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Appendix E

Assessment of the Technical and Economic Potential for CHP in Commonwealth Edison's Service Territory

Draft Report

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Introduction

Combined heat and power (CHP), also known as cogeneration, produces electricity and useful thermal energy in an integrated system. CHP systems can range in size from hundreds of megawatts, such as those being operated at refineries and in enhanced oil recovery fields down to a few kilowatts that are used in small commercial and even residential applications. Combining electricity and thermal energy generation into a single process can save up to 35 percent of the energy required to perform these tasks separately. This report presents the results of a CHP market assessment undertaken for Commonwealth Edison (ComEd) to identify the technical and economic potential for CHP market penetration given the current market and incentives for CHP installations in ComEd's service territory.

Technical Potential for CHP

This section provides an estimate of the technical market potential for CHP in the industrial, commercial/institutional, and multifamily residential market sectors. Two different types of CHP markets were included in the evaluation of technical potential. Both of these markets were evaluated for high load factor (80 percent load factor and above) and low load factor (51 percent load factor) applications, resulting in four distinct market segments that are analyzed:

- High load factor traditional CHP (heating only)
- Low load factor traditional CHP (heating only)
- High load factor cooling CHP (heating and cooling)
- Low load factor cooling CHP (heating and cooling)

Traditional CHP

Traditional CHP electrical output is produced to meet all or a portion of the base load for a facility, and the thermal energy is used to provide steam or hot water. Depending on the type of facility, the appropriate sizing could be either electric or thermal limited. Industrial facilities often need more thermal energy than electrical energy to produce their products, leading them to have "excess" thermal load compared to their on-site electric load. Commercial facilities almost always have excess electric load compared to their thermal load. Two subcategories were considered:

- *High load factor applications:* This market provides for continuous or nearly continuous operation. It includes all industrial applications and round-the-clock commercial/institutional operations such as colleges, hospitals, hotels, and prisons.
- *Low load factor applications:* Some commercial and institutional markets provide an opportunity for coincident electric/thermal loads for a period of 4,000–5,000 hours per year. This sector includes applications such as office buildings, schools, and laundries.

Combined Cooling Heating and Power

All or a portion of the thermal output of a CHP system can be converted to air conditioning or refrigeration with the addition of a thermally activated cooling system. This type of system can potentially expand benefits of CHP to facilities that do not have the year-round thermal load to support a traditional CHP system. A typical system would provide the annual hot-water load, a portion of the space-heating load in the winter months, and a portion of the cooling load during the summer months. Two subcategories were considered:

- *Incremental high load factor applications:* These markets represent round-the-clock commercial/ institutional facilities that could support traditional CHP, but with cooling, incremental capacity could be added while maintaining a high level of utilization of the thermal energy from the CHP system. All of the market segments in this category are also included in the high load factor traditional market segment, so only the incremental capacity for these markets is added to the overall totals.
- *Low load factor applications:* These represent markets that otherwise could not support CHP due to a lack of heating thermal load, but with the addition of cooling, they can support CHP with low load hours. These applications include schools, big box retail stores, museums, movie theaters, supermarkets, and restaurants.

Estimating the Technical Potential

The estimation of technical market potential consists of the following elements:

- *Identification of applications where CHP provides a reasonable fit to the electric and thermal needs of the user:* Target applications were identified based on reviewing the electric and thermal energy consumption data for various building types and industrial facilities.
- *Quantification of the number and size distribution of target applications:* Several data sources were used to identify the number of applications by sector that meet the thermal and electric load requirements for CHP.
- *Estimation of CHP potential by megawatt capacity:* Total CHP potential is then derived for each target application based on the number of target facilities in each size category and sizing criteria appropriate for each sector.
- *Subtraction of existing CHP from the identified sites to determine the remaining technical market potential.*

The technical market potential does not consider screening for economic rate of return or other factors such as ability to retrofit, owner interest in applying CHP, capital availability, natural gas availability, and variation of energy consumption within customer application/size class. The technical potential as outlined is useful in understanding the potential size and size distribution of the target CHP markets. Identifying technical market potential is a preliminary step in the assessment of market penetration.

The basic approach to developing the technical potential is described below:

- *Identify existing CHP in the state:* The analysis of CHP potential starts with identifying existing CHP. In ComEd's service territory, as of the beginning of 2015, there are 18 operating CHP plants totaling 77.5 MW of capacity.[1] Of this existing CHP capacity, 33 percent of the sites and 74 percent of the capacity are in the industrial sector. This existing CHP capacity is deducted from any identified technical potential. A summary of the existing CHP capacity by industry is shown in Table 1.
- *Identify applications where CHP provides a reasonable fit to the electric and thermal needs of the user:* Target applications were identified based on reviewing the electric and thermal energy (heating and cooling) consumption data for various building types and industrial facilities. Data sources include the U.S. Department of Energy (DOE) Energy Information Administration (EIA) Commercial Buildings Energy Consumption Survey, the DOE Manufacturing Energy Consumption Survey, and various market summaries developed by DOE, Gas Technology Institute, and the American Gas Association. Existing CHP installations in the commercial/institutional and industrial sectors were also reviewed to understand the required profile for CHP applications and to identify target applications.
- *Quantify the number and size distribution of target applications:* Once applications that could technically support CHP were identified, the ICF CHP Technical Potential Database was used to identify potential CHP sites by Standard Industrial Classification (SIC) code or application and by location. The ICF CHP Technical Potential Database is based on a variety of sources for facility-level information, including EPA Greenhouse Gas Reporting Rule Database, the Dun and Bradstreet Hoovers Database, the Manufacturers News Database, Major Industrial Plant Database, and industry-specific data sources (Lockwood Post, Iron & Steel Directory, Oil & Gas Journal, etc.). Commercial application–specific information was used from the American Hospital Association, the Database of Accredited Post-Secondary Institutions, the Department of Justice (prisons), the Department of Education, etc.
- *Estimate CHP potential in terms of megawatt capacity:* Total CHP potential was then derived for each target application based on the number of target facilities in each size category. It was assumed that the CHP system would be sized to meet the thermal demand for the facility unless the thermal loads (heating and cooling) would exceed the average electric demand. Table 2 and Table 3 present the specific target market sectors, the number of potential sites, and the potential megawatt contribution from CHP. There are two distinct applications and two levels of annual load, resulting in a total of four market segments. In traditional CHP, the thermal energy is recovered and used for heating, process steam, or hot water. In cooling CHP, the system provides both heating and cooling needs for the facility. High load factor applications operate at 80 percent load factor and above; low load factor applications operate at an assumed average of 4,500 hours per year (51 percent) load factor.

[1] CHP Installation Database. (2015). This database is maintained by ICF International for Oak Ridge National Laboratory.

