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CPUC Self-Generation Incentive Program

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

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Table of Contents

List of Tables

List of Figures

Executive Summary

The Self-Generation Incentive Program (SGIP) was initiated in March 2001 by the California Public Utilities Commission (CPUC). The intent of the SGIP is to help promote the development of distributed generation facilities located at utility customer sites that partially or completely offset their energy needs. The SGIP reflects energy policies stemming from the original enactment of the Public Utility Regulatory Policies Act (PURPA) of 1978. A primary focus of PURPA was to help improve the overall efficiency of the electricity system by expanding the use of cogeneration facilities that could generate both power and heat for beneficial purposes. In order to be eligible for special power purchase provisions established under PURPA, qualifying cogeneration facilities had to achieve specified levels of energy efficiency and useful waste heat recovery. In a ruling on June 14, 2001, the CPUC adopted waste heat recovery and efficiency standards as set forth in Public Utility Code (PUC) Section 218.5 for non-renewable qualifying facilities implemented under the SGIP.

Cogeneration facilities represent a very important component of the SGIP. As of the end of 2005, cogeneration facilities made up nearly 60% of the installed generating capacity of the SGIP. However, questions have been raised about levels of energy efficiency and useful waste heat recovery being achieved at SGIP cogeneration facilities. Impact evaluations conducted by Itron in 2005 indicated that a number of cogeneration facilities were not achieving the requirements established under PUC 218.5. In December 2005, the SGIP Working Group directed Itron to investigate the levels of energy efficiency and useful waste heat recovery being achieved at SGIP Level 3/3N cogeneration facilities. If Itron found that SGIP cogeneration facilities were having problems meeting PUC 218.5 requirements, probable causes of the problems were to be identified and, where feasible, possible solutions recommended to promote better ways to achieve improved system efficiencies and useful waste heat recovery.

ES.1 Approach

On behalf of the SGIP Working Group, Itron conducts periodic measurement and evaluation (M&E) of distributed generation facilities installed under the SGIP. As a result, a certain amount of directly metered data is available on the amount of electricity generated, heat recovered, and fuel used at each site. In addition, Itron has access to electricity, fuel use, or recovered waste heat data monitored by the utilities, Itron, or third-party providers. Based on this information, Itron estimated actual achieved efficiencies and useful waste heat recovery levels for each facility and compared them against the PUC 218.5 requirements. The M&E

team then identified those facilities that had significant problems complying with the requirements (i.e., the “poor” performers) and identified the facilities that exceeded the requirements (i.e., the “good” performers). By comparing the design and operational aspects of the “good” performers against the “poor” performers, the Itron M&E team was able to isolate possible causes of problems in achieving PUC 218.5 requirements. In-depth analyses, surveys, and site visits were then used to develop recommendations on ways in which to obtain improved efficiencies and better useful waste heat recovery.

ES.2 Findings

Incentive Level 3/3N cogeneration facilities implemented under the SGIP to date use two different systems for power generation and heat recovery: 1) reciprocating internal combustion engines (ICEs) and 2) microturbines. Based on the evaluation of these two cogeneration technologies, Itron developed the following findings:

1. Overall, Level 3/3N cogeneration systems exceeded PUC 218.5(a) requirements for useful waste heat recovery. As shown in Table ES-1, Level 3 and 3N cogeneration systems combined achieved an average PUC 218.5(a) level of 43.4%. This is significantly higher than the 5% requirement. In addition, this level of useful waste heat recovery should help mitigate any potential concerns that the Federal Energy Regulatory Commission (FERC) may have regarding SGIP facilities only minimally meeting useful waste heat recovery operations.
2. Overall, Level 3/3N cogeneration facilities failed to achieve PUC 218.5(b) requirements. As shown in Table ES-1, Level 3 and 3N cogeneration systems combined achieved an average PUC 218.5(b) level of 36.8%, falling short of the required 42.5% efficiency.
3. When compared against one another, microturbines seem to have a better level of waste heat recovery than reciprocating ICEs. This may be partially due to the incorporation of heat exchangers into the microturbine unit and may be partially due to their lower electrical conversion efficiencies – leaving more heat available for energy recovery in the exhaust stream.
4. Microturbines were found to have a significantly higher capacity factor than ICEs, meaning that microturbines are operating more often and/or closer to design capacity.
5. ICEs were found to have significantly higher electrical conversion efficiencies than microturbines, contributing to their relatively higher PUC 218.5(b) results.

Table ES-1: CPUC Program Goals versus Actual Performance

Measure of Performance		218.5(a) % Useful Thermal	218.5(b) Plant Efficiency
CPUC Goals		5.0%	42.5%
Actual Program Overall Performance		43.4%	36.8%
	ICEs	40.2%	37.9%
	Microturbines	48.9%	34.2%

Itron identified several contributing factors to poor performance. In general, these factors can be placed in two distinct groups: system/component design problems and equipment problems. Design problems involve all decisions and analyses through system startup. Equipment problems include equipment failures occurring after system startup.

Design Approach Issues

- Hours of operation are routinely overstated (i.e., planned versus actual annual hours).
- The Waste Heat Utilization Worksheet (WHUW) does not quantify the coincidence of electrical demand with thermal demand. As a result, some applications assumed coincident power generation and thermal energy recovery and use. This results in a mismatch and possibly over-sizing of equipment,
- The generator rating used in the WHUW often does not account for parasitic loads, thereby overstating electrical output.
- Electrical conversion efficiencies are routinely overstated.
- Fuel may be reported in Higher Heating Value (HHV) rather than Lower Heating Value (LHV)

Technical Operating Issues

- Heat exchanger failures occur due to unexpected reactions with working fluids.
- Engine cylinder head failure is higher than expected for ICEs.
- Absorption chiller failures cause reduced useful waste heat recovery.
- Recuperator failures cause poor electrical power output for microturbines, thereby reducing overall system efficiencies.
- Gas compressor failure for microturbines causes loss of power and reduced electrical and system efficiencies.
- Operating temperature fluctuations have an effect on system electrical efficiency (this can be both a design and operating issue).
- Irregular maintenance leads to reduced operation and lower waste heat recovery and system efficiency.

Economic Issues

- "Spark gap" caused many cogeneration systems to shut down from October 2005 until very recently

ES.3 Recommendations

Design to Minimum of Electrical and Thermal Loads. Coincident electrical and thermal loads are imperative for successful cogeneration system performance. Without a coincident electric and thermal load, the cogeneration system should be downsized to meet the minimum of the electric or thermal load. This would ensure full-load operation of the cogeneration system.

