Self-Generation Incentive Program

Combined Heat and Power Performance Investigation

Presented to

The SGIP Working Group

April 1, 2010

Presented by

SUMMIT BLUE CONSULTING
A part of Navigant Consulting
1722 14th St., Suite 230
Boulder, CO 80302

phone 720.564.1130
fax 720.564.1145

www.navigantconsulting.com

Submitted to:

Betsy Wilkins, Evaluation Manager for the SGIP Working Group

Submitted by:

Summit Blue Consulting
A part of Navigant Consulting, Inc.
1722 14th Street, Suite 230
Boulder, CO 80302
720.564.1130

Prepared by:

Jennifer Barnes, Jennifer.Barnes@NavigantConsulting.com
Ryan Firestone, Ryan.Firestone@NavigantConsulting.com
Kevin Cooney, Kevin.Cooney@NavigantConsulting.com

Table of Contents

Section 1. Introduction

The CPUC Self-Generation Incentive Program (SGIP) Eighth-Year Impact Evaluation[1] identified dramatic decreases in capacity factors for combined heat and power (CHP) systems driven by internal combustion (IC) engines and microturbines. The average capacity factor of these systems decreased by approximately 30 percentage points from the first to the sixth year. The report stated that "understanding reasons for changes requires additional process evaluation information."

The SGIP operates in the service areas of Pacific Gas and Electric (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), and the San Diego Gas and Electric Company (SDG&E). The SGIP is administered by PG&E, SCE, and SCG in their respective territories. The California Center for Sustainable Energy (CCSE) administers the SGIP in SDG&E's territory.[2]

This report documents the examination of performance decline for CHP systems in the SGIP. Performance decline and related metrics were determined for natural gas fired fuel cells, microturbines, internal combustion (IC) engines, and gas turbines from metered hourly system output data for all 208 metered participating sites across California from 2002 through 2008.[3] Phone interviews with representatives from 43 sites[4] were used to enhance findings.

The population of metered CHP systems is assumed to be representative of the entire population of SGIP CHP systems. The PAs have not suggested otherwise. Therefore, the results presented in this report that are based on metered data are considered to be representative of the entire SGIP CHP population.

---

[1] Itron, Inc. "CPUC Self-Generation Incentive Program Eighth-Year Impact Evaluation – Revised Final Report", July 2009. Vancouver, WA. http://www.cpuc.ca.gov/NR/rdonlyres/11A75E09-31F8-4184-B3A4-2DCCB5FB0D2D/0/SGIP_Impact_Report_2008_Revised.pdf.

[2] Together, PG&E, SCE, SCG, and CCSE are referred to the "Program Administrators" or "PAs" in this report.

[3] Additional SGIP CHP systems were not metered and are not included in this analysis. This analysis was intended to review metered data as means of investigating observed declines in capacity factor over time. There has been no indication by the program administrators that metered sites are not representative of the SGIP CHP system population as a whole.

[4] Thirty-nine unique host customers were interviewed. Four of these host customers had two incented systems each in the interview sample.

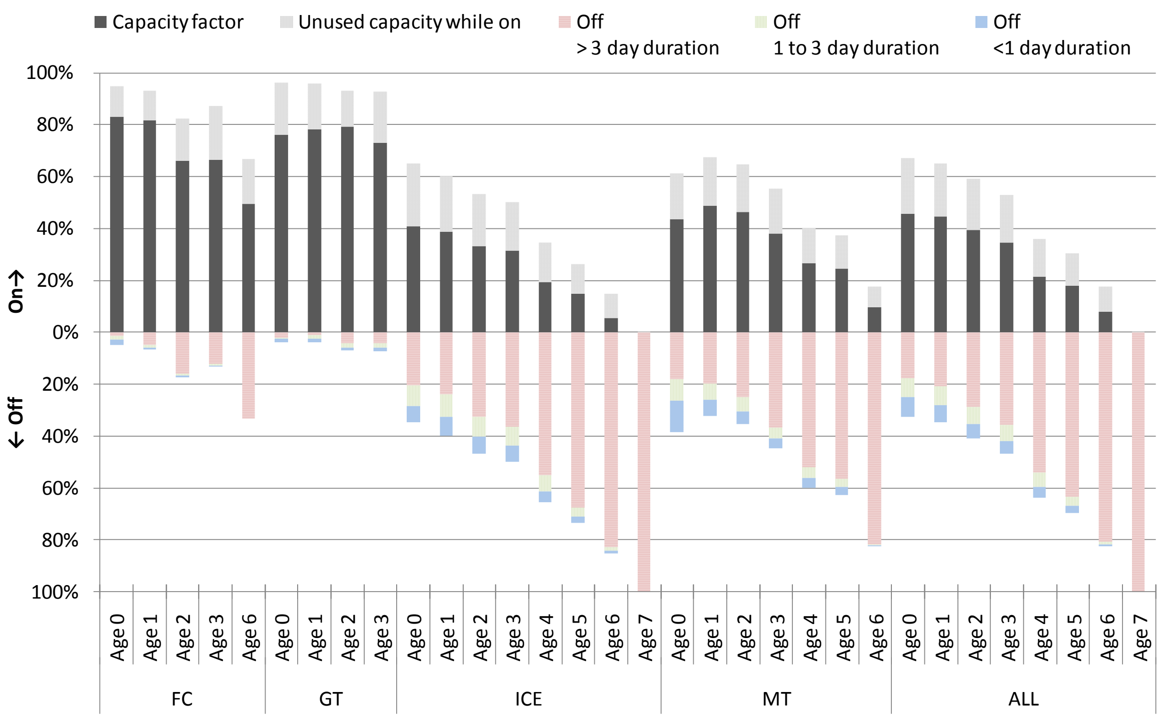
1.1 *Select Findings*

This analysis sought to characterize the observed performance degradation in SGIP CHP systems. Figure 1 graphically summarizes the most significant performance trends observed in the output data. As percentages of the full rated capacity of the system, each bar shows from top to bottom:

- **Unused capacity while on** –the unutilized capacity of the system during hours that the system is on.
- **Capacity factor** – the utilized capacity of the system.
- **Off, < 1 day duration** – the percentage of all hours that the system has zero output for less than 24 hours at a time.
- **Off, 1 to 3 day duration** - the percentage of all hours that the system has zero output for 24 to 72 hours at a time.
- **Off, > 3 day duration** - the percentage of all hours that the system has zero output for more than 72 hours at a time.

Each vertical bar has a length of 100 percent and represents the potential output of systems if they were running at rated capacity at all hours (24/7). Therefore, the solid black portion of each bar shows the capacity factor, and the other portions of the bar show unutilized potential.

Figure 1. Disaggregation of performance as percentages of rated capacity



Based on the data available for metered systems, it was observed that:

- There is a 5.9 percentage point average annual decrease in capacity factor across all technology types:
  - Due primarily to increases in time spent not operating (as a percentage of all hours, 8.2 percentage point increase per year). Increases were in long duration (greater than three days) off events.
  - Secondarily due to reductions in output level during on times (2.5 percentage point decrease in load level, relative to rated capacity, per year).

- Decreases in electrical efficiency (0.4 percentage points per year, relative to fuel input) and thermal heat recovery occurred over time (1.8 percentage points per year, relative to fuel input).

- Controlling for the cost to produce on-site electricity, on average, system aging results in a 4.3 percentage point annual reduction in capacity factor.

» On average, each increase of one cent per kWh in on-site electricity production cost reduces capacity factor by 1.2 percentage points.

» Unexpected levels of maintenance and economic complexity have dampened participant satisfaction. Mitigating risk and uncertainty to participants[5] may be as important as financial incentives. Fuel cell satisfaction appears significantly higher than that for other technologies, in part due to contracts for premium maintenance and stable energy prices.

1.2 Report Organization

The remainder of this report describes the data analysis and interviewing efforts and results. Section 2 describes the data collection process and provides basic statistics of the data. Section 3 presents year-over-year trends observed in the data, which are used to identify causes of observed performance degradation. In order to disaggregate the effects of system age and fuel costs on system output, a multivariate analysis is presented in Section 4, while Section 5 presents the results of the interviews. Section 6 discusses the results of the study as a whole.

[5] Participant risk and uncertainty can be mitigated by such mechanisms as providing stable fuel and maintenance costs and high-performance maintenance contracts.

Section 2. Data Characterization

Summit Blue Consulting (Summit Blue) received CHP output data for the 208 metered SGIP CHP projects with a total installed capacity of 107 MW. Output data from all sites were analyzed; electric billing data for 79 of these sites were also analyzed; and the hosts of 43 of these sites were interviewed to correlate host experience to observed data. This section describes the process of organizing the hourly output data.

The population of metered CHP systems is assumed to be representative of the entire population of SGIP CHP systems. The PAs have not suggested otherwise. Therefore, the results presented in this report that are based on metered data are considered to be representative of the entire SGIP CHP population.

2.1 Causes of Performance Variation

This analysis began with an enumeration of the reasons for a *perceived* variation in individual CHP system performance over time. It is important to emphasize that this is *perceived* variation because the review examined the output of the data acquisition system, not the CHP systems themselves. Variation in output could just as reasonably come from changes in the data acquisition system as from the CHP system itself.

Five general types of perceived variation were identified and are described below:

- **Type 1 - Changes in the level of output –** Over time, the average system load during times of operation may change. This can be due to:
  - **Involuntary changes, equipment efficiency –** The efficiency of equipment may change due to components settling into place or wearing-out.
  - **Voluntary changes, dispatched system output level –** Voluntary changes may be made to match system output (electric and/or thermal) to changing site energy needs or to improve system reliability.

- **Type 2 – Changes to the schedule of output –** The operating schedule of the system may change over time.
  - **Involuntary changes** – Changing maintenance requirements may alter the frequency of routine, brief (less than one day) shut-downs.
  - **Voluntary changes** – The operating schedule of the system may be changed to meet changes in site energy needs.

» **Type 3 –Elimination of output –** The system may be shut down completely for long (greater than two days) periods of time.
   - **Involuntary changes –** These periods of no output can be caused by system failures requiring maintenance expertise and parts before restarting.
   - **Voluntary changes –** Operators may voluntarily shut down their systems if the economics of operation (fuel cost, electricity costs, maintenance costs) no longer favor generation, or if their electric and thermal needs change.
   - **Involuntary to voluntary –** What begins as an involuntary outage due to system failure may be extended into a voluntary outage if an operator decides not to repair the system, or delays the repair of the system.

» **Type 4 - Changes to data acquisition that affect the reported level of output –** CHP system output is assumed from data acquisition reports. However, data acquisition systems are subject to modification in reported output due to:
   - **Transducer drift** – Over time, the sensors measuring power or current may drift from calibration. This drift should be unbiased and would not be expected to affect average values observed in the population.
   - **Change in transducer placement** – The placement of the sensors can affect the reported output. Sensors may be unintentionally moved.

   The accumulated impact of these Type 4 changes to data acquisition equipment could distort the perceived effects of Type 1 changes.

» **Type 5 - Changes to data acquisition system that eliminate reported output (i.e., no output reported after change) –** A report of no output, or of missing data, can be the result of the following data acquisition related occurrences:
   - Failure of data acquisition system (including communication equipment and systems).
   - Termination of data acquisition service.
   - Removal or displacement of transducers from the CHP system (possibly unknowingly during a repair/modification).

   Type 5 variation appears as data gaps in the output data.

All of these types of variation, except for Type 4 variation, are uniquely observable in the system output data and are reported on in this analysis. Types 1, 2, and 3 variation can each have involuntary (equipment performance) or voluntary (typically directly or indirectly due to project economics) causes.

2.2 *SGIP CHP Output Data*

Output data were disaggregated into hours of missing data, hours of zero output,[6] and all other hours (deemed "normal" or "on" hours). A dataset was created that contained an observation for each hour from the first output hour of each CHP site to the end of 2008. Based on these fields, each record was characterized by:

» **On hours -** Hours of system operation that recorded an electric net generation output greater than two percent of rated capacity. Allowing a two percent threshold minimizes false positives caused by data acquisition signal noise or drift.

» **Off hours** - Hours of system operation that recorded an electric net generation output less than two percent of rated capacity.

» **Missing** - Some hours were missing from the dataset and were considered data gaps. It is assumed for this study that data gaps occurred because of problems with the data acquisition system rather than because of problems with the CHP system. The corollary of this assumption is that the operation of the CHP systems during the data gaps is the same as what is seen during the periods of recorded data. Hours of use, output levels, and zero use would all be similar. Essentially, data gaps were ignored in this study of the causes of system degradation.[7]

The original dataset provided to Summit Blue contained estimates of annual capacity factor for each site and year. This annual capacity factor was developed by Itron, Inc. for its annual SGIP impact evaluations after careful review of the data patterns for each site. The capacity factors provided do not necessarily match the simple average of all the hours of operation and zero hours and, therefore, may have been adjusted by Itron, Inc. for the likelihood of operating

---

[6] For this analysis, all hours with output less than two percent of rated capacity were deemed "zero" hours. This prevents data acquisition signal noise while a system is not running from being interpreted as an "on" hour.

[7] It is possible that some missing data is actually due to CHP system failure, rather than data acquisition failure. Further study into the causes of missing data would be required to determine the extent to which CHP system failure results in data gaps. However, if the system output during periods of data gaps was lower than during periods of data presence, the performance results in this analysis would be overstated.

patterns within the data gaps. Additional computed metrics provided in the dataset were the average annual electrical efficiency and the average annual system efficiency[8] for each system.

The tables in the following subsections summarize the character of the output data provided. Systems are categorized by PA and by the first year of operation. Results are weighted by system (i.e., each system has equal weight) rather than by installed capacity (i.e., greater weight for larger systems) to prevent larger systems from biasing character statements.

[8] System efficiency, as defined by PUC 216.6(b): the sum of the electric generation and half of heat recovery as a percentage of energy entering the system as fuel. For example, a system with an electrical efficiency of 30 percent and that recovered 25 percent of fuel energy as thermal energy would have a system efficiency of 42.5 percent: Thirty percent from electric generation plus one half of 25 percent (12.5 percent) from recovered thermal energy.

2.2.1 Project Count and Installed Capacity

The following tables summarize the project count, total installed capacity, and average installed capacity per project by year of installation for the data provided. Table 1 summarizes this information by PA; Table 2 summarizes this information by technology type. **Note that the counts and capacities reported are *not* cumulative**, for example, a project installed in 2002 would not be counted again in 2003.

Table 1. Total installed capacity, average installed capacity, and project count by PA and year of installation

		Install Year[1]							
PA		2002	2003	2004	2005	2006	2007	2008	*All Years*
Pacific Gas & Electric	total installed capacity (kW)	3,763	11,910	7,277	3,780	3,710	780		31,220
	average system capacity (kW)	538	662	560	315	412	260		504
	number of sites	7	18	13	12	9	3	0	62
Southern California Edison	total installed capacity (kW)	2,388	5,107	2,690	5,384	1,715	1,240		18,924
	average system capacity (kW)	597	464	207	359	429	620		378
	number of sites	4	11	13	15	4	2	0	50
Southern California Gas	total installed capacity (kW)	1,520	17,645	9,615	5,968	4,825	244		39,817
	average system capacity (kW)	380	608	740	1,492	689	122		675
	number of sites	4	29	13	4	7	2	0	59
California Center for Sustainable Energy	total installed capacity (kW)	3,306	1,372	1,260	4,095	5,027	910	1,309	17,429
	average system capacity (kW)	276	343	420	455	2,514	228	655	471
	number of sites	12	4	3	9	2	4	2	37
All PAs	total installed capacity (kW)	10,977	36,034	20,842	19,227	15,277	3,174	1,309	107,390
	average system capacity (kW)	407	581	496	481	694	289	655	516
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

NAVIGANT CONSULTING

SUMMIT BLUE CONSULTING, LLC

Table 2. Total installed capacity, average installed capacity, and project count by technology type[9] and year of installation

Type		Install Year[1] 2002	2003	2004	2005	2006	2007	2008	*All Years*
Fuel Cell	total installed capacity (kW)	200			2,000	3,950	500	250	6,900
	average system capacity (kW)	200			1,000	564	500	250	575
	number of sites	1	0	0	2	7	1	1	12
Internal Combustion Engine	total installed capacity (kW)	9,735	33,422	18,619	9,039	5,270	2,120	1,059	79,814
	average system capacity (kW)	608	777	548	430	659	353	1,059	609
	number of sites	16	43	34	21	8	6	1	131
Microturbine	total installed capacity (kW)	1,042	2,612	840	3,688	1,530	554		10,266
	average system capacity (kW)	104	137	120	231	255	139		166
	number of sites	10	19	7	16	6	4	0	62
Gas Turbine	total installed capacity (kW)			1,383	4,500	4,527			10,410
	average system capacity (kW)			1,383	4,500	4,527			3,470
	number of sites	0	0	1	1	1	0	0	3
All Types	total installed capacity (kW)	10,977	36,034	20,842	19,227	15,277	3,174	1,309	107,390
	average system capacity (kW)	407	581	496	481	694	289	655	516
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

2.2.2 Data Gaps

The following tables summarize the average number of data gaps as a percentage of all possible hours, from the first hour of output data provided through the end of 2008. Missing data may be the result of data acquisition system failure, data acquisition service termination, or data acquisition response to zero output. Table 3 summarizes this information by PA; Table 4 summarizes this information by technology type. Note the significant difference in data gaps between sites in the CCSE program (1 percent) and sites in the other PAs' programs (12 percent to 19 percent). This disparity is likely the result of a unique metering requirement by CCSE. To receive an SGIP incentive, CCSE requires that all host customers agree to allow SDG&E to install a revenue-grade net generator output meter on their projects. SDG&E maintains and reads the meter, ensuring that the data is consistently available.

[9] The SGIP technologies are: fuel cells (FC), internal combustion engines (IC engines or ICE), microturbines (MT), and gas turbines (GT).

Table 3. Data gaps by PA and year of installation

PA		Install Year[1] 2002	2003	2004	2005	2006	2007	2008	All Years
Pacific Gas & Electric	average % missing data	11%	13%	10%	11%	6%	46%		12%
	number of sites	7	18	13	12	9	3	0	62
Southern California Edison	average % missing data	19%	18%	22%	11%	13%	0%		16%
	number of sites	4	11	13	15	4	2	0	50
Southern California Gas	average % missing data	4%	26%	17%	18%	10%	2%		19%
	number of sites	4	29	13	4	7	2	0	59
California Center for Sustainable Energy	average % missing data	1%	0%	0%	0%	0%	7%	0%	1%
	number of sites	12	4	3	9	2	4	2	37
All PAs	average % missing data	7%	19%	15%	9%	8%	15%	0%	13%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.

Red bars show the relative magnitude of values by PA, for all Install Years.

Green bars show the relative magnitude of values by Install Year, for all PAs.

[1]Counts and capacities reported for each install year are not cumulative.

Table 4. Data gaps by technology type and year of installation

Type		Install Year[1] 2002	2003	2004	2005	2006	2007	2008	All Years
Fuel Cell	average % missing data	29%			2%	8%	8%	0%	8%
	number of sites	1	0	0	2	7	1	1	12
Internal Combusion Engine	average % missing data	7%	19%	13%	8%	10%	26%	0%	14%
	number of sites	16	43	34	21	8	6	1	131
Microturbine	average % missing data	3%	18%	27%	12%	7%	1%		13%
	number of sites	10	19	7	16	6	4	0	62
Gas Turbine	average % missing data			9%	8%	0%			6%
	number of sites	0	0	1	1	1	0	0	3
All Types	average % missing data	7%	19%	15%	9%	8%	15%	0%	13%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.

Red bars show the relative magnitude of values by PA, for all Install Years.

Green bars show the relative magnitude of values by Install Year, for all PAs.

[1]Counts and capacities reported for each install year are not cumulative.

2.2.3 Percent on Time

The following tables summarize the average number of normal hours (i.e., data present and non-zero) as a percentage of all hours of data present, excluding data gaps. As described at the beginning of this section, it was assumed that system performance during periods of data gaps was no different than at times of data present. Therefore, data gaps do not affect these values. Table 5 summarizes this information by PA. Table 6 summarizes this information by technology type.

