4. Combined Heat and Power

Navigant conducted an analysis of combined heat and power (CHP) systems to identify DSM opportunities from this technology. Navigant developed a stand-alone model for this analysis because the approach varied considerably from the analysis of EE measures considered in this study and because the results from this analysis indicate a large, but uncertain potential from CHP systems. Using this tool, Navigant evaluated the cost-effectiveness of CHP systems driven by a range of prime-movers, system configurations, and usage levels and then identified individual customers that may be well suited to the systems that we found to be cost effective.

Navigant limited this analysis to large commercial and industrial customers and assumed that CHP systems would be fueled by natural gas. Although the model is capable of analyzing both natural gas-fired and opportunity fuel-fired systems, Navigant did not have the data available to determine the availability of opportunity fuels at or near sites. This type of analysis must be highly customized to individual sites and must include a valuation of opportunity fuel feed stocks currently used for other purposes (or disposed of). This type of analysis was beyond the scope of this study.

4.1 *CHP Methodology*

Navigant used the following approach to determine CHP potential:

1. Collect input data for measure characterization.
2. Screen available CHP technologies for TRC cost-effectiveness.
3. Screen TRC cost-effective technologies for participant test cost-effectiveness.
4. Identify customer base suited to cost-effective systems.
5. Estimate economic and achievable potential.
6. Model technology diffusion to estimate incremental and cumulative adoption over time.

4.1.1 CHP Input Data

Navigant collected the following data in order to determine measure cost-effectiveness

» Avoided energy costs ($/kWh) – avoided costs ($/MWh) provided for on-peak, off-peak, and weekend times of use, by month and year. See section 3.7.1 for avoided energy cost assumptions.

» Avoided electric capacity costs ($/kW-yr) – See section 3.7.1 for avoided capacity cost assumptions.

» Avoided natural gas costs – Natural gas costs (in $/1000 cubic feet) from the U.S. DOE EIA forecast of MidContinent wellhead gas prices[46].

[46]U.S. DOE EIA, website "Annual Energy Outlook 2011" http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2011&subject=8-AEO2011&table=72-AEO2011&region=0-0&cases=ref2011-d020911a

- Retail electricity costs – Current large general service rates ($/kWh) in KCP&L territory, marginal rate (over 360 hours of use) used for 2012[47]. To forecast rates beyond 2012, an annual escalation of 2.3% of 2012 rates was assumed.
- Retail electric capacity costs - Current large general service rates ($/kW/month) in KCP&L territory, marginal rate (over 7,500 kW) used for 2012[48]. To forecast rates beyond 2012, an annual escalation of 2.3% of 2012 rates was assumed.
- Retail natural gas costs - Natural gas costs (in $/1000 cubic feet) from the U.S. DOE EIA forecast of industrial gas prices for the west-north-central census division[49].
- CHP prime-mover costs and performance - Capital cost ($/kW), operation and maintenance (O&M) Cost ($/kWh), heat rate (Btu/kWh), electric output to thermal output ratio (E/T) (kWh/kWh), lifetime (years), and availability (unitless) for CHP systems of a range of sizes driven by reciprocating engines, microturbines, fuel cells, steam turbines and gas turbines developed from data from several sources[50,51,52].
- Absorption chiller costs and performance – Coefficient of performance (COP), capital cost ($/ton), O&M cost ($/ton-year) from the Midwest Clean Energy Application Center[53]
- Discount rate – After tax discount rates for each utility provided by the Companies (see section 3.7.1).
- Technology diffusion rate - Assumed a bass diffusion model with a marketing effectiveness (p) of 0.03 and word-of-mouth strength (q) of 0.365[54]. A start year of 2014 was assumed, based on the time required to get projects of this magnitude implemented.

