in high technical potential markets that have not yet been cost-effectively developed due to lack of understanding of technology;
- b. Reducing perceived risk of installing and operating on-site generation by offering comparable standardization of CHP systems and in the field service agreements;
- c. Creating replicable CHP systems to reduce design errors and limit uncertainty with the associated performance, time, and cost impacts;
- d. Establishing standard and pre-qualified CHP technology systems and vendors to install them, leading to shorter decision times and lower hurdle rates, including at the property inspection phases such as occupancy inspections;
- e. Reducing customer acquisition costs for CHP vendors, which can be passed on to the consumer; and
- f. Expanding CHP product offerings, improving quality, and controlling costs by promoting increased competition.

This paper will describe the development and implementation of this project.

#### **Introduction**

CHP is an efficient and clean approach to generating electric power and useful thermal energy from a single fuel source. The average efficiency of delivered electricity in the United States has remained at approximately 34 percent (Higher Heating Value) since the 1960s – the energy lost in wasted heat from power generation in the U.S. is greater than the total energy use of Japan. CHP captures this waste energy and uses it to provide heating and cooling to factories and businesses, saving them money and improving the environment. CHP is a commercially available clean energy solution that directly addresses a number of national priorities including

improving the competitiveness of U.S. manufacturing, increasing energy efficiency, reducing emissions, enhancing American energy infrastructure, improving energy security and growing the American economy.

While CHP has been in use in the United States for more than 120 years, it remains an underutilized resource today. CHP currently represents approximately 8 percent of U.S. generating capacity compared to over 30 percent in countries such as Denmark, Finland and the Netherlands. Its use in the U.S. has been limited, particularly in recent years, by a host of market and non-market barriers. Nevertheless, the outlook for increased use of CHP is bright -- policymakers at the federal and state level are beginning to recognize the potential benefits of CHP and the role it could play in providing reliable, cost-effective energy services to U.S. industry and businesses. A number of states have developed innovative approaches to increase the deployment of CHP to the benefit of users, utilities and ratepayers. CHP is being looked at as a productive investment by some companies facing significant costs to upgrade outdated gas, coal and oil-fired boilers. In addition, CHP can provide a cost-effective source of highly-efficient new generating capacity. Finally, the economics of CHP are improving as a result of the changing outlook in the long-term supply and price of North American natural gas – a preferred fuel for many CHP applications. Additional economic benefit is anticipated with the introduction of packaged CHP technology systems as solutions for commercial, institutional and industrial facilities on the national level. Both performance risk and up-front installation costs are reduced with economies of scale in mass production and ancillary costs (permitting, financing, etc.) are streamlined with the market becoming more accustomed to CHP technologies and performance.

Currently, over 81 gigawatts (GW) of CHP capacity operate at more than 4,400 sites across the United States. CHP has been long used in industrial applications, providing power and steam to energy intensive industries such as chemicals, paper, refining, food processing, and metals manufacturing, and is growing in use in commercial and institutional applications, providing power, heating and cooling to hospitals, schools, university campuses, hotels, nursing homes, office buildings and apartment complexes. While investment in CHP declined in the mid-2000's due to a number of market and regulatory issues, CHP's potential role as an energy source for the future is much greater than recent market trends would indicate. As shown in Figure 1, estimates of the technical potential<sup>1</sup> for additional CHP at industrial facilities are just about 64 GW of electric capacity, with the corresponding technical potential for CHP at commercial and institutional facilities just about 99 GW, for a total of about 141 GW. The vast majority of this potential is in systems less than 10 MW in size (54% of industrial potential and 84% of commercial/institutional potential are in systems less than 10 MW), the size range specifically targeted by the CHP eCatalog.