- *Estimate the growth of new facilities in the target market sectors:* The technical potential included economic projections for growth through 2030 by ComEd's target market sectors. The growth factors used in the analysis for growth between the present and 2030 by individual sector are shown in Table 4. These growth projections were taken from the EIA 2014 Annual Energy Outlook and were used in this analysis as an estimate of the growth in new facilities or expansion of existing facilities. In cases where an economic sector is declining, it was assumed that no new facilities would be added to the technical potential for CHP.

Table 1. Existing CHP in ComEd Territory

SIC	Application	No. Sites	Capacity (MW)
20	Food Processing	1	6.4
26	Paper	3	6.8
28	Chemicals	1	4.6
29	Refinery	1	39.6
8062	Hospitals	4	6.3
8211	Schools, K–12	2	0.3
8221	Colleges/Universities	6	13.5
	Total	18	77.5

Table 2. ComEd Technical Market Potential for CHP in Existing Facilities—Industrial Sector

SIC	Application	50–500 kW		500–1,000 kW		1–5 MW		5–20 MW		>20 MW		Total No. of Sites	Total On-Site Potential (MW)
		No. of Sites	On-Site Potential (MW)	No. of Sites	On-Site Potential (MW)	No. of Sites	On-Site Potential (MW)	No. of Sites	On-Site Potential (MW)	No. of Sites	On-Site Potential (MW)		
20	Food and Beverage	251	48	45	34	63	116	9	75	2	134	**370**	**406**
22	Textiles	29	7	8	6	5	11	0	0	0	0	**42**	**24**
24	Lumber and Wood	113	16	9	5	2	8	1	9	0	0	**125**	**39**
25	Furniture	1	0	0	0	0	0	0	0	0	0	**1**	**0**
26	Paper	119	30	33	23	31	66	4	46	1	20	**188**	**186**
27	Printing/Publishing	21	3	1	1	1	1	0	0	0	0	**23**	**5**
28	Chemicals	284	55	58	43	90	188	37	340	11	293	**480**	**919**
29	Petroleum Refining	0	0	4	3	10	21	0	0	3	186	**17**	**210**
30	Rubber/Misc. Plastics	333	54	25	16	9	15	4	25	0	0	**371**	**109**
32	Stone/Clay/Glass	0	0	0	0	2	6	0	0	0	0	**2**	**6**
33	Primary Metals	65	16	28	19	27	64	4	27	0	0	**124**	**126**
34	Fabricated Metals	71	10	2	1	0	0	0	0	0	0	**73**	**11**
35	Machinery/Computer Equipment	3	0	2	1	1	1	0	0	0	0	**6**	**3**
37	Transportation Equipment	68	12	14	9	14	30	0	0	0	0	**96**	**51**
38	Instruments	5	1	0	0	1	1	0	0	0	0	**6**	**2**
39	Misc. Manufacturing	20	3	3	2	0	0	0	0	0	0	**23**	**5**
49	Gas Processing	0	0	0	0	0	0	1	12	0	0	**1**	**12**
	Total	**1,383**	**254**	**232**	**164**	**256**	**528**	**60**	**535**	**17**	**633**	**1,948**	**2,113**

Table 3. ComEd Technical Market Potential for CHP in Existing Facilities—Commercial Sector

SIC	Application	50–500 kW		500–1,000 kW		1–5 MW		5–20 MW		>20 MW		Total No. of Sites	Total On-Site Potential (MW)
		No. of Sites	On-Site Potential (MW)	No. of Sites	On-Site Potential (MW)	No. of Sites	On-Site Potential (MW)	No. of Sites	On-Site Potential (MW)	No. of Sites	On-Site Potential (MW)		
4222	Refrigerated Warehouses	27	4	2	1	1	1	0	0	0	0	**30**	**6**
43	Post Offices	19	2	1	1	0	0	0	0	0	0	**20**	**3**
4581	Airports	1	0	0	0	0	0	1	11	1	38	**3**	**50**
4952	Water Treatment/Sanitary	18	2	1	1	0	0	0	0	0	0	**19**	**2**
52	Big Box Retail	554	83	20	12	6	10	0	0	0	0	**580**	**106**
7542	Carwashes	54	4	0	0	0	0	0	0	0	0	**54**	**4**
8211	Schools	515	89	33	23	3	4	0	0	0	0	**551**	**115**
9100	Government Facilities	138	18	9	6	10	15	1	6	0	0	**158**	**46**
5411	Food Sales	313	65	2	1	0	0	0	0	0	0	**315**	**66**
5812	Restaurants	550	52	6	4	0	0	0	0	0	0	**556**	**56**
7997	Golf/Country Clubs	165	21	0	0	0	0	0	0	0	0	**165**	**21**
7011	Hotels	256	34	46	29	23	46	0	0	0	0	**325**	**109**
7211	Laundries	28	5	2	1	1	1	0	0	0	0	**31**	**8**
7374	Data Centers	65	10	6	4	3	8	0	0	0	0	**74**	**22**
7832	Movie Theaters	6	1	0	0	0	0	0	0	0	0	**6**	**1**
7991	Health Clubs	119	16	13	8	2	6	0	0	0	0	**134**	**30**
8051	Nursing Homes	318	40	6	4	5	10	0	0	0	0	**329**	**54**
8062	Hospitals	19	6	28	20	63	131	2	12	0	0	**112**	**168**
8221	Colleges/Universities	80	14	13	9	40	119	18	158	4	115	**155**	**415**
9711	Military	6	1	2	2	2	3	1	13	0	0	**11**	**19**
8412	Museums	19	2	2	2	0	0	0	0	0	0	**21**	**4**
9223	Prisons	3	0	0	0	7	13	3	51	0	0	**13**	**64**
6513	Multifamily Buildings	1	59	1	143	1	44	0	0	0	0	**3**	**247**
6512	Commercial Buildings	1	155	1	542	1	232	0	0	0	0	**3**	**930**
	Total	**3,275**	**684**	**194**	**813**	**168**	**645**	**26**	**251**	**5**	**154**	**3,668**	**2,546**