Additionally, Navigant made the following assumptions in the model

- System usage – high, medium, and low case scenarios were considered, each with different assumptions about the percentage of CHP system equivalent full load hours during each time of use:
    - High case: 95% of on-peak hours, 80% of off-peak hours, 80% of weekend hours

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[47] KCP&L, "Commercial and industrial electric service pricing." http://www.kcpl.com/brochures/CIPricing_KS.pdf
[48] KCP&L, "Commercial and industrial electric service pricing.", http://www.kcpl.com/brochures/CIPricing_KS.pdf
[49] U.S. DOE EIA, website "Annual Energy Outlook 2011" http://205.254.135.7/forecasts/archive/aeo11/source_natural_gas.cfm
[50] Combined Heat and Power: Policy Analysis and 2011-2030 Market Assessment (2012). Prepared for the California Energy Commission by ICF International. http://www.meede.org/wp-content/uploads/CHP-Policy-Analysis_Market-Assessment_California_Feb-20121.pdf
[51] US EPA Catalog of CHP Technologies. http://www.epa.gov/chp/basic/catalog.html
[52] Itron, Inc., "CPUC Self-Generation Incentive Program Tenth-Year Impact Evaluation, Final Report" http://www.cpuc.ca.gov/NR/rdonlyres/CF952F3B-0C3C-481D-968A-420F92FC2901/0/SGIP_2010_Impact_Eval_Report.pdf
[53] Midwest Clean Energy Application Center, Combined Heat and Power Resource Guide, http://www.midwestcleanenergy.org/Archive/pdfs/chp_resource_guide_2003sep.pdf
[54] See Mahajan, V., Muller, E., and Wind, Y. (2000). New Product Diffusion Models. Springer. Chapter 12 for estimation of the Bass diffusion parameters for dozens of technologies. This model uses the median value of 0.365 for the word-of-mouth strength in the base case scenario. The Marketing Effectiveness parameter was assumed to be 0.03, representing a somewhat aggressive value that exceeds the most likely value of 0.021 (75th percentile value is 0.055) per Mahajan 2000 but is slightly lower than the 0.04 value used for EE due to the higher complexity of CHP applications.

- Medium case: 80% of on-peak hours, 25% of off-peak hours, 25% of weekend hours
- Low case: 70% of on-peak hours, 0% of off-peak hours, 0% of weekend hours

» Thermal energy utilization – 85% of recovered heat from the CHP system was assumed to be utilized.

» Fuel for heat efficiency – a base case heating efficiency of 77% was assumed, the base case heating fuel was assumed to be natural gas

» Cooling coefficient of performance – a base case cooling COP of 5 was assumed, the base case cooling fuel was assumed to be electricity

» Project first year program administrative costs - $0.01/annual kWh reduction, modeled as a one-time cost applied at the start of the project.

» Project ongoing program administrative costs - $0.001/annual kWh reduction, modeled as an annual cost applied to the second through tenth years of the project.

4.1.2 CHP TRC Screening

Navigant began the analysis by determining what types of CHP systems would pass the TRC test. Navigant did not include administrative costs in this measure-level analysis. Navigant could then focus the remainder of the analysis on these specific systems and the sites that these CHP systems would likely be suited to.

For the TRC screening, systems defined by all possible combinations of the following parameters were considered:

» Prime mover – fuel cell, gas turbine, micro turbine, reciprocating engine, steam turbine,

» System size – a range of sizes appropriate to each technology was considered

» Heat utilization – heating, cooling, or both. Any system using heat for cooling included the costs of an absorption chiller sized to that CHP system.

» Usage - the low, medium, and high usage cases described above

Each possible system was analyzed using a detailed model of energy generation, net changes in electricity and natural gas consumption (relative to a base case of no on-site generation), and costs (capital, O&M, program administration, net electricity and natural gas costs). Navigant considered each time of use period in each month of the system's expected lifetime. From the usage case definitions, we determined the number of equivalent full load hours in each time of use period and the computed the fuel requirements, energy offsets, and O&M costs for that time of use period.