Table 5. Percent of annual hours that system is on, by PA and year of installation

		Install Year[1]							
PA		2002	2003	2004	2005	2006	2007	2008	All Years
Pacific Gas & Electric	average % of time system is on	42%	54%	51%	81%	74%	33%		59%
	number of sites	7	18	13	12	9	3	0	62
Southern California Edison	average % of time system is on	28%	44%	52%	57%	73%	65%		52%
	number of sites	4	11	13	15	4	2	0	50
Southern California Gas	average % of time system is on	42%	45%	44%	63%	61%	30%		47%
	number of sites	4	29	13	4	7	2	0	59
California Center for Sustainable Energy	average % of time system is on	43%	34%	7%	61%	86%	78%	68%	50%
	number of sites	12	4	3	9	2	4	2	37
All PAs	average % of time system is on	40%	47%	46%	66%	71%	55%	68%	52%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

Table 6. Percent of annual hours that system is on, by technology type and year of installation

		Install Year[1]							
Type		2002	2003	2004	2005	2006	2007	2008	All Years
Fuel Cell	average % of time system is on	92%			93%	83%	99%	96%	88%
	number of sites	1	0	0	2	7	1	1	12
Internal Combustion Engine	average % of time system is on	36%	48%	43%	60%	46%	52%	39%	47%
	number of sites	16	43	34	21	8	6	1	131
Microturbine	average % of time system is on	42%	43%	52%	68%	86%	48%		55%
	number of sites	10	19	7	16	6	4	0	62
Gas Turbine	average % of time system is on			94%	97%	92%			94%
	number of sites	0	0	1	1	1	0	0	3
All Types	average % of time system is on	40%	47%	46%	66%	71%	55%	68%	52%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

2.2.4 Percent of Rated Capacity When On

The following tables summarize the average system output during normal hours as a percentage of rated capacity. This metric is the ratio of system output to system potential output during on hours. It is different than the capacity factor in that capacity factor is the ratio of system output to system potential output during all hours (i.e., rated capacity x 8760 hours). Table 7 summarizes this information by PA; Table 8 summarizes this information by technology type.

Table 7. Average operating level when systems are on, as percent of rated capacity, by PA and year of installation

		Install Year[1]							
PA		2002	2003	2004	2005	2006	2007	2008	*All Years*
Pacific Gas & Electric	average % of rated load when system is on	49%	55%	58%	65%	72%	12%		57%
	number of sites	7	18	13	12	9	3	0	62
Southern California Edison	average % of rated load when system is on	64%	61%	61%	64%	77%	89%		64%
	number of sites	4	11	13	15	4	2	0	50
Southern California Gas	average % of rated load when system is on	39%	50%	63%	69%	72%	57%		56%
	number of sites	4	29	13	4	7	2	0	59
California Center for Sustainable Energy	average % of rated load when system is on	57%	56%	55%	79%	81%	76%	84%	66%
	number of sites	12	4	3	9	2	4	2	37
All PAs	average % of rated load when system is on	53%	54%	60%	68%	74%	57%	84%	60%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

Table 8. Average operating level when systems are on, as percent of rated capacity, by technology type and year of installation

TYPE		Install Year[1] 2002	2003	2004	2005	2006	2007	2008	*All Years*
Fuel Cell	average % of rated load when system is on	91%			75%	86%	83%	95%	85%
	number of sites	1	0	0	2	7	1	1	12
Internal Combusion Engine	average % of rated load when system is on	47%	56%	59%	65%	55%	43%	73%	56%
	number of sites	16	43	34	21	8	6	1	131
Microturbine	average % of rated load when system is on	60%	48%	63%	71%	84%	72%		63%
	number of sites	10	19	7	16	6	4	0	62
Gas Turbine	average % of rated load when system is on			76%	89%	81%			82%
	number of sites	0	0	1	1	1	0	0	3
All Types	average % of rated load when system is on	53%	54%	60%	68%	74%	57%	84%	60%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

2.2.5 Capacity Factor

The following tables summarize the average system capacity factor.[10] Table 9 summarizes this information by PA; Table 10 summarizes this information by technology type.

[10] These values were provided to Summit Blue by Itron, Inc. as part of the dataset.

Table 9. Average capacity factor, as a percent of rated capacity, by PA and year of installation

		Install Year[1]							
PA		2002	2003	2004	2005	2006	2007	2008	*All Years*
Pacific Gas & Electric	average capacity factor	28%	36%	38%	52%	60%	19%		41%
	number of sites	7	18	13	12	9	3	0	62
Southern California Edison	average capacity factor	24%	33%	35%	37%	55%	57%		37%
	number of sites	4	11	13	15	4	2	0	50
Southern California Gas	average capacity factor	26%	32%	30%	45%	48%	20%		33%
	number of sites	4	29	13	4	7	2	0	59
California Center for Sustainable Energy	average capacity factor	30%	21%	6%	50%	74%	56%	60%	38%
	number of sites	12	4	3	9	2	4	2	37
All PAs	average capacity factor	28%	33%	32%	45%	56%	40%	60%	37%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

Table 10. Average capacity factor, as a percent of rated capacity, by technology type and year of installation

		Install Year[1]							
PA		2002	2003	2004	2005	2006	2007	2008	*All Years*
Fuel Cell	average capacity factor	86%			72%	72%	82%	91%	76%
	number of sites	1	0	0	2	7	1	1	12
Internal Combusion Engine	average capacity factor	22%	34%	29%	38%	30%	33%	29%	31%
	number of sites	16	43	34	21	8	6	1	131
Microturbine	average capacity factor	33%	30%	40%	49%	70%	39%		41%
	number of sites	10	19	7	16	6	4	0	62
Gas Turbine	average capacity factor			71%	85%	76%			77%
	number of sites	0	0	1	1	1	0	0	3
All Types	average capacity factor	28%	33%	32%	45%	56%	40%	60%	37%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

2.2.6 Electric Conversion Efficiency

The following tables summarize the average electric conversion efficiency.[11] Table 11 summarizes this information by PA; Table 12 summarizes this information by technology type.

Table 11. Average electric conversion efficiency, by PA and year of installation

PA		Install Year[1] 2002	2003	2004	2005	2006	2007	2008	*All Years*
Pacific Gas & Electric	average electric efficiency	26%	28%	27%	29%	27%	30%		28%
	number of sites	7	18	13	12	9	3	0	62
Southern California Edison	average electric efficiency	28%	26%	27%	27%	31%	27%		27%
	number of sites	4	11	13	15	4	2	0	50
Southern California Gas	average electric efficiency	20%	25%	29%	26%	33%	24%		26%
	number of sites	4	29	13	4	7	2	0	59
California Center for Sustainable Energy	average electric efficiency	24%	24%	26%	30%	40%	31%	37%	28%
	number of sites	12	4	3	9	2	4	2	37
All PAs	average electric efficiency	25%	26%	27%	28%	31%	29%	37%	27%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

[11] These values were provided to Summit Blue as part of the dataset. The methods used to compute these values are described in the" *CPUC Self-Generation Incentive Program Eighth-Year Impact Evaluation*" (Itron, Inc., July 2009). http://www.cpuc.ca.gov/NR/rdonlyres/11A75E09-31F8-4184-B3A4-2DCCB5FB0D2D/0/SGIP_Impact_Report_2008_Revised.pdf.

Table 12. Average electric conversion efficiency, by technology type and year of installation

PA		Install Year[1] 2002	2003	2004	2005	2006	2007	2008	All Years
Fuel Cell	average electric efficiency	41%			42%	42%	40%	41%	42%
	number of sites	1	0	0	2	7	1	1	12
Internal Combustion Engine	average electric efficiency	27%	28%	28%	30%	26%	30%	33%	28%
	number of sites	16	43	34	21	8	6	1	131
Microturbine	average electric efficiency	20%	20%	23%	24%	23%	24%		22%
	number of sites	10	19	7	16	6	4	0	62
Gas Turbine	average electric efficiency			21%	30%	38%			30%
	number of sites	0	0	1	1	1	0	0	3
All Types	average electric efficiency	25%	26%	27%	28%	31%	29%	37%	27%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

2.2.7 CPUC 216.6 Cogeneration System Performance

The following tables summarize the average overall system efficiency.[12, 13] Table 13 summarizes this information by PA; Table 14 summarizes this information by technology type. On average, microturbines and IC engines do not meet the PUC 216.6(b) 42.5 percent system efficiency requirement. As is shown in Section 3.6, the trend in decline of recovered heat over time is relatively small (approximately one percentage point per year); even in the first year of operation, microturbines and IC engines are not, on average, meeting the PUC 216.6(b) requirement. This poor performance of SGIP microturbines and IC engines is the subject of the report "In-Depth Analysis of Useful Waste Heat Recovery and Performance of Level 3/3N

[12] System efficiency, as defined by PUC 216.6(b): the sum of the electric generation and half of heat recovery as a percentage of energy entering the system as fuel. For example, a system with an electrical efficiency of 30 percent and that recovered 25 percent of fuel energy as thermal energy would have a system efficiency of 42.5 percent: Thirty percent from electric generation plus one half of 25 percent (12.5 percent) from recovered thermal energy.

[13] These values were provided to Summit Blue as part of the dataset. The methods used to compute these values are described in the*" CPUC Self-Generation Incentive Program Eighth-Year Impact Evaluation"* (Itron, Inc., July 2009). http://www.cpuc.ca.gov/NR/rdonlyres/11A75E09-31F8-4184-B3A4-2DCCB5FB0D2D/0/SGIP_Impact_Report_2008_Revised.pdf.

Systems."[14] Key reasons for poor performance cited in this study were poor system design (overstated system efficiency and improper consideration of site electrical and thermal loads).

Table 13. Average system efficiency, as percent of rated capacity, by PA and installation year

		Install Year[1]							
PA		2002	2003	2004	2005	2006	2007	2008	*All Years*
Pacific Gas & Electric	average system efficiency 216.6(b)	33%	36%	37%	38%	35%	36%		36%
	number of sites	7	18	13	12	9	3	0	62
Southern California Edison	average system efficiency 216.6(b)	37%	34%	35%	35%	40%	34%		35%
	number of sites	4	11	13	15	4	2	0	50
Southern California Gas	average system efficiency 216.6(b)	27%	34%	36%	38%	39%	33%		35%
	number of sites	4	29	13	4	7	2	0	59
California Center for Sustainable Energy	average system efficiency 216.6(b)	34%	34%	32%	39%	57%	39%	44%	37%
	number of sites	12	4	3	9	2	4	2	37
All PAs	average system efficiency 216.6(b)	33%	35%	36%	37%	39%	36%	44%	36%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

[14] Itron, Inc. "In-Depth Analysis of Useful Waste Heat Recovery and Performance of Level 3/3N Systems - Final Report," submitted to The Self Generation Incentive Program Working Group, February 2007. http://www.pge.com/includes/docs/pdfs/shared/newgenerator/selfgeneration/SGIP_ThermalAnalysisReport.pdf

Table 14. Average system efficiency, as percent of rated capacity, by technology type and year of installation

PA		Install Year[1] 2002	2003	2004	2005	2006	2007	2008	*All Years*
Fuel Cell	average system efficiency 216.6(b)	50%			57%	50%	45%	48%	51%
	number of sites	1	0	0	2	7	1	1	12
Internal Combusion Engine	average system efficiency 216.6(b)	34%	36%	35%	36%	31%	37%	40%	36%
	number of sites	16	43	34	21	8	6	1	131
Microturbine	average system efficiency 216.6(b)	30%	31%	34%	34%	33%	34%		32%
	number of sites	10	19	7	16	6	4	0	62
Gas Turbine	average system efficiency 216.6(b)			52%	53%	66%			57%
	number of sites	0	0	1	1	1	0	0	3
All Types	average system efficiency 216.6(b)	33%	35%	36%	37%	39%	36%	44%	36%
	number of sites	27	62	42	40	22	11	2	208

Blue bars show the relative magnitude of values by PA and Install Year.
Red bars show the relative magnitude of values by PA, for all Install Years.
Green bars show the relative magnitude of values by Install Year, for all PAs.
[1]Counts and capacities reported for each install year are not cumulative.

2.3 *Site Electric Purchase*

CHP systems are typically prohibited from being net exporters of power by their interconnection agreements with the utilities. Hosts need to restrict the output of their CHP systems if their electric demand is less than the capacity of their CHP systems. In order to examine this issue, we requested hourly billing data from the IOUs for a subsample of 100 sites, and received useful data for 79 of these sites.

Sample selection was done through sample stratification (by PA and by technology type) and scoring of sites as an estimate of the time spent at part load. Part load was defined as electrical output between 10 percent and 90 percent of the rated capacity of the system. These cutoff points were chosen because output under 10 percent is not likely normal generation operation, and output above 90 percent is at relatively full capacity. Therefore, output between 10 percent and 90 percent is assumed to be normal operation that is in some way limited to less than full capacity.

A score for each site was developed by dividing the number of hourly data points indicating part load operation by the total number of data points provided. Thus, a score of one implies that the system is always in part load operation, while a score of zero implies that the system is never in part load operation. Therefore, a higher score implies greater likelihood of net export constraints and better candidate for site load review.

Sample size selection was designed to optimize the statistical significance per strata. First, for strata with less than seven sites, all sites were included in the sample. Seven strata, with a total of 15 sites, met this description. For the remaining strata, the sample size per strata was proportional to the square root of the population size of the strata. The sites with the highest part load scores (as defined above) were selected from each strata. The following table summarizes the sample strata, the number of sites in each strata, and the number of sites selected for load review in each strata.

Table 15. Count and part-load scores for dataset population, billing data request sample, and useful billing data sample

PA	Type		Number of sites	Average part load score	Maximum part load score	Minimum part load score
PG&E	FC	Population	5	45%	17%	93%
		Load request sample	5	45%	17%	93%
		Useful data from sample	5	45%	17%	93%
	MT	Population	11	54%	19%	98%
		Load request sample	7	65%	44%	98%
		Useful data from sample	3	60%	45%	71%
	ICE	Population	45	32%	0%	93%
		Load request sample	15	66%	26%	93%
		Useful data from sample	12	66%	26%	93%
	GT	Population	1	65%	65%	65%
		Load request sample	1	65%	65%	65%
		Useful data from sample	1	65%	65%	65%
SCE	FC	Population	1	1%	1%	1%
		Load request sample	1	1%	1%	1%
		Useful data from sample	0	N/A	N/A	N/A
	MT	Population	19	37%	0%	99%
		Load request sample	10	59%	35%	99%
		Useful data from sample	9	57%	35%	99%
	ICE	Population	30	36%	0%	100%
		Load request sample	12	64%	33%	100%
		Useful data from sample	9	59%	33%	97%
	GT	Population	0	N/A	N/A	N/A
		Load request sample	0	N/A	N/A	N/A
		Useful data from sample	0	N/A	N/A	N/A
SCG	FC	Population	2	39%	33%	45%
		Load request sample	2	39%	33%	45%
		Useful data from sample	1	45%	45%	45%
	MT	Population	19	31%	0%	92%
		Load request sample	10	51%	32%	92%
		Useful data from sample	7	51%	32%	92%
	ICE	Population	37	30%	0%	99%
		Load request sample	13	53%	14%	99%
		Useful data from sample	10	47%	14%	86%
	GT	Population	1	38%	38%	38%
		Load request sample	1	38%	38%	38%
		Useful data from sample	0	N/A	N/A	N/A
CCSE	FC	Population	4	38%	26%	55%
		Load request sample	4	38%	26%	55%
		Useful data from sample	3	32%	26%	43%
	MT	Population	13	23%	0%	81%
		Load request sample	8	34%	13%	81%
		Useful data from sample	8	34%	13%	81%
	ICE	Population	19	22%	1%	83%
		Load request sample	10	36%	18%	83%
		Useful data from sample	10	36%	18%	83%
	GT	Population	1	73%	73%	73%
		Load request sample	1	73%	73%	73%
		Useful data from sample	1	73%	73%	73%

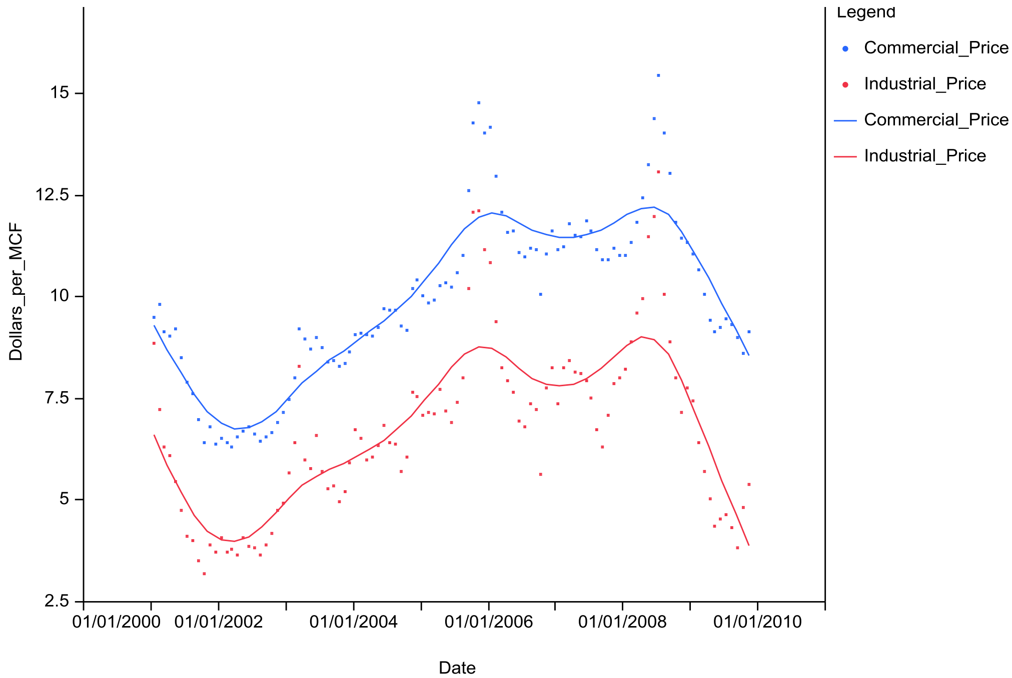
2.4 Natural Gas Prices

Natural gas prices directly affect the economics of CHP. In order to examine the relationship between capacity factors and gas prices, historical monthly natural gas prices were obtained from the U.S. Department of Energy's Energy Information Administration (EIA) website.[15] This data series provides historical prices for both commercial customers and industrial customers. SGIP CHP customers may be on either commercial or industrial rates, or special self-generation rates. This information was not provided with the customer site and load data. We assumed a 50/50 blend of commercial and industrial rates for this analysis. Figure 2 shows the commercial and industrial rates used in to estimate gas prices for this analysis. Note that natural gas prices increased steadily from 2002 to 2008, the period for which we received system performance data.

Natural gas prices dropped significantly in 2009. Section 4 examines the effects of fuel cost and system age on system output. Including 2009 output data in this analysis might allow for a more precise disaggregation of impacts because it is a year in which age and fuel price are not correlated.

[15] http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm.

Figure 2. Industrial and commercial natural gas prices



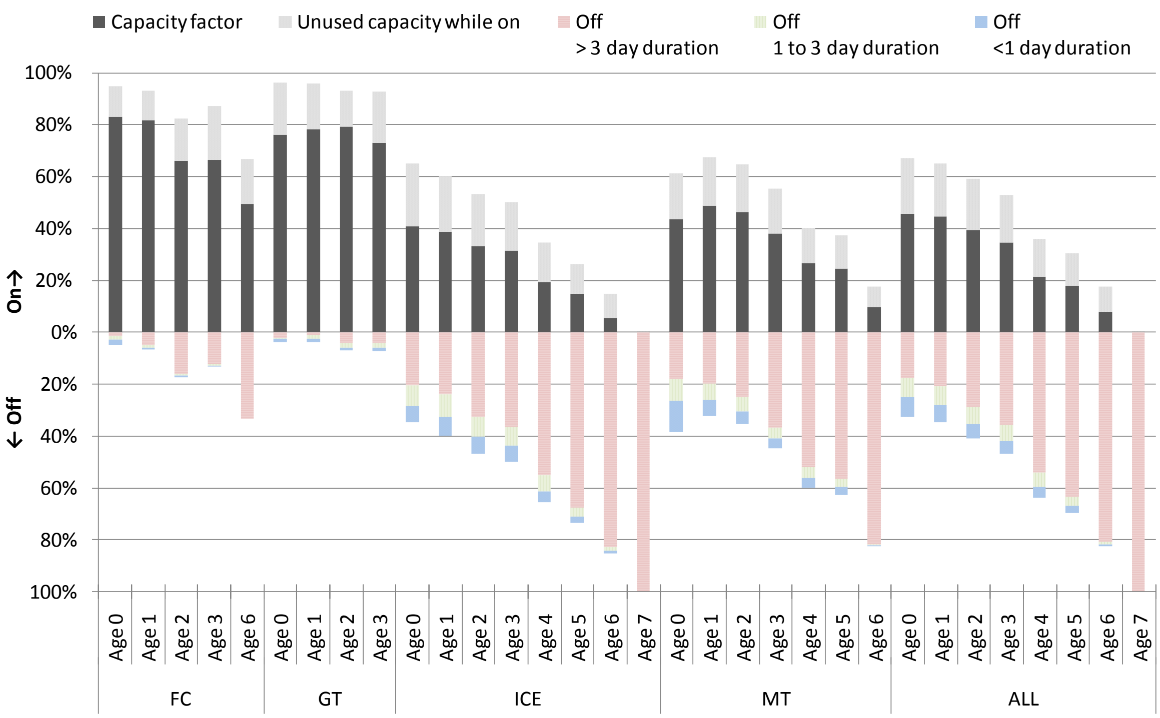
Section 3. Year-Over-Year Trends

Year-over-year performance and data character were examined for each system to identify trends in output and periods of off time. These trends can be used to infer CHP system performance and data acquisition performance.