Table 4. ComEd Sector Growth Projections Through 2030

	NAICS	SIC	Application	Yearly 2015–2030 Growth Rate	Cumulative 2015–2030 Growth Rate
Industrial	311	20	Food and Beverage	2.0%	36.3%
	313	22	Textiles	3.1%	62.0%
	321	24	Lumber and Wood	1.0%	17.1%
	337	25	Furniture	1.9%	34.6%
	322	26	Paper	2.0%	37.4%
	323	27	Printing/Publishing	0.0%	0.0%
	325	28	Chemicals	3.3%	67.5%
	324	29	Petroleum Refining	0.0%	0.0%
	326	30	Rubber/Misc. Plastics	2.5%	49.0%
	327	32	Stone/Clay/Glass	2.5%	49.1%
	331	33	Primary Metals	2.0%	37.9%
	332	34	Fabricated Metals	2.3%	44.2%
	333	35	Machinery/Computer Equip.	3.2%	66.4%
	336	37	Transportation Equip.	3.1%	62.0%
	334	38	Instruments	3.4%	70.1%
	316	39	Misc. Manufacturing	4.5%	102.4%
	221	49	Gas Processing	1.3%	39.2%
Commercial/Institutional	221	4952	Water Treatment/Sanitary	0.66%	18.8%
	922	9223	Prisons	1.51%	27.1%
	928	9711	Military	1.51%	27.1%
	812	7211	Laundries	1.51%	27.1%
	811	7542	Carwashes	1.51%	27.1%
	713	7991	Health Clubs	1.51%	27.1%
	713	7997	Golf/Country Clubs	1.51%	27.1%
	493	4222	Refrigerated Warehouses	1.51%	27.1%
	531	6513	Multifamily Buildings	1.50%	47.2%
	721	7011	Hotels	1.24%	21.9%
	518	7374	Data Centers	4.00%	177.2%
	623	8051	Nursing Homes	1.29%	22.7%
	622	8062	Hospitals	1.29%	22.7%
	611	8221	Colleges/Universities	0.43%	7.1%
	491	43	Post Offices	1.51%	27.1%
	444	52	Big Box Retail	0.91%	15.6%
	488	4581	Airports	1.51%	27.1%
	445	5411	Food Sales	1.00%	17.3%
	722	5812	Restaurants	1.07%	18.6%
	531	6512	Commercial Buildings	1.24%	21.9%
	512	7832	Movie Theaters	0.49%	8.1%
	611	8211	Schools	0.43%	7.1%
	712	8412	Museums	0.49%	8.1%
	921	9100	Government Facilities	1.24%	21.9%

Economic Potential for CHP

The economic potential for CHP is quantified using payback for CHP systems. Payback is defined as the amount of time (i.e., number of years) before a system can recoup its initial investment. For each site included in the technical potential analysis, an economic payback is calculated based on the appropriate CHP system cost and performance characteristics and energy rates for that system size and application. This section lays out the economic conditions for ComEd that were used to calculate the payback for each technical potential application and size range.

Energy Price Projections

The expected future relationship between purchased natural gas and electricity prices, called the *spark spread* in this context, is one major determinant of the ability of a facility with electric and thermal energy requirements to cost-effectively utilize CHP.

Electric Price Estimation

Because state-average spark spreads may mask the differences in specific utility rates on project economics, ICF researched ComEd's applicable rates (i.e., full-service and partial-service/standby rates) to develop an avoided cost estimate for each utility. The avoided cost is an important concept for evaluating the treatment of on-site generation by partial requirement tariff structures. One of the key economic values of on-site generation is the displacement of purchased electricity and the avoidance of those costs. Ideally, the reduction in electricity price should be commensurate with the reduction in purchased electricity. In other words, if the on-site system reduces electricity consumption by 80 percent, the cost of electricity purchases would also be reduced by 80 percent in an ideal scenario. However, only a portion of the full retail rate is avoided by on-site generation due to fixed customer charges, demand charges, and standby rate structures. The economics of CHP are negatively impacted if partial requirements rates are structured such that only a small portion of the electricity price can be avoided.

Based on ICF's rate analysis, the average prices for ComEd CHP customers, for high load factor, low load factor, and cooling (to reflect higher rates during daytime summer hours) are provided in Table 5, including retail rates and the avoided cost of electricity for CHP-generated power.

Table 5. ComEd CHP Customer Electric Rate Summary

Tariff Assumption		Medium Load Delivery	Large Load Delivery	Very Large Load Delivery	Extra Large Load Delivery	High Voltage Delivery
Voltage		Secondary	Secondary	Primary	Primary	Trans.
Capacity Assumption (kW)		275	750	3,000	12,500	40,000
	Load Factor	50–500 kW	500–1,000 kW	1–5 MW	5–20 MW	>20 MW
Retail Rate ($/kWh)	High Load Factor	$0.0798	$0.0797	$0.0773	$0.0765	$0.0664
	Low Load Factor	$0.0877	$0.0890	$0.0854	$0.0843	$0.0694
	Cooling	$0.1086	$0.1126	$0.1067	$0.1048	$0.0777
Avoided Cost of Electricity ($/kWh)	High Load Factor	$0.0694	$0.0690	$0.0674	$0.0670	$0.0612
	Low Load Factor	$0.0721	$0.0731	$0.0706	$0.0700	$0.0616
	Cooling	$0.0773	$0.0807	$0.0770	$0.0762	$0.0622
% Avoided Cost	High Load Factor	87%	87%	87%	88%	92%
	Low Load Factor	82%	82%	83%	83%	89%
	Cooling	71%	72%	72%	73%	80%

To estimate the escalation of electric prices over the 2015–2030 timeframe, forecasts from EIA's 2015 Annual Energy Outlook for the RFC West region were used to escalate ComEd rates by 0.66 percent per year. The annual price forecasts provided were converted to 5-year averages for use in the market model.

Natural Gas Price Estimation

The natural gas prices used in the analysis are shown in Table 6. These prices reflect 12-month average Illinois state-average rates from EIA spanning 2014 and 2015.[2] The specific rate for each size range is as follows:

- 50–500 kW: IL commercial average
- 500–1,000 kW: IL industrial average + 10 percent
- 1–5 MW: IL industrial average
- 5–20 MW: IL industrial average – 10 percent
- >20 MW: IL city gate average + $1/MMBtu

The escalation rate for natural gas prices over the 2015–2030 timeframe was 2.54 percent per year and was taken from the EIA Annual Energy Outlook 2015 reference case, for the RFC West region.

Table 6. Natural Gas Price by CHP System Size Bin ($/MMBtu)

Year	50–500 kW	500–1,000 kW	1–5 MW	5–20 MW	>20 MW
2015	$9.13	$8.22	$7.10	$6.39	$5.31
2015–2020	$9.73	$8.76	$7.56	$6.80	$5.65
2020–2025	$11.03	$9.93	$8.57	$7.71	$6.41
2025–2030	$12.50	$11.26	$9.72	$8.74	$7.27

[2] Energy Information Administration. *Natural gas prices.* Retrieved from http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_SOR_a.htm

CHP Technology Cost and Performance

CHP systems use fuel to generate electricity and useful heat for the customer. There are many different technologies and products that are capable of generating electricity and useful heat. While these technologies differ in terms of system configuration and operation, the economic value of CHP depends on key factors common to all CHP technologies:

- *Installed capital cost of the system, on a unit basis expressed in $/kW:* A subset of capital costs are emissions treatment equipment costs that are required to bring some CHP systems into compliance with California (or other regional non-attainment areas) emissions requirements.
- *Fuel required to generate electricity, commonly expressed as the heat rate in Btu/kWh:* All heat rates in this report are expressed in terms of the high heating value (HHV) of the fuel. This is the same basis on which natural gas is measured and priced for sale. Vendors typically express engine heat rates in terms of lower heating value (LHV), which does not include the heat of vaporization of the moisture content of the exhaust. Consequently, vendor efficiency and heat rate quotes for natural gas fueled equipment are about 10–11 percent higher than HHV estimates, which reflect the difference in the HHV and LHV heat contents for a given volume of natural gas.
- *Useful thermal energy produced per unit of electricity output (again expressed as Btu/kWh).*
- *Non-fuel operating and maintenance costs, expressed on unit basis in $/kWh:* These annual costs include amortization of overhaul costs that can be required after a number of years of operation.
- *Economic life of the equipment.*

The cost and performance parameters for the representative CHP systems used in this analysis are based on information collected for the EPA CHP Catalog of Technologies.[3] Data are presented on the representative CHP system characteristics that were used for each size range category in Table 7. The top portion of the table shows the CHP system characteristics for traditional heat utilization (hot water or steam) while the bottom portion of the table shows the additional cost and performance parameters associated with a CHP system used for cooling. These costs depend on the sizing of the absorption chiller, which in turn depends on the amount of usable waste heat that the CHP system produces.