Require Actual Electrical Efficiency. To date, most prime mover efficiency data entries involve a nameplate value that does not adequately account for parasitic loads or part-load operation.

Require Documentation for Load Profile and Hours of Operation. Electric and thermal load profiles should be developed as part of the application process. These are key indicators of the success of the cogeneration system but are often times estimated using assumptions and estimates without empirically based documentation.

1

Introduction

1.1 Purpose

Cogeneration systems offer the hope of providing two or more energy uses from one fuel source, resulting in higher energy utilization, lower overall emissions rates, and a more cost-effective operating strategy for the facility. Realization of these goals requires the optimized design of the system to take advantage of both the facility heat and power requirements, as well as optimizing the operations of the installed equipment. Recent process and impact evaluation results of the Self Generation Incentive Program (SGIP) suggest that there may be systematic issues with the design and/or the operational strategies of many rebated cogeneration systems that are resulting in “lower than expected” efficiency. The SGIP Working Group requested that the program evaluation team investigate these issues and identify potential solutions.

The purpose of this study is to identify the amount of useful waste heat recovered and the resulting PUC 218.5 efficiency of Incentive Level 3/3N cogeneration projects implemented under the SGIP. Through a combination of in-depth surveys and detailed analysis, this study identifies probable reasons for lower than expected useful waste heat recovery and low overall plant efficiencies. The results of this study include a set of recommendations of possible ways to promote better cogeneration system design and operation, thereby increasing useful waste heat recovery and operating cogeneration plant efficiency.

1.2 Background

Overview of the Self-Generation Incentive Program (SGIP)

Purpose and Enabling Legislation

In response to Assembly Bill 970, which required the California Public Utilities Commission (CPUC) to initiate certain load control and distributed generation program activities, the CPUC issued Decision 01-03-073 (D.01-03-073) on March 27, 2001. This Decision mandated implementation across the service territories of California’s investor-owned utilities (IOUs) of a self-generation program designed to produce significant public (e.g., environmental and energy distribution system) benefits for all ratepayers, including gas ratepayers. To meet this mandate, the California Self-Generation Incentive Program (SGIP) was created to offer financial incentives to customers of IOUs who install certain types of distributed generation (DG) facilities to meet all or a portion of their energy needs. The SGIP has been operational since July 2001. Assembly Bill 1685, signed into law October 12, 2003, extended the program through December 31, 2007, and requires combustion-based projects using nonrenewable or fossil fuels to satisfy new air emissions requirements. The CPUC will adopt annual statewide allocations for program years 2005 through 2007 before the end of the year.

The SGIP provides financial incentives for the installation of certain electric generation equipment on the customer side of the utility meter that meet all or a portion of the electric needs of an eligible customer's facility. Several key parties direct the SGIP design and implementation. Under the direction of the California legislature and CPUC, the SGIP is administered on a regional joint-delivery basis through three IOUs—Southern California Edison (SCE), Pacific Gas and Electric Company (PG&E), Southern California Gas Company (SoCalGas)—and one non-utility Program Administrator, the San Diego Regional Energy Office (SDREO).[1] A high-level overview of the critical SGIP milestones associated with these parties is presented in Table 1-1 below.

Table 1-1: Major SGIP Milestones by Key Party

	SGIP Party		
Calendar Year	**Legislature**	**CPUC**	**Program Administrators/Applicants**
2000	Legislation underlying SGIP (AB970) is enacted		
2001		Order underlying SGIP issued (D.01-03-073)	First SGIP application received (July 2001)
2002		Order splitting Level 3 into Level 3-N/3-R[2] issued (D.02-09-051)	1st SGIP incentives awarded for completed projects
2003	Legislation extending SGIP passes (AB1685)		On-line SGIP capacity exceeds 50 MW
2004		Order modifying SGIP issued (D.04-12-045)	1st SGIP wind project on-line
2007			Currently scheduled deadline for SGIP project completion (December 31, 2007)

1 SDREO is the program administrator for San Diego Gas & Electric customers.

2 This division separates non-renewable (N) and renewable (R) fuel.

Allocated Funding and Eligible Technologies

The SGIP was initially authorized an annual statewide allocation of $125 million for program years 2001 through 2004 for incentives and program administration costs. Program year 2005 had an incentive budget of $112.5 million. The program continues to grow; PY2006 has an incentive budget of $382.5 million with $307.5 million of incentive budget dedicated to solar photovoltaic projects.

DG technologies eligible for SGIP support are presented in Table 1-2, which summarizes key design elements governing SGIP projects coming on-line before the end of 2005. For each incentive level and eligible technology, the SGIP incentive is limited to the first 1,000 kW of system capacity.[3]

Table 1-2: Summary of SGIP Design for Projects On-Line as of 12/31/2005

Program Incentive Category	Maximum Incentive Offered ($/watt)	Maximum Incentive as a % of Eligible Project Cost[1]	Minimum System Size (kW)	Eligible Generation Technologies
Level 1	$3.50	50%	30	■ Photovoltaics (PV)
	$4.50			■ Fuel Cells[2]
	$1.50			■ Wind Turbines
Level 2	$2.50	40%	None	■ Fuel Cells[3,4]
Level 3[6]	$1.30	30%	None	■ Microturbines[2,3,4,5]
	$1.00			■ ICEs and small gas turbines[2,3,4,5]
Level 3-R	$1.30	40%	None	■ Microturbines[2]
	$1.00			■ ICEs and small gas turbines[2]
Level 3-N	$0.80	30%	None	■ Microturbines[3,4,5]
	$0.60			■ ICEs and small gas turbines[3,4,5]

1. Removed for PY2005
2. Operating on renewable fuel
3. Operating on non-renewable fuel
4. Using sufficient waste heat recovery
5. Meeting reliability criteria
6. Incentive Category not applicable to PY2005

3 CPUC rulings have increased the eligible maximum system size beyond 1,000 kW, although the maximum incentives basis remains capped at 1,000 kW.

As suggested by the timeline presented in Table 1-1, the SGIP has evolved. Its term and eligibility criteria have been modified, new incentive levels have been created (i.e., Levels 3-R and 3-N), and other incentive levels have been retired (i.e., Level 3). New for PY2005 was the elimination of the maximum incentive level as a percent of eligible project cost.