As a starting point for this section, Figure 3 graphically summarizes the most significant performance trends observed in the output data. As percentages of the full rated capacity of the system, each bar shows from top to bottom:

- **Unused capacity while on** –the unutilized capacity of the system during hours that the system is on.
- **Capacity factor** – the utilized capacity of the system.
- **Off, < 1 day duration** – the percentage of all hours that the system has zero output for less than 24 hours at a time.
- **Off, 1 to 3 day duration** - the percentage of all hours that the system has zero output for 24 to 72 hours at a time.
- **Off, > 3 day duration** - the percentage of all hours that the system has zero output for more than 72 hours at a time.

Figure 3. Disaggregation of performance as percentages of rated capacity



This graph shows the clear and dramatic capacity factor decrease of IC engines and microturbines, driven primarily by an increase in long duration off periods, but also by a decrease in operating levels when systems are on. The rest of this section examines these trends and their statistical significance in more detail.

The tables in this section summarize annual percentage point changes in metrics. Cells in tables provide the estimated value, the 90 percent confidence range, and the number of data points that these statistics are based on. Cells highlighted in green indicate statistically significantly non-zero trends at the 90 percent confidence level. In other words, with 90 percent confidence, we can say that these values are non-zero, that is, there is a trend. Cells that are not highlighted in green are not statistically significantly different than zero at the 90 percent confidence level.

Most performance trends showed no statistically significant difference across PAs, so results in this section are shown by technology type only. *Appendix B: Trend Data by PA* provides these results by PA.

3.1 *Capacity Factor*

This research was motivated by observed reductions in capacity factor of SGIP microturbine and IC engines, which have been identified in the program's seventh- and eighth-year impact evaluations. Table 16 summarizes the year-over-year percentage point reduction in capacity factor, by technology type. Consistent with the impact evaluations, we observe an average 5.9 percentage point annual reduction in capacity factor across all technologies. Statistically significant trends are also observed for all technologies except for gas turbines; the population of metered gas turbines (3) is too small to draw strong conclusions about this technology type. The following trend analyses seek to disaggregate to causes of this reduction in capacity factor.

Table 16. Annual percentage point trend in capacity factor, by technology type and year of installation

		Install Year[2]						
Type		2002	2003	2004	2005	2006	2007	*All Years*
Fuel Cell	average annnual percentage point trend[1]	-7.8%			-6.8%	-13.8%	4.4%	-6.7%
	90% confidence interval	[-10.9%,-4.6%]			[-14.3%,0.8%]	[-20.2%,-7.4%]		[-10.0%,-3.5%]
	number of site-years	5	0	0	8	17	2	33
Internal Combustion Engine	average annnual percentage point trend[1]	-6.4%	-5.5%	-3.9%	-5.2%	-13.1%	-12.8%	-5.2%
	90% confidence interval	[-8.7%,-4.1%]	[-7.4%,-3.7%]	[-6.3%,-1.4%]	[-9.9%,-0.6%]	[-25.3%,-1.0%]	[-34.5%,8.9%]	[-6.3%,-4.1%]
	number of site-years	70	184	136	68	18	10	496
Microturbine	average annnual percentage point trend[1]	-6.7%	-1.1%	-7.6%	2.1%	-5.7%	-23.2%	-4.8%
	90% confidence interval	[-9.9%,-3.6%]	[-4.2%,1.9%]	[-14.2%,-1.0%]	[-3.0%,7.2%]	[-15.1%,3.7%]	[-67.0%,20.5%]	[-6.5%,-3.1%]
	number of site-years	58	79	24	56	15	6	238
Gas Turbine	average annnual percentage point trend[1]			-3.2%	-4.5%	0.0%		-1.1%
	90% confidence interval			[-4.7%,-1.7%]	[-8.6%,-0.4%]	[-1.4%,1.5%]		[-4.9%,2.8%]
	number of site-years	0	0	4	3	3	0	10
All Types	average annnual percentage point trend[1]	-7.5%	-4.2%	-4.0%	-2.1%	-13.0%	-12.2%	-5.9%
	90% confidence interval	[-9.5%,-5.5%]	[-5.8%,-2.6%]	[-6.3%,-1.7%]	[-5.6%,1.3%]	[-20.6%,-5.3%]	[-32.9%,8.6%]	[-6.8%,-5.0%]
	number of site-years	133	263	164	135	53	18	777

Green indicates a statistically significant non-zero trend

[1] *Annual trend in capacity factor*

[2] *Counts and capacities reported for each install year are not cumulative.*

3.2 Hours of Operation

Table 17 shows the year-over-year trend in hours of operation, as a percentage of all hours, excluding data gaps. On average, the percentage on time decreases 8.2 percentage points per year. Gas turbines were the only technology with no statistically significant trend, although the small sample size limits conclusions. Note that while the average trends for systems installed in 2006 and 2007 are large, the confidence intervals are quite wide (due to the small sample size), suggesting that the actual trend may not be so large.

Table 17. Annual percentage point trend in hours of operation as a percent of all hours, by technology type and year of installation

		Install Year[2]						
Type		2002	2003	2004	2005	2006	2007	*All Years*
Fuel Cell	average annnual percentage point trend[1]	-5.3%			-5.2%	-8.8%	1.0%	-4.7%
	90% confidence interval	[-8.5%,-2.0%]			[-11.5%,1.0%]	[-15.9%,-1.6%]		[-7.7%,-1.7%]
	number of site-years	5	0	0	8	17	2	33
Internal Combusion Engine	average annnual percentage point trend[1]	-11.4%	-8.8%	-4.7%	-4.2%	-22.0%	-31.9%	-7.8%
	90% confidence interval	[-15.0%,-7.8%]	[-11.5%,-6.1%]	[-8.4%,-0.9%]	[-11.2%,2.8%]	[-42.1%,-1.9%]	[-76.5%,12.7%]	[-9.4%,-6.2%]
	number of site-years	70	184	136	68	18	10	496
Microturbine	average annnual percentage point trend[1]	-10.2%	-4.1%	-14.7%	4.7%	-7.5%	-24.2%	-7.2%
	90% confidence interval	[-14.2%,-6.1%]	[-8.5%,0.2%]	[-24.4%,-5.0%]	[-2.2%,11.6%]	[-14.7%,-0.3%]	[-68.2%,19.9%]	[-9.5%,-4.9%]
	number of site-years	58	79	24	56	15	6	238
Gas Turbine	average annnual percentage point trend[1]			-1.9%	0.8%	-6.0%		-1.4%
	90% confidence interval			[-4.4%,0.7%]	[-0.1%,1.7%]	[-8.2%,-3.9%]		[-3.5%,0.6%]
	number of site-years	0	0	4	3	3	0	10
All Types	average annnual percentage point trend[1]	-11.0%	-7.4%	-5.3%	-0.5%	-14.2%	-19.8%	-8.2%
	90% confidence interval	[-13.7%,-8.4%]	[-9.6%,-5.1%]	[-8.8%,-1.8%]	[-5.2%,4.3%]	[-22.7%,-5.7%]	[-50.0%,10.3%]	[-9.5%,-6.9%]
	number of site-years	133	263	164	135	53	18	777

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of all hours of data presence that indicate non-zero system output*

[2] *Counts and capacities reported for each install year are not cumulative.*

3.3 *Off Time, By Duration of Outage*

Periods of off time were categorized as short duration (Type 2 variation in output: less than 24 hours), medium duration (Type 2 or 3 variation in output: 24 to 72 hours), and long duration (Type 3 variation in output: greater than 72 hours). We hypothesized that short and medium duration off periods would be due to operating schedule (e.g., system not run at night), routine maintenance, and minor unscheduled maintenance issues. Long duration periods would be due to unscheduled maintenance or voluntary decisions to stop operating the system.

Short duration trends are shown in Table 18. The trends are the year over year percentage point change in total number of hours (excluding data gaps) represented by short duration off events. On average, the short duration off time decreases by 1.0 percentage points per year.

Table 18. Annual percentage point trend in hours of short-duration off-time, as a percent of all hours, by technology type and year of installation

		Install Year[2]						
Type		**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	***All Years***
Fuel Cell	average annnual percentage point trend[1]	**0.0%**			**-0.4%**	**-1.4%**	**-0.4%**	**-0.5%**
	90% confidence interval	[-0.1%,0.0%]			[-0.7%,-0.2%]	[-2.6%,-0.2%]		[-0.9%,-0.1%]
	number of site-years	5	0	0	8	17	2	33
Internal Combusion Engine	average annnual percentage point trend[1]	**-2.4%**	**-1.4%**	**-0.6%**	**-0.6%**	**-0.1%**	**0.0%**	**-0.9%**
	90% confidence interval	[-3.3%,-1.6%]	[-2.1%,-0.7%]	[-1.4%,0.3%]	[-2.5%,1.4%]	[-2.5%,2.3%]	[-3.3%,3.2%]	[-1.3%,-0.6%]
	number of site-years	70	184	136	68	18	10	496
Microturbine	average annnual percentage point trend[1]	**-3.2%**	**-1.1%**	**0.2%**	**-1.0%**	**-0.4%**	**1.7%**	**-1.5%**
	90% confidence interval	[-4.1%,-2.3%]	[-2.4%,0.3%]	[-0.4%,0.9%]	[-3.6%,1.6%]	[-0.8%,0.1%]	[-18.7%,22.0%]	[-2.2%,-0.8%]
	number of site-years	58	79	24	56	15	6	238
Gas Turbine	average annnual percentage point trend[1]			**0.0%**	**-0.1%**	**0.3%**		**0.0%**
	90% confidence interval			[-0.2%,0.2%]	[-0.6%,0.4%]	[-0.9%,1.4%]		[-0.3%,0.2%]
	number of site-years	0	0	4	3	3	0	10
All Types	average annnual percentage point trend[1]	**-2.5%**	**-1.3%**	**-0.6%**	**-0.7%**	**-0.5%**	**-1.8%**	**-1.0%**
	90% confidence interval	[-3.2%,-1.9%]	[-1.9%,-0.7%]	[-1.3%,0.1%]	[-2.2%,0.8%]	[-1.4%,0.3%]	[-8.7%,5.2%]	[-1.3%,-0.7%]
	number of site-years	133	263	164	135	53	18	777

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of all hours of data presence that are short duration (< 1 day) outages*

[2] *Counts and capacities reported for each install year are not cumulative.*

Medium duration trends are shown in Table 19. On average, medium duration off time decreases by 0.8 percentage points per year, although this metric *increases* slightly for gas turbines and is not statistically significant for fuel cells.

Table 19. Annual percentage point trend in hours of medium-duration off-time, as a percent of all hours, by technology type and year of installation

		Install Year[2]						
Type		2002	2003	2004	2005	2006	2007	*All Years*
Fuel Cell	average annnual percentage point trend[1]	-0.4%			0.2%	-0.4%	-0.7%	-0.3%
	90% confidence interval	[-0.8%,0.1%]			[-0.1%,0.5%]	[-1.3%,0.4%]		[-0.6%,0.0%]
	number of site-years	5	0	0	8	17	2	33
Internal Combusion Engine	average annnual percentage point trend[1]	-2.6%	-1.5%	-0.6%	-0.9%	-0.4%	-0.9%	-1.0%
	90% confidence interval	[-3.7%,-1.5%]	[-2.2%,-0.8%]	[-1.7%,0.5%]	[-2.6%,0.7%]	[-3.8%,2.9%]	[-3.7%,1.8%]	[-1.4%,-0.6%]
	number of site-years	70	184	136	68	18	10	496
Microturbine	average annnual percentage point trend[1]	-1.5%	-0.7%	-0.4%	-0.8%	-0.5%	3.3%	-1.1%
	90% confidence interval	[-2.1%,-0.8%]	[-1.9%,0.5%]	[-0.9%,0.2%]	[-2.9%,1.3%]	[-1.5%,0.4%]	[-22.2%,28.7%]	[-1.6%,-0.5%]
	number of site-years	58	79	24	56	15	6	238
Gas Turbine	average annnual percentage point trend[1]			0.4%	-0.3%	0.7%		0.5%
	90% confidence interval			[-0.2%,1.0%]	[-0.3%,-0.3%]	[0.0%,1.3%]		[0.0%,0.9%]
	number of site-years	0	0	4	3	3	0	10
All Types	average annnual percentage point trend[1]	-1.7%	-1.3%	-0.8%	-0.8%	-0.3%	-2.8%	-0.8%
	90% confidence interval	[-2.4%,-1.1%]	[-1.9%,-0.6%]	[-1.7%,0.2%]	[-2.0%,0.5%]	[-1.3%,0.8%]	[-11.7%,6.2%]	[-1.2%,-0.5%]
	number of site-years	133	263	164	135	53	18	777

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of all hours of data presence that are medium duration (1 to 3 days) outages*

[2] *Counts and capacities reported for each install year are not cumulative.*

Long duration trends are shown in Table 20. On average, long duration off times increase by 10.1 percentage points per year, although there is no statistically significant trend for gas turbines. This increase in long duration off time tends to consume short duration off events, which explains the decrease in the short and medium duration events. For example, routine night-time (short duration) or weekend (medium duration) shut-downs no longer show up in the data as distinct events when the system is down for several weeks (long duration).

Table 20. Annual percentage point trend in hours of long-duration off-time, as a percent of all hours, by technology type and year of installation

Type		Install Year[2] 2002	2003	2004	2005	2006	2007	*All Years*
Fuel Cell	average annnual percentage point trend[1]	**5.7%**			**5.4%**	**10.5%**	**0.0%**	**5.4%**
	90% confidence interval	[2.7%,8.6%]			[-0.6%,11.4%]	[4.2%,16.9%]		[2.7%,8.1%]
	number of site-years	5	0	0	8	17	2	34
Internal Combustion Engine	average annnual percentage point trend[1]	**16.6%**	**11.7%**	**5.7%**	**5.6%**	**22.5%**	**32.9%**	**9.8%**
	90% confidence interval	[13.1%,20.1%]	[9.1%,14.3%]	[1.8%,9.6%]	[-1.0%,12.2%]	[2.8%,42.3%]	[-10.0%,75.7%]	[8.2%,11.4%]
	number of site-years	70	184	136	68	18	10	496
Microturbine	average annnual percentage point trend[1]	**14.8%**	**5.9%**	**14.8%**	**-3.0%**	**8.4%**	**19.2%**	**9.8%**
	90% confidence interval	[10.9%,18.8%]	[1.4%,10.4%]	[5.0%,24.6%]	[-9.3%,3.3%]	[1.3%,15.5%]	[-40.2%,78.6%]	[7.5%,12.0%]
	number of site-years	58	79	24	56	15	6	238
Gas Turbine	average annnual percentage point trend[1]			**1.4%**	**-0.4%**	**5.1%**		**1.0%**
	90% confidence interval			[-1.3%,4.2%]	[-0.8%,0.0%]	[2.4%,7.8%]		[-0.9%,3.0%]
	number of site-years	0	0	4	3	3	0	10
All Types	average annnual percentage point trend[1]	**15.4%**	**9.9%**	**6.6%**	**1.9%**	**15.0%**	**24.3%**	**10.1%**
	90% confidence interval	[12.9%,17.9%]	[7.7%,12.2%]	[3.1%,10.2%]	[-2.5%,6.2%]	[7.0%,23.1%]	[-4.7%,53.4%]	[8.8%,11.3%]
	number of site-years	133	263	164	135	53	18	778

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of all hours of data presence that are long duration (> 3 days) outages*

[2] *Counts and capacities reported for each install year are not cumulative.*

Together, these short, medium, and long term duration trend results show that the increase in observed off time is almost entirely due to an increase long duration off time.

3.4 *Load Level When On*

Table 21 summarizes the average load level during on hours, as a percentage of rated capacity. On average, there is a 2.5 percentage point annual reduction in load level, although this trend is only statistically significant for IC engines and fuel cells.

Table 21. Annual percentage point trend in load level during on-hours, as a percent of rated capacity, by technology type and year of installation

		Install Year[2]						
Type		**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	***All Years***
Fuel Cell	average annnual percentage point trend[1]	**-4.0%**			**-2.4%**	**-6.4%**	**4.0%**	**-3.2%**
	90% confidence interval	[-5.5%,-2.5%]			[-8.2%,3.5%]	[-10.2%,-2.7%]		[-5.5%,-1.0%]
	number of site-years	5	0	0	8	17	2	33
Internal Combusion Engine	average annnual percentage point trend[1]	**-4.0%**	**-0.4%**	**-0.2%**	**-0.1%**	**-1.2%**	**-2.8%**	**-2.3%**
	90% confidence interval	[-6.8%,-1.2%]	[-2.1%,1.2%]	[-2.5%,2.1%]	[-3.4%,3.2%]	[-13.8%,11.3%]	[-27.7%,22.2%]	[-3.4%,-1.3%]
	number of site-years	52	160	116	62	15	8	423
Microturbine	average annnual percentage point trend[1]	**-2.8%**	**0.7%**	**1.7%**	**-0.3%**	**-0.2%**	**-11.5%**	**-1.5%**
	90% confidence interval	[-6.4%,0.8%]	[-2.2%,3.7%]	[-3.2%,6.5%]	[-3.4%,2.9%]	[-5.1%,4.6%]	[-49.1%,26.1%]	[-3.1%,0.0%]
	number of site-years	39	66	20	51	15	6	197
Gas Turbine	average annnual percentage point trend[1]			**-1.5%**	**-5.5%**	**5.0%**		**0.4%**
	90% confidence interval			[-3.9%,0.9%]	[-12.6%,1.6%]	[1.2%,8.8%]		[-3.5%,4.3%]
	number of site-years	0	0	4	3	3	0	10
All Types	average annnual percentage point trend[1]	**-4.6%**	**-0.1%**	**0.3%**	**-0.1%**	**-3.2%**	**-4.6%**	**-2.5%**
	90% confidence interval	[-6.9%,-2.3%]	[-1.5%,1.4%]	[-1.7%,2.4%]	[-2.3%,2.1%]	[-8.4%,2.0%]	[-22.0%,12.8%]	[-3.4%,-1.7%]
	number of site-years	96	226	140	124	50	16	663

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of rated output during non-zero system output*

[2] *Counts and capacities reported for each install year are not cumulative.*

3.5 *Electric Efficiency*

Table 22 summarizes the average annual percentage point trend in electrical efficiency. On average, there is a 0.4 percentage point annual reduction electrical efficiency, although this trend is only statistically significant for fuel cells. This implies that this trend is small enough that it is only observable at the largest level of aggregation.

Table 22. Annual percentage point trend in electric efficiency, by technology type and year of installation

		Install Year[2]						
Type		2002	2003	2004	2005	2006	2007	*All Years*
Fuel Cell	average annnual percentage point trend[1]	**-1.0%**			**-0.7%**	**-1.4%**	**-2.6%**	**-0.9%**
	90% confidence interval	[-1.2%,-0.8%]			[-2.3%,0.8%]	[-2.4%,-0.3%]		[-1.4%,-0.4%]
	number of site-years	5	0	0	8	17	2	33
Internal Combusion Engine	average annnual percentage point trend[1]	**0.1%**	**-0.1%**	**0.6%**	**0.1%**	**0.5%**	**0.7%**	**-0.1%**
	90% confidence interval	[-0.4%,0.5%]	[-0.4%,0.2%]	[0.2%,1.1%]	[-0.4%,0.5%]	[0.4%,0.6%]	[0.6%,0.7%]	[-0.3%,0.1%]
	number of site-years	54	172	129	65	16	10	456
Microturbine	average annnual percentage point trend[1]	**0.1%**	**0.2%**	**0.5%**	**0.5%**	**-1.5%**	**0.0%**	**0.0%**
	90% confidence interval	[-0.2%,0.4%]	[-0.1%,0.5%]	[0.3%,0.7%]	[0.2%,0.9%]	[-3.3%,0.4%]		[-0.1%,0.2%]
	number of site-years	49	71	24	56	15	6	221
Gas Turbine	average annnual percentage point trend[1]			**-0.3%**	**-2.5%**	**-0.1%**		**-1.8%**
	90% confidence interval			[-0.4%,-0.1%]	[-5.0%,0.0%]	[-2.3%,2.2%]		[-5.7%,2.1%]
	number of site-years	0	0	4	3	3	0	10
All Types	average annnual percentage point trend[1]	**0.0%**	**0.0%**	**0.4%**	**0.0%**	**-1.2%**	**1.5%**	**-0.4%**
	90% confidence interval	[-0.5%,0.4%]	[-0.3%,0.3%]	[0.0%,0.8%]	[-0.7%,0.7%]	[-3.7%,1.3%]	[-2.5%,5.5%]	[-0.6%,-0.2%]
	number of site-years	108	243	157	132	51	18	720

Green indicates a statistically significant non-zero trend

[1] *Annual trend in electric efficiency*

[2] *Counts and capacities reported for each install year are not cumulative.*

This trend of decreased electrical efficiency may be attributable to the decrease in operating level of systems when on (Section 3.4), as systems (except fuel cells) tend to be most efficient when operated at rated capacity.