As discussed below in the Results subsection, Navigant found that some steam turbines and gas turbines with electrical capacity of 500 kW and larger passed the TRC screening, primarily systems which used recovered heat for heating or for heating and cooling. While Navigant found gas turbines under 5 MW to be not cost effective, this contradicts Navigant's observation that gas turbines in the 2.5 MW to 5 MW, 5 MW to 10 MW, and 10 MW to 50 MW ranges are adopted at higher rates than steam turbines[55]. We

[55] Navigant reviewed all CHP installations reported in the ICF International CHP Installation database (http://www.eea-inc.com/chpdata/index.html) in Texas, Louisiana, Oklahoma, Arkansas, Kansas, Missouri, Illinois, Nebraska, and Iowa from 2004 to the present. We observed that gas turbines were three times as prevalent as steam

recognize the considerable uncertainty in our capital cost estimates and decided that combining technologies to define measures would reflect the CHP market most accurately. Navigant therefore developed measures by electrical capacity of systems, rather than prime-movers, and used a weighted average of results from steam turbines and gas turbine in each measure. We have identified in bold the considered systems in Table 4-1 and state the weightings used to define each measure in Table 4-5. Navigant only considered measures with a weighted average TRC of 1.0 or greater in our analysis of economic potential.

In addition to the measure level TRCs, which did not include program administrative costs, Navigant computed a program-level TRC, which *did* include administrative costs. To do this, Navigant first identified all measures with a measure-level TRC (excluding administrative costs) of one or greater. Navigant then took a weighted average of the TRCs of these measures, this time computed *inclusive* of administrative costs. The weighting of measures was proportional to each measure's annual kWh potential.

4.1.3 CHP Participant Test Screening

Navigant's next step was to determine the participant cost-effectiveness of systems passing the TRC screen. The same model used for TRC screening was used for the participant test. However, avoided costs were replaced by retail rates, and incentives were included.

Navigant found that no systems passed a participant test without incentives. This finding was corroborated by the current and historical lack of CHP adoption in the region. However, Navigant found that when incentives on par with those offered elsewhere in the U.S. were included, the systems that passed the TRC screen also passed the participant test. The incentive level used for the results provided in this report was a performance-based incentive of $0.03/kWh, for the first 10 years of the system operation.

A common problem with CHP systems is that they do not remain online as long as the expected lifetime assumed by the program incenting them[56]. To address this issue, Navigant modeled incentives as long-term, performance based incentives, rather than upfront rebates. While the logistics of implementing a 10 year period of monitoring and incentives may be challenging, this financial structure ensures that the ongoing economics of self-generation remain favorable for much of the expected lifetime of the system.

4.1.4 CHP Target Market Identification

After determining the systems that passed TRC and participant tests, Navigant identified customers that that would be candidates for adoption of the large CHP systems being considered. Customers were considered candidates if they had an onsite demand for heating and/or cooling on par with the thermal output of a given CHP system.

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turbines in the 2.5 MW to 5 MW capacity range, and twice as prevalent as steam turbines in the 5 MW to 50 MW capacity range. No gas turbines smaller than 2.5 MW were observed.

[56] For example, the California Self Generation Incentive Program found that capacity factors for fuel cells, reciprocating engines, and micro turbines fell to nearly half of their initial levels within six years. Itron, Inc. 2011 "CPUC Self-Generation Incentive Program, Tenth-Year Impact Evaluation" for PG&E and the SGIP Working Group.

Navigant's analysis was limited by the information available on customers. The customer database provided to Navigant by KCP&L identified the annual electricity consumption and the building/business type of customers. Navigant assumed that these largest customers used natural gas to provide heating and that their heating and cooling loads – relative to their electric loads – followed patterns observed in other regions of the country for similar analyses. Navigant could not identify customers with access to opportunity fuels such as biogas or combustible agricultural waste: this would have required a detailed study of individual customers, their processes, and their existing valuation of the byproducts of their processes. Table 4-2 through Table 4-4 in the Results section summarize the number of customers, by building or industry type, identified as candidates for each size CHP system.

4.1.5 CHP Economic and Achievable Potential

Navigant defined economic potential as the summation of CHP potential at all sites identified as candidates for CHP systems. Table 4-6 through Table 4-9 in the Results subsection summarize the economic potential of CHP systems at each utility and collectively.