The variety of SGIP terms and conditions affecting on-line projects has increased over time and will continue to increase in the future. For example, beginning January 1, 2005, combustion-based projects using non-renewable or fossil fuels were required to satisfy certain new air pollutant emissions requirements stipulated in Assembly Bill 1685.[4]

Current Status

Numbers and Installed Capacities of Projects

The SGIP has continued to grow over the years. Table 1-3 provides a summary of applicants in the program through the end of 2005. As of December 31, 2005, the SGIP had over 1,400 live applicants representing over 156 MW of installed generating capacity. Live applicants are all applicants not classified as withdrawn or rejected. On-line projects consist of all projects that have entered normal operations (i.e., after startup and initial commissioning).

Table 1-3: Summary of SGIP Program Applicants On-Line as of 12/31/2005

Program Incentive Category	Number of Live Applicants	Capacity of Live Applicants (kW)	Number of Projects On-Line	Installed Capacity (kW)
Level 1	1,064	173,672	463	54,695
Level 2	12	7,750	2	800
Level 3	98	47,820	94	46,748
Level 3-R	31	11,966	8	11,966
Level 3-N	240	128,429	110	53,182
Total	1,445	369,637	677	156,785

Cogeneration Technologies in the SGIP

There are three cogeneration technologies eligible for incentives under the SGIP: fuel cells, microturbines, and reciprocating ICEs. Each of these technologies operates somewhat differently in terms of electrical conversion efficiency, theoretical heat recovery, and emissions. The remainder of this section presents, for each of these technologies, a description of the typical configuration and operating characteristics, their presence in the

4 For additional information regarding SGIP program design governing projects entering the SGIP in 2005 and later years, the relevant legislation, orders, decisions, and SGIP Handbook updates are the best source of information.

program in terms of number of applicants as well as capacity, and some of the more common suppliers of the technology.

Fuel Cells

Typical Configuration and Operating Characteristics

Fuel cells hold great promise of delivering high electrical conversion efficiencies with little or no emissions. This is achieved by combining two gases, such as hydrogen and oxygen, which undergo an electrochemical reaction producing electricity, heat, and water. Oxygen is readily available in the atmosphere and hydrogen is typically obtained by reforming natural gas or methane. Heat is typically recovered via a heat exchanger and generally used for process heating at the site where the fuel cell is installed. Table 1-4 is a summary of typical operating characteristics, efficiencies, and capacities of various types of fuel cells.

Table 1-4: Typical Fuel Cell Characteristics

	MCFC	PAFC	PEMFC	SOFC
Electrolyte	Molten carbonate salt	Liquid phosphoric acid	Ion exchange membrane	Solid metal oxide
Operating Temperature	1100–1830°F (600–1000°C)	300–390°F (150–200°C)	140–212°F (60–100°C)	1100–1830°F (600–1000°C)
Reforming	External/Internal	External	External	External/Internal
Oxidant	CO_2/O_2/Air	O_2/Air	O_2/Air	O_2/Air
Efficiency (without cogeneration)	45-60%	35-50%	35-50%	45-60%
Maximum Efficiency (with cogeneration)	85%	80%	60%	85%
Maximum Power Output Range (size)	2 MW	1 MW	250 kW	220 kW
Waste Heat Uses	Excess heat can produce high-pressure steam	Space heating or water heating	Space heating or water heating	Excess heat can be used to heat water or produce steam

Source: fuelcellsworks.com

Numbers and Installed/Operating Capacities

As of the end of 2005, there were 14 active fuel cell applications in the SGIP, two Level 1 fuel cells using renewable fuel, and 12 Level 2 fuel cells using nonrenewable fuel. Table 1-5 provides a breakdown of the status of these applicants. As the table shows, both renewable-fueled projects are completed. Per program guidelines, renewable-fueled projects are not subject to heat recovery requirements and, therefore, are not metered for heat recovery.

Table 1-5: Number of Sites and Capacity of Fuel Cells Through 2005

			Number of Sites				Capacity (kW)			
Level	Technology	Fuel Type	Active Applicants	Paid Incentive	Metered for Heat Recovery	Percent Metered[1]	Active Applicants	Paid Incentive	Metered for Heat Recovery	Percent Metered[1]
1	Fuel Cell	Renewable	2	2	N/A	N/A	750	750	N/A	N/A
2	Fuel Cell	Nonrenewable	12	3	2	67%	7,750	1,800	1,200	67%
TOTAL			14	5	2	67%	8,500	2,550	1,200	67%

Common Suppliers

Three fuel cell suppliers across 14 live applications, identified through either current or paid applications, have received incentives through the SGIP, as identified in Table 1-6. Of these, there is one predominant manufacturer installing fuel cells in the program.

Table 1-6: Fuel Cell Suppliers

	Nonrenewable		Renewable		Total	
Manufacturer	Count	System Size (kW)	Count	System Size (kW)	Count	System Size (kW)
Fuel Cell Energy	9	6750	2	750	11	7500
International Fuel Cells	1	200			1	200
United Technology Company	2	800			2	800
Total	12	7750	2	750	14	8500

Microturbines

Typical Configuration and Operating Characteristics

Microturbines are small combustion turbines generally the size of a refrigerator with capacities below 300 kW. Their potential benefits include a small footprint, which allows them to be used where space is limited, light weight, low emissions, ability to use waste fuels, and high responsiveness. In typical configurations, microturbines are fueled by compressed natural gas, methane, or propane. This fuel is ignited in a controlled combustion process and the combustion gasses are forced through nozzles that act to turn a turbine at a very high rotation (e.g., over 40,000 rpm), thereby generating electricity. Waste heat is captured from the exhaust combustion gasses and typically transferred to a working fluid, such as hot water for use in process or space heating.

Table 1-7 is a summary of microturbine characteristics for a variety of microturbines in the marketplace circa 2003.