[3] EPA CHP Partnership Program. *Catalog of CHP technologies.* Retrieved from https://www.epa.gov/chp/catalog-chp-technologies

Table 7. CHP Cost and Performance Assumptions

Market Size Bin	50–500 kW	500–1,000 kW	1–5 MW	5–20 MW	>20 MW
Technology	Rich Burn ICE	Lean Burn ICE	Lean Burn ICE	GT	GT
Capacity, kW	275	750	3,000	12,500	40,00
Capital and O&M Costs					
Total Capital Cost, $/kW	$2,900	$2,727	$1,920	$1,980	$1,260
O&M Costs, $/kWh	$0.023	$0.021	$0.016	$0.010	$0.009
Performance					
Heat Rate, Btu/kWh	12,637	10,342	9,800	12,482	9,488
Thermal Output, Btu/kWh	6,700	4,034	4,200	5,262	3,118
Thermal Utilization, %	80%	80%	80%	90%	100%
Electric Efficiency, %	27.0%	33.0%	34.8%	27.3%	36.0%
CHP Efficiency	80.0%	79.3%	78.3%	69.5%	68.8%
Air Conditioning Cost and Performance					
Avoided AC Efficiency, kW/ton	0.79	0.79	0.43	0.47	0.47
Absorption Cooling Efficiency, Btu/ton	17,143	17,143	17,143	11,215	11,215
Tons of Cooling	107	176	735	5,865	11,121
kW AC/kW Generated	0.31	0.19	0.11	0.22	0.13
Capital Cost, $/ton	$2,030	$1,820	$1,328	$950	$950
Capital Cost Adder, $/kWe	$793	$428	$325	$446	$264

These equipment costs were applied from 2015 to 2020 in the analysis. Costs were slightly declined and performance was marginally improved for 2020–2025 and 2025–2030, based on expected developments and improvements in CHP equipment offerings.

Economic Potential Results

CHP project economics are site-specific. Electricity rates and tariff structures, natural gas prices, and site-specific conditions (i.e., space availability and integration into existing thermal and electric systems, permitting, siting, and grid interconnection requirements) all contribute to the unique economics of each CHP system. An estimate of economic potential by system size range was developed for this analysis using a ComEd electric rate analysis, average natural gas prices, and representative CHP equipment cost and performance characteristics.

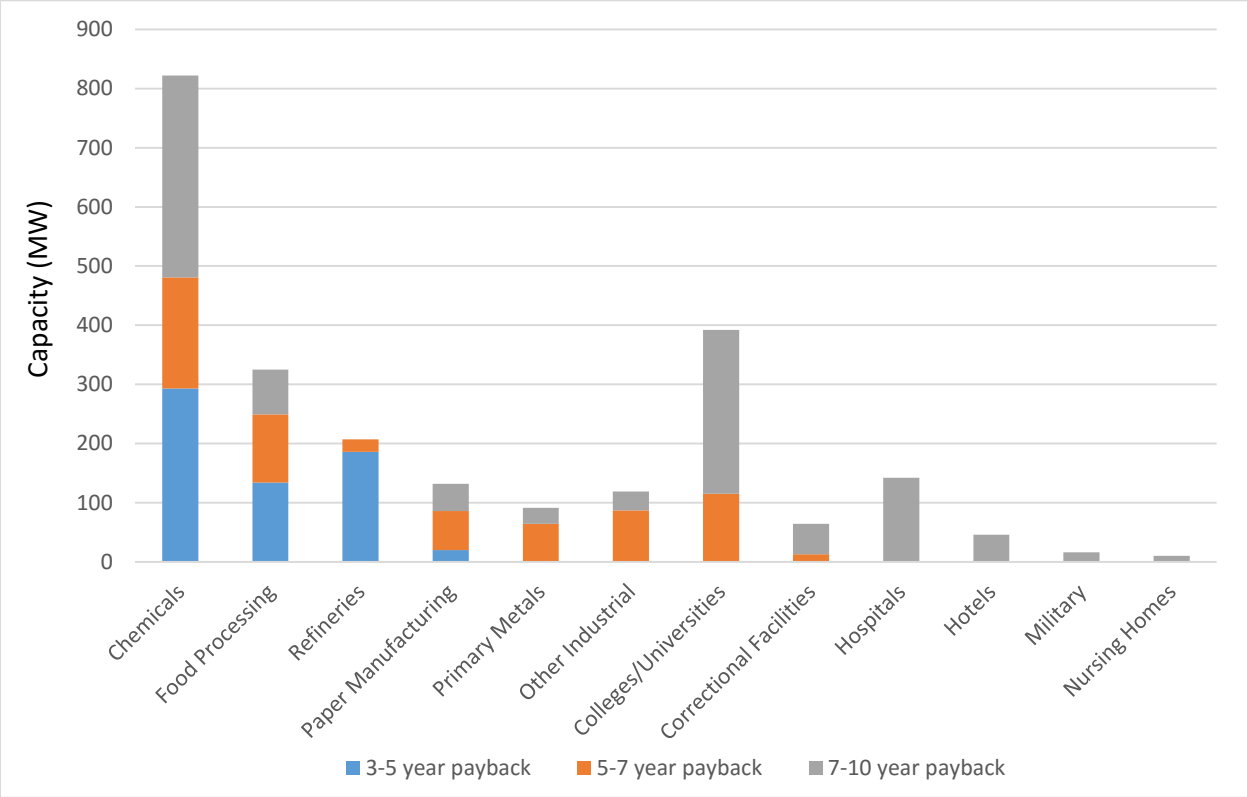
A simple payback calculation was performed for each facility in ComEd's service territory, and the results are presented in Table 8. This calculation is based on the electric rates, natural gas prices, and CHP cost and performance for 2015–2020. As shown, 2,411 MW of the technical potential is estimated to have a payback period of less than 10 years, with 633 MW of this potential falling under a 5-year payback. All of the sites with payback periods under 5 years are large industrial facilities with more than 20 MW CHP systems. Other high load factor applications with CHP systems in the 1–20 MW range (including hospitals, hotels, universities, and smaller industrial facilities) show economic potential in the 5- to 10-year payback range. If all of the ComEd facilities with economic potential (less than 10-year payback) installed a CHP system, the impact would be over 18,000 GWh/year, with close to 2,000 GWh coming from the public sector. However, only small percentage of these potential sites are actually likely to adopt CHP.