Navigant estimated achievable CHP potential based on their analysis of adoption of high cost ($100,000 and greater) energy efficiency measures in the U.S. Department of Energy's Industrial Assessment Center (IAC) database[57]. The IAC database documents EE measures recommended to industrial sites as part of a standardized energy audit conducted by IAC members. CHP is not considered in these audits. Auditors estimate the cost and simple payback period of each recommendation. Auditors revisit sites approximately one year after the audit and document which recommendations were implemented. From this data, Navigant was able to develop a payback acceptance curve for high-cost measures. There were only a few measures in the database as expensive (multi-million dollar) as MW-scale CHP systems. Navigant therefore examined all recommended measures that cost $100,000 or more.

At an incentive level of $0.03/kWh, the cost-effective CHP measures have a simple payback period of 1.6 to 6.5 years. For the IAC-based payback acceptance curve, measures in this payback range had an adoption rate of 27 to 34%. Navigant therefore assumed that one third of economic potential was realistically achievable. The large capital costs of these systems make them incomparable to other energy efficiency measures, so that the traditional payback acceptance curves used for other EE measures would not apply here. The relatively low ratio of achievable to economic potential reflects significant technical, financial, and institutional barriers to the adoption of large mechanical systems.

Measures with a payback period less than six months had an adoption rate of approximately 40% on the IAC-based payback acceptance curve. Navigant assumed a maximum achievable potential of 50% to account for this observed maximum adoption rate plus additional adoption facilitated by financing arrangements (e.g. third party ownership) that would be more likely to be available for CHP systems than for the EE measures in the IAC database. The maximum achievable potential scenario assumes the same $0.03/kWh incentive level as the realistic achievable potential scenario for CHP. Therefore these two scenarios are intended to reflect the uncertainty in the likely adoption of these expensive and complex measures.

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[57] http://iac.rutgers.edu/database/

4.1.6 Technology Diffusion

As discussed above, Navigant assumed CHP technology diffusion curve comparable to that used in the other portions of this potential study. However, the curve was shifted forward in time (first participants in 2015), based on the time required to get projects of this magnitude implemented.

This diffusion assumption results in a fractional number of participants per year. In reality, the total number of achievable participants is small (~24 per utility) and the incremental participation in a given year would be discrete and may be zero in some years.

4.2 CHP Results

Table 4-1 states the cost and performance parameters assumed for each considered CHP system, and the resulting TRC values for the high usage cases for each of the three thermal output utilization scenarios (heating, cooling, heating and cooling). Steam turbines and gas turbines are the only technologies to pass the TRC test. Table 4-2 through Table 4-4 summarize the number of candidate customers identified for each utility, by customer segment and size of system (in kW of electrical capacity). More than half of the candidate sites for systems 1 MW and larger are in the "Chemicals" segment. About 41% of the candidate sites for systems between 500 kW and 1 MW are in the "Food" segment. Candidates are distributed across all three utilities.

Navigant developed a measure for each of the five largest CHP system size categories. For each measure, a weighted average of costs and impacts for steam turbines and gas turbines was used. The weights, costs, impacts, and cost-effectiveness of each measure are shown in Table 4-5.

Table 4-6 through Table 4-9 show the economic and equilibrium achievable potential for each utility. Table 4-10 shows the cumulative achievable potential by year, from 2014 to 2034.

The program-level TRC for this collection of measures is 1.42, and the participant test value is 1.70.

Although we think including gas turbines with TRCs of less than 1.0 in some measures leads to the most accurate reflection of the CHP market, as discussed in section 4.1.2, we also executed our CHP model *without* this adjustment in order to examine the impact of this decision on the potential results. For this run of the model, Navigant excluded gas turbines in the 2.5 MW to 5 MW range, so that the measure defined by this range was solely based on steam turbines results. This resulted in no change in electrical potential (by design of the analysis) and an approximately 10% increase in natural gas impact of this measure.