Table 1-7: Typical Microturbine Characteristics

Characteristics	Company Marketing Literature, as of April 2003				Study by Onsite Energy Corporation (DOE), as of January 2000		Study by Arthur D Little (DOE), as of January 2000		
	Capstone	Elliott	Honeywell	Ingersoll-Rand	Year 2000	Year 2020	Year 2000	Year 2005	Year 2010
Size (kW)	30, 60*	45, 60, 100*, 200	Parallon 75*	IR70*, 250	100kW Based on Parallon75 model		25-300	25-300	25-1,000
Package costs ($/kW) (Total if applicable)	$925	-	-	$1,285	$800 ($1,970)	$350 ($915)	750-900	500-700	400-600
Electrical efficiency LHV (%)	28% (±2)	29.5%	27.5%	28%	28.4%	39.8%	30%	33-36%	38-42%
Heat rate LHV (Btu/kWh)	12,200	11,600	12,400	12,200	12,000	8,557	-	-	-
Exhaust gas temperature	305 C	274 C	-	-	-	-	-	-	-
Total exhaust energy (Btu/hr)	541,000	543,000	338,000	100,000-400,000	449,800	274,800	-	-	-
NOx (ppm)	<9 ppm	< 20 ppm	<50 ppm	<9 ppm	< 10 ppm	2-3 ppm	9-25 ppm	-	< 9 ppm
SOx	-	-	-	-	-	-	Negligible	-	Negligible
PM	-	-	-	-	-	-	Negligible	-	Negligible
Life (hours)	50,000	-	-	80,000	-	-	-	-	-

Source: Critical Infrastructure Modeling and Assessment Program, "Workshop on Combined Heat and Power Development in Virginia," May 30, 2003 (www.cimap.vt.edu/workshop/03/APPENDIX-C.pdf)

Numbers and Installed/Operating Capacities

As of the end of 2005, there were 129 active microturbine applications in the SGIP. These applicants are divided into renewable, nonrenewable, and mixed fuel types. Table 1-8 provides a breakdown of the status of these applicants. As the table shows, although most of the applicants have completed their projects, many of the larger projects are still under development. This is to be expected as larger projects often involve more coordination and front-end engineering. Per program guidelines, renewable-fueled projects are not subject to heat recovery requirements and, therefore, are not metered for heat recovery.

Table 1-8: Number of Sites and Capacity of Microturbines Through 2005

			Number of Sites				Capacity (kW)			
Level	Technology	Fuel Type	Active Applicants	Paid Incentive	Metered for Heat Recovery	Percent Metered[1]	Active Applicants	Paid Incentive	Metered for Heat Recovery	Percent Metered[1]
3	Microturbine	Nonrenewable	29	29	19	65.5%	4,989	4,989	3,589	72%
3N	Microturbine	Nonrenewable	81	42	0	0%	16,249	8,496	0	0%
3N	Microturbine	Mixed	2	1	0	0%	320	70	0	0%
3R	Microturbine	Renewable	16	9	N/A	N/A	3,380	1,390	N/A	N/A
3R	Microturbine	Mixed	1	0	0	N/A	240	0	0	N/A
TOTAL			129	81	19	26%	25,178	14,945	3,589	24%

Common Suppliers

Seven suppliers of microturbines across 113 (not all of the 129 applicants have identified the manufacturer) live applications, identified through either current or paid applications, received incentives through the SGIP, as identified in Table 1-9. Of these, there are two predominant manufacturers installing microturbines in the program: Capstone and Ingersoll Rand.

Table 1-9: Microturbine Suppliers

	Nonrenewable		Renewable		Total	
Manufacturer	Count	System Size (kW)	Count	System Size (kW)	Count	System Size (kW)
Bowman	3	392.2	0	0	3	392.2
Capstone	87	11990	7	1080	94	13070
Ingersoll Rand	11	2610	10	2070	21	4680
Kawasaki	2	2806	0	0	2	2806
Simmax	1	250	0	0	1	250
Turbec	4	500	0	0	4	500
United Technologies Corp.	4	1620	0	0	4	1620
Grand Total	113	20408.2	17	3150	130	23558.2

Internal Combustion Engines

Typical Configuration and Operating Characteristics

Reciprocating ICEs have been a preferred means of electricity generation for over the past hundred years. Power is produced when a mixture of air and fuel is ignited, causing expansion of pistons connected to a crankshaft that turns a generator. ICEs typically range in capacity from a few kilowatts to over 5 MW. While ICEs can consist of diesel or spark-ignited systems, only spark-ignited engines are used in the SGIP. Spark-ignition engines are predominately fueled with natural gas, but can be fired using propane, gasoline, and waste fuels such as landfill gas. Currently, ICEs are more commonly being used for combined heat and power applications due to their rapid start up and good load following capabilities. Waste heat can be recovered from the engine exhaust and cooling systems to produce either hot water or low pressure steam. Table 1-10 is a summary of performance and operating characteristics for ICEs .

Table 1-10: Typical ICE Characteristics

Cost & Performance Characteristics[6]	System 1	System 2	System 3	System 4	System 5
Baseload Electric Capacity (kW)	100	300	800	3,000	5,000
Total Installed Cost (YR 2001 $/kW)[7]	$1,515	$1,200	$1000	$920	$920
Electric Heat Rate (Btu/kWh), HHV[8]	11,147	10,967	10,246	9,492	8,758
Electrical Efficiency (%), HHV	30.6%	31.1%	33.3%	36.0%	39.0%
Engine Speed (rpm)	1800	1800	1200	900	720
Fuel Input (MMBtu/hr)	1.11	3.29	8.20	28.48	43.79
Required Fuel Gas Pressure (psig)	<3	<3	<3	43	65
CHP Characteristics					
Exhaust Flow (1000 lb/hr)	1.0	3.3	10.9	48.4	67.1
Exhaust Temperature (Fahrenheit)	1060	1067	869	688	698
Heat Recovered from Exhaust (MMBtu/hr)	0.20	0.82	2.12	5.54	7.16
Heat Recovered from Cooling Jacket (MMBtu/hr)	0.37	0.69	1.09	4.37	6.28
Heat Recovered from Lube System (MMBtu/hr)	0	0	0.29	1.22	1.94
Total Heat Recovered (MMBtu/hr)	0.57	1.51	3.50	11.12	15.38
Total Heat Recovered (kW)	167	443	1,025	3,259	4,508
Form of Recovered Heat	Hot H_20	Hot H_20	Hot H_20	Hot H_20	Hot H_20
Total Efficiency (%)[9]	81%	77%	76%	75%	74%
Thermal Output/Fuel Input (%)	51%	46%	43%	39%	35%
Power/Heat Ratio[10]	0.60	0.68	0.78	0.92	1.11
Net Heat Rate (Btu/kWh)[11]	4,063	4,687	4,774	4,857	4,914
Effective Electrical Efficiency[12]	0.84	0.73	0.71	0.70	0.69

Source: EEA

Numbers and Installed/Operating Capacities

As of the end of 2005, there were 232 active ICE applications in the SGIP. These applicants are divided into renewable, nonrenewable, and mixed fuel types. Table 1-11 provides a breakdown of the status of these applicants. As the table shows, although most of the applicants have completed their projects, many larger projects are still under development. Of the 125 projects that have received an incentive payment, 27% have heat recovery metering equipment installed. Per program guidelines, renewable-fueled projects are not subject to heat recovery requirements and, therefore, are not metered for heat recovery.