3.6 *System Efficiency, PUC 216.6(b)*

Table 23 summarizes the average annual percentage point trend in system efficiency, as defined in PUC 216.6(b). On average, there is a 1.3 percentage point annual reduction in system efficiency, and is statistically significant at the technology level for all technologies except fuel cells. In light of an electrical efficiency annual decline of 0.4 percentage points, this annual decline in system efficiency of 1.3 percentage points implies that the amount of recovered heat is declining more rapidly than the electrical efficiency. One possible cause for this decline in recovered heat is failure of heat recovery and utilization equipment, a phenomenon identified in SGIP "In-Depth Analysis of Useful Waste Heat Recovery and Performance of Level 3/3N Systems" report.[16]

Table 23. Annual percentage point trend in system efficiency (PUC 216.6(b)), by technology type and year of installation

		Install Year[2]						
Type		**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	***All Years***
Fuel Cell	**average annnual percentage point trend[1]**	**-1.6%**			**0.6%**	**-2.8%**	**-10.9%**	**-0.8%**
	90% confidence interval	[-2.3%,-1.0%]			[-5.4%,6.7%]	[-5.0%,-0.6%]		[-2.5%,0.9%]
	number of site-years	5	0	0	8	17	2	33
Internal Combusion Engine	**average annnual percentage point trend[1]**	**-1.3%**	**-1.9%**	**-0.6%**	**-0.7%**	**2.8%**	**6.4%**	**-1.1%**
	90% confidence interval	[-1.9%,-0.7%]	[-2.3%,-1.4%]	[-1.3%,0.0%]	[-1.3%,-0.1%]	[-0.1%,5.6%]	[2.5%,10.3%]	[-1.4%,-0.8%]
	number of site-years	54	172	129	65	16	10	456
Microturbine	**average annnual percentage point trend[1]**	**-0.2%**	**-0.9%**	**-0.1%**	**-0.2%**	**-2.9%**	**-1.2%**	**-0.4%**
	90% confidence interval	[-0.7%,0.4%]	[-1.5%,-0.4%]	[-0.5%,0.2%]	[-0.7%,0.4%]	[-5.5%,-0.3%]	[-1.2%,-1.2%]	[-0.7%,-0.2%]
	number of site-years	49	71	24	56	15	6	221
Gas Turbine	**average annnual percentage point trend[1]**			**-2.2%**	**-19.5%**	**-19.1%**		**-10.1%**
	90% confidence interval			[-3.2%,-1.2%]	[-26.5%,-12.5%]	[-32.2%,-6.1%]		[-15.7%,-4.6%]
	number of site-years	0	0	4	3	3	0	10
All Types	**average annnual percentage point trend[1]**	**-0.9%**	**-1.6%**	**-0.8%**	**-0.7%**	**-3.5%**	**2.6%**	**-1.3%**
	90% confidence interval	[-1.4%,-0.4%]	[-2.0%,-1.2%]	[-1.4%,-0.2%]	[-1.6%,0.3%]	[-6.9%,-0.1%]	[-1.5%,6.7%]	[-1.5%,-1.0%]
	number of site-years	108	243	157	132	51	18	720

Green indicates a statistically significant non-zero trend

[1] *Annual trend in system efficiency, PUC 216.6(b) : electric efficiency plus one half of recovered thermal energy*

[2] *Counts and capacities reported for each install year are not cumulative.*

---

[16] Itron, Inc. "In-Depth Analysis of Useful Waste Heat Recovery and Performance of Level 3/3N Systems - Final Report," submitted to The Self Generation Incentive Program Working Group, February 2007. http://www.pge.com/includes/docs/pdfs/shared/newgenerator/selfgeneration/SGIP_ThermalAnalysisReport.pdf

3.7 Data Gaps

Table 24 summarizes the annual percentage point trend in data gaps as a percentage of all hours, by PA and by year of installation. No statistically significant trends are observed at the PA level, but in aggregate, a statistically significant 1.3 percentage point annual increase in data gaps is observed.

Table 24. Annual percentage point trend in data gaps, as a percentage of all hours, by PA and year of installation

PA		Install Year[2] 2002	2003	2004	2005	2006	2007	*All Years*
Pacific Gas & Electric	average annnual percentage point trend[1]	**-0.2%**	**-0.8%**	**6.8%**	**2.6%**	**-8.9%**	**37.3%**	**0.7%**
	90% confidence interval	[-4.5%,4.1%]	[-3.8%,2.2%]	[0.8%,12.7%]	[-2.2%,7.5%]	[-14.5%,-3.3%]	[-35.8%,110.4%]	[-1.2%,2.7%]
	number of site-years	35	93	62	39	24	4	257
Southern California Edison	average annnual percentage point trend[1]	**10.8%**	**-4.5%**	**-5.8%**	**-3.9%**	**-18.7%**	**49.8%**	**2.1%**
	90% confidence interval	[2.6%,19.1%]	[-9.1%,0.1%]	[-10.9%,-0.6%]	[-9.6%,1.7%]	[-31.1%,-6.3%]	[-32.4%,132.1%]	[-0.3%,4.6%]
	number of site-years	19	57	50	51	9	4	196
Southern California Gas	average annnual percentage point trend[1]	**10.9%**	**-4.9%**	**-1.2%**	**-11.2%**	**-6.5%**	**-6.2%**	**1.7%**
	90% confidence interval	[-1.4%,23.1%]	[-9.2%,-0.6%]	[-6.7%,4.4%]	[-24.1%,1.6%]	[-17.0%,3.9%]	[-9.6%,-2.9%]	[-1.0%,4.4%]
	number of site-years	19	120	56	13	14	4	226
California Center for Sustainable Energy	average annnual percentage point trend[1]	**-0.2%**	**0.0%**	**0.0%**	**-0.2%**	**0.0%**	**9.4%**	**-0.6%**
	90% confidence interval	[-0.4%,0.0%]	[-0.1%,0.2%]	[0.0%,0.0%]	[-0.6%,0.2%]	[0.0%,0.0%]	[-34.8%,53.7%]	[-1.2%,0.0%]
	number of site-years	75	23	15	36	6	8	171
All PAs	average annnual percentage point trend[1]	**3.4%**	**-1.4%**	**0.9%**	**-0.8%**	**-7.7%**	**21.2%**	**1.3%**
	90% confidence interval	[1.1%,5.8%]	[-3.6%,0.7%]	[-2.2%,4.0%]	[-3.6%,2.0%]	[-11.9%,-3.5%]	[-3.7%,46.0%]	[0.2%,2.4%]
	number of site-years	148	293	183	139	53	20	850

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of all hours that data is missing for*

[2] *Counts and capacities reported for each install year are not cumulative.*

Table 25 summarizes this data by technology type. Statistically significant increases in data gaps for fuel cells and gas turbines are observed. Given that the population of these technology types is small, increased data gaps for these systems reduce the potential for statistically significant long-term conclusions.

Table 25. Annual percentage point trend in data gaps, as a percentage of all hours, by technology type and year of installation

		Install Year[2]						
Type		2002	2003	2004	2005	2006	2007	*All Years*
Fuel Cell	average annnual percentage point trend[1]	**7.8%**			**-4.1%**	**-8.5%**	**-20.4%**	**6.9%**
	90% confidence interval	[-5.6%,21.2%]			[-8.9%,0.7%]	[-16.6%,-0.4%]		[1.8%,12.0%]
	number of site-years	7	0	0	8	17	2	35
Internal Combustion Engine	average annnual percentage point trend[1]	**3.8%**	**-1.6%**	**2.1%**	**2.0%**	**-16.6%**	**10.0%**	**1.4%**
	90% confidence interval	[0.3%,7.3%]	[-4.3%,1.0%]	[-1.2%,5.5%]	[-2.5%,6.4%]	[-24.3%,-8.9%]	[-21.6%,41.7%]	[-0.1%,2.8%]
	number of site-years	79	207	154	72	18	10	553
Microturbine	average annnual percentage point trend[1]	**2.9%**	**-0.9%**	**-17.6%**	**-4.1%**	**-1.6%**	**46.7%**	**0.0%**
	90% confidence interval	[-0.2%,6.0%]	[-4.7%,2.9%]	[-23.5%,-11.7%]	[-7.7%,-0.4%]	[-7.5%,4.2%]	[-0.9%,94.3%]	[-1.8%,1.8%]
	number of site-years	62	86	24	56	15	8	251
Gas Turbine	average annnual percentage point trend[1]			**19.6%**	**-0.1%**	**0.0%**		**14.8%**
	90% confidence interval			[2.0%,37.2%]	[-23.7%,23.4%]	[0.0%,0.0%]		[4.5%,25.0%]
	number of site-years	0	0	5	3	3	0	11
All Types	average annnual percentage point trend[1]	**3.4%**	**-1.4%**	**0.9%**	**-0.8%**	**-7.7%**	**21.2%**	**1.3%**
	90% confidence interval	[1.1%,5.8%]	[-3.6%,0.7%]	[-2.2%,4.0%]	[-3.6%,2.0%]	[-11.9%,-3.5%]	[-3.7%,46.0%]	[0.2%,2.4%]
	number of site-years	148	293	183	139	53	20	850

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of all hours that data is missing for*

[2] *Counts and capacities reported for each install year are not cumulative.*

3.8 Summary of Trend Analyses

Table 26 summarizes the observed trends presented in this section, by technology type. The number of data points in each cell is the number of site-years: three years of data for a single site would count three site-years. *Trends that are statistically significant are highlighted in green.* Generally, statistically significant trends are seen at the technology level for all technologies except gas turbines; there are only three gas turbines in the metered data population. All metrics evaluated showed statistically significant trends at the aggregate population level.

- **Decline in capacity factor** (5.9 percentage points per year) is due to an increase in off time (8.2 percentage points, as a percentage of all hours, per year) and a decrease in output levels during on times:
  - The increase in off-time is due to an increase in long duration (greater than three days off events); these long duration events subsume both on hours and short and medium duration off hours.
- **Electrical efficiency** shows a modest decrease (0.4 percentage points per year), which may be attributable to the decreased operating levels of systems during on times.
- **System efficiency** is decreasing more rapidly than electrical efficiency, implying that less thermal energy is being utilized each year.

» **Data acquisition** systems provide a stable amount of data for IC engines and microturbines. However, significant increases in data gaps for fuel cells and gas turbines are observed. These technologies have the smallest populations and are in the most need of consistent data quality to make long-term conclusions.

Table 26. Summary of annual trends by technology type

Type		Capacity Factor	Hours of Operation	Short Duration Off Time	Medium Duration Off Time	Long Duration Off Time	Load Level When On	Electric Efficiency	System Efficiency, PUC 216.6(b)	Data Gaps
Fuel Cell	average annnual percentage point trend	**-6.7%**	**-4.7%**	**-0.5%**	**-0.3%**	**5.4%**	**-3.2%**	**-0.9%**	**-0.8%**	**6.9%**
	90% confidence interval	[-10.0%,-3.5%]	[-7.7%,-1.7%]	[-0.9%,-0.1%]	[-0.6%,0.0%]	[2.7%,8.1%]	[-5.5%,-1.0%]	[-1.4%,-0.4%]	[-2.5%,0.9%]	[1.8%,12.0%]
	number of site-years	33	33	33	33	34	33	33	33	35
Internal Combustion Engine	average annnual percentage point trend	**-5.2%**	**-7.8%**	**-0.9%**	**-1.0%**	**9.8%**	**-2.3%**	**-0.1%**	**-1.1%**	**1.4%**
	90% confidence interval	[-6.3%,-4.1%]	[-9.4%,-6.2%]	[-1.3%,-0.6%]	[-1.4%,-0.6%]	[8.2%,11.4%]	[-3.4%,-1.3%]	[-0.3%,0.1%]	[-1.4%,-0.8%]	[-0.1%,2.8%]
	number of site-years	496	496	496	496	496	423	456	456	553
Microturbine	average annnual percentage point trend	**-4.8%**	**-7.2%**	**-1.5%**	**-1.1%**	**9.8%**	**-1.5%**	**0.0%**	**-0.4%**	**0.0%**
	90% confidence interval	[-6.5%,-3.1%]	[-9.5%,-4.9%]	[-2.2%,-0.8%]	[-1.6%,-0.5%]	[7.5%,12.0%]	[-3.1%,0.0%]	[-0.1%,0.2%]	[-0.7%,-0.2%]	[-1.8%,1.8%]
	number of site-years	238	238	238	238	238	197	221	221	251
Gas Turbine	average annnual percentage point trend	**-1.1%**	**-1.4%**	**0.0%**	**0.5%**	**1.0%**	**0.4%**	**-1.8%**	**-10.1%**	**14.8%**
	90% confidence interval	[-4.9%,2.8%]	[-3.5%,0.6%]	[-0.3%,0.2%]	[0.0%,0.9%]	[-0.9%,3.0%]	[-3.5%,4.3%]	[-5.7%,2.1%]	[-15.7%,-4.6%]	[4.5%,25.0%]
	number of site-years	10	10	10	10	10	10	10	10	11
All Types	average annnual percentage point trend	**-5.9%**	**-8.2%**	**-1.0%**	**-0.8%**	**10.1%**	**-2.5%**	**-0.4%**	**-1.3%**	**1.3%**
	90% confidence interval	[-6.8%,-5.0%]	[-9.5%,-6.9%]	[-1.3%,-0.7%]	[-1.2%,-0.5%]	[8.8%,11.3%]	[-3.4%,-1.7%]	[-0.6%,-0.2%]	[-1.5%,-1.0%]	[0.2%,2.4%]
	number of site-years	777	777	777	777	778	663	720	720	850

Green indicates a statistically significant non-zero trend

Section 4. Multivariate Analysis of Capacity Factor Influences

Section 3 illustrated that there has been a steady decline in capacity factor of SGIP CHP systems over time, and that this decline is due primarily to an increase in long-duration (greater than three days) off events. However, gas prices increased steadily during the analysis years (from $5.32/MMBtu in 2002 to $11.09/MMBtu in 2008), making it unclear whether aging systems with increased maintenance needs, or gas prices were the cause of this decline. This section examines these two factors using a multivariate regression model. This analysis is repeated for the sites that we received billing data for, with the inclusion of site load constraints as an independent variable.

The following linear model of annual capacity factor as a function of system age and average annual gas prices was used:

$$CF = \beta_0 + \beta_{NGcost} NGcost + \beta_{Age} Age$$

Where

» *CF* is the capacity factor.

» β_0 is the estimated constant term.

» β_{NGCost}, is the estimated influence of gas cost ($/MMBtu) on capacity factor.

» β_{Age} is the estimated influence of age (years) on capacity factor.

» *NGcost* is the average annual natural gas cost ($/MMBtu).

» *Age* is the age of the system (years) during the calendar year of the data point.

This analysis was conducted for each technology type separately, and for all technologies in aggregate. The results are presented in Table 27. In this table, estimates are presented as percentage points. For example, across all technologies, a 6.2 percentage point decrease in capacity factor is observed per one year increase in age of systems. This implies that a system with a capacity factor of 0.500 in one year would be expected to have a capacity factor of 0.438 the next year, assuming gas prices stayed the same. Note that all technology types except gas turbines exhibit a statistically significant decrease in capacity factor due to age, yet only fuel cells exhibit a statistically significant decrease in capacity factor due to natural gas price.

Table 27. Capacity factor changes based on system age and fuel cost

		Variables: System Age (Years)	Variables: Gas Cost($/MMBtu)*
Fuel Cell	average percentage point change in capacity factor	**-4.4%**	**-6.0%**
	90% confidence range	[-7.5%,-1.2%]	[-9.2%,-2.8%]
	number of site-years	30	30
Microturbine	average percentage point change in capacity factor	**-4.7%**	**1.5%**
	90% confidence range	[-6.8%,-2.6%]	[-1.3%,4.2%]
	number of site-years	226	226
IC Engine	average percentage point change in capacity factor	**-5.2%**	**0.1%**
	90% confidence range	[-6.5%,-3.9%]	[-1.9%,2.0%]
	number of site-years	483	483
Gas Turbine	average percentage point change in capacity factor	**-1.8%**	**1.7%**
	90% confidence range	[-6.7%,3.0%]	[-4.2%,7.6%]
	number of site-years	7	7
All Types	average percentage point change in capacity factor	**-6.2%**	**1.5%**
	90% confidence range	[-7.3%,-5.1%]	[-0.1%,3.0%]
	number of site-years	755	755

*1 MMBtu = 1 Mcf = 10 therms

On average, holding the cost of natural gas constant, a one year increase in system age results in a 6.2 percentage poing decrease in capacity factor. For example, if a system had a capacity factor of 50% in its first year, then we'd expect it to have a capacity factor of 43.8% in the second year, 37.6% in the third year, etc.

There is a statistically signifcant correlation between capacity factor and system age with 90% confidence that the average capacity factor in the population decrease between 7.3 percentage points and 5.1 percentage points per year of age.

755 datapoints were used to determine this relationship. Each datapoint is data from one site for one year.

The result of the previous model, that natural gas price is not a statistically significant influence on capacity factor, is somewhat surprising given that many respondents cited gas prices as factor in their operations changes (Section 5). However, for an individual site, the decision to run a CHP system or not is not based directly on the cost of natural gas, but rather on the calculus of whether it is less expensive to operate the CHP system or to purchase the electricity and fuel for thermal loads. This depends not only on gas prices, but also on system efficiency and the site's need for recoverable heat. It was therefore considered a separate model, in which capacity factor is a function of age and of the cost of CHP produced electricity ($/kWh). This normalizes for differences in electrical efficiencies across sites. By netting out the value of recovered waste heat, we also accounted for differences in the value of waste heat across sites.

The following linear model of annual capacity factor as a function of system age and average annual gas prices was used:

$$CF = \beta_0 + \beta_{GenerationCost} Generation\ Cost + \beta_{Age} Age$$

Where

- » *CF* is the capacity factor.
- » β_0 is the estimated constant term.

» $\beta_{GenerationCost}$ is the estimated influence of the CHP cost to generate electricity ($/kWh) on capacity factor.

» β_{Age} is the estimated influence of age (years) on capacity factor.

» *GenerationCost* is the average CHP cost to generate electricity ($/kWh), considering only gas costs (and not maintenance costs) and discounting costs for the value of recovered heat (assuming that this heat would have otherwise been provided by natural gas at the same price rate).

» *Age* is the age of the system (years) during the calendar year of the datapoint.

The results of this model are presented in Table 30. This model proved to be a better fit to the data. Here, the indirect influence of fuel cost on capacity factor *is* statistically significant for all technologies except gas turbines. On average, a one cent increase in the cost to generate electricity results in 1.2 percentage point decrease in capacity factor, and a one year increase in system age results in a 4.3 percentage point decrease in capacity factor.

Table 28. Capacity factor changes based on system age and cost to self-generate electricity

		Variables	
		System Age (Years)	Cost to Self-Generate Electricity (¢/kWh)
Fuel Cell	average percentage point change in capacity factor	**-4.8%**	**-4.4%**
	90% confidence range	[-7.9%,-1.7%]	[-6.8%,-2.0%]
	number of site-years	30	30
Microturbine	average percentage point change in capacity factor	**-2.3%**	**-2.5%**
	90% confidence range	[-4.2%,-0.4%]	[-3.7%,-1.4%]
	number of site-years	226	226
IC Engine	average percentage point change in capacity factor	**-4.2%**	**-0.8%**
	90% confidence range	[-5.3%,-3.0%]	[-1.2%,-0.5%]
	number of site-years	483	483
Gas Turbine	average percentage point change in capacity factor	**-0.3%**	**-0.3%**
	90% confidence range	[-7.1%,6.5%]	[-2.5%,1.9%]
	number of site-years	7	7
All Types	average percentage point change in capacity factor	**-4.3%**	**-1.2%**
	90% confidence range	[-5.3%,-3.3%]	[-1.6%,-0.9%]
	number of site-years	755	755

On average, a one cent increase in the cost to generate electricity results in 1.2 percentage point decrease in capacity factor, and a one year increase in system age results in a 4.3 percentage point decrease in capacity factor.