Table 4-1. Modeled CHP Systems[58] and Resulting TRC For High Usage Cases

Generator Type	Range	Capital Cost ($/kW)	O&M Cost ($/kWh)	Heat Rate (Btu/kWh)	Electrical to Thermal Energy Output Ratio	Lifetime (years)	Availability	TRC - thermal output for heating	TRC - thermal output for cooling	TRC - thermal output for heating and cooling
Fuel Cell	100 to 500 kW	$5,875	0.037	9307	1.28	8	0.89	0.09	0.04	0.06
Fuel Cell	500 to 1,000 kW	$5,395	0.036	8279	1.72	8	0.89	0.1	0.06	0.08
Fuel Cell	1,000 to 2,500 kW	$5,258	0.033	8022	2.16	8	0.89	0.1	0.07	0.08
Gas Turbine	500 to 1,000 kW	$3,606	0.012	16047	0.47	20	0.95	0.37	0.16	0.29
Gas Turbine	1,000 to 2,500 kW	$2,632	0.01	15240	0.53	20	0.95	0.49	0.22	0.38
Gas Turbine	**2,500 to 5,000 kW**	**$1,938**	**0.009**	**13199**	**0.66**	**20**	**0.95**	**0.72**	**0.42**	**0.59**
Gas Turbine	**5,000 to 10,000 kW**	**$1,464**	**0.008**	**11883**	**0.71**	**20**	**0.95**	**1.07**	**0.67**	**0.86**
Gas Turbine	**10,000 to 50,000 kW**	**$1,138**	**0.005**	**9462**	**1**	**20**	**0.95**	**1.68**	**1.2**	**1.39**
Microturbine	100 to 500 kW	$3,000	0.022	12247	0.69	6	0.95	0.08	0	0.01

[58] Systems identified in bold were included in our assessment of economic potential. The primary criterion for inclusion was a TRC for thermal output of heating of greater than ~1.0, though exceptions apply as discussed in section 4.1.2.

Generator Type	Range	Capital Cost ($/kW)	O&M Cost ($/kWh)	Heat Rate (Btu/kWh)	Electrical to Thermal Energy Output Ratio	Lifetime (years)	Availability	TRC - thermal output for heating	TRC - thermal output for cooling	TRC - thermal output for heating and cooling
Microturbine	500 to 1,000 kW	$2,900	0.02	12247	0.69	6	0.95	0.09	0	0.01
Reciprocating Engine	100 to 500 kW	$2,417	0.021	11501	0.68	7	0.95	0.18	0.04	0.11
Reciprocating Engine	500 to 1,000 kW	$1,840	0.015	9760	0.79	7	0.95	0.31	0.12	0.21
Reciprocating Engine	1,000 to 2,500 kW	$1,491	0.014	9616	0.88	7	0.95	0.34	0.14	0.24
Reciprocating Engine	2,500 to 5,000 kW	$1,338	0.013	9134	1.05	7	0.95	0.36	0.17	0.26
Reciprocating Engine	5,000 to 10,000 kW	$1,338	0.013	9134	1.05	7	0.95	0.36	0.18	0.26
Steam Turbine	**500 to 1,000 kW**	**$1,167**	**0.005**	**13661**	**0.5**	**15**	**0.89**	**1.15**	**0.47**	**0.73**
Steam Turbine	**1,000 to 2,500 kW**	**$950**	**0.005**	**13661**	**0.5**	**15**	**0.89**	**1.35**	**0.53**	**0.83**
Steam Turbine	**2,500 to 5,000 kW**	**$496**	**0.005**	**13661**	**0.48**	**15**	**0.89**	**2.21**	**0.78**	**1.21**
Steam Turbine	**5,000 to 10,000 kW**	**$496**	**0.005**	**13661**	**0.48**	**15**	**0.89**	**2.21**	**0.78**	**1.21**
Steam Turbine	**10,000 to 50,000 kW**	**$496**	**0.005**	**13661**	**0.48**	**15**	**0.89**	**2.21**	**0.78**	**1.21**

Table 4-2. Number of Candidate Customers by Segment and CHP Electrical Capacity - GMO