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<sup>1</sup> The technical market potential is an estimation of market size constrained only by technological limits—the ability of CHP technologies to fit existing customer energy needs. The technical potential includes sites that have the energy consumption characteristics that could apply CHP. The technical market potential does not consider screening for other factors such as ability to retrofit, owner interest in applying CHP, capital availability, fuel availability, and variation of energy consumption within customer application/size classes. All of these factors affect the feasibility, cost and ultimate acceptance of CHP at a site and are critical in the actual economic implementation of CHP

Application (no export of electricity)	50-500 kW)	0.5 - 1 MW	1 - 5 MW	5 - 10 MW	5 - 20 MW	> 20 MW	Total
Industrial	6,281	4,351	15,567	9,064	7,971	21,157	65,381
Commercial	20,068	18,100	20,284	5,504	3,948	8,026	75,930
Total	26,349	22,451	35,470	14,568	11,919	30,183	140,941

*Table 1. U.S. Technical Potential for Additional Combined Heat and Power. (US DOE 2016)*

One of the primary barriers to CHP development has been the high upfront capital cost of the system, especially when considering that they are installed at facilities whose core business is something other than power generation. Prior to 2000, CHP systems have generally been custom-engineered for each installation, a process that involves developers and/or engineers designing CHP systems, ordering all the components separately and then assembling it onsite. This custom approach, most often, placed the end-user with an operating system with multiple sources of components and multiple warranties and required interfacing with multiple service organizations.

The Electric Power Research Institute (EPRI) examined fifteen companies to determine their packaged CHP system performance capabilities, dispatch strategies, applications, economics, sales, and distribution and service networks utilized. (Thimsen 2004) This research concluded the following:

1. Pre-engineered, packaged CHP systems simplify installation and offer cost savings associated with a standardized design.
2. The packaged CHP “industry” is relatively young. Five of the companies began sales of their packaged CHP products after 2000.
3. The deployment of packaged CHP units is likely limited by the business case or supply/distribution capacity rather than market saturation.

EPRI’s 2004 packaged CHP findings were further confirmed by New York State Research and Development Authority’s (NYSERDA) CHP program efforts since 2000 which are highlighted in this paper. This paper will outline US DOE’s interest in CHP, the need to reduce risk to increase CHP uptake, NYSERDA’s packaged system program success, US DOE’s eCatalog applied research effort, the need for a public/private partnership technology delivery mechanism and, finally, revisiting the EPRI conclusions to measure the potential for success.

## **Federal Interest in CHP**

Manufacturing and industry interests in the US have historically supported the advancement of CHP as it helps maintain their economic competitiveness by lowering their day-to-day cost of operation and reducing their exposure to process disruptions caused by grid outages. The thermal energy recovered from generating power on-site with a CHP system can be used to provide process heating, space heating and cooling, and refrigeration depending on the needs of the particular installation. The US DOE supports a robust CHP program as a means to revitalize and grow Americas industrial base by improving energy infrastructure.

**Efficiency & Reliability.** Flexible CHP technologies offer strategies to meet user energy needs cost-effectively, efficiently and safely. For example, CHP systems simultaneously produce

double or triple energy from a single source at overall efficiencies of up to 80% energy efficiency compared to about 50% for conventional separate heat and power. CHP reduces fuel usage and greenhouse gas emissions (by about one-third) and increases grid safety and stability in support of solar and wind options. CHP systems provide localized, autonomous, often modular systems that eliminate transmission line power loss and enable the collection and storage of energy from many sources, providing greater security against outages, stronger grid resilience, and lower environmental impacts.

**Increased Profitability.** Reducing fuel usage, lowering the cost of clean operations, and making project approvals easier to obtain all contribute to the bottom line. CHP system operation has historically proven to provide reliable operation through electric grid outages, providing vital services and production continuation.

**Energy Independence.** By efficiently using domestically produced natural gas and emerging domestic renewable fuels such as landfill and digester gas, CHP systems help reduce America's dependence on foreign fuel.

**Cleaner Air.** CHP's high efficiency and reliance on clean fuels lowers emissions of both criteria pollutants and greenhouse gases.

## **Economic Risk**

CHP's relatively high capital cost remains a significant issue hindering market development. When a site must pay for the CHP system and infrastructure and amortize the cost of CHP equipment and supporting infrastructure under strict private sector accounting rules, this often creates an unacceptable risk scenario that stops projects. Some states offset CHP capital costs with incentives<sup>2</sup> so that society can secure the efficiency, resiliency and emissions benefits<sup>3</sup> that CHP offers. However, incentives are not a long-term solution. This is why states like, New York, are investing in means to reduce CHP risk<sup>4</sup> and also reinventing their energy delivery economics to more accurately reflect real-time costs<sup>5</sup>.