Table 8. CHP Economic Potential in ComEd's Service Territory

Application	Payback Period				Total
	<3 years	3–5 years	5–7 years	7–10 years	<10 years
High Load Factor—Traditional	0	633	895	768	**2,296**
High Load Factor—Cooling	0	0	115	0	**115**
Low Load Factor—Traditional	0	0	0	0	**0**
Low Load Factor—Cooling	0	0	0	0	**0**
All Applications	**0**	**633**	**1,010**	**768**	**2,411**

Figure 1 shows the economic potential for ComEd CHP by sector and payback period. Chemical plants represent the largest opportunity for CHP development, followed by colleges/universities and food processing facilities. About 10 percent of the economic potential comes from CHP applications in the public sector (correctional facilities, military bases, colleges/universities, and some hospitals).

Figure 1. Economic Potential for ComEd CHP by Sector and Payback Period



CHP Market Penetration Analysis

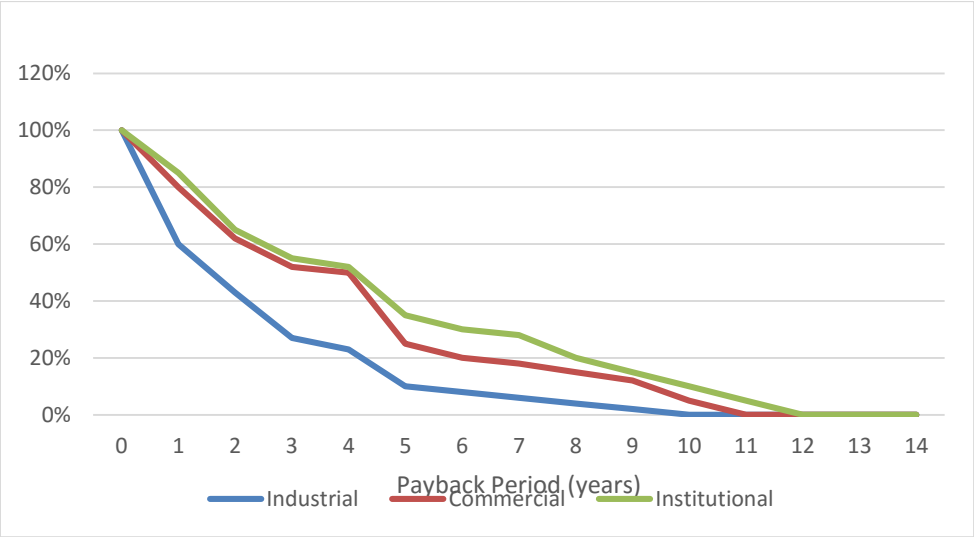
Based on the calculated economic potential, a market diffusion model is used to determine the cumulative CHP market penetration over the analysis timeframe. The market penetration represents an estimate of CHP capacity that will likely enter the market between 2015 and 2030. This value discounts the economic potential to reflect non-economic screening factors and the rate that CHP is likely to actually enter the market. For this analysis, the potential adoption from 2017 to 2030 is highlighted.

Rather than use a single yearly payback value as the sole determinant of economic potential, estimated market acceptance rates have also been included in the penetration analysis. These acceptance rates are based on a survey of commercial, institutional, and industrial facility operators, identifying the level of payback required to consider installing CHP.

Figure 2 shows the percentage of survey respondents that would accept CHP investments at different payback levels.[4] As can be seen from the figure, more than 30 percent of customers surveyed would reject a project that promised to return their initial investment in just 1 year. For most of the customer types, a little more than half would reject a project with a payback of 2 years. This type of payback translates into a project with a return on investment of around 50 percent. Potential explanations for rejecting a project with such high returns include:

1. The average customer does not believe that the results are valid and is attempting to mitigate this perceived risk by requiring very high projected returns before a project would be accepted.
2. The facility has limited capital and is rationing its ability to raise capital for higher-priority projects (market expansion, product improvement, etc.).

Figure 2. Customer Payback Acceptance Curve



For the analysis, these acceptance rates were applied to the payback periods obtained for industrial, commercial, and institutional customers. For each market segment, the CHP market penetration represents the technical potential multiplied by the share of customers that would accept the payback calculated in the economic potential analysis.

The rate of market penetration is based on a *Bass diffusion curve* with allowance for growth in the maximum market. This function determines cumulative market penetration over the analysis timeframe. Smaller systems are assumed to take a longer time to reach maximum market penetration than larger

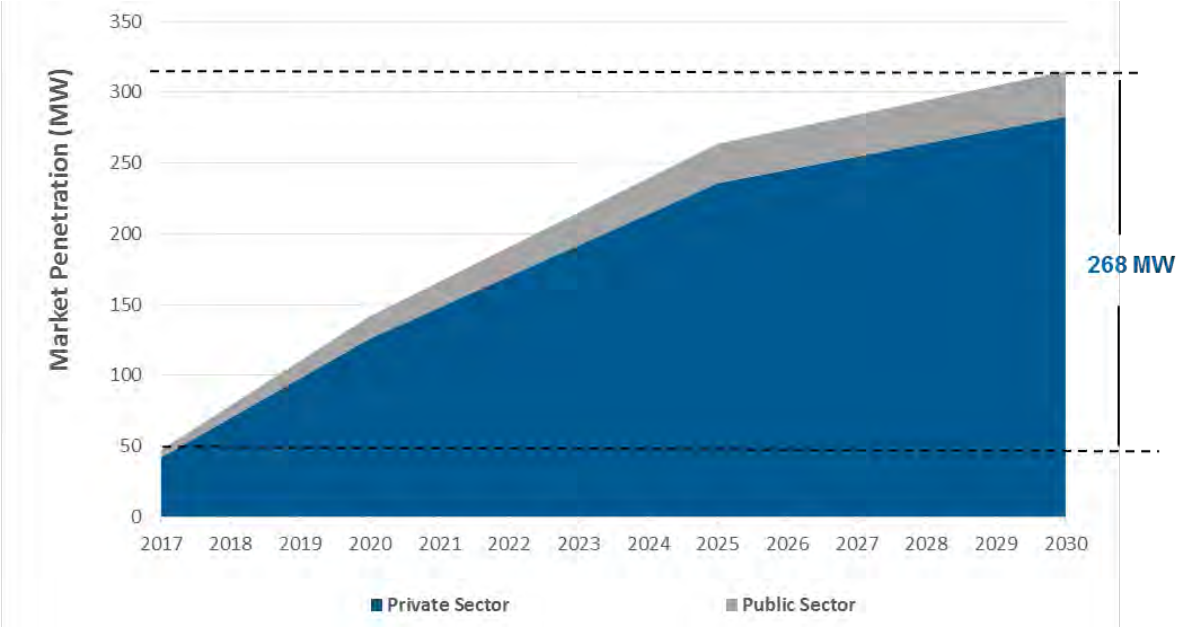
[4] California Energy Commission. (2005, July). Assessment of California CHP market and policy options for increased penetration.

systems. Cumulative market penetration using a Bass diffusion curve takes a typical S-shaped curve. In the generalized form used in this analysis, growth in the number of ultimate adopters is allowed. The shape of the curve is determined by an initial market penetration estimate and growth rate of the technical market potential.