Segment	Application of Waste Heat	Usage Case	500 to 1,000 kW	1,000 to 2,500 kW	2,500 to 5,000 kW	5,000 to 10,000 kW	10,000 to 50,000 kW	Total
Chemicals	Heating	High		6			1	7
Fab Metals	Heating	High	4					4
Food	Heating	High	8	3				11
Healthcare	Heating and Cooling	Medium	1					1
Motor Freight Transportation	Heating	High	2					2
Office - Large	Heating and Cooling	Low	3	1				4
Other Industrial	Heating	High	1					1
Rubber-Plastics	Heating	High		1				1
Stone-Clay-Glass	Heating	High			2			2
Transportation Equipment	Heating	High	1					1
		Total	20	11	2	0	1	34

Table 4-3. Number of Candidate Customers by Segment and CHP Electrical Capacity – KCP&L MO

Segment	Application of Waste Heat	Usage Case	500 to 1,000 kW	1,000 to 2,500 kW	2,500 to 5,000 kW	5,000 to 10,000 kW	10,000 to 50,000 kW	Total
Chemicals	Heating	High		3			2	5
Food	Heating	High	4	2		1		3
Healthcare	Heating and Cooling	Medium	6					
Office - Large	Heating and Cooling	Low	2	1				1
Petroleum	Heating	High		2				2
Rubber-Plastics	Heating	High		1				1
Stone-Clay-Glass	Heating	High		1	1			2
		Total	12	10	1	1	2	26

Table 4-4. Number of Candidate Customers by Segment and CHP Electrical Capacity – KCP&L KS

Segment	Application of Waste Heat	Usage Case	500 to 1,000 kW	1,000 to 2,500 kW	2,500 to 5,000 kW	5,000 to 10,000 kW	10,000 to 50,000 kW	Total
Segment	Application of Waste Heat	Usage Case	500 to 1,000 kW	1,000 to 2,500 kW	2,500 to 5,000 kW	5,000 to 10,000 kW	10,000 to 50,000 kW	Total
Chemicals	Heating	High		6				6
Food	Heating	High	3					3
Healthcare	Heating and Cooling	Medium	1					1
Motor Freight Transportation	Heating	High	1					1
Office - Large	Heating and Cooling	Low		1				1
Rubber-Plastics	Heating	High		1				1
		Total	5	8	0	0	0	13

Table 4-5. Measure Level Results

CHP System Range	Measure % Steam Turbine	Measure % Gas Turbine	Capital Cost per CHP system (without incentive)	Annual O&M Costs	Annual NG Increase (therms)	Annual Electricity Reduction (kWh)	Annual Demand Reduction (kW)	Measure Life (years)	TRC	Participant Test	Number of Candidate Sites
500 to 1,000 kW	100%	0%	$875,250	$25,422	311,297	5,084,348	712	15	1.15	1.39	37
1,000 to 2,500 kW	100%	0%	$1,662,500	$59,317	726,360	11,863,478	1,662	15	1.35	1.62	29
2,500 to 5,000 kW	33%	67%	$5,483,025	$205,573	1,848,695	26,570,000	3,561	18	1.21	1.28	3
5,000 to 10,000 kW	33%	67%	$8,584,200	$374,785	3,365,108	53,140,001	7,121	18	1.45	1.51	1
10,000 to 50,000 kW	33%	67%	$27,784,200	$1,062,800	12,178,350	212,560,002	28,485	18	1.85	1.92	3

Table 4-6. Economic and Achievable Potential by CHP System Size for All Utilities

Measure	Economic Potential - kWh	Economic Potential - kW	Realistically Achievable Potential - kWh	Realistically Achievable Potential - kW	Maximum Achievable Potential - kWh	Maximum Achievable Potential - kW
500 to 1,000 kW	188,120,858	26,349	62,079,883	8,695	94,060,429	13,174
1,000 to 2,500 kW	344,040,848	48,187	113,533,480	15,902	172,020,424	24,094
2,500 to 5,000 kW	79,710,001	10,682	26,304,300	3,525	39,855,000	5,341
5,000 to 10,000 kW	53,140,001	7,121	17,536,200	2,350	26,570,000	3,561
10,000 to 50,000 kW	637,680,006	85,455	210,434,402	28,200	318,840,003	42,728
Total	1,302,691,712	177,794	429,888,265	58,672	651,345,856	88,897