A second important issue that legacy approaches to the market meant that packaged CHP systems were specifically designed for each project, often leading to unnecessary design differences in delivering the same amount of electric and thermal energy to different sites. This can lead to higher soft costs, higher packaging costs, higher installation costs, higher commissioning costs, higher delivery time and perhaps increased downtime.

NYSERDA's packaged system catalog program set out to tackle both the CHP system capital cost and business case problems identified by EPRI in 2004.

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<sup>2</sup> <http://database.aceee.org/state/deployment-incentives>

<sup>3</sup> <https://energy.gov/eere/amo/benefits-combined-heat-and-power>

<sup>4</sup> See CHP System Risk Reduction below

<sup>5</sup> <https://rev.ny.gov/>

## CHP System Risk Reduction

NYSERDA launched its CHP deployment program in 2000. Since that time NYSERDA has evolved their program from technology demonstration to acquisition of CHP for grid load relief and, finally, today focusing on market transformation via standardization and market maturity. NYSERDA continues to fully support CHP for all its benefits, but is now formulating its efforts under the following two axioms: (Levy 2016)

- *Public policy objectives encourage the deployment of clean & efficient CHP*
- *The perpetual use of publicly-funded subsidies is a less-desirable mechanism than transforming the market to where it can be self-sustaining*

So, what does this look like. First, NYSERDA decided to re-align the way CHP projects are transacted in the marketplace to achieve genuine cost reductions, and increase customer confidence. Using its considerable presence in the State, NYSERDA created a customer outreach program focused on facilitating customer identification and acquisition to reduce CHP vendor marketing costs. This market engagement work, NYSERDA's involvement and support during the buying process, is often overlooked, but it is immensely important in reducing acquisition costs for the CHP packaged system vendors, as well as reducing risk perception by the end-user community.

Second, NYSERDA created a mechanism to facilitate replicable project designs to reduce design errors, associated performance losses, and re-work expenses; and reduce uncertainty among Authorities Having Jurisdiction; thereby reduce installation time and costs. NYSERDA has enacted a program where incentives are streamlined for preapproved packaged systems offered by vetted vendors. The packaged CHP systems are published in a Packaged CHP Catalog that includes schematics and comparable performance data for each preapproved package. NYSERDA's Catalog currently has 18 packaged systems vendors vetted by NYSERDA and offering single point responsibility for 203 NYSERDA vetted packaged CHP systems offered in the catalog<sup>6</sup>. Figure 1 provides an example of NYSERDA's catalog two-page system data sheet.

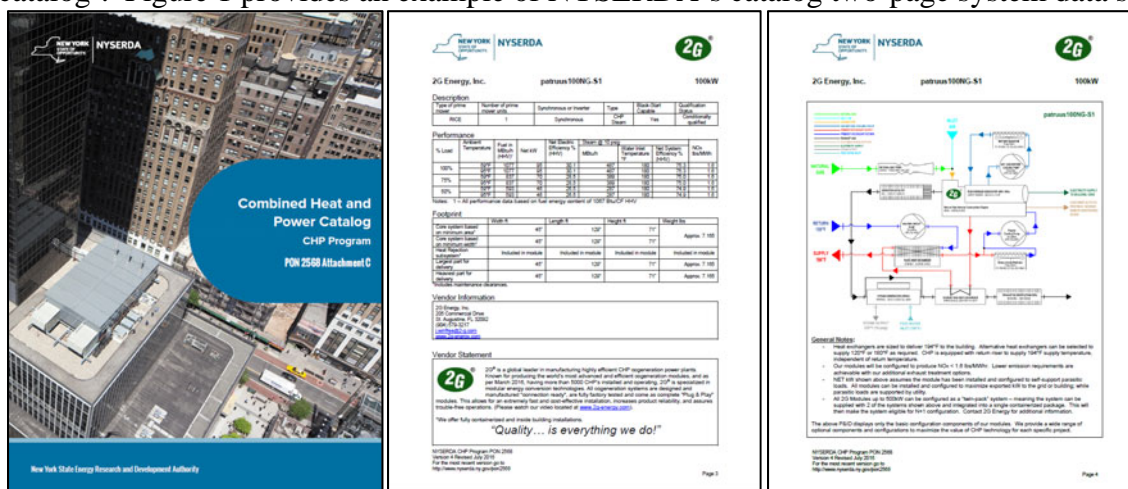


Figure 1. Example of NYSERDA Catalog Packaged CHP System Cut-Sheets

<sup>6</sup> <https://www.nyserdera.ny.gov/-/media/Files/FO/.../PON%202568/2568attc.pdf>