Naturally Occurring Potential: 2017–2030

In 2015 and 2016, 47 MW of CHP adoption is expected to have occurred in ComEd's territory, with 5 MW of this penetration coming from the public sector. By 2030, in the absence of any incentives, 315 MW of penetration is expected. So 268 MW (315 – 47) of new, naturally occurring penetration is estimated from 2017 to 2030, translating to about 2,000 GWh annually by 2030. Around 240 MW of this potential, or up to 1,800 GWh annually, would come from privately owned companies that are eligible for ComEd–funded CHP incentives. Figure 3 shows the projected CHP penetration rate with no incentives, also referred to as the naturally occurring market potential, over the analysis timeframe.

Figure 3. ComEd Naturally Occurring Market Potential for CHP (No Incentives, 2017–2030)



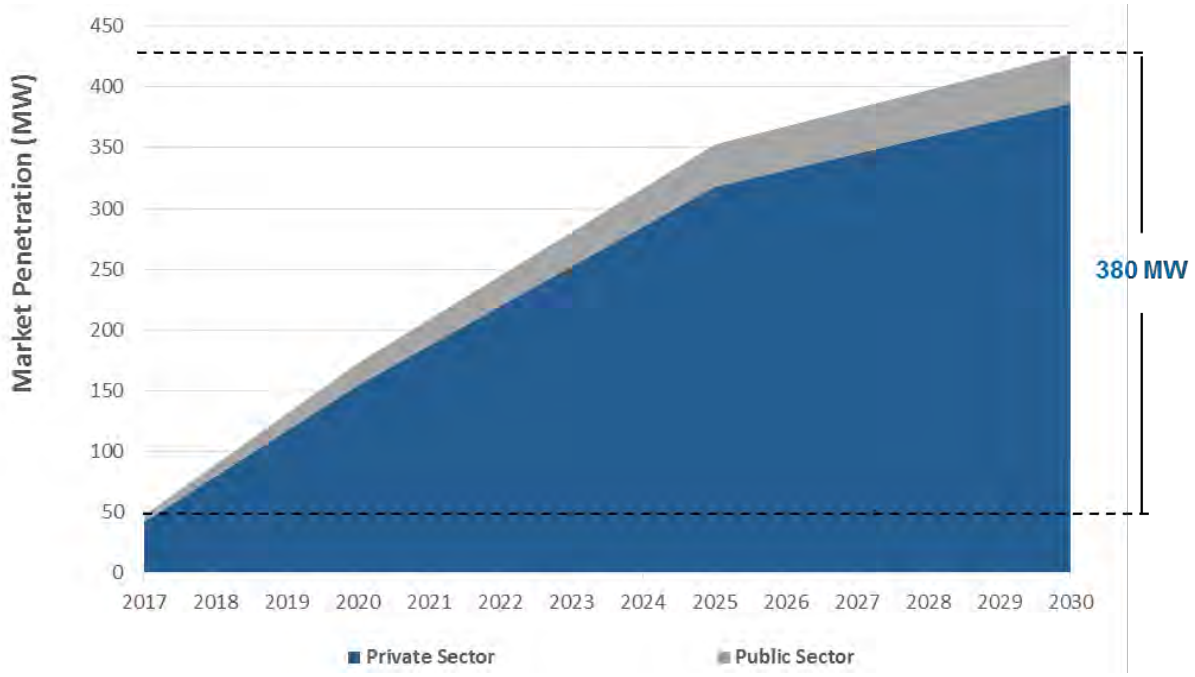
ComEd Program Potential

The proposed CHP incentive program for ComEd would provide $0.07/kWh for the first year to eligible CHP systems in the private sector, with a cap of $2 million per project. Publicly owned facilities would be eligible for a similar incentive, but the funding for public projects would come from the Illinois Department of Commerce and Economic Opportunity, rather than ComEd. Based on the established efficiency criteria, all of the CHP systems modeled in this analysis would be eligible for the incentive, which was applied to the market penetration estimates from 2017 to 2030.

With the program incentive, an estimated 112 GW of additional CHP capacity would be adopted by 2030, assuming that all eligible CHP customers can use the incentive. This would equate to about 840 GWh

annually by 2030. The total estimated CHP adoption for ComEd with the program incentive from 2017 to 2030 is shown in Figure 4.

Figure 4. ComEd Program Potential for CHP (Total Adoption, 2017–2030)



Only about 10 percent of the estimated CHP market penetration comes from the public sector, meaning that ComEd could be providing incentives for up to 340 MW of new private sector CHP capacity through 2030. However, 240 MW of this potential comes from customers that would have likely adopted CHP in the absence of the incentive, with 100 MW of new CHP adoption due to the incentive, or about 750 GWh annually by 2030.

Estimated Program Costs for ComEd Incentive

The majority of estimated market penetration, in terms of total megawatts and megawatt-hours, comes from facilities with CHP systems sized 5 MW or larger. All eligible systems in this size range would likely receive the maximum $2 million in available funding, but these projects are also likely to be considered free riders that would have moved forward without the incentive. The primary effect of the program incentive is that many more systems in the 1–5 MW size range would be expected to adopt CHP. The average incentive amount for these systems is estimated at $1.3 million, as CHP systems sized below 4 MW are unlikely to hit the $2 million cap.[5]

While economics for CHP are calculated at the individual facility level, the market penetration forecasts do not assume that particular facilities would move forward with a CHP project. Instead, the penetration estimates apply average adoption percentages over time to aggregate groups of facilities based on sector

[5] A full year of CHP power generation with a $0.07/kWh incentive applied to 7,500 full load equivalent hours is slightly over $2 million for a 4 MW system. A 4 MW system would hit the $2 million cap, but most systems sized below 4 MW would not hit the cap.

and payback period. Despite the uncertainty with which projects will move forward, some estimates can be applied based on the total quantity of adoption estimated for each size range.

Table 9 shows the estimated number of new CHP projects for the private sector in 2017–2020, 2020–2025, and 2025–2030 for each size range, both naturally occurring and with the ComEd incentive included.