Table 1-11: Number of Sites and Capacity of ICEs Through 2005

			Number of Sites				Capacity (kW)			
Level	Technology	Fuel Type	Active Applicants	Paid Incentive	Metered for Heat Recovery	Percent Metered[1]	Active Applicants	Paid Incentive	Metered for Heat Recovery	Percent Metered[1]
3	IC Engine	Nonrenewable	64	57	19	33%	40,397	37,172	10,608	29%
3	IC Engine	Mixed	1	1	0	0%	900	900	0	0%
3	IC Engine	Renewable	1	1	N/A	N/A	970	970	970	100%
3N	IC Engine	Nonrenewable	151	65	14	22%	98,959	41,271	10,244	25%
3N	IC Engine	Mixed	1	0	0	N/A	750	0	0	N/A
3R	IC Engine	Renewable	14	2	N/A	N/A	8,346	780	0	0%
TOTAL			232	126	33	27%	150,322	81,093	21,822	27%

Common Suppliers

Table 1-12 is a listing of common ICE suppliers under the SGIP. Nineteen ICE suppliers are identified. Five of the suppliers provide almost 70% of the ICEs used in the program: Waukesha, Hess Microgen, Coast Intelligen, Tecogen, and GE Jenbacher.

Table 1-12: ICE Suppliers

	Nonrenewable		Renewable		Total	
Manufacturer	Count	System Size (kW)	Count	System Size (kW)	Count	System Size (kW)
BluePoint Energy	5	1300	0	0	5	1300
Caterpillar	12	14391	7	3426	19	17817
Coast Intelligen	29	11155	0	0	29	11155
Cummins	13	11612	0	0	13	11612
Deutz	5	5527	0	0	5	5527
DTE	10	2325	0	0	10	2325
GE Jenbacher	10	10210	2	2060	12	12270
Generac	2	300	0	0	2	300
Guascor	5	4358	0	0	5	4358
Hercules Energy	1	150	0	0	1	150
Hess Microgen	42	25734	0	0	42	25734
Jenbacher	7	10130	3	2910	10	13040
JES AG	1	995	0	0	1	995
Kohler Pow er Systems	1	100	0	0	1	100
New Millenium Pow er	2	1050	0	0	2	1050
Stamford New age	0	0	1	200	1	200
Tecogen	25	3690	0	0	25	3690
Vector	1	30	0	0	1	30
Waukesha	37	32295	2	1400	39	33695
Grand Total	210	137622	15	9996	225	147618

Waste Heat Recovery and Efficiency Goals for Cogeneration Projects

Federal Guidelines/Requirements (FERC)

In 1978, Congress passed the Public Utility Regulatory Policies Act (PURPA) to help increase generation of electricity from non-utility sources, termed "qualifying facilities." At the time, PURPA established sets of operational guidelines for qualifying facilities including fuel use, size, fuel efficiency, and reliability. Under the efficiency guidelines, qualifying cogeneration facilities are required to have the useful power output of the facility plus one-half of the useful thermal energy output equal to no less than 42.5% of their total energy input. PURPA became the guiding set of requirements for cogeneration systems installed across the nation.

The Federal Energy Regulatory Commission (FERC) is currently considering modifying PURPA. Among the proposed changes is increased emphasis on ensuring that recovered waste heat is used for "productive and beneficial" purposes at industrial, commercial, or institutional facilities.[5] In particular, FERC proposes to examine individual qualifying facilities to make certain that recovered waste heat usage is "productive and beneficial" and not a "sham." FERC is considering similar provisions to ensure that electricity production from qualifying facilities helps offset the electrical needs of the industrial, commercial, or institutional facilities at which they are located. Within this context, FERC intends to critically examine facilities where the thermal output only minimally meets the 5% of thermal input requirements. In these instances, FERC is concerned that such facilities are essentially designed to provide most of their electrical output to the utilities rather than meeting the intent of PURPA.

State Guidelines/Requirements

California Public Utilities Code Section 218.5 covers efficiency and useful waste heat recovery from cogeneration facilities installed under the SGIP as follows:

> *"218.5. "Cogeneration" means the sequential use of energy for the production of electrical and useful thermal energy. The sequence can be thermal use followed by power production or the reverse, subject to the following standards:*
>
> *(a) At least 5 percent of the facility's total annual energy output shall be in the form of useful thermal energy.*
>
> *(b) Where useful thermal energy follows power production, the useful annual power output plus one-half the useful annual thermal energy output equals not less than 42.5 percent of any natural gas and oil energy input."*

[5] Federal Energy Regulatory Commission. *Notice of Proposed Rulemaking, Revised Regulations Governing Small Power Producers and Cogeneration Facilities*. Docket No. RM05-36-000, October 11, 2005

1.3 Scope of Study

The scope of this study is confined to the useful waste heat recovery and system efficiency performance of Incentive Level 3 and 3N[6] cogeneration facilities implemented under the SGIP. On June 14, 2001, the CPUC, under Decision D.01-06-035, adopted the *waste heat* and *efficiency standards for qualifying cogeneration facilities* implemented under the SGIP.[7] In that ruling, the CPUC adopted the waste heat and efficiency standards set forth in California Public Utility Code Section 218.5 as follows:

a) <u>Waste Heat Recovery</u>: At least 5% of the facility's total energy output must be in the form of useful heat recovery, and

b) <u>System Efficiency</u>: The annual electric output plus one-half of the useful thermal output must be greater than or equal to 42.5% of the total annual fuel input of the system.

Within the SGIP, Incentive Level 2, 3, and 3N systems are considered qualifying cogeneration facilities. Incentive Level 3R (i.e., renewable-fueled cogeneration units or prime movers/electric generators) are not required to meet the above heat recovery or system efficiency requirements. Incentive Level 2 fuel cells are excluded from the scope of this study.