NYSERDA summarized its approach in Figure 2 by showing a shift from the current market condition where the customer demands lower paybacks to compensate for perceived risks on their part and the market delivers higher cost systems to compensate for perceived risks by the vendors in sales, marketing and installation to a future state where packaged CHP system cost is reduced (reducing CHP system payback period) and end-user risk is reduced (increasing acceptable CHP system payback period).

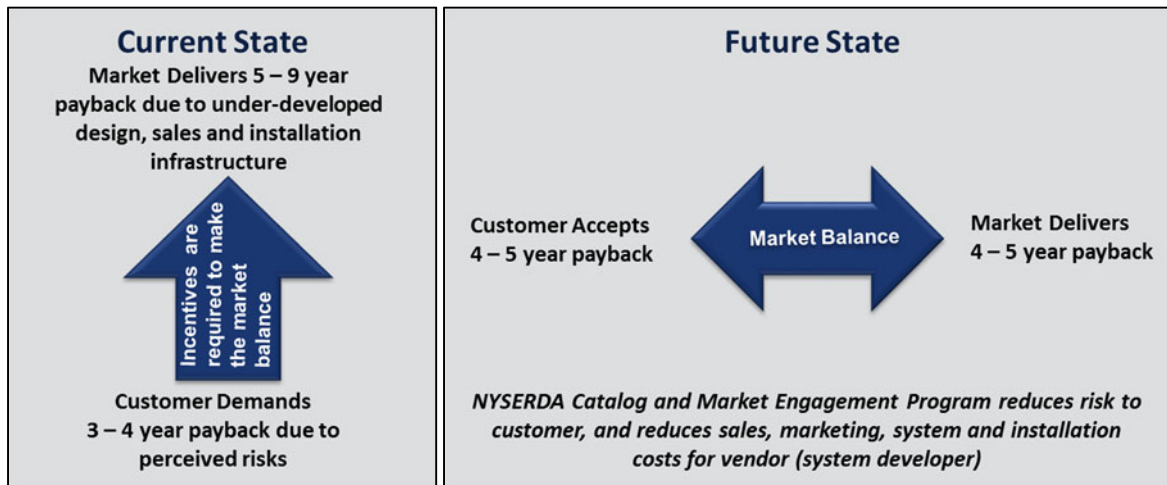


Figure 2. Risk Reduction for Current State to Future State. Source: NYSERDA

Results of the NYSERDA packaged CHP system program are significant. Projects submitted through the Catalog program are significantly more robust than those developed through prior programs.

- *Gets good projects:* In the initial four years, 175 projects have approached NYSERDA and 171 continue to move forward. 112 projects have submitted full-and-complete applications of which a third have equipment delivered to the site or further progress. For the period beginning 2013 through the end of 2015, in aggregate 36 applications achieved full-and-complete status, of which in aggregate 31 have equipment delivered to the site or further progress.
- *Robust market traction:* 11 of the 16 original vendors had projects at end-of-2016. In early 2017 another two vendors were added to the program.
- *Accelerates timelines:* Application-to-Operation time down from 25 to 15 months (40% time compression)
- *Reduces cost:* Anecdotally have observed reduction in soft costs, such as customer acquisition with overall project costs down 25%

## Federal Focus

The US DOE had followed NYSERDA's packaged CHP system program from its inception and took note of its successful implementation. This led to an assessment of the efficacy of applying this approach nationally, leading to the key question - can NYSERDA's packaged CHP program be scaled to the national level? Can the US DOE create a national packaged CHP system program that addresses NYSERDA's two market transforming axioms raises several issues that must be researched at the national level.