Table 9. Estimated Program Potential from 2017 to 2030: Number of Private Sector CHP Projects With and Without Program Incentive

Size Range	Estimated Number of New Private Sector CHP Projects							
	Naturally Occurring Potential				Potential with Program Incentive			
	2017–2020	2020–2025	2025–2030	Total 2017–2030	2017–2020	2020–2025	2025–2030	Total 2017–2030
1–5 MW (~$1.3 million per project)	2	7	4	**13**	10	22	11	**43**
5–20 MW ($2 million per project)	1	3	1	**5**	2	4	1	**7**
>20 MW ($2 million per project)	2	3	1	**6**	2	3	1	**6**
All Size Ranges	**5**	**13**	**6**	**24**	**14**	**29**	**13**	**56**

The ComEd incentive program would have the most impact on projects in the 1–5 MW size range. Without the program incentive, these projects have marginal economics with payback periods close to 10 years. With the incentive, however, economics are significantly improved, and more of these smaller facilities would adopt CHP. The larger (more than 5 MW) facilities that hit the $2 million incentive cap are more likely to be considered free riders, as their economics were already fairly promising without the incentive, but many of these projects would still be expected to use available program funds. Overall, the ComEd program is expected to more than double the amount of CHP installations from 2017 to 2030, due mostly to the large number of projects that would move forward with 1–5 MW CHP systems.

Table 10 contains the estimated annual program costs, compared to the free rider cost for each size range. In accordance with the recommended free ridership planning assumption of 32 percent for ComEd's custom project programs, the cost for free riders is limited to 32 percent of the total program costs.[6] Many of the would-be free riders are expected to be filtered out through a pre-screening process, and the assumption is that they will still adopt CHP without the incentive.

Administrative costs are assumed to be 9 percent of the total program incentive cost, based on typical commercial and industrial energy efficiency program costs as well as specific costs for the Baltimore Gas and Electric CHP grant program, which are in the range of 8–10 percent for implementation and administrative support.

Table 10. Estimated Program Costs for ComEd CHP Incentive

Year	Annual Private Sector Program Funding*	Cumulative Private Sector Program Funding*

[6] The Illinois Stakeholder Advisory Group's recommended net-to-gross ratio for program year 8 is 68 percent, which suggests a free ridership percentage of 32 percent.

	(thousand $)		(thousand $)	
	Free Riders	ComEd Program Incentive	Free Riders	ComEd Program Incentive
2017	$0	$0	$0	$0
2018	$2,120	$6,620	$2,120	$6,620
2019	$2,120	$6,620	$4,240	$13,240
2020	$2,120	$6,620	$6,360	$19,860
2021	$2,120	$6,900	$8,570	$26,760
2022	$2,120	$6,900	$10,780	$33,660
2023	$2,120	$6,900	$12,990	$40,560
2024	$2,120	$6,900	$15,200	$47,460
2025	$2,120	$6,900	$17,410	$54,360
2026	$930	$2,910	$18,340	$57,270
2027	$930	$2,910	$19,270	$60,180
2028	$930	$2,910	$20,200	$63,090
2029	$930	$2,910	$21,130	$66,000
2030	$930	$2,910	$22,060	$68,910

* Funding applied to new CHP projects, with a 32 percent free rider limitation.

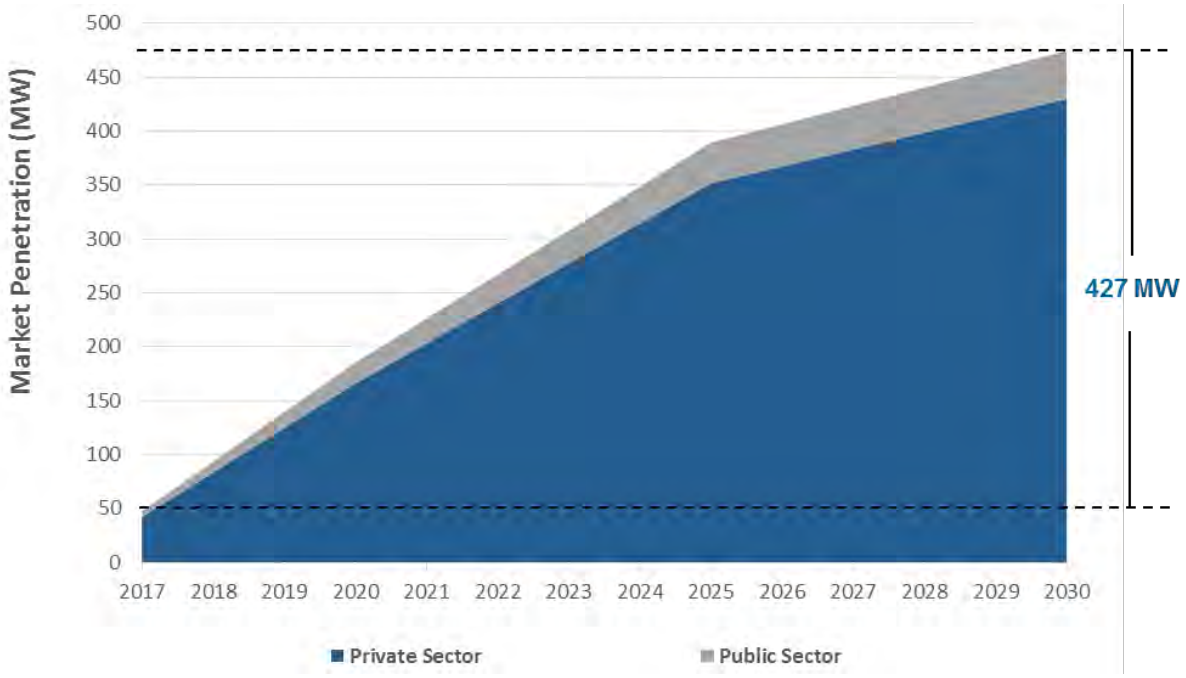
Includes program implementation and administration, at 9 percent of the incentive cost

ComEd's CHP program would have a significant impact on project economics, persuading many more potential customers to adopt CHP. The program would cost an estimated $68.9 million through 2030, and it would require the most funding in the 2020–2025 timeframe, at close to $7 million per year.

ComEd Maximum Achievable Potential

The maximum achievable program potential for ComEd was estimated by applying a CHP incentive equal to a program offered by Baltimore Gas and Electric. This program offers about a 35 percent increase in the available incentive for small (less than 4 MW) CHP projects, capped at $2.5 million for larger projects, as opposed to $2 million. It is assumed that this incentive would be available to all new CHP installations, with ComEd only providing funding for applicable private sector projects. The market penetration estimates for 2015 and 2016 are the same as before, with the maximum incentive applied from 2017 to 2030 to estimate the total additional penetration. The results are presented in Figure 5. ComEd Maximum Achievable Potential for CHP (Total Adoption, 2017–2030).