This analysis was repeated for the subset of sites for which utility electric billing data were provided. For these sites, the purchased electricity as a percentage of total site load was included as an additional variable to examine the extent to which net export constraints affect capacity factor. The revised model is:

$$CF = \beta_0 + \beta_{GenerationCost} Generation\ Cost + \beta_{Age} Age + \beta_{SiteLoad} SiteLoad$$

Where, additionally:

- » $\beta_{SiteLoad}$ is the estimated influence of percent of electricity generated (as opposed to purchased) on capacity factor.
- » *SiteLoad* is percentage of site electricity load met by CHP during hours in which the CHP system was operating – that is, the ratio of CHP generated electricity to the sum of CHP generated electricity and electricity purchased during hours of CHP operation.

The results of this model are presented in Table 29. **Note that these results are for the subset of sites for which useful billing data were received.** This was not a random sample, but rather was selected to examine those sites with systems that spent the most time at part load. For this subset of the population, on average, a 0.4 percentage point increase in capacity factor is seen for each percentage point increase in total site load, year over year. For example, a site whose total site annual kWh consumption (generated plus purchased) increased by one percentage point from one year to the next would be expected to have a 0.4 percentage point increase in capacity factor. These sites show a statistically significantly greater sensitivity to the cost to produce electricity than the population as a whole.

Table 29. Capacity factor changes based on changes in site electricity demand, system age, and cost to self-generate electricity

		Variables		
		Percentage Point Change in Site kWh/Year	System Age (Years)	Cost to Self-Generate Electricity (¢/kWh)
Fuel Cell	average percentage point change in capacity factor	**0.2%**	**-3.2%**	**-5.1%**
	90% confidence range	[-0.1%,0.5%]	[-7.5%,1.1%]	[-9.7%,-0.4%]
	number of site-years	17	17	17
Microturbine	average percentage point change in capacity factor	**0.4%**	**2.3%**	**-4.8%**
	90% confidence range	[0.2%,0.6%]	[0.0%,4.5%]	[-6.6%,-2.9%]
	number of site-years	106	106	106
IC Engine	average percentage point change in capacity factor	**0.4%**	**-4.9%**	**-0.4%**
	90% confidence range	[0.3%,0.6%]	[-6.7%,-3.1%]	[-1.9%,1.0%]
	number of site-years	158	158	158
Gas Turbine	average percentage point change in capacity factor	**0.4%**	**-3.6%**	**0.7%**
	90% confidence range	[-0.6%,1.4%]	[-7.2%,-0.1%]	[-1.0%,2.4%]
	number of site-years	4	4	4
All Types	average percentage point change in capacity factor	**0.4%**	**-2.1%**	**-2.8%**
	90% confidence range	[0.3%,0.5%]	[-3.5%,-0.7%]	[-3.7%,-1.9%]
	number of site-years	294	294	294

A 0.4 percentage point increase in capacity factor is seen for each percentage point increase in total site load, year over year.

Section 5. Participant Interviews

Participant interviews were conducted with representatives from 43 CHP sites[17] for which performance data were provided. The objectives of these interviews were to 1) collect qualitative information on system performance and factors affecting system performance, and 2) correlate performance data to participant experience.

An overarching theme to consider when reviewing the results of the CHP participant interviews is that the systems themselves are technically complex, and the decision-making regarding the operation of the systems is multi-faceted. Both technical and economic factors play a significant role in the long-term performance of a CHP system.

This section first describes the sample selection approach and the topics discussed in participant interviews. A discussion of interview results starts by characterizing the operations and maintenance practices of participants, then the performance experiences of interview respondents. A discussion of the factors affecting system performance follows; market and policy factors are discussed first, followed by technical factors. Next, the section discusses the systems that are no longer operational, outlining the reasons the systems are no longer running. The section concludes with an overview of additional findings that do not fit well into the primary discussion topics.

As will be discussed in Section 5.1, the interview sample was not an entirely random one, but rather was selected to ensure a range of technology types, PAs, and performance characteristics. **Therefore, results from the interviews are not necessarily representative of the entire population of sites**.

5.1 Sample Selection

The interview sample was drawn from the population of 208 SGIP program participants with CHP systems for which performance data were available. These systems were installed between 2001 and 2008. The sample was designed to include at least two sites of each technology type for each PA, as well as a range of performance characteristics and installation years.

---

[17] Thirty-nine (39) unique host customers were interviewed. Four of these host customers had two incented systems each in the interview sample.

System performance was categorized based on the range of monthly capacity factors on record for a given site, as well as the site's outage history. The first step in examining the performance record for each site was to segment each site's monthly capacity factors into the following categories:

» **Normal** - monthly capacity factor is within a normal range for the site.

» **Low** - monthly capacity factor is more than 1.5 standard deviations below the monthly mean for the site.

» **High** - monthly capacity factor is more than 1.5 standard deviations below the monthly mean for the site.

» **Zero** - the site recorded zero use for the month. This is distinct from a month of *missing* data.

Depending on the pattern of monthly capacity factors for each site over time, the sites were then categorized according to their overall performance record based on the type of performance they exhibited while operating (usage categories) and their outage history (outage categories).

Usage categories included:

» **Normal** - sites with no significant variation in output.

» **Erratic** - sites with both significant decreases and increases in output.

» **Increase** - sites with a significant increase in output, followed by a return to normal output.

» **Decrease** - sites with a significant decrease in output, followed by a return to normal output.

Outage categories included:

» **Normal** - sites with no month-long outages.

» **Outage** - sites with an outage, followed by a return to normal output.

» **Terminal** - sites with a terminal outage (i.e., the system stopped operating and no further usage was recorded for the site).

After sorting sites according to utility and technology type, sites were randomly selected and then reviewed to ensure a mix of performance experiences and system ages were represented. A primary sample of 40 was selected, and a replacement sample of an additional 40 sites was selected to provide interviewers with ample number of sites upon which to draw to achieve the target of 40 completed interviews. The replacement sample was selected using the same approach as the primary sample.

5.2 Interview Topics

Interview subjects were asked to describe their systems and the performance of their systems. Key topics addressed in the interviews included:

» System ownership and operations arrangement.

» How waste heat is used.

» Factors driving the system's operating schedule.

» Staff turnover.

» Equipment quality and performance.

» Maintenance and performance monitoring practices.

» Recollection of specific outages and periods of atypical performance.

» Appropriateness of system design.

» Whether the system is operational, the reasons for the system's current condition, and whether there are plans to reinitiate system operations, if currently non-operational.

The complete interview guide is provided in *Appendix A: Interview Guide.*

5.3 Summary of Respondents

The research team completed interviews with program participants representing 43 CHP sites. Table 30 summarizes the interview respondents by their technology type, installation year and average system size. For visual clarity, cells with zero values are left blank. The majority of respondents installed systems during the 2003-2005 timeframe. The greatest number of respondents (20 sites) had installed IC engines; these tended to be in the 300 kW to 1 MW size range. Fourteen respondents had microturbines; these systems ranged in size from 60 kW to 400 kW. Seven respondents had fuel cells; these systems ranged in size from 250 kW to 1 MW. Only two respondents had gas turbines: a 1 MW system and a 4.5 MW system.

Table 30. Summary of number of interview respondents by technology, installation year and average system size

PA	Technology Type	Installation Year									
		2001	2002	2003	2004	2005	2006	2007	2008	All Years	Average System Size (kW)
PG&E	Fuel Cell					1	2			3	833
	Gas Turbine				1					1	1,383
	IC Engine			2	5	1	1			9	481
	Microturbine			2						2	360
SCE	Fuel Cell									0	n/a
	Gas Turbine									0	n/a
	IC Engine	1			1					2	325
	Microturbine				3	1				4	75
SCG	Fuel Cell									0	n/a
	Gas Turbine					1				1	4,500
	IC Engine			3	1					4	1,010
	Microturbine		1	2		1				4	357
CCSE	Fuel Cell						2	1	1	4	563
	Gas Turbine									0	n/a
	IC Engine		1			2		2		5	557
	Microturbine		2	1				1		4	79
All PAs	Fuel Cell					1	4	1	1	7	679
	Gas Turbine				1	1				2	2,942
	IC Engine	1	1	5	7	3	1	2		20	590
	Microturbine		3	5	3	2		1		14	197

blank cells indicate zero systems in the sample

Source: Summit Blue interviews with SGIP participants

Appendix C: Monthly Capacity Factor and Events of Interview Respondent Sites illustrates the historic monthly capacity factors for each respondent and uses color coding to identify events (observed changes in capacity factor) that respondents were able to recollect and describe.

5.4 *System Ownership*

Seventy-two percent of respondents (31 respondents) own and operate their systems. Of the remaining 28 percent, most are owned by a third party that sells electricity to the host site through a power purchase agreement arrangement (PPA), and one site is leased from a third party.

5.5 System Operations

Respondents indicate that a variety of factors affect a facility manager's decisions to install a CHP system as well as regarding its operating schedule. Decision-makers typically consider gas and electricity price projections when determining whether a CHP system will be economically viable. A building's load profile and the CHP system's technical operating requirements (i.e., manufacturer specifications) are also factored into upfront decision-making regarding whether to install a CHP system and how to operate it. However, a different set of factors may determine the system's daily operating schedule.

Respondents were asked about the most important factors that affect the CHP operating schedules on a day-to-day basis. On the whole, respondents indicated that practical considerations were the dominant factor in their decision making, and that ongoing fluctuations in market conditions do not have a significant impact on daily operating schedules. Their comments were grouped into the following categories:

1. **Load following** - operations follow building load requirements (e.g., the system's operating schedule is set based on the facility's hours of operations or thermal demand).

2. **Continuous operation, economic reasons** - system operates continuously because there is always load to meet and it is always cost-effective to operate the system.

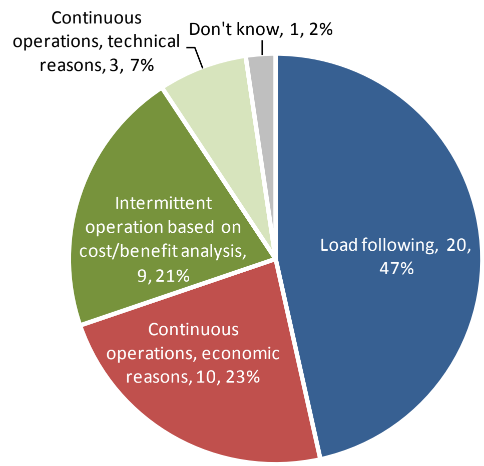
3. **Continuous operation, technical reasons** - system operates continuously due to equipment requirements (e.g., fuel cell performance is best when operated continuously).

4. **Intermittent operation** - operations vary in response to gas and electricity prices.

As shown in Figure 4, load following was the dominant operating schedule (20 of 43 sites, 47 percent of sites). The next most common category of respondents is those who run their systems continuously for economic reasons (10 sites, 23 percent). A separate group of respondents also operate their systems continuously, but primary for the purpose of enhancing equipment performance (3 sites, 7 percent). Specifically, fuel cell manufacturers encourage fuel cell system owners to run the equipment continuously, as the technology does not respond well to shifts in operations. Nine sites (21 percent) reported that they regularly adjust their operating schedule based on changes in gas and electricity prices.

Some respondents noted that they have conducted periodic studies of their system's economics to determine whether or not to take the system out of operation based on economic factors. However, the day-to-day operating schedule for their system is determined based on building load requirements.

Figure 4. Primary operating regimes



The interview sample was not an entirely random one, but rather was selected to ensure a range of technology types, PAs, and performance characteristics. Therefore, results from the interviews are not necessarily representative of the entire population of sites.

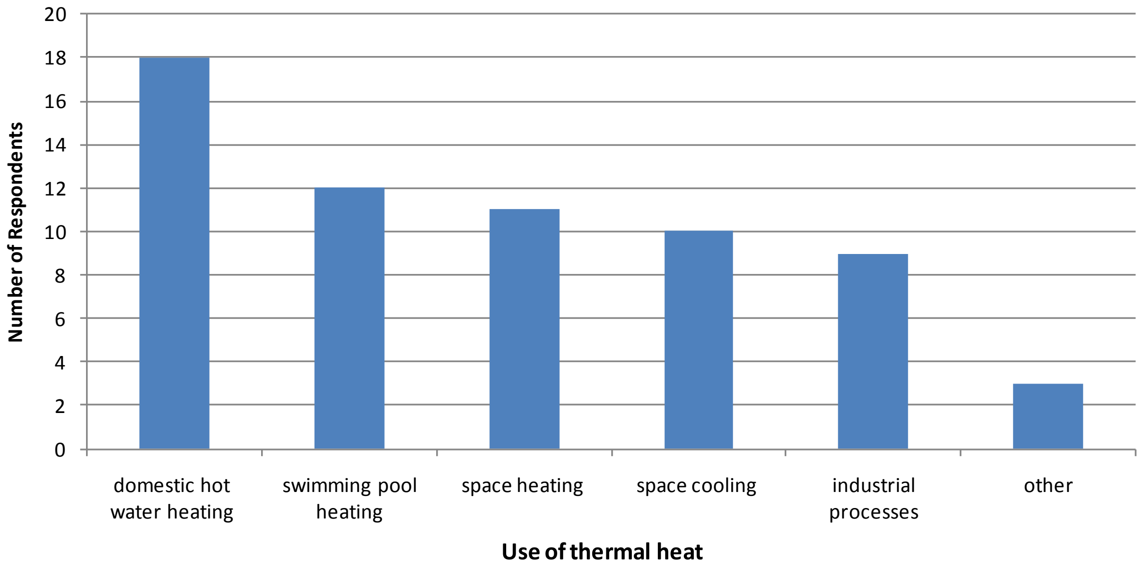
Source: Participant interviews, n=43

5.6 *Use of Recovered Heat*

Respondents were asked how they use the heat output (waste heat) from their CHP systems. Results are presented in Figure 5. Sixteen respondents indicated that they use their system's heat output in multiple ways, therefore, multiple uses were recorded for some sites, and the total number of responses shown in Figure 5 exceeds the total number of respondents.

The most common use of heat output is for domestic hot water. Respondents representing 18 sites (42 percent of all respondent sites) reported using heat output for this purpose. Twelve sites (28 percent of all respondent sites) use waste heat to heat swimming pools. These respondents included schools, public facilities and health clubs. Eleven sites (26 percent of all respondent sites) reported using heat output for space heating. Representatives from 10 sites reported using the heat output to run an absorption chiller. Nine respondents use heat output to drive their industrial or manufacturing processes. Two respondents described using heat output for other purposes including as a heat source to run emissions control equipment and to produce chilled water to support manufacturing and industrial processes. There was no correlation between waste heat usage and technology type.

Figure 5. Uses of Waste Heat



The interview sample was not an entirely random one, but rather was selected to ensure a range of technology types, PAs, and performance characteristics. Therefore, results from the interviews are not necessarily representative of the entire population of sites.

Source: Summit Blue interviews of SGIP participants

5.7 Maintenance

Most respondents explained that their systems are complex and require regular maintenance from highly specialized technicians in order to perform properly. Seventy-nine percent of respondents (34 respondents) either have, or have at some point had a service contract for their system. Service contracts vary in the breadth of components they cover. In some cases, a respondent's service contract would cover the engine, but the system owner was responsible for all other components. For most respondents with service contracts, however, the service provider is responsible for keeping the entire system running smoothly.

5.8 System Performance

Forty percent of all respondents reported that projections for the financial performance of their CHP system investment were not being realized. This is due to a variety of market, policy, and technical factors that are discussed in the following sections.

In general, respondents could not recall the dates or duration of any specific outage event. Therefore, it was difficult to precisely correlate program metered data with respondent description of system performance. However, 85 percent of respondents' (35 sites) recollections of their systems' performance were either entirely or somewhat consistent with the metered data for the systems.[18] Those categorized as "somewhat consistent" include sites for which the respondents' comments are generally consistent with performance data, though there are some minor inconsistencies. For example, major outage dates may be off by several months, or the respondent reported particularly poor performance, though the data show the performance was more positive than reported. Sites categorized as "inconsistent" include those for which respondents' comments are fundamentally different from the metered data. In all cases in which a site was categorized as inconsistent, the respondents' comments regarding the status of the system's operating status was dramatically different from that shown in the metered data (e.g., the respondent reported that the system was running during a long period of time for which performance records indicate the system was not operational).

Respondents were asked a variety of questions related to their systems' performance. Questions included:

1. Have you experienced problems with system performance?
2. Have equipment problems resulted in lower than expected system performance?
3. Does the system generally operate reliably?
4. Can you recall any periods of time during which there was a significant system outage, or that the system operated at a capacity that was significantly lower than normal?

A summary of responses to the first three questions is presented in Figure 6. Results are presented as the percentage of respondents for each technology type in order to reflect the overall representation of technology types among respondents. Note that neither of the two respondents with gas turbines reported equipment or performance problems, so there is no reference to gas turbines in the discussion of performance problems and equipment failures that follows.

---

[18] Interviews were conducted with 39 respondents. Four of those respondents oversaw two CHP sites that had received SGIP funding, bringing the total number of sites discussed in the interviews to 43. However, metered data for only 41 of the sites were available. Therefore, discussion of metered data pertains to those 41 sites.

Fuel Cells

All seven fuel cell systems experienced problems with system performance. Forty-three percent of respondents with fuel cells expressed that the equipment problems resulted in lower than expected system performance. Eighty-six percent of respondents with fuel cells (6 respondents) characterized their fuel cell systems as "generally reliable" despite the fact that they had experienced problems with system performance. Furthermore, 100 percent of respondents with fuel cells indicated that their system components are "high quality," and that their systems were designed appropriately to meet the needs of their facilities.

On the whole, respondents with fuel cells were generally positive in their discussion of the technology, though one noted frustration with their service provider, and two noted that the newer generation of the technology is even better than what is installed at their facility. The generally positive experience of these respondents may reflect the fact that respondents who installed the fuel cell systems understood it to be an early-stage technology, and fuel cell manufacturers have taken steps to mitigate the site hosts' financial risks that may result from the growing pains of the emerging technology. In some cases, the fuel cell manufacturer owns the system and sells power to the site host through a PPA. In other cases, the fuel cell manufacturer entered into contracts with the site host that guarantee that poor performance will not affect the site host's bottom line. In both cases, the risk mitigation strategies appear to improve the site hosts' level of satisfaction with the technology.

Microturbines

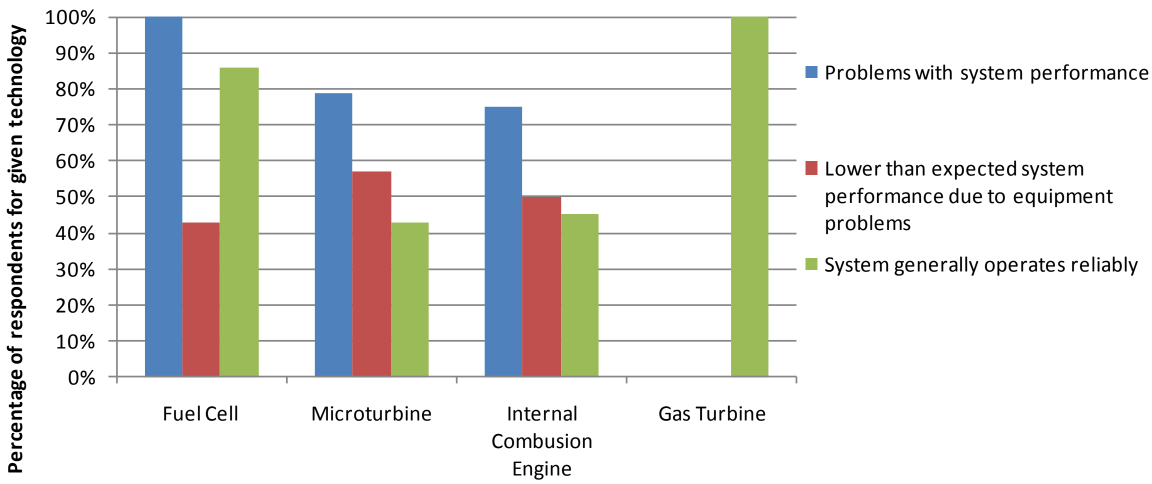
In contrast to the experience of respondents with fuel cells, respondents with microturbines had higher expectations for their systems' performance and were less likely to have a risk-mitigation strategy, such as a PPA, in place. The respondents were more disappointed by their experience with their systems than were respondents with fuel cells. 57 percent of the respondents with microturbines (8 respondents) reported that system performance fell short of their expectations. Only 43 percent of respondents with microturbines (6 respondents) characterized their systems as reliable. Sixty-four percent of respondents with microturbines (9 respondents) characterized their systems' components as "high quality" and designed to suit the needs of their facility.