The current NYSERDA system packagers have expressed strong interest in the eCatalog as they have collectively seen improved system designs and performance by the collective industry. This was a key finding, even though the NYSERDA catalog increased competition among the packaged system providers, the level of operation performance improvements enhanced CHP's reputation as an energy solution. This "rising tide raising all boats" effect was clearly seen as a positive outcome by all NYSERDA vendor partners. Other CHP packagers have also expressed interest in the eCatalog as a means to showcase their systems recognized by US DOE. The US DOE CHP for Resiliency Accelerator Partners<sup>7</sup> and other state entities have also expressed interest in the efficacy of a national eCatalog for packaged CHP systems as well as stronger market engagement best practice exchanges.

While CHP, as a concept, is as old as America's first power plant<sup>8</sup>, successfully designing advanced packaged CHP systems, applying them across different applications, throughout 50 state energy regulatory schemes, a myriad of CHP system delivery entities, hundreds of utilities, state and local energy agencies and measuring results is a daunting endeavor. Examining this effort through the lens of the US DOE's Technology Readiness, this is an applied research activity focused on trying to realize capital cost and project timeline reduction for CHP systems across the country using a web-based packaged CHP systems eCatalog as a key to improve system delivery to the market place. The eCatalog will further enable utilities, state and local jurisdictions to develop a robust means of providing US DOE recognized packaged systems to support and grow their local industrial base. The eCatalog will be tested through a robust public/private partnership market engagement program.

## **CHP eCatalog**

The CHP eCatalog will be an open source, web-based system that will host US DOE recognized packaged CHP systems (Recognized System<sup>7</sup>) that will include select features designed to reduce economic and performance risk for the CHP user. The CHP eCatalog will be a public/private partnership focusing on packaged CHP systems less than 10 MW in individual prime-mover capacity. The eCatalog will be hosted, in addition to the US DOE, by state and local jurisdictions, as well as utilities.

The CHP eCatalog will be centered on private sector Vendor partners. A Vendor partner must be fully responsible for all aspects of marketing / installing / maintaining / servicing the package and may be an original equipment manufacturer, a system integrator, or any other entity that offers to install Recognized Systems<sup>9</sup> in at least one Qualified Service Territory<sup>10</sup>. A Vendor partner must provide a single point of responsibility for site integration, installation, all maintenance and service activities (planned and unplanned) related to Recognized System for a

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<sup>7</sup> <https://betterbuildingsinitiative.energy.gov/accelerators/combined-heat-and-power-resiliency>

<sup>8</sup> [https://en.wikipedia.org/wiki/Pearl\\_Street\\_Station](https://en.wikipedia.org/wiki/Pearl_Street_Station)

<sup>9</sup> Recognized Packaged CHP Systems that are pre-engineered, pre-tested products that meet the specifications and requirements in this Guide and have demonstrated performance as an integrated system based on one of the three ASERTTI CHP Testing Protocols or equivalent.

<sup>10</sup> A Qualified Service Territory is a city, state, geographic region or utility service territory where a Vendor partner offers a single point of responsibility for Packaged CHP System installation, commissioning and a Bumper-to-Bumper Assurance Plan including all system components

period of not less than five (5) years from the date of electric grid interconnection recognition. The Vendor partner may use subcontracted teams to fulfill these obligations. Regardless of the teaming arrangement, however, the Vendor partner remains fully responsible for all aspects. Vendor partner, or a Vendor partner team, must have demonstrated experience designing, installing and maintaining CHP equipment. A Vendor partner must submit at least one Packaged CHP System with their initial application.

The CHP eCatalog is structured (**Error! Reference source not found.**) to receive five discrete interactions:

- Application to become an approved **Vendor partner**. These private sector companies or teams form the backbone of the CHP supply chain end-user interface.
- Application to become an approved **CHP packager**. These private sector companies provide Recognized Package CHP Systems available to **Vendor partners** who do not make such systems themselves.
- Applications for **Recognized Packaged CHP Systems**. All packaged system applications are reviewed and vetted against a specific set of guidelines. (see Recognition Process)
- **End-Users** can enter the CHP eCatalog to learn about Packaged CHP Systems, shop for a CHP Packaged CHP System for a particular site, and begin the buying process.
- After installation, Packaged CHP System **Performance** will be monitored, assessed and posted to provide project and fleetwide data for analysis and future improvement.