Accurate estimates of waste heat and system efficiency require monitored data on fuel consumption, thermal energy recovery, and electrical energy production. More complete performance data sets are primarily available for the operating years of 2004 and 2005. For these reasons, Itron has further refined the scope of this study to the assessment of waste heat and system efficiency performance of Level 3 and 3N SGIP facilities operating under calendar years 2004 and 2005.

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6 Incentive Level 3 facilities include both eligible non-renewable-fueled and renewable-fueled cogeneration systems prior to the CPUC establishing Incentive Levels 3R and 3N under Decision D.02-09-051.

7 D.01-06-035, "Interim Opinion: Waste Heat Recovery and Reliability for Section 3999.15(b) Distributed Generation Incentives," June 14, 2001

2

Approach

2.1 Overview

The overall purpose of this report is to investigate the level of success to which SGIP nonrenewable fueled cogeneration facilities are 1) achieving the required levels of efficiency and useful waste heat recovery, 2) where appropriate, identify known causes of failures to meet the required levels, and 3) recommend possible ways to promote better system efficiency and useful waste heat recovery. This section describes the approach used in meeting these study objectives. In general, Itron employed four steps. First, metered electricity, heat and fuel use interval data were retrieved to identify facility efficiencies and useful waste heat recovery levels. Second, by comparing the achieved levels of efficiency and useful waste heat recovery against the required levels, "outliers," were isolated, i.e., those facilities which either significantly failed to meet the required levels or those that tended to exceed the requirements. Third, by examining *poor* versus *good* performing outliers, we could identify possible causes of low system efficiency and/or low useful waste heat recovery. Lastly, through interviews and site visits we could confirm design or operational practices that lead to facilities either being *good* or *poor* performers.

2.2 Obtaining Actual Performance from SGIP Projects

One of the challenges in identifying actual efficiencies and useful waste heat recovery at SGIP facilities involves obtaining reliable metered data on a consistent basis. A defining characteristic of the program-level monitoring approach is the reliance on various diverse meter installers and data providers. The range of meter installers and data providers encountered to date is summarized in Table 2-1. In some cases, utilities as well as program applicants and /or host costumers may be undertaking electric, fuel or heat metering and monitoring activities for their own purposes. In these instances, the metering and monitoring team is pursuing opportunities available for utilizing the diverse set of existing metering and monitoring capabilities, thereby minimizing overall program data collection costs.

Table 2-1: Sources of Meter Installers and Data Providers

ENGO	FUEL	HEAT
PG&E	PG&E	Itron Team
SCE	SoCalGas	Applicants
SDG&E	Long Beach Energy	Hosts
LADWP	Itron Team	
Itron Team	Applicants	
Applicants	Hosts	
Hosts		

While utilization of existing data collected by applicants and/or host customers offers the advantage of decreasing the program's overall M&E metering acquisition and installation costs, it does so at the additional costs of increasing data collection coordination costs, data collection and schedule risk, and data validation costs.

Electric Net Generator Output

Electric net generator output (ENGO) refers to a measure of system output that includes effects of the prime mover/generator electric parasitic loads (EPL) (e.g., onsite controls, pumps, fans, compressors, prime movers, generators and heat recovery systems). ENGO data is critical in assessing system and electrical efficiencies from the SGIP facilities. The basis of ENGO measurements is illustrated with the following equation:

$$ENGO = EGGO - EPL$$

Where: ENGO = Electric net generator output
EGGO = Gross generator output
EPL = System Electric parasitic load.

Sometimes it is not possible to measure ENGO directly with a single meter. In those cases, EGGO (only) is measured and EPL is either metered separately or estimated. ENGO is then calculated using the above mentioned equation.

Electric net generator output metered data in 15-minute intervals is required to achieve the objectives of the program evaluation. Due to the wide variety of formats in which data is received, conversion of raw data to a common format is essential in order to ensure that all data received is treated consistently. There are two major steps involved to process the data and to ensure data quality. These steps include:

- Converting raw data to a common format
- Review of the processed data

Converting Raw Data to a Common Format

As mentioned earlier, raw data is received in a wide variety of formats. The raw data are standardized so that they can be systematically stored and processed. This data manipulation is accomplished by using SAS statistical analysis software.

ENGO data received in 1-minute format is aggregated and converted to 15-minute format by calculating the average kWh value reported during that period. Hourly ENGO data is converted to 15-minute format by assuming constant load throughout the hour. A sample of the ENGO raw data are illustrated in Table 2-2.

Table 2-2: Sample ENGO raw data format

LR	SA		
XX63257	CC5459		
		KW	KVARH
6/12/2005	0:00	67.68	0
6/12/2005	0:01	67.69	0
6/12/2005	0:02	67.56	0
6/12/2005	0:03	68.53	0
6/12/2005	0:04	67.34	0

The AC Power data may represent average demand during an interval or an instantaneous snapshot at beginning/middle/end of period and may be represented in units of kWh, MW, KW, Watts, tenths of kW etc. Identifying the basis of the metered data is critical to the process of creating a uniform dataset. Raw data in the above format is converted to a permanent SAS dataset, as shown in Table 2-3.

Table 2-3: Sample of Processed ENGO Data

ID	DTID_LST	ENGO	ENGO_F
xxx	12JUN05:00:00:00	16.94	M
xxx	12JUN05:00:15:00	16.82	M
xxx	12JUN05:00:30:00	16.99	M
xxx	12JUN05:00:45:00	16.70	M

All ENGO data is ultimately stored in 15-minute format, in units of kWh, in permanent SAS datasets. In, a brief description of each column is given.

Table 2-4: ENGO Common Data File Format

Field Name	Data Element	Data Basis
ID	Unique Project Identifier	Application ID
DTID_LST	Date and time corresponding to energy value	SAS date time value representing the beginning of a 15-minute period
ENGO	Electric net generator output	Electric energy produced, expressed in terms of kWh
ENGO_F	Data flag for field ENGO	'M' = Metered directly (including cases where interval of raw data is <15 minutes) 'R' = Ratio using other metered data collected at this site (e.g., hourly or monthly ENGO data) 'E' = Estimated (e.g., from heat rate)

Fuel

The two main sources of raw fuel data for Level 3 and 3N projects are natural gas utilities and Itron M&E metering. As an initial step, Itron investigates whether a dedicated fuel meter has been installed and data are available. If possible, Itron obtains data from the gas utility responsible for the dedicated fuel meter. In cases where a gas meter is not present, Itron installs a pulse output gas meter with data logging capability at 15-minute intervals. If the data comes from Itron data loggers, the processing time is minimal because the raw data is already in 15-minute time interval. However, if the raw data is provided by utilities then the data is typically reported in monthly or *billing cycle* intervals. In Table 2-5, a sample of raw fuel from utility is provided.