Table 4-7. Economic and Achievable Potential by CHP System Size – GMO

Measure	Economic Potential - kWh	Economic Potential - kW	Realistically Achievable Potential - kWh	Realistically Achievable Potential - kW	Maximum Achievable Potential - kWh	Maximum Achievable Potential - kW
Measure	Economic Potential - kWh	Economic Potential - kW	Achievable Potential - kWh	Achievable Potential - kW	Maximum Achievable Potential - kWh	Maximum Achievable Potential - kW
500 to 1,000 kW	101,686,950	14,243	33,556,694	4,700	50,843,475	7,121
1,000 to 2,500 kW	130,498,253	18,278	43,064,423	6,032	65,249,126	9,139
2,500 to 5,000 kW	53,140,001	7,121	17,536,200	2,350	26,570,000	3,561
5,000 to 10,000 kW	-	-	-	-	-	-
10,000 to 50,000 kW	212,560,002	28,485	70,144,801	9,400	106,280,001	14,243

Table 4-8. Economic and Achievable Potential by CHP System Size – KCP&L MO

Measure	Economic Potential - kWh	Economic Potential - kW	Achievable Potential - kWh	Achievable Potential - kW	Maximum Achievable Potential - kWh	Maximum Achievable Potential - kW
500 to 1,000 kW	61,012,170	8,546	20,134,016	2,820	30,506,085	4,273
1,000 to 2,500 kW	118,634,775	16,616	39,149,476	5,483	59,317,388	8,308
2,500 to 5,000 kW	26,570,000	3,561	8,768,100	1,175	13,285,000	1,780
5,000 to 10,000 kW	53,140,001	7,121	17,536,200	2,350	26,570,000	3,561
10,000 to 50,000 kW	425,120,004	56,970	140,289,601	18,800	212,560,002	28,485
Total	684,476,950	92,814	225,877,393	30,628	342,238,475	46,407

Table 4-9. Economic and Achievable Potential by CHP System Size – KCP&L KS

Measure	Economic Potential - kWh	Economic Potential - kW	Achievable Potential - kWh	Achievable Potential - kW	Maximum Achievable Potential - kWh	Maximum Achievable Potential - kW
500 to 1,000 kW	25,421,738	3,561	8,389,173	1,175	12,710,869	1,780
1,000 to 2,500 kW	94,907,820	13,293	31,319,581	4,387	47,453,910	6,647
2,500 to 5,000 kW	-	-	-	-	-	-
5,000 to 10,000 kW	-	-	-	-	-	-
10,000 to 50,000 kW	-	-	-	-	-	-
Total	120,329,558	16,854	39,708,754	5,562	60,164,779	8,427

Table 4-10. Cumulative Realistic Achievable Potential by Year

Year	GMO - GWh	GMO - MW	KCP&L MO - GWh	KCP&L MO - MW	KCP&L KS - GWh	KCP&L KS - MW	All Utilities - GWh	All Utilities - MW
2014	-	-	-	-	-	-	-	-
2015	2.30	0.31	3.16	0.43	0.56	0.08	6.02	0.82
2016	4.60	0.63	6.32	0.86	1.11	0.15	12.04	1.64
2017	11.50	1.57	15.81	2.16	2.78	0.38	30.09	4.11
2018	20.70	2.83	28.46	3.88	5.00	0.68	54.17	7.39
2019	32.20	4.40	44.27	6.04	7.78	1.06	84.26	11.50
2020	46.17	6.30	63.47	8.66	11.16	1.52	120.80	16.49
2021	62.27	8.50	85.61	11.68	15.05	2.05	162.93	22.24
2022	79.52	10.85	109.32	14.92	19.22	2.62	208.07	28.40
2023	96.94	13.23	133.27	18.19	23.43	3.20	253.63	34.62
2024	113.04	15.43	155.40	21.21	27.32	3.73	295.76	40.37
2025	126.68	17.29	174.15	23.77	30.62	4.18	331.44	45.24
2026	137.69	18.79	189.29	25.83	33.28	4.54	360.25	49.17
2027	146.06	19.94	200.81	27.41	35.30	4.82	382.17	52.16
2028	151.98	20.74	208.94	28.52	36.73	5.01	397.65	54.27
2029	156.09	21.30	214.58	29.29	37.72	5.15	408.39	55.74
2030	158.72	21.66	218.20	29.78	38.36	5.24	415.27	56.68
2031	160.36	21.89	220.46	30.09	38.76	5.29	419.57	57.26
2032	161.34	22.02	221.81	30.27	38.99	5.32	422.15	57.62
2033	162.00	22.11	222.72	30.40	39.15	5.34	423.87	57.85
2034	162.17	22.13	222.94	30.43	39.19	5.35	424.30	57.91