IC Engines

Respondents with IC engines were somewhat more satisfied with the level of performance of their system than those with microturbines. 50 percent (10 respondents) expressed that the system performance had fallen short of their expectations due to equipment performance problems. Forty-five percent of respondents with IC engine systems (9 respondents) characterized their systems as reliable. Fifty-five percent of respondents with IC engine systems

(11 respondents) indicated that their systems' components are "high quality," and that their systems were designed appropriately to meet the needs of their facilities.

Figure 6. System performance summary by technology



The interview sample was not an entirely random one, but rather was selected to ensure a range of technology types, PAs, and performance characteristics. Therefore, results from the interviews are not necessarily representative of the entire population of sites.

Neither of the two gas turbine hosts interviewed expressed peformance problems or lower than expected performance.

Source: Summit Blue interviews of SGIP participants

The types of equipment performance problems experienced by respondents are summarized in Figure 7. The types of problems were so varied that the "other" category was a significant category for all three technologies for which respondents reported problems.[19] The most fundamental system component for microturbines and IC engines, the engine or turbine, was problematic for 50 percent of respondents with microturbines (7 respondents), and 45 percent of respondents with IC engines (9 respondents). Heat exchangers were a problem for 50 percent of respondents with microturbines (7 respondents), and for 15 percent of respondents with IC

[19] Neither of the two respondents with gas turbines reported experiencing equipment problems.

engine systems (3 respondents). Five out of seven of the respondents with fuel cells noted that their fuel cell stacks needed to be replaced significantly ahead of schedule.

In many cases, the most significant equipment problems were those associated with peripheral system components. The gas compressor was a problem for 29 percent of respondents with microturbines (4 respondents). Controls were a problem for two fuel cell systems and two IC engine systems. Fuel quality was a problem for one IC engine system.

The many "other" equipment components with which respondents reported problems include:

» Electrical components (2 ICE, 1 FC).

» Motors (1 ICE, 1 FC).

» Pumps (2 MT, 1 ICE).

» Water quality for fuel cells (2 FC).[20]

» Ignition system (2 ICE).

» Plumbing (1 MT).

» Filters (1 FC).

» Heat regulation (2 ICE).

» Emissions control equipment (1 ICE).

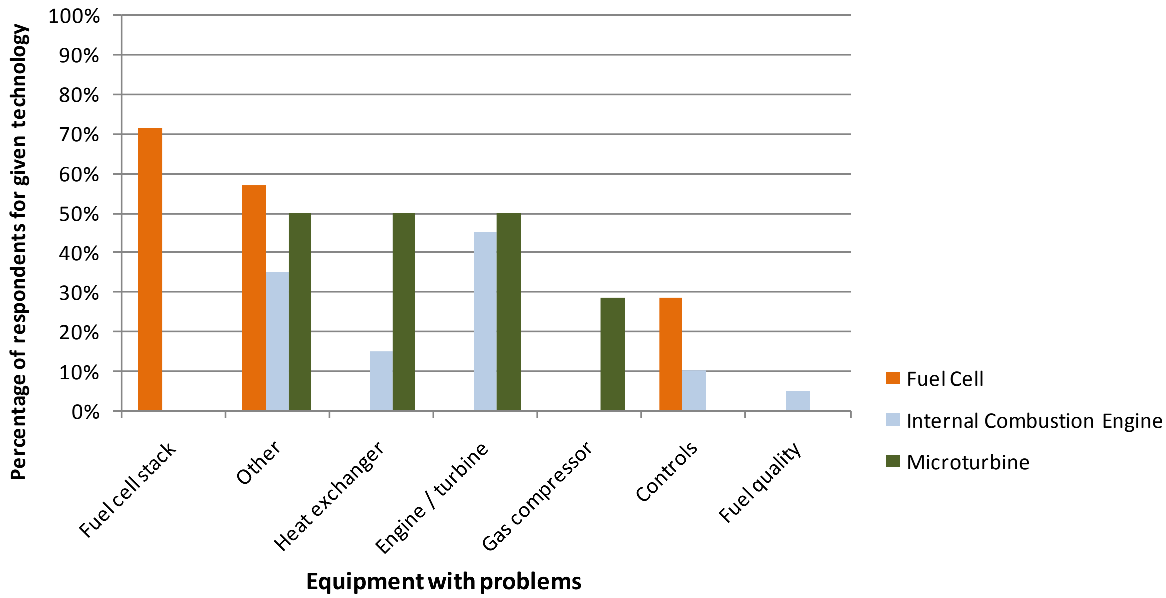
» System has too limited a tolerance for operating conditions (i.e., power quality issues) (1 ICE, 1 FC).

» Valves (1 ICE, 1 MT).

» Cooling system (1 ICE).

[20] Two respondents with fuel cell systems indicated that the water supplying the system was not pure enough and was causing buildup of minerals that were having a negative effect on system performance.

Figure 7. Summary of equipment problems by technology



The interview sample was not an entirely random one, but rather was selected to ensure a range of technology types, PAs, and performance characteristics. Therefore, results from the interviews are not necessarily representative of the entire population of sites.

Neither of the two gas turbine hosts interviewed expressed equipment problems.

Source: Summit Blue interviews of SGIP participants

A number of respondents from all technology categories (with the exception of gas turbines) reported that the systems require far more maintenance and repair than anticipated. Some select comments from respondents include:

"At any given time, there's always one component that's failing or needs attention."

-Public entity, microturbine owner

"The technology is just not a great fit for providing reliable energy supply. There are too many maintenance needs."

-Industrial entity, internal combustion system owner

"We're not seeing the economic benefits we anticipated due to the system's excessive maintenance needs."

-Public entity, internal combustion system owner

"The maintenance issues are significant, but that is part of being an early-adopter."

-Private entity, fuel cell site host

Only a few respondents noted that age was a factor in their equipment performance problems. A number of respondents described having significant problems getting the system running initially, but noted that the system ran more smoothly once the initial problems had been resolved.

5.9 Market and Policy Factors Affecting Performance

5.9.1 Net Metering

A critical market factor that affects CHP system economics noted by a number of respondents is the lack of net metering for non-fuel cell CHP systems. In the absence of net metering, CHP systems receive no financial reward for producing electricity in excess of that which they used on-site. A few respondents indicated that they would operate their system at a higher capacity if they could sell the excess generation back to their utility. Operating at an increased capacity would make the systems run more efficiently and would improve the financial viability of operating many CHP systems.

5.9.2 Utility Charges and Policies

Several respondents also noted that utility demand charges and other fees significantly lower their CHP system's financial returns. These respondents assert that the utilities have opposed CHP systems for many years because they have a negative impact on utility revenues. They expressed that owners of CHP systems are not financially rewarded for the benefits provided to the electric grid by CHP systems (e.g., improved grid reliability, and voltage support), and that if more favorable policies were in place, many more CHP systems would be economically viable to operate. One respondent described having been back-charged for public purpose fees associated with installing a CHP system. The fees were introduced as a result of a decision made over a year after the respondent made the decision to invest in the CHP system.

Another utility policy that several respondents described as having a negative impact on CHP system performance is that CHP systems are automatically shut down when there is an interruption in power supply from the electric grid. Some respondents with poor power quality at their sites explained that these operational disturbances cause significant maintenance problems (i.e., staff need to respond to bring the CHP system back online), and detract substantially from their projects' financial performance.

Two respondents explained that their relationship with the utility is such that their CHP system automatically ramps down when their facility's demand drops below a certain threshold to ensure that their facility always maintains a baseline level of demand for electricity supplied from the utility.

5.9.3 Emissions Controls and Requirements

A few respondents with IC engine systems explained that emissions control requirements are extremely stringent and characterized the requirements as overly burdensome for power systems that are relatively clean. These respondents explained that they anticipate air quality requirements to become increasingly stringent in the future, and that this may result in their organization deciding to take the system offline.

5.9.4 Natural Gas and Electricity Prices

As noted earlier, 40 percent of all respondents reported that projections for the financial performance of their CHP system investment were not being realized. It is inherently difficult to project the future of market forces that will have a critical bearing on a project's actual performance. CHP systems are fueled by natural gas, and the electricity they produce offsets electricity they would otherwise purchase from their utility. Therefore, the economic viability of a CHP system is integrally related to the "spark spread," or the difference between natural gas and electricity prices. A large spark spread (i.e., when a facility can purchase natural gas for relatively low prices, and generate electricity that offsets relatively high priced electricity rates) is ideal for CHP system's financial performance. Unfortunately, the spark spread that has resulted from volatile energy markets during the last decade has not fulfilled many CHP system owners' expectations.

Several CHP system owners reported that they hold contracts for natural gas procurement through entities other than their utility. In some cases, these were multi-year contracts. Fixed pricing for natural gas procurement can help mitigate CHP financial performance risk substantially. One CHP system owner indicated that he does not have enough demand to be able to enter into such contracts and cannot avoid market volatility.

While energy markets are always in flux, 2000 - 2001 was a period of particularly great uncertainty in California's energy markets. Two respondents explained that their systems were installed as a response to the power crisis, during a time when there was significant optimism about the potential for CHP systems within a deregulated electric industry.

5.10 Technical Factors Affecting Performance

5.10.1 System Capacity

Several system owners reported that it doesn't make economic sense for them to run their system at full capacity. In some cases, this is due to the fact that the system is over-sized for its facility and the facility cannot sell excess generated electricity to its utility. If these systems had been properly sized for their facilities, there would be less system capacity being underutilized. Reasons for over-sizing systems include poor design, changes to site load over time, a highly variable site load, and the unavailability of properly sized components.

For most systems, an ability to generate at a higher output level would provide financial and technical benefits. However, one respondent noted that his system does not operate reliably when it is running at a high capacity factor, so he deliberately runs it at a low capacity factor. Several respondents with microturbine and fuel cell systems did note that the vintage technology installed at their facilities is now outdated and that the manufacturer of their equipment has since developed more robust models.

5.10.2 Waste Heat

A handful of respondents noted that their systems do not run well during the summer because the opportunity to utilize heat output from the CHP system is minimized. In these instances, the waste heat is used for heating a swimming pool, process steam, and heating digester gas. Two respondents from facilities with highly variable demand for their CHP systems' heat output also reported dissatisfaction with their systems' performance.

5.10.3 System Maintenance

Another factor contributing to sub-optimal performance is that the systems are complex and maintenance-intensive, so they are heavily dependent on the services of third-party maintenance providers. Many maintenance contractors are slow in responding to clients whose systems require maintenance and repair. Sixteen percent of all respondents (7 respondents) described having received poor quality service from their maintenance contractors. An additional four respondents described circumstances indicating that there is significant volatility in the market for CHP service providers. Some PPA provider companies have changed ownership a number of times. For at least one CHP system owner, this has resulted in significant legal challenges and expenses when the new company did not fulfill its contractual obligations.

Maintenance contracts are expensive with costs reaching tens of thousands of dollars per year depending on the size of the system and scope of the contract. Some schools and other small public entities have had to rely on their own staff to maintain the CHP system due to budget constraints. These respondents reported that their staff are not qualified to properly maintain the complex CHP systems installed at their sites.

5.11 Summary of Systems that Have Ceased Operating

Twenty-six percent of the CHP systems overseen by respondents (11 systems) have ceased operating. As shown in Table 31, seven of the inoperable systems are microturbines, two are IC engines and one is a fuel cell. Fifty percent of microturbine hosts that were interviewed have ceased operating their systems.

Table 31. Summary of systems that have ceased operating, by technology

Technology type	Number of sites interviewed	Number of interviewed sites that have ceased operation	Percent of interviewed sites that have ceased operation
Fuel cells	7	1	14%
Gas turbines	2	0	0%
IC engines	20	3	15%
Microturbines	14	7	50%

Microturbine owners gave a number of different reasons for taking their systems out of operation, as follows:

1. Two different system owners cited maintenance requirements:

   i. One indicated that site personnel were not able to maintain the system after the maintenance contract expired; and

   ii. The other indicated that the maintenance requirements for his poorly performing system were excessive.

2. Economics forced three projects to cease operations:

   i. When the cost of natural gas spiked, the third party owner could not generate enough revenue to justify maintaining the system;

   ii. One system was rendered uneconomical when energy prices changed; and

iii. A system owner determined that it was not economically viable to bring his two systems back online after a mechanical failure.

3. A microturbine system owner replaced a faulty heat exchanger once but became frustrated when it failed again, so he stopped running the system; and

4. After acquiring the host facility, the new microturbine owner believed that the system was installed for the purpose of providing emergency backup power, but it was unable to do so due to utility and SGIP program policies.

IC engine owners also cited a number of reasons for taking their systems out of operation:

1. One host customer noted three influencing factors:

   a. The system was extremely unreliable;

   b. The company was required to pay expensive demand charges if the unit was down for even 15 minutes; and

   c. The service contractor provided poor quality service, then went out of business.

2. A second system owner took his system out of operation after frustration over chronic operational issues. The respondent noted that the system frequently shut down from overheating and that, when operational, didn't produce sufficient waste heat.

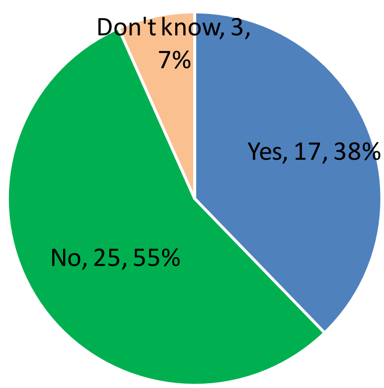
3. The third IC engine owner inherited his system from the previous site owners, who had shut the system when gas prices rose.

One **fuel cell** system was taken offline after its fuel cell stacks were depleted. The system is owned by the fuel cell manufacturer and the site host purchases electricity from the system owner through a PPA. According to the respondent, under the terms of the agreement, the third party is required to keep the system operational, but due to budget problems the company chose not to replace the fuel cell stack to restore function to the system. The respondent reports that he has no practical means of challenging this outcome, but wishes to find a way to make the system operational again.

5.12 Retrospective Decision Making

Host customers were asked if they would choose to install their systems again, given their experience with their systems and current market factors. Respondents from 53 percent of the sites (23 respondents) reported that they would not choose to install their CHP systems again if faced with the decision today (Figure 8). Three of these respondents said they would install a different type of on-site generation system today. One respondent would install a gas turbine because he believes that they are less likely than IC engines to be affected by the increasingly stringent emissions control requirements. Two respondents said they would choose to install PV or wind turbines instead of a CHP system if faced with the decision again. One of these respondents explained that at the time of his CHP installation, PV was relatively unproven. This respondent commented on the irony of the fact that he initially dismissed PV, assuming it would be more complex than an IC engine because he thought it would require battery back-up. Others cited unfavorable financial performance of their existing systems, volatility of energy prices, poor energy pricing conditions, and system reliability concerns as reasons not to install a CHP system.

Figure 8. Summary of respondents who would install CHP if faced with decision today



The interview sample was not an entirely random one, but rather was selected to ensure a range of technology types, PAs, and performance characteristics. Therefore, results from the interviews are not necessarily representative of the entire population of sites.

Source: Summit Blue Consulting interviews of SGIP participants, n=43

Section 6. Conclusions and Recommendations

This purpose of this investigation was to identify and quantify reasons for the performance degradation in SGIP CHP systems noted in recent SGIP impact evaluations. The results presented here suggest that this degradation is due primarily to increased long-duration outages (greater than three days) and secondarily to reduced levels of output during on-time. As a percent of all hours, off time increases approximately 8 percentage points per year. Adding to the reduction in capacity factor is a 2.5 percentage point annual reduction in operating level when CHP systems are on. Figure 9 graphically summarizes these effects; Table 32 quantifies these observed trends.

Figure 9. Disaggregation of performance as percentages of rated capacity

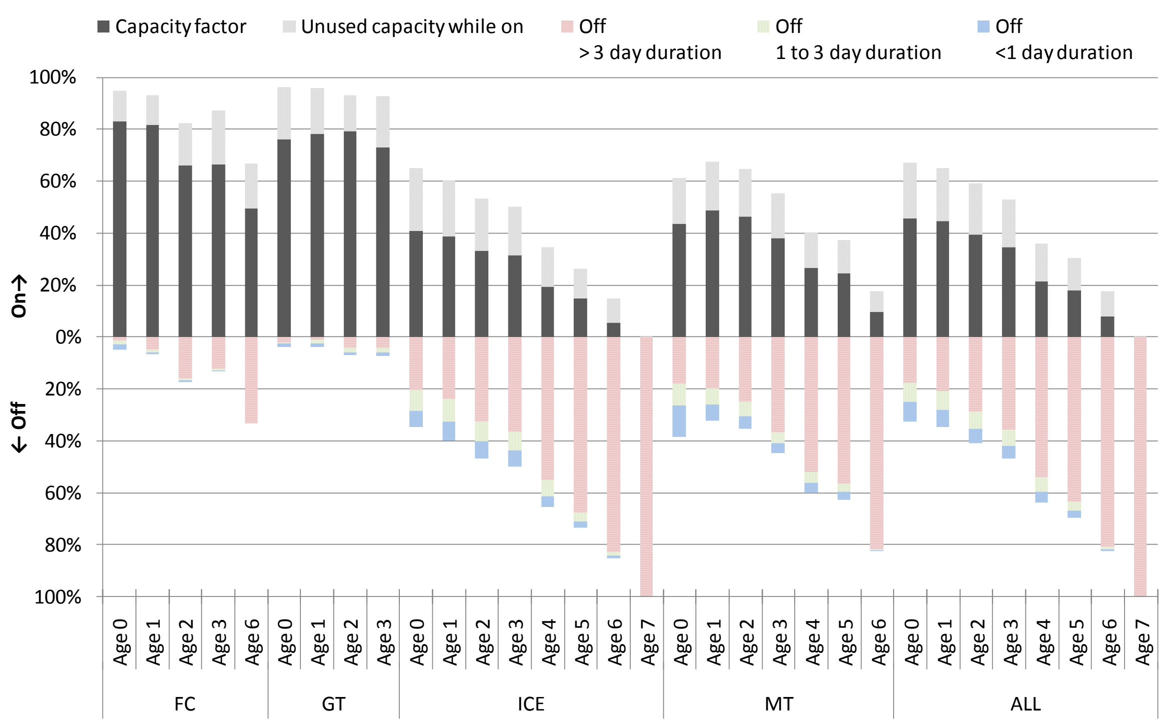


Table 32. Summary of annual trends by technology type

Type		Capacity Factor	Hours of Operation	Short Duration Off Time	Medium Duration Off Time	Long Duration Off Time	Load Level When On	Electric Efficiency	System Efficiency, PUC 216.6(b)	Data Gaps
Fuel Cell	average annnual percentage point trend	**-6.7%**	**-4.7%**	**-0.5%**	-0.3%	**5.4%**	**-3.2%**	**-0.9%**	-0.8%	**6.9%**
	90% confidence interval	[-10.0%,-3.5%]	[-7.7%,-1.7%]	[-0.9%,-0.1%]	[-0.6%,0.0%]	[2.7%,8.1%]	[-5.5%,-1.0%]	[-1.4%,-0.4%]	[-2.5%,0.9%]	[1.8%,12.0%]
	number of site-years	33	33	33	33	34	33	33	33	35
Internal Combusion Engine	average annnual percentage point trend	**-5.2%**	**-7.8%**	**-0.9%**	**-1.0%**	**9.8%**	**-2.3%**	-0.1%	**-1.1%**	1.4%
	90% confidence interval	[-6.3%,-4.1%]	[-9.4%,-6.2%]	[-1.3%,-0.6%]	[-1.4%,-0.6%]	[8.2%,11.4%]	[-3.4%,-1.3%]	[-0.3%,0.1%]	[-1.4%,-0.8%]	[-0.1%,2.8%]
	number of site-years	496	496	496	496	496	423	456	456	553
Microturbine	average annnual percentage point trend	**-4.8%**	**-7.2%**	**-1.5%**	**-1.1%**	**9.8%**	-1.5%	0.0%	**-0.4%**	0.0%
	90% confidence interval	[-6.5%,-3.1%]	[-9.5%,-4.9%]	[-2.2%,-0.8%]	[-1.6%,-0.5%]	[7.5%,12.0%]	[-3.1%,0.0%]	[-0.1%,0.2%]	[-0.7%,-0.2%]	[-1.8%,1.8%]
	number of site-years	238	238	238	238	238	197	221	221	251
Gas Turbine	average annnual percentage point trend	-1.1%	-1.4%	0.0%	0.5%	1.0%	0.4%	-1.8%	**-10.1%**	**14.8%**
	90% confidence interval	[-4.9%,2.8%]	[-3.5%,0.6%]	[-0.3%,0.2%]	[0.0%,0.9%]	[-0.9%,3.0%]	[-3.5%,4.3%]	[-5.7%,2.1%]	[-15.7%,-4.6%]	[4.5%,25.0%]
	number of site-years	10	10	10	10	10	10	10	10	11
All Types	average annnual percentage point trend	**-5.9%**	**-8.2%**	**-1.0%**	**-0.8%**	**10.1%**	**-2.5%**	**-0.4%**	**-1.3%**	**1.3%**
	90% confidence interval	[-6.8%,-5.0%]	[-9.5%,-6.9%]	[-1.3%,-0.7%]	[-1.2%,-0.5%]	[8.8%,11.3%]	[-3.4%,-1.7%]	[-0.6%,-0.2%]	[-1.5%,-1.0%]	[0.2%,2.4%]
	number of site-years	777	777	777	777	778	663	720	720	850

Green indicates a statistically significant non-zero trend

Furthermore, both system age and the cost to produce electricity are both independently correlated to capacity factor. On average, controlling for fuel costs, capacity factors decrease by 4.3 percentage points per year of system age. Each additional cent per kWh that it costs to generate electricity on-site reduces capacity factor by 1.2 percentage points per year; variables affecting costs include fuel costs, the site's need for waste heat, and system efficiency. Table 33 summarizes these results.