Table 2-5: Sample Utility Raw Fuel Data Format

MONTH USED	YEAR USED	TARIFF	TOTAL THERMS	TOTAL REVENUE	GNN_ID	BA_ID	TITLE	NEGO_CONTRACT
1	2004	AB-00	17517	1136	0017662600	0007662612	As Used	0
2	2004	AB-01	14981	978.5	0027662600	1107662612	As Used	0
3	2004	AB-02	5560	394.6	0037662600	2207662612	As Used	0

Fuel data is ultimately stored in 15-minute data, in units of kBtu, in permanent Sas datasets. The transformation of monthly or billing cycle fuel data into 15-minute interval data is accomplished by assuming a constant electrical efficiency rate for each billing cycle and dividing the ENGO data by this efficiency. In more explicit terms, ENGO data are summed over the date range of the raw FUEL data to create an ENGO total kWh value that corresponds to the exact time period of the FUEL data. The ENGO total kWh value is divided by the FUEL kBtu total to obtain one kWh/kBtu ratio for the billing cycle. 15-minute ENGO data are then divided by this ratio to obtain 15-minute FUEL data.

Raw data in the above format is converted to a permanent SAS dataset which has the format shown in Table 2-6.

Table 2-6: Sample of Processed Fuel Data Format

ID	DTID_LST	FUEL	FUEL_F
xxx	12JUN05:00:00:00	1287.465	R
xxx	12JUN05:00:15:00	1264.956	R
xxx	12JUN05:00:30:00	1295.687	R
xxx	12JUN05:00:45:00	1270.567	R

Since the fuel data are a ratio using other metered data (ENGO in this case) the flag is set to "R". A detailed data file format description is provided in Table 2-7.

Table 2-7: FUEL Common Data File Format

Field Name	Data Element	Data Basis
ID	Unique Project Identifier	Application ID
DTID_LST	Date and time corresponding to energy value	SAS date time value representing the beginning of a 15-minute period
FUEL	Fuel consumption	Fuel consumption, expressed in terms of kBtu
FUEL_F	Data flag for field FUEL	'M' = Metered directly (including cases where interval of raw data is <15 minutes) 'R' = Ratio using other metered data collected at this site (e.g., hourly or monthly FUEL data) 'E' = Estimated (e.g., from heat rate)

Useful Thermal Energy Recovery:

Participating systems subject to heat recovery requirements use a variety of means to recover heat, as well as a variety of means to utilize recovered heat for useful purposes. Heat recovery is typically accomplished through:

- Engine block via water-to-water heat exchanger;
- Exhaust via air-to-water heat exchanger;
- Exhaust via air-to-air heat exchanger;

- Exhaust via heat recovery steam boiler; or
- Exhaust directly.

Recovered heat must be applied to a useful purpose to be credited to PUC 218.5 and other efficiency measures. Heat utilization is typically accomplished via:

- Use of recovered heat for space heating, water heating, or process heating; and/or
- Use of recovered heat to operate a heat recovery absorption chiller (HRAC);

Thermal data is ultimately stored in 15-minute data, in units of kBtu, in permanent SAS datasets. As discussed earlier, main sources of raw thermal data are Applicants and Itron data loggers. If the data comes from Itron data loggers, the processing time is minimal because the raw data is already stored in 15-minute time intervals. However, if the raw data comes from Applicants then the data may be reported in monthly or billing cycle intervals. In Table 2-8, a sample of raw thermal data from an Applicant is provided.

Table 2-8: Sample Raw Thermal Data Format

Local Time	timestamp	BTUdelHHW1	TONhdelCW1	fallback
31Dec04 23:00:00	2005-Jan-01 07:00:00.000	379240000	123387.5	0
31Dec04 23:15:00	2005-Jan-01 07:15:00.000	379240000	123387.5	0
31Dec04 23:30:00	2005-Jan-01 07:30:00.000	379240000	123387.5	0

Raw data in the above format is converted to a permanent SAS dataset which has the following format, as presented in Table 2-9. When data are received from an Applicant, a Host, or some other party, extensive validation steps must be passed before the data are incorporated into the analysis.

Table 2-9: Sample of Processed Thermal Data Format

ID	DTID_LST	HEAT	HEAT_F
xxx	12JUN05:00:00:00	0	M
xxx	12JUN05:00:15:00	0	M
xxx	12JUN05:00:30:00	0	M
xxx	12JUN05:00:45:00	0	M

Since the heat data in this example are metered directly, the flag is set to “M”. A detailed data file format description is provided in Table 2-10.

Table 2-10: HEAT Common Data File Format

Field Name	Data Element	Data Basis
ID	Unique Project Identifier	Application ID
DTID_LST	Date and time corresponding to energy value	SAS date time value representing the beginning of a 15-minute period
HEAT	Fuel consumption	Fuel consumption, expressed in terms of kBtu
HEAT_F	Data flag for field HEAT	'M' = Metered directly (including cases where interval of raw data is <15 minutes) 'R' = Ratio using other metered data collected at this site (e.g., hourly or monthly HEAT data) 'E' = Estimated (e.g., from heat rate)

Review of the Processed Data

All data files are reviewed to identify any periods of time where data are suspicious (e.g., net electric power generated is greater than the system size) or where trends suggested abrupt data change. In cases where suspicious data or abrupt changes are observed, Itron checks with the provider of the data to see if the behavior can be explained. In cases where anomalous behavior cannot be explained, the metered data are not included in the analysis.

For all the cogenerations systems, ENGO, fuel, and thermal data are aggregated to calculate monthly, annual, and overall electrical conversion efficiencies, total system efficiencies, and PUC 218.5 efficiencies for all months where data are available. Cases where theses efficiencies are outside reasonable bounds are flagged for further examination.