Table 4-11. Cumulative Maximum Achievable Potential by Year

Year	GMO - GWh	GMO - MW	KCP&L MO - GWh	KCP&L MO - MW	KCP&L KS - GWh	KCP&L KS - MW	All Utilities - GWh	All Utilities - MW
2014	-	-	-	-	-	-	-	-
2015	3.49	0.48	4.79	0.65	0.84	0.11	9.12	1.24
2016	6.97	0.95	9.58	1.31	1.68	0.23	18.24	2.49
2017	17.43	2.38	23.96	3.27	4.21	0.57	45.59	6.22
2018	31.37	4.28	43.12	5.89	7.58	1.03	82.07	11.20
2019	48.79	6.66	67.08	9.16	11.79	1.61	127.66	17.42
2020	69.95	9.55	96.17	13.13	16.91	2.31	183.03	24.98
2021	94.35	12.88	129.71	17.70	22.80	3.11	246.86	33.69
2022	120.49	16.44	165.64	22.61	29.12	3.97	315.25	43.03
2023	146.88	20.05	201.92	27.56	35.50	4.84	384.29	52.45
2024	171.27	23.38	235.46	32.14	41.39	5.65	448.13	61.16
2025	191.93	26.20	263.87	36.01	46.39	6.33	502.19	68.54
2026	208.61	28.47	286.80	39.14	50.42	6.88	545.83	74.50
2027	221.31	30.20	304.25	41.52	53.49	7.30	579.05	79.03
2028	230.27	31.43	316.57	43.21	55.65	7.60	602.49	82.23
2029	236.50	32.28	325.13	44.37	57.16	7.80	618.78	84.45
2030	240.48	32.82	330.60	45.12	58.12	7.93	629.20	85.87
2031	242.97	33.16	334.02	45.59	58.72	8.01	635.71	86.76
2032	244.46	33.36	336.08	45.87	59.08	8.06	639.62	87.30
2033	245.46	33.50	337.45	46.06	59.32	8.10	642.23	87.65
2034	245.71	33.53	337.79	46.10	59.38	8.10	642.88	87.74

4.3 CHP Conclusions

MW-scale steam- and gas-turbine CHP systems appear to be cost-effective in the KCP&L territory. While the number of sites with achievable potential is small (~24 per utility), the equilibrium realistic achievable potential is approximately 58 MW. Candidate sites include both traditional CHP adopters (i.e, industrial and medical sites) and less typical CHP adopters that could utilize thermal energy for both heating and cooling (i.e., large offices).

Additional potential may exist at sites with access to opportunity fuels, such as waste water treatment facilities, agricultural sites, and wood processing sites. However, a custom analysis would be required of each site to address highly variable factors such as the quantity of available fuel, and the economics of using the opportunity fuel for power generation instead of its current use, and the need/ability to export generated power. Historically, CHP systems have been mothballed when natural gas prices rise; systems fueled by opportunity fuels do not bear this risk.

Regardless of the fuel, valuable services that can potentially be provided to customers are identifying candidate sites, providing preliminary cost-effectiveness analyses, and providing independent review of contractor proposals and savings claims.

Long term performance based incentives could help ensure that project economics remain favorable – and that systems remain in operation – for the expected lifetime of the systems.

Finally, it is important to recognize that there is an expected small number of participants, which will inevitably have discrete patterns of incremental participation -- likely be one or two new participants in some years and zero in others.