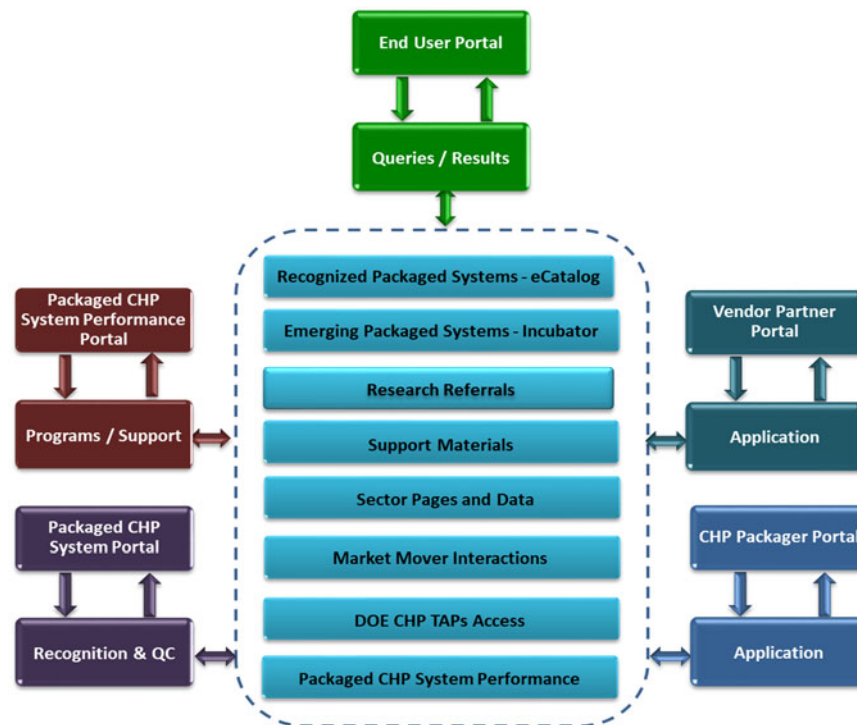


Figure 3 CHP eCatalog Database Structure

## Market Engagement

It is clear from the NYSERDA results that while their packaged CHP system catalog was an important part of their successful program, but it was not sufficient to achieve success. NYSERDA incorporated a robust market engagement program in conjunction with the Catalog. NYSERDA has direct control over all the aspects of its CHP program including: market outreach, customer acquisition and incentives offered. Since these are state and local matters, the US DOE does not have the same role as state government, however, there is a very important role for the US DOE to use its convening, data and technical support base. US DOE plans to continue its public/private partnership designed to increase deployment of CHP in key markets by sharing information, providing tools and technical assistance and identifying best practices to overcome the market impediments that currently limit CHP market development. The overarching goal of this public/private partnership is to support the growing number of states, localities and utilities that are implementing programs and policies to increase the use of CHP in support of key economic, security, efficiency and environmental goals.

The public/private partnership will provide partners with tools, resources, technical assistance and peer-to-peer networking opportunities to support the development and implementation of robust market engagement programs to fast-track the deployment of CHP systems in their jurisdictions. Applicable market engagement programs can range from simple end-user education to technical assistance offerings to policy and regulatory initiatives to CHP incentive programs depending on the objectives, needs and available resources of each partner. Partners will, in collaboration with US DOE, demonstrate practical and effective best practices, and robust market engagement support increased deployment of CHP.