Table 33. Capacity factor changes based on system age and cost to self-generate electricity

		Age	¢/kWh
FC	estimate	**-4.8%**	**-4.4%**
	90% confidence range	[-7.9%,-1.7%]	[-6.8%,-2.0%]
	n	30	30
MT	estimate	**-2.3%**	**-2.5%**
	90% confidence range	[-4.2%,-0.4%]	[-3.7%,-1.4%]
	n	226	226
ICE	estimate	**-4.2%**	**-0.8%**
	90% confidence range	[-5.3%,-3.0%]	[-1.2%,-0.5%]
	n	483	483
GT	estimate	**-0.3%**	**-0.3%**
	90% confidence range	[-7.1%,6.5%]	[-2.5%,1.9%]
	n	7	7
ALL	estimate	**-4.3%**	**-1.2%**
	90% confidence range	[-5.3%,-3.3%]	[-1.6%,-0.9%]
	n	755	755

Additionally, a slight annual decrease in electrical efficiency was observed (0.4 percentage points per year), possibly due to the decreasing trend in operating levels. System efficiency is decreasing more rapidly (1.3 percentage points per year) than electrical efficiency, due to a decreased portion of recoverable heat being utilized. One cause for this effect may be the technical problems with heat exchangers noted by several of the hosts interviewed.

6.1 System Operations

The interviews with CHP hosts underscored the complexity of CHP systems. CHP systems are technically complex, requiring expertise for both scheduled and unscheduled maintenance to keep a system running. This makes the host customers heavily dependent on the services of third-party maintenance providers. Unfortunately, many maintenance contractors are slow in responding to clients whose systems require maintenance and repair. This is supported by the negative effect of age on capacity factor observed in the data, even when controlling for increasing fuel prices.

These interviews also highlighted the economic complexity of CHP systems: fuel costs, use for recoverable heat, unpredictable demand changes, maintenance costs, maintenance contract costs, and costs to litigate deficient maintenance service must all be considered on an ongoing basis. At any given time, system operators must consider all of these factors in their decisions to operate the system or not.

6.2 System Performance

Many of the sites interviewed reported that system performance and economics did not live up to what was proposed to them. Fifty-three percent would not install a system again if they were making the decision now.

However, host experience with fuel cells is a notable exception. Although all seven of the host customers interviewed experienced technical problems with their systems, six of the seven were satisfied with the performance of their systems and five of the seven said that they would install a CHP system if faced with the decision today. Interviews revealed that fuel cell hosts often received risk mitigating contractual arrangements with manufacturers and developers, and that their systems received adequate maintenance to keep the system running. These types of arrangements and services typical of fuel cell systems may be a positive example for promoters of other CHP systems because they reduce the complexity of the system from the perspective of the site.

6.3 Market and Policy Factors

A few respondents with IC engines anticipate air quality requirements becoming increasingly stringent in the future, and predict that this may result in their organizations deciding to take their systems offline.

The economic viability of a CHP system is integrally related to the "spark spread," or the difference between natural gas and electricity prices. Unfortunately, the spark spread that has resulted from volatile energy markets during the last decade has not fulfilled many CHP system owners' expectations.

The requirement that CHP systems are automatically shut down when there is an interruption in power supply from the electric grid has caused a significant maintenance burden and detracted substantially from the financial performance of several respondents' systems.

6.4 Recommendations

The SGIE and the PAs can support long-term CHP operation in the following ways:

1. ***Institute measures to mitigate the uncertainties of CHP system operation.*** Doing so will support predictable and long-term results and satisfaction by keeping CHP operation simpler and economically favorable for participants. Offering long-term, favorable gas rates and reduced electric demand charges, and requiring long-term maintenance contracts and product warrantees can help mitigate operational and economic uncertainties. The lack of these factors are currently contributing to performance degradation. However, the additional costs of instituting these measures may outweigh the benefits to program participants and ratepayers.

2. ***Undertake activities to bring existing but non-functioning systems back online.*** Numerous SGIP-incented systems have been retired well before the end of their useful lives for maintenance or economic reasons. The SGIP has overcome a major hurdle in getting these systems installed to begin with; it may be worthwhile to provide additional support to these systems to get them back online and keep them operating for their full useful lives. Support might include subsidizing new, longer-term maintenance contracts, offering favorable, long-term gas contracts, and providing engineering resources to identify and correct operational issues. However, providing these services may be considered double-paying for capacity that the program and rate payers have already procured through previous SGIP incentives. The benefits of bringing this capacity back on line relative to the additional costs should be explored further.

In addition, customers can support long-term system performance by ensuring that their maintenance contracts and power purchase agreements contain the appropriate terms and safeguards. Some systems were shut down when the maintenance or power purchase agreement vendors failed to provide adequate levels of service or determined that the arrangement was no longer economical for them. Agreements should have penalties for failing to provide adequate system maintenance or for taking the systems off-line before the end of the term of the agreement. However, these high-quality service agreements may cost more to the participant.

Section 7. Appendix A: Interview Guide

The following guide was used for the CHP host interviews:

I. System Information

1. My records show that you installed a CHP / Cogeneration system with the following characteristics (summarize from records noting: year/month of installation, size of system kW/MW, technology type). Is this correct? *[Interviewer: You may wish to complete a table summarizing key system characteristics prior to the interview.]*
    a. System Characteristics/Comments
    b. Technology Type
    c. Month / Year of Installation
    d. System Size (kW)
    e. Location (zip code)
    f. Other

2. What fuel does the system run on?

3. How is the waste heat used on-site?

4. When applying to the program, did you encounter difficulty in meeting the waste heat and/or overall system efficiency requirements? (Y/N)
    a. Please explain.

5. Where is the system located on-site? [Prompt if needed, e.g., in a dedicated room, outside, what is the area surrounding the system like?]

6. [If have not yet confirmed through prior conversations with others] Does your company own and operate the system? (Y/N)
    a. [If do not own] Could you describe the ownership arrangement? [If no, collect contact information for appropriate contact who is responsible for operating the system, then ask the current contact on the phone only the highlighted questions in this guide.]
    b. Comments on operations (for example, who operates the system).

7. Is the person that spearheaded the effort to complete the installation for your company still at the company and involved with ensuring the ongoing performance of the system? (Y/N)
    a. Have there been changes in the staff who oversee the system's performance?

b. Comments related to staff turnover / system oversight (specify year of change or "don't know").

II. System Operations / Schedule

8. [If prior comments indicate system is no longer operational, or has been removed from the site.]
   a. [As appropriate] When and why was the system removed and/or stop operating?
   b. [As appropriate] Does your company have plans to make the system operational again or install a new system? (Y/N)

9. Could you describe the operating schedule for your system and how decisions are made regarding when the system should run and at what capacity?

10. What are the main drivers behind the operating schedule you have in place? Please elaborate. [Read list if respondent cannot think of drivers on their own.]
    Drivers: If multiple drivers noted, number accordingly, with 1= strongest driver.
    a. Variation in natural gas prices
    b. Electric rate structure
    c. Net export restrictions
    d. Waste heat usage limitations
    e. Seasonal factors (i.e., if it's a winery, agricultural facility)
    f. Other factors
    g. List other factors (if applicable)
    h. Other comments on drivers.

11. Have the operations schedules changed at the facility since the system was installed? (Y/N)
    a. Explain.

12. [If operating, and not already addressed earlier] Does the system typically operate at full capacity? (Y/N)
    a. Explain.

13. [If operating] How long do you expect you will continue operating the system (i.e., what is the expected lifetime of the investment)?

14. Are there any contractual reasons why you would (did) stop running the system before the end of the equipment's lifetime?

15. Would you operate (have operated) the system differently if, rather than receiving an up-front incentive, you (or the project owner) were paid on a per kWh generated basis (a performance based incentive)? (Y/N)
    a. [If yes] Please explain.

III. Equipment Performance

16. Have you had any problems with your system's performance, for example: [prompt from list below]? (Y/N)
    Problem Type?/Check (x) if "yes"
    a. Engine / turbine
    b. Heat exchanger
    c. Fuel quality
    d. Interruption of fuel supply
    e. Other
    f. If "other," please explain

17. [If have had problems] Please explain.

18. [If an equipment performance problem] Do you have a sense of whether this equipment failure was due to the age of the system, or whether it was due to poor product quality?

19. [If appropriate] Was equipment replaced as a result of these problems? (Y/N)
    a. Explain.

20. Have equipment problems resulted in lower-than-expected level of system performance? (Y/N)

21. Do you currently have any (or have you previously had any) problems with waste heat utilization after the system became operational? (Y/N)

22. [If yes] Please elaborate.

23. [If not noted already] Can you think of any periods of time in particular when the system was operating at substantially lower capacity than usual? (Y/N) [If interviewer has observed significant issues based on data review, note these to interviewee as a prompt.]
    a. Explain.

24. [If not noted already] Can you recall any significant system downtime or outages that you've experienced? (Y/N) [If interviewer has observed significant issues based on data review, note these to interviewee as a prompt.]
    a. When did these occur?
    b. What caused these outages (for example, equipment failure, failure to adhere to operations & maintenance schedule)?

25. Has the system had any start-up problems? (Y/N)
    a. Explain.

26. [If not already addressed] Does the system generally operate reliably? (Y/N)
    a. Explain.

    [INTERVIEWER NOTES ON PERFORMANCE OVER TIME]

27. [DO NOT READ] Respondent's recollection of system performance consistent with our records? (Y/N)

    [INTERVIEWER NOTES ON OUTAGES]

28. [DO NOT READ] Respondent's recollection of outages consistent with our records? (Y/N)

IV. System Maintenance

29. Who maintains the system?
    a. Has this changed since the system was first installed? (Y/N)

30. Do you have a service contract?
    a. Comments on service contract.

31. [If operating] Does the system require routine maintenance? (Y/N)
    a. [If yes] Please explain.

32. What type of maintenance schedule (if any) do you (or the maintenance contractor) follow?

33. Have system maintenance requirements increased as the system has aged? (Y/N)
    a. [If yes] How?

34. Do you have a performance monitoring system in place? (Y/N)
    a. [If yes] Please describe.
    b. [If no] How do you know when the system requires maintenance?

35. Is the system still under warranty? (Y/N)
    a. Probe about whether the warranty / lack of warranty affects the maintenance practices.

36. [If not already addressed] Has any part of the system been replaced since initial operation, or has the unit required any repair? (Y/N)
    a. [If yes] Please describe.
    b. Was the repair or replacement done under warranty? (Y/N)

V. System Design and Installation

37. Do you feel the equipment that makes up your cogen system is high quality? (Y/N)
    a. Please elaborate.

38. Do you feel the system was designed properly so that it suits the specific needs of your facility? (Y/N)

39. I'm particularly interested in knowing whether the thermal loads of your facility are properly matched to the waste heat produced by the system. Do you feel the system is properly sized for your facility? (Y/N)
    a. Please explain.

40. Are there any changes you would make to the system design that we haven't discussed yet? (Y/N)
    a. Please explain.

VI. Closing

41. If you had it to do over again and you were making the decision whether or not to install the cogen system today (meaning you were basing your decision on current market factors) would you still chose to go ahead with the installation? (Y/N)
    a. Explain.

42. If I have a clarification question as I'm reviewing my notes, is it alright to call you back or email you?

Section 8. Appendix B: Trend Data by PA

For the most part, statistically significant differences in trends across PAs were not seen. For brevity, these results were not presented in Section 3. They are provided in this appendix.

Table 34. Annual percentage point trend in capacity factor, by PA and year of installation

		Install Year[2]						
PA		2002	2003	2004	2005	2006	2007	*All Years*
Pacific Gas & Electric	average annual percentage point trend[1]	-9.8%	-4.3%	-1.0%	-3.0%	-9.0%	-20.2%	-5.8%
	90% confidence interval	[-14.1%,-5.5%]	[-7.0%,-1.6%]	[-5.4%,3.3%]	[-8.5%,2.4%]	[-20.3%,2.4%]	[-45.1%,4.8%]	[-7.5%,-4.1%]
	number of site-years	33	88	49	38	24	4	236
Southern California Edison	average annual percentage point trend[1]	-8.0%	-4.8%	-7.7%	-2.1%	-6.9%	-42.4%	-5.8%
	90% confidence interval	[-10.9%,-5.0%]	[-8.6%,-1.1%]	[-11.8%,-3.5%]	[-7.5%,3.3%]	[-26.4%,12.7%]	[-119.9%,35.1%]	[-7.8%,-3.9%]
	number of site-years	14	51	49	48	9	3	177
Southern California Gas	average annual percentage point trend[1]	-0.5%	-3.4%	-4.8%	4.5%	-17.7%	-5.8%	-3.4%
	90% confidence interval	[-7.8%,6.8%]	[-6.5%,-0.4%]	[-8.5%,-1.1%]	[-10.7%,19.6%]	[-37.4%,2.0%]	[-37.2%,25.6%]	[-5.4%,-1.4%]
	number of site-years	11	101	51	13	14	4	194
California Center for Sustainable Energy	average annual percentage point trend[1]	-7.2%	-4.9%	-2.4%	-1.9%	-15.1%	14.5%	-7.3%
	90% confidence interval	[-10.0%,-4.5%]	[-7.3%,-2.6%]	[-5.4%,0.5%]	[-9.4%,5.6%]	[-29.7%,-0.5%]	[-10.2%,39.2%]	[-9.1%,-5.4%]
	number of site-years	75	23	15	36	6	7	170
All PAs	average annual percentage point trend[1]	-7.5%	-4.2%	-4.0%	-2.1%	-13.0%	-12.2%	-5.9%
	90% confidence interval	[-9.5%,-5.5%]	[-5.8%,-2.6%]	[-6.3%,-1.7%]	[-5.6%,1.3%]	[-20.6%,-5.3%]	[-32.9%,8.6%]	[-6.8%,-5.0%]
	number of site-years	133	263	164	135	53	18	777

Green indicates a statistically significant non-zero trend

[1] *Annual trend in capacity factor*

[2] *Counts and capacities reported for each install year are not cumulative.*

Table 35. Annual percentage point trend in hours of operation as a percent of all hours, by PA and year of installation

		Install Year[2]						
PA		2002	2003	2004	2005	2006	2007	*All Years*
Pacific Gas & Electric	average annual percentage point trend[1]	-11.6%	-8.8%	0.9%	-1.2%	-9.8%	-66.7%	-7.9%
	90% confidence interval	[-16.8%,-6.4%]	[-12.2%,-5.4%]	[-5.7%,7.5%]	[-8.2%,5.9%]	[-21.2%,1.7%]	[-176.3%,43.0%]	[-10.1%,-5.7%]
	number of site-years	33	88	49	38	24	4	236
Southern California Edison	average annual percentage point trend[1]	-13.7%	-7.2%	-11.9%	-0.9%	-10.0%	-52.7%	-9.2%
	90% confidence interval	[-17.3%,-10.0%]	[-12.6%,-1.9%]	[-18.4%,-5.3%]	[-9.7%,8.0%]	[-25.5%,5.5%]	[-141.5%,36.1%]	[-12.1%,-6.2%]
	number of site-years	14	51	49	48	9	3	177
Southern California Gas	average annual percentage point trend[1]	2.7%	-5.7%	-7.5%	12.3%	-20.5%	-8.4%	-4.2%
	90% confidence interval	[-11.2%,16.6%]	[-10.3%,-1.0%]	[-12.9%,-2.1%]	[-8.3%,32.9%]	[-47.3%,6.4%]	[-37.3%,20.5%]	[-7.2%,-1.2%]
	number of site-years	11	101	51	13	14	4	194
California Center for Sustainable Energy	average annual percentage point trend[1]	-12.0%	-7.0%	-5.5%	-2.2%	-13.7%	12.7%	-9.9%
	90% confidence interval	[-15.5%,-8.6%]	[-10.6%,-3.4%]	[-11.4%,0.5%]	[-10.7%,6.3%]	[-24.4%,-3.1%]	[-17.8%,43.2%]	[-12.1%,-7.6%]
	number of site-years	75	23	15	36	6	7	170
All PAs	average annual percentage point trend[1]	-11.0%	-7.4%	-5.3%	-0.5%	-14.2%	-19.8%	-8.2%
	90% confidence interval	[-13.7%,-8.4%]	[-9.6%,-5.1%]	[-8.8%,-1.8%]	[-5.2%,4.3%]	[-22.7%,-5.7%]	[-50.0%,10.3%]	[-9.5%,-6.9%]
	number of site-years	133	263	164	135	53	18	777

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of all hours of data presence that indicate non-zero system output*

[2] *Counts and capacities reported for each install year are not cumulative.*

Table 36. Annual percentage point trend in hours of short-duration off-time, as a percent of all hours, by PA and year of installation

PA		Install Year[2] 2002	2003	2004	2005	2006	2007	*All Years*
Pacific Gas & Electric	average annnual percentage point trend[1]	**-2.5%**	**-0.4%**	**-0.4%**	**-1.3%**	**-1.1%**	**0.0%**	**-0.5%**
	90% confidence interval	[-3.9%,-1.1%]	[-1.4%,0.6%]	[-1.3%,0.4%]	[-4.3%,1.7%]	[-2.0%,-0.1%]		[-1.1%,0.1%]
	number of site-years	33	88	49	38	24	4	236
Southern California Edison	average annnual percentage point trend[1]	**-4.2%**	**-1.8%**	**-1.2%**	**1.2%**	**0.3%**	**4.6%**	**-1.2%**
	90% confidence interval	[-5.8%,-2.7%]	[-2.7%,-0.9%]	[-2.2%,-0.1%]	[-1.1%,3.5%]	[-2.2%,2.9%]	[-4.6%,13.7%]	[-1.8%,-0.5%]
	number of site-years	14	51	49	48	9	3	177
Southern California Gas	average annnual percentage point trend[1]	**-3.3%**	**-1.4%**	**-0.3%**	**-6.9%**	**-1.2%**	**3.5%**	**-1.5%**
	90% confidence interval	[-5.3%,-1.2%]	[-2.3%,-0.5%]	[-2.0%,1.4%]	[-11.1%,-2.6%]	[-4.1%,1.8%]	[-21.4%,28.4%]	[-2.2%,-0.9%]
	number of site-years	11	101	51	13	14	4	194
California Center for Sustainable Energy	average annnual percentage point trend[1]	**-2.1%**	**-1.6%**	**-0.4%**	**-0.6%**	**0.0%**	**-5.7%**	**-1.2%**
	90% confidence interval	[-2.9%,-1.4%]	[-4.1%,0.8%]	[-2.1%,1.2%]	[-3.5%,2.2%]	[-0.7%,0.8%]	[-18.0%,6.7%]	[-1.9%,-0.5%]
	number of site-years	75	23	15	36	6	7	170
All PAs	average annnual percentage point trend[1]	**-2.5%**	**-1.3%**	**-0.6%**	**-0.7%**	**-0.5%**	**-1.8%**	**-1.0%**
	90% confidence interval	[-3.2%,-1.9%]	[-1.9%,-0.7%]	[-1.3%,0.1%]	[-2.2%,0.8%]	[-1.4%,0.3%]	[-8.7%,5.2%]	[-1.3%,-0.7%]
	number of site-years	133	263	164	135	53	18	777

Green indicates a statistically significant non-zero trend

[1] Annual trend in the percent of all hours of data presence that are short duration (< 1 day) outages

[2] Counts and capacities reported for each install year are not cumulative.