Figure 5. ComEd Maximum Achievable Potential for CHP (Total Adoption, 2017–2030)



With the maximum achievable incentive, an estimated 427 GW of CHP would be adopted by 2030. This is 159 GW of additional CHP capacity compared to the estimated adoption with no available incentive. These estimates assume that all eligible CHP customers (including free riders) would use the incentive. With effective pre-screening, some of the potential free riders would not be eligible for the incentive, but the assumption is that they will still move forward and install CHP. With the incentive, the 427 MW of new CHP capacity from 2017 to 2030 would equate to about 1,190 GWh annually by the end of the program, with around 10 percent coming from the public sector.

Estimated Program Costs for Maximum Achievable Incentive

All eligible CHP systems sized over 4 MW would likely receive the maximum $2.5 million in available funding from the maximum incentive.[7] Smaller systems would receive less, and a $1.8 million average incentive is estimated for systems in the 1–5 MW size range.

Table 11 shows the expected number of new CHP projects for the private sector in 2017–2020, 2020–2025, and 2025–2030 for each size range, both naturally occurring and with the maximum incentive included.

[7] The maximum achievable potential was determined using a CHP incentive program modeled after Baltimore Gas and Electric's 2016 incentive. This is referred to as the *maximum incentive* in this report.

Table 11. Maximum Achievable Potential from 2017–2030: Number of Private Sector CHP Projects With and Without Maximum Incentive

Size Range	Estimated Number of New Private Sector CHP Projects							
	Naturally Occurring Potential: Private Sector				Potential with Maximum Incentive: Private Sector			
	2017–2020	2020–2025	2025–2030	Total 2017–2030	2017–2020	2020–2025	2025–2030	Total 2017–2030
1–5 MW (~$1.8 million per project)	2	7	4	**13**	13	29	14	**56**
5–20 MW ($2.5 million per project)	1	3	1	**5**	2	4	1	**7**
>20 MW ($2.5 million per project)	2	3	1	**6**	2	3	1	**6**
All Size Ranges	**5**	**13**	**6**	**24**	**17**	**36**	**16**	**69**

As with the ComEd program potential, applying this incentive primarily has an effect on CHP projects using 1–5 MW engines. In fact, compared to the estimated potential with the ComEd program, the only new CHP installations that would move forward with the maximum incentive are in the 1–5 MW size range. Overall, the total number of 1–5 MW CHP systems installed from 2017–2030 would quadruple compared to the number of installations from naturally occurring potential.

Generally, there are few facilities capable of supporting CHP systems over 5 MW in size, and the economics for high load factor applications that can support these systems are already strong. So in these larger size ranges, the incentives would primarily support free riders.

Table 12 depicts the estimated program costs for the maximum incentive by year, compared to the free rider cost for each size range. As with the ComEd program, the free rider percentage is limited to 32 percent of the total program costs for the maximum achievable potential scenario. This is the recommended planning percentage for ComEd's custom projects.[8]

Administrative costs are assumed to be 9 percent of the total program incentive cost, based on typical commercial and industrial energy efficiency program costs as well as specific costs for the Baltimore Gas & Electric CHP grant program, which are in the range of 8–10 percent for implementation and administrative support.

[8] The Illinois Stakeholder Advisory Group's recommended net-to-gross ratio for program year 8 is 68 percent, which suggests a free ridership percentage of 32 percent.

Table 12. Estimated Program Costs for Maximum Achievable CHP Incentive

Year	Annual Private Sector Program Funding* (thousand $)		Cumulative Private Sector Program Funding* (thousand $)	
	Free Riders	ComEd Maximum Incentive	Free Riders	ComEd Maximum Incentive
2017	$0	$0	$0	$0
2018	$3,870	$12,100	$3,870	$12,100
2019	$3,870	$12,100	$7,740	$24,200
2020	$3,870	$12,100	$11,610	$36,300
2021	$4,450	$13,900	$16,060	$50,200
2022	$4,450	$13,900	$20,510	$64,100
2023	$4,450	$13,900	$24,960	$78,000
2024	$4,450	$13,900	$29,410	$91,900
2025	$4,450	$13,900	$33,860	$105,800
2026	$1,920	$5,990	$35,780	$111,790
2027	$1,920	$5,990	$37,700	$117,780
2028	$1,920	$5,990	$39,620	$123,770
2029	$1,920	$5,990	$41,540	$129,760
2030	$1,920	$5,990	$43,460	$135,750

* Funding applied to new CHP projects, with a 32 percent free rider limitation

Includes program implementation and administration, at 9 percent of the incentive cost

Overall, the program cost for maximum achievable incentive through 2030 is estimated at $135.8 million. Compared to the naturally occurring potential, the expected number of CHP projects for ComEd from 2017 to 2030 would nearly triple with the maximum incentive, due almost entirely to projects that would move forward with CHP engines in the 1–5 MW size range. While the number of smaller CHP projects would increase substantially with this incentive, it would require a funding increase of nearly 100 percent compared to the ComEd program incentive. While the ComEd incentive required $68.9 million for 56 total CHP projects, the maximum incentive would require $135.8 million for 69 total projects to move forward from 2017 to 2030.

Summary

The presence of the ComEd CHP incentive is likely to triple the number of expected CHP installations in the 1–5 MW size range from 2017 to 2030. The economics for projects at hospitals, colleges, hotels, small manufacturing facilities, and other high load factor CHP applications in this size range would improve substantially with the incentive. Larger projects with CHP systems over 5 MW may also take advantage of the incentive, but there are not as many ComEd sites with this level of CHP potential, and most of them would be considered free riders, likely to move forward with CHP with or without the incentive. Effective pre-screening of potential CHP program customers is expected to limit free ridership to about 32 percent of the total program cost.

CHP economics in ComEd's territory continue to be challenging for projects smaller than 1 MW. Even with the maximum incentive[9] applied, none of these small projects are estimated to have attractive economics for customers to adopt CHP when using natural gas as a fuel. There may be opportunities for smaller systems using biomass or waste fuels that were not analyzed in this study.

There are many potential CHP projects in the 1–5 MW range, which is where the economics and performance of reciprocating engines begin to substantially improve. With the maximum incentive applied, the number of CHP installations in the 1–5 MW size range would quadruple compared to the naturally occurring potential from 2017 to 2030.

Even when estimating the maximum achievable potential, the number of CHP installations over 5 MW does not substantially increase compared to the naturally occurring potential, and most of these projects would be considered free riders if they applied for the incentive.

Overall, with the ComEd program incentive, about 340 MW of CHP capacity is expected to come online from 2017 to 2030 in the private sector. This is an increase of 100 MW, or about 750 GWh/year by 2030, compared to the naturally occurring potential. Most of this new potential would come from CHP systems in the 1–5 MW size range at industrial facilities, colleges, hospitals, and other high load factor applications. The total program costs for ComEd's CHP incentive are expected to reach about $69 million through 2030. Increasing the available incentive for CHP systems would further improve market penetration, but the associated program costs would become substantially higher for a relatively small increase in CHP capacity.

[9] The maximum achievable potential was determined using a CHP incentive program modeled after Baltimore Gas and Electric's 2016 incentive. This is referred to as the *maximum incentive* in this report.