The Goals of the public/private partnership are to:

- Increase the deployment of efficient, cost-effective CHP systems by supporting partners (states, utilities, municipalities) that provide robust market engagement programs
- Promote the adoption of innovative policy and regulatory initiatives that address market failures that currently impede adoption of efficient, cost-effective CHP by industrial, commercial, institutional and multi-family customers
- Reduce perceived risks to customers and vendors in deploying combined heat and power through access to better information, analytic tools, technical assistance and access to CHP eCatalog
- Expand CHP product offerings, improve quality, and control costs by promoting CHP system and vendor competition
- Provide potential users with linkages to ancillary services (financial energy services, incentives, etc.) to demystify and streamline the CHP development process

The benefits to the partners include assistance in increasing market acceptance of a local energy solution that can reduce operating costs for large energy users, improve overall economic competitiveness, promote economic development, provide enhanced resiliency for critical infrastructure, and relieve grid strain and vulnerability. The partners will receive US DOE assistance in designing CHP programs that match the technical potential for CHP in their jurisdiction; have access to tools, resources and technical assistance in implementation of those programs; and receive public recognition as a leader in CHP.

## Conclusions

Returning to EPRI's 2004 findings (Thimsen 2004) and reexamining them in light of US DOE's forthcoming CHP public/private partnership deployment activities will provide some sense of the future of CHP technologies and markets:

1. *The pre-engineered, packaged CHP systems simplify installation and offer cost savings associated with a standardized design.*

This statement, on its face, is true. NYSERDA also proved that this statement is factually true and has developed a measure of quantification. The NYSERDA application-to-operation timeframe has been reduced from 25 to 17 months (40% time compression. Overall project costs have been reduced about 25%) largely resulting from reduced soft costs, such as customer acquisition and permitting. The eCatalog will endeavor to expand the concept nationwide and over a larger span of sizes as NYSERDA catalog currently has systems up to 1.3 MW and the eCatalog will go up to 10 MW.

2. *The packaged CHP "industry" is relatively young. Five of the companies began sales of their packaged CHP products since 2000 or will introduce them soon.*

The packaged CHP industry was indeed young in 2004 when EPRI issued its report. EPRI's report interviewed 15 CHP packagers at that time to develop its results<sup>11</sup>. Two of these companies are active in the packaged CHP system market today. Today, the NYSERDA catalog currently has 18 CHP packagers<sup>12</sup> offering in New York State 203 different standardized packaged systems for commercial, institutional and industrial applications. Many of these early packagers fell victim to poor design choices, bad business models, skewed markets and/or predatory utility practices. The CHP market has significantly matured since 2004 with better equipment, designs, installation practices and improved market conditions. The eCatalog will significantly expand the portfolio of packaged CHP systems.

3. *The deployment of packaged CHP units is likely limited by the business case or supply/distribution capacity rather than market saturation.*

Today there are a growing number of states, localities and utilities that are implementing programs and policies to increase the use of CHP in support of key economic, security, efficiency and environmental goals. These government and utility entities are recognizing the benefits of CHP within their jurisdictions or service territories. In fact, utilities in regulated states are beginning to recognize the benefits of CHP in integrated resource planning. The eCatalog and market engagement programs are designed to improve the business case for CHP through system cost reduction, quality improvement, operational improvement and eventually working with utilities and jurisdictions to improve business models in deregulated and regulated utility jurisdictions.

EPRI was on the right track, in 2004, concluding that standardized packaged CHP systems reduce cost and overall risk, and furthermore, the real limitation to full deployment of packaged CHP systems lies in the business case models. Establishing an effective national eCatalog for recognized packaged systems with single point responsibility and support and a public/private partnership to develop state, local and utility best practices for CHP deployment to provide a pathway toward full packaged CHP system deployment is designed to address this business case model limitation. The eCatalog and continuing public/private market engagement efforts also support NYSERDA's two market transforming axioms.

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<sup>11</sup> BluePoint Energy, Brotherhood Aircogen, Coast Intelligen, DTE Energy Technologies, Hess Microgen, IR Energy Systems, Kohler Power Systems, Marathon Engines, Marson Energy Systems, Plug Power, STM Power, Tecogen, UTC Power, Vector Cogen, and Vericor Power Systems

<sup>12</sup> 2G Cenergy, Aegis Energy Services, Co-Energy America, Cogen Power, Elite Energy Engineering LLC, Ener-G Rudox Inc, FlexEnergy, Inc, GEM Energy, IntelliGen Power Systems, Kraft Power Corporation, LC Associates, Lightfoot Energy Solutions, RSP Systems, Stewart & Stevenson, Tecogen, Inc, Unison Energy

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