Table 37. Annual percentage point trend in hours of medium-duration off-time, as a percent of all hours, by PA and year of installation

PA		Install Year[2] 2002	2003	2004	2005	2006	2007	*All Years*
Pacific Gas & Electric	average annnual percentage point trend[1]	**-2.9%**	**-0.8%**	**-1.1%**	**-1.8%**	**-0.6%**	**0.0%**	**-0.8%**
	90% confidence interval	[-4.4%,-1.5%]	[-1.6%,0.1%]	[-2.4%,0.2%]	[-4.1%,0.4%]	[-1.4%,0.1%]		[-1.4%,-0.3%]
	number of site-years	33	88	49	38	24	4	236
Southern California Edison	average annnual percentage point trend[1]	**-2.0%**	**-2.2%**	**-1.8%**	**0.6%**	**0.2%**	**3.0%**	**-1.3%**
	90% confidence interval	[-4.1%,0.2%]	[-3.4%,-1.1%]	[-3.2%,-0.4%]	[-1.9%,3.0%]	[-1.2%,1.7%]	[-5.3%,11.4%]	[-2.0%,-0.5%]
	number of site-years	14	51	49	48	9	3	177
Southern California Gas	average annnual percentage point trend[1]	**-4.5%**	**-0.8%**	**0.5%**	**-1.8%**	**-1.6%**	**3.3%**	**-1.1%**
	90% confidence interval	[-7.4%,-1.6%]	[-1.9%,0.4%]	[-1.6%,2.7%]	[-5.4%,1.8%]	[-6.1%,3.0%]	[-30.5%,37.0%]	[-1.9%,-0.2%]
	number of site-years	11	101	51	13	14	4	194
California Center for Sustainable Energy	average annnual percentage point trend[1]	**-0.8%**	**-1.9%**	**-0.7%**	**-1.0%**	**0.7%**	**-7.5%**	**-0.8%**
	90% confidence interval	[-1.6%,-0.1%]	[-4.1%,0.3%]	[-3.1%,1.6%]	[-3.0%,1.1%]	[0.4%,1.0%]	[-21.2%,6.2%]	[-1.4%,-0.1%]
	number of site-years	75	23	15	36	6	7	170
All PAs	average annnual percentage point trend[1]	**-1.7%**	**-1.3%**	**-0.8%**	**-0.8%**	**-0.3%**	**-2.8%**	**-0.8%**
	90% confidence interval	[-2.4%,-1.1%]	[-1.9%,-0.6%]	[-1.7%,0.2%]	[-2.0%,0.5%]	[-1.3%,0.8%]	[-11.7%,6.2%]	[-1.2%,-0.5%]
	number of site-years	133	263	164	135	53	18	777

Green indicates a statistically significant non-zero trend

[1] Annual trend in the percent of all hours of data presence that are medium duration (1 to 3 days) outages

[2] Counts and capacities reported for each install year are not cumulative.

Table 38. Annual percentage point trend in hours of long-duration off-time, as a percent of all hours, by PA and year of installation

PA		Install Year[2] 2002	2003	2004	2005	2006	2007	All Years
Pacific Gas & Electric	average annnual percentage point trend[1]	17.5%	10.0%	0.7%	4.3%	11.4%	66.7%	9.4%
	90% confidence interval	[13.2%,21.7%]	[6.9%,13.2%]	[-5.9%,7.2%]	[-0.7%,9.2%]	[-0.2%,23.0%]	[-43.0%,176.3%]	[7.3%,11.5%]
	number of site-years	33	88	49	38	24	4	236
Southern California Edison	average annnual percentage point trend[1]	19.8%	11.2%	14.7%	-0.9%	9.4%	45.1%	11.5%
	90% confidence interval	[14.8%,24.7%]	[5.8%,16.6%]	[8.4%,21.0%]	[-9.3%,7.4%]	[-4.3%,23.1%]	[-26.4%,116.5%]	[8.6%,14.4%]
	number of site-years	14	51	49	48	9	3	177
Southern California Gas	average annnual percentage point trend[1]	5.1%	7.8%	7.3%	-3.7%	23.1%	1.5%	6.8%
	90% confidence interval	[-10.3%,20.4%]	[3.1%,12.4%]	[1.8%,12.7%]	[-24.9%,17.4%]	[-1.3%,47.4%]	[-85.9%,88.9%]	[3.8%,9.8%]
	number of site-years	11	101	51	13	14	4	194
California Center for Sustainable Energy	average annnual percentage point trend[1]	15.0%	10.5%	6.6%	3.7%	13.0%	0.4%	11.9%
	90% confidence interval	[11.5%,18.4%]	[5.0%,16.0%]	[-2.3%,15.5%]	[-4.3%,11.8%]	[2.2%,23.8%]	[-5.6%,6.4%]	[9.6%,14.1%]
	number of site-years	75	23	15	36	6	7	171
All PAs	average annnual percentage point trend[1]	15.4%	9.9%	6.6%	1.9%	15.0%	24.3%	10.1%
	90% confidence interval	[12.9%,17.9%]	[7.7%,12.2%]	[3.1%,10.2%]	[-2.5%,6.2%]	[7.0%,23.1%]	[-4.7%,53.4%]	[8.8%,11.3%]
	number of site-years	133	263	164	135	53	18	778

Green indicates a statistically significant non-zero trend

[1] Annual trend in the percent of all hours of data presence that are long duration (> 3 days) outages

[2] Counts and capacities reported for each install year are not cumulative.

Table 39. Annual percentage point trend in load level during on-hours, as a percent of rated capacity, by PA and year of installation

PA		Install Year[2] 2002	2003	2004	2005	2006	2007	All Years
Pacific Gas & Electric	average annnual percentage point trend[1]	-5.4%	0.7%	-0.8%	-2.8%	-0.4%	-5.0%	-1.5%
	90% confidence interval	[-9.6%,-1.3%]	[-1.5%,3.0%]	[-4.1%,2.5%]	[-6.7%,1.0%]	[-7.4%,6.5%]		[-3.0%,-0.1%]
	number of site-years	22	81	42	38	22	2	207
Southern California Edison	average annnual percentage point trend[1]	-10.8%	1.0%	1.5%	2.7%	0.9%	-10.0%	-0.7%
	90% confidence interval	[-20.2%,-1.4%]	[-1.5%,3.6%]	[-2.9%,5.9%]	[-1.0%,6.4%]	[-13.4%,15.3%]	[-10.0%,-10.0%]	[-2.6%,1.1%]
	number of site-years	10	41	40	43	9	3	149
Southern California Gas	average annnual percentage point trend[1]	-1.1%	0.3%	-1.4%	1.3%	-6.6%	5.0%	-1.3%
	90% confidence interval	[-5.3%,3.0%]	[-2.8%,3.4%]	[-5.1%,2.3%]	[-6.5%,9.1%]	[-22.2%,9.0%]	[-42.5%,52.5%]	[-3.1%,0.6%]
	number of site-years	7	82	48	10	13	4	164
California Center for Sustainable Energy	average annnual percentage point trend[1]	-3.6%	-4.8%	10.5%	1.6%	-6.3%	-0.3%	-5.6%
	90% confidence interval	[-6.7%,-0.5%]	[-8.3%,-1.2%]	[4.3%,16.6%]	[-1.6%,4.8%]	[-16.0%,3.5%]	[-11.8%,11.2%]	[-7.3%,-3.9%]
	number of site-years	57	22	10	33	6	7	143
All PAs	average annnual percentage point trend[1]	-4.6%	-0.1%	0.3%	-0.1%	-3.2%	-4.6%	-2.5%
	90% confidence interval	[-6.9%,-2.3%]	[-1.5%,1.4%]	[-1.7%,2.4%]	[-2.3%,2.1%]	[-8.4%,2.0%]	[-22.0%,12.8%]	[-3.4%,-1.7%]
	number of site-years	96	226	140	124	50	16	663

Green indicates a statistically significant non-zero trend

[1] Annual trend in the percent of rated output during non-zero system output

[2] Counts and capacities reported for each install year are not cumulative.

Table 40. Annual percentage point trend in electric efficiency, by PA and year of installation

		Install Year[2]						
PA		2002	2003	2004	2005	2006	2007	*All Years*
Pacific Gas & Electric	average annnual percentage point trend[1]	**-0.4%**	**-0.5%**	**0.3%**	**-0.2%**	**-1.0%**	**0.7%**	**-0.4%**
	90% confidence interval	[-1.5%,0.7%]	[-1.1%,0.0%]	[-0.8%,1.4%]	[-1.6%,1.3%]	[-5.1%,3.2%]		[-0.8%,0.1%]
	number of site-years	22	84	46	38	22	4	216
Southern California Edison	average annnual percentage point trend[1]	**1.0%**	**0.2%**	**0.2%**	**0.3%**	**0.5%**	**3.7%**	**0.3%**
	90% confidence interval	[0.2%,1.8%]	[-0.3%,0.7%]	[-0.5%,0.8%]	[-0.5%,1.0%]	[-5.4%,6.3%]	[-4.9%,12.3%]	[0.0%,0.6%]
	number of site-years	13	47	49	48	9	3	172
Southern California Gas	average annnual percentage point trend[1]	**1.0%**	**0.2%**	**0.2%**	**1.0%**	**-3.1%**	**0.0%**	**0.0%**
	90% confidence interval	[-0.4%,2.3%]	[-0.4%,0.7%]	[-0.4%,0.7%]	[-1.3%,3.2%]	[-8.1%,1.9%]		[-0.4%,0.3%]
	number of site-years	7	90	51	13	14	4	179
California Center for Sustainable Energy	average annnual percentage point trend[1]	**0.0%**	**0.5%**	**2.6%**	**0.2%**	**-0.1%**	**2.1%**	**-1.0%**
	90% confidence interval	[-0.4%,0.4%]	[-0.4%,1.4%]	[0.8%,4.5%]	[-1.5%,1.9%]	[-3.2%,3.1%]	[-6.1%,10.2%]	[-1.4%,-0.5%]
	number of site-years	66	22	11	33	6	7	153
All PAs	average annnual percentage point trend[1]	**0.0%**	**0.0%**	**0.4%**	**0.0%**	**-1.2%**	**1.5%**	**-0.4%**
	90% confidence interval	[-0.5%,0.4%]	[-0.3%,0.3%]	[0.0%,0.8%]	[-0.7%,0.7%]	[-3.7%,1.3%]	[-2.5%,5.5%]	[-0.6%,-0.2%]
	number of site-years	108	243	157	132	51	18	720

Green indicates a statistically significant non-zero trend

[1] *Annual trend in electric efficiency*

Table 41. Annual percentage point trend in system efficiency (PUC 216.6(b)), by PA and year of installation

		Install Year[2]						
PA		2002	2003	2004	2005	2006	2007	*All Years*
Pacific Gas & Electric	average annnual percentage point trend[1]	**-1.1%**	**-2.2%**	**-1.0%**	**-0.4%**	**-2.2%**	**3.5%**	**-1.5%**
	90% confidence interval	[-2.4%,0.1%]	[-2.8%,-1.5%]	[-2.8%,0.8%]	[-2.8%,1.9%]	[-6.1%,1.6%]		[-2.1%,-0.9%]
	number of site-years	22	84	46	38	22	4	216
Southern California Edison	average annnual percentage point trend[1]	**-0.5%**	**-1.4%**	**-0.5%**	**-0.6%**	**3.5%**	**3.0%**	**-0.6%**
	90% confidence interval	[-1.8%,0.8%]	[-2.1%,-0.7%]	[-0.9%,-0.1%]	[-1.0%,-0.3%]	[-4.1%,11.1%]	[1.5%,4.5%]	[-0.9%,-0.2%]
	number of site-years	13	47	49	48	9	3	172
Southern California Gas	average annnual percentage point trend[1]	**-0.5%**	**-1.4%**	**-1.2%**	**-1.9%**	**-3.9%**	**-1.2%**	**-1.2%**
	90% confidence interval	[-2.0%,0.9%]	[-2.1%,-0.8%]	[-1.9%,-0.4%]	[-8.1%,4.3%]	[-10.3%,2.6%]	[-1.2%,-1.2%]	[-1.7%,-0.7%]
	number of site-years	7	90	51	13	14	4	179
California Center for Sustainable Energy	average annnual percentage point trend[1]	**-0.7%**	**-0.8%**	**1.0%**	**-0.1%**	**-10.1%**	**5.8%**	**-1.6%**
	90% confidence interval	[-1.3%,-0.1%]	[-2.0%,0.5%]	[-1.5%,3.6%]	[-1.8%,1.6%]	[-22.8%,2.6%]	[-3.2%,14.8%]	[-2.1%,-1.0%]
	number of site-years	66	22	11	33	6	7	153
All PAs	average annnual percentage point trend[1]	**-0.9%**	**-1.6%**	**-0.8%**	**-0.7%**	**-3.5%**	**2.6%**	**-1.3%**
	90% confidence interval	[-1.4%,-0.4%]	[-2.0%,-1.2%]	[-1.4%,-0.2%]	[-1.6%,0.3%]	[-6.9%,-0.1%]	[-1.5%,6.7%]	[-1.5%,-1.0%]
	number of site-years	108	243	157	132	51	18	720

Green indicates a statistically significant non-zero trend

[1] *Annual trend in system efficiency, PUC 216.6(b) : electric efficiency plus one half of recovered thermal energy*

[2] *Counts and capacities reported for each install year are not cumulative.*

Table 42. Annual percentage point trend in data gaps, as a percentage of all hours, by PA and year of installation

PA		Install Year[2] 2002	2003	2004	2005	2006	2007	*All Years*
Pacific Gas & Electric	average annnual percentage point trend[1]	**-0.2%**	**-0.8%**	**6.8%**	**2.6%**	**-8.9%**	**37.3%**	**0.7%**
	90% confidence interval	[-4.5%,4.1%]	[-3.8%,2.2%]	[0.8%,12.7%]	[-2.2%,7.5%]	[-14.5%,-3.3%]	[-35.8%,110.4%]	[-1.2%,2.7%]
	number of site-years	35	93	62	39	24	4	257
Southern California Edison	average annnual percentage point trend[1]	**10.8%**	**-4.5%**	**-5.8%**	**-3.9%**	**-18.7%**	**49.8%**	**2.1%**
	90% confidence interval	[2.6%,19.1%]	[-9.1%,0.1%]	[-10.9%,-0.6%]	[-9.6%,1.7%]	[-31.1%,-6.3%]	[-32.4%,132.1%]	[-0.3%,4.6%]
	number of site-years	19	57	50	51	9	4	196
Southern California Gas	average annnual percentage point trend[1]	**10.9%**	**-4.9%**	**-1.2%**	**-11.2%**	**-6.5%**	**-6.2%**	**1.7%**
	90% confidence interval	[-1.4%,23.1%]	[-9.2%,-0.6%]	[-6.7%,4.4%]	[-24.1%,1.6%]	[-17.0%,3.9%]	[-9.6%,-2.9%]	[-1.0%,4.4%]
	number of site-years	19	120	56	13	14	4	226
California Center for Sustainable Energy	average annnual percentage point trend[1]	**-0.2%**	**0.0%**	**0.0%**	**-0.2%**	**0.0%**	**9.4%**	**-0.6%**
	90% confidence interval	[-0.4%,0.0%]	[-0.1%,0.2%]	[0.0%,0.0%]	[-0.6%,0.2%]	[0.0%,0.0%]	[-34.8%,53.7%]	[-1.2%,0.0%]
	number of site-years	75	23	15	36	6	8	171
All PAs	average annnual percentage point trend[1]	**3.4%**	**-1.4%**	**0.9%**	**-0.8%**	**-7.7%**	**21.2%**	**1.3%**
	90% confidence interval	[1.1%,5.8%]	[-3.6%,0.7%]	[-2.2%,4.0%]	[-3.6%,2.0%]	[-11.9%,-3.5%]	[-3.7%,46.0%]	[0.2%,2.4%]
	number of site-years	148	293	183	139	53	20	850

Green indicates a statistically significant non-zero trend

[1] *Annual trend in the percent of all hours that data is missing for*

[2] *Counts and capacities reported for each install year are not cumulative.*

Section 9. Appendix C: Monthly Capacity Factor and Events of Interview Respondent Sites

The following graphics illustrate the monthly capacity factor as each of the sites interviewed by Summit Blue for this analysis. Each row represents a respondent and each column represents a month. Light blue bars of varying height reflect the capacity factor for that month. Background colors indicate an observed event that the respondent was able to recollect and explain.

Figure 10. Respondent Site Histories for Gas Turbines and Fuel Cells

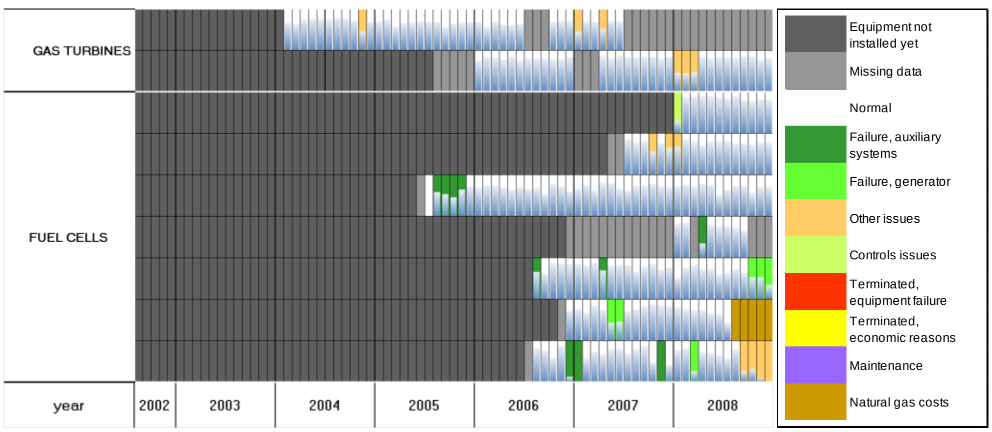


Figure 11. Respondent Site Histories for Microturbines

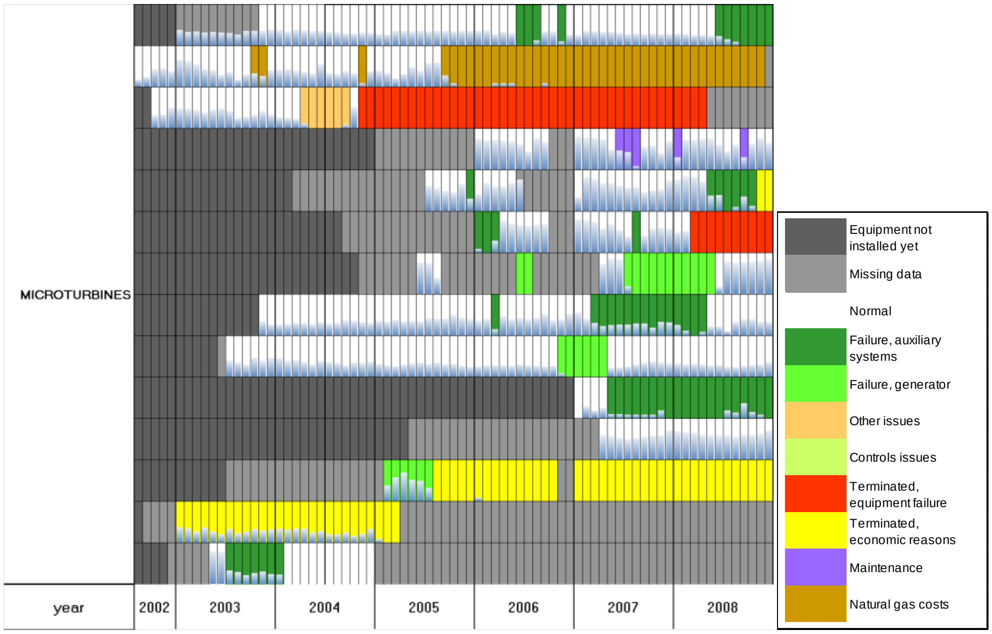


Figure 12. Respondent Site Histories for IC Engines