2.3 Isolating Possible Problems and Solutions: Identification of "Outlier" Facilities

"Good" and "Poor" Performers

All the sites which record PUC 218.5(b) efficiency greater than 42.5% are considered as good performers. Similarly, sites with PUC 218.5(b) efficiency less than 42.5% are considered as bad performers. Itron analyzed 47 sites for system efficiency analysis and out of these only 12 sites are good performers and the remaining 35 are bad performers.

Table 2-11: Distribution of Performance by Technology

Technology	Total n	Good	Bad	% of Sites Good
FC	1	1	0	100%
ICE	28	8	20	28.6%
MT	18	3	15	16.7%
Total	47	12	35	25.5%

Nearly 29% of the IC Engines sites qualified as good performers, in part because they record high electrical conversion efficiency (approx. 27%). In comparison, only 17% of the microturbine sites qualified as good performers, possibly tied to their lower electrical conversion efficiencies (nearly 22%).

When looking at performance on the basis of total system capacity (kW), as shown in Table 2-12, a significantly different result is revealed. Nearly 44% of the installed microturbine capacity is currently meeting PUC 218.5(b), while only 23% of the installed IC engine capacity is meeting the requirements of PUC 218.5(b).

Table 2-12: Installed Capacity by Performance and Technology

Technology	Total (kW)	Good (kW)	Bad (kW)	% of Capacity Good
FC	200	200	0	100.0%
ICE	17743	4075	13668	23.0%
MT	3557.2	1563	1994.2	43.9%
Total	21500.2	5838	15662.2	27.2%

2.4 Evaluation of Performance and Possible Problems

Electrical and Overall System Efficiencies

<u>*Electrical Conversion Efficiency*</u>

Electrical Conversion Efficiency is a particularly important element of the PUC 218.5(b) system efficiency, because in the equation electrical energy (kBtu) is credited at a rate of 100%, whereas heat energy is credited at the much lesser rate of 50%. It is also important because it represents a significant efficiency component that can be used to compare actual performance against expected performance.

Electrical conversion efficiencies are calculated using the following equation:

$$ElecEff_t = \frac{ENGO_t kWh * 3.412 \, {}^{kBtu}\!/_{kWh}}{FUEL_t kBtu}$$

Where:

ElecEff	=	Electrical Efficiency
t	=	time period of interest
ENGO	=	Electric net generator output, in kWh
FUEL	=	Fuel input, in kBtu

Overall System Efficiency

Overall system efficiency is the sum of electrical conversion efficiency and rate of useful thermal energy recovered by the system. This measure is important because it represents a significant performance benchmark that can be used to compare cogeneration system performance against the performance of alternative technologies.

Overall system efficiencies are calculated using the following equation:

$$OverallEff_t = ElecEff_t + \frac{HEAT_t kBtu}{FUEL_t kBtu}$$

Where:

HEAT	=	Useful thermal energy recovered, in kBtu
FUEL	=	Fuel input, in kBtu

Useful Thermal Energy Recovery

Level 2 fuel cells and Level 3/3-N engines/turbines are subject to certain heat recovery and system efficiency requirements during the implementation stage of the Self-Generation Incentive Program. A variety of means are used to recover heat for useful purposes, and to apply that heat to provide various forms of onsite heating and cooling services. The evaluation of the performance and identification of possible problems involves an investigation into why the system was designed as it was, how the host is using the heat recovered, and what technologies or situations are present to maximize (or minimize) thermal energy recovery. Each installation has a unique story to tell in this regard. Itron's approach to this aspect of the evaluation is to analyze all available program materials, such as the *Waste Heat Utilization Worksheet*, the applicants *Inspection Report*, metered data, and anecdotal information obtained through years of collecting data and speaking with hosts and applicants.

2.5 Interviews and Site Visits

After sites were identified as either poor performers or good performers, each site was thoroughly examined using all available information, including system owner interview results from the PY2004 impact evaluation. Most performance issues could be sufficiently described by investigating monitoring system data in detail. In some cases, questions were identified that could not be answered by the available data on a site-specific basis. In other cases, site visits were conducted to further investigate operational characteristics that may compromise cogeneration system performance.

Site Interviews

The interview guide from PY2004 was modified and fielded to all Applicants to provide an element of consistency over time as well as to cross-check earlier findings, if available. In some cases, questions were answered this year that were not previously answered. Interviews were completed for four (4) Applicants accounting for 19 installed systems. Two of the Applicants were also interviewed during PY2004 impact evaluation. For these interviews, contact notes were thoroughly reviewed prior to conducting the interview.

Site Visits

Site visits were deemed necessary for three (3) systems to further investigate causes for performance issues. In these cases, there was either insufficient evidence to form a conclusion, or there was some doubt that the metered data was accurate. Site visits included an interview with the Applicant (or the most qualified on-site personnel available), spot checks of the monitoring system, and a walk-thru of the facility to uncover sources of inefficiencies.

3

Findings

This section presents a summary of findings of our analysis with respect to useful waste heat recovery, electrical efficiency, and overall system efficiency. An effort was made to develop consistent metrics for each site to facilitate comparison across all sites and technologies, and across manufacturers within technologies. At the end of each subsection, possible remedies for common problems are provided. These suggestions are two fold. First, there are systematic improvements that can be made at the time of application to the program that would result in a more realistic estimate of system operation. Second, there are some suggestions that can be implemented for existing systems to improve their operational efficiency.

The winter of 2005 provided an interesting phenomenon for cogeneration systems. Natural gas prices experienced substantial increases to the point where it was not economically feasible to operate cogeneration systems in facilities paying market prices for natural gas. This “spark gap” issue complicated the analysis because applicants and hosts often were only capable of speaking about recent operational issues and unable to separate thermal efficiency from operational status. Applicants with long-term natural gas contracts were insulated from this issue and typically operated through the winter.

3.1 Useful Waste Heat Recovery

Useful waste heat recovery is defined as heat that is recovered from the cogeneration system for some useful purpose. That purpose could include supplying process heat or cooling (usually through equipment like absorption chillers), thereby offsetting the purchase of natural gas or electricity that otherwise would have been required to provide heating or cooling. In application, recovered waste heat is typically the heat contained in the engine cooling jacket water and/or the hot exhaust gases released from the combustion process. The heat is transferred from the jacket water and/or exhaust gas into a working fluid (usually water) via a heat exchanger and then routed through other equipment to provide the necessary heating or cooling. The amount of heat captured and harnessed for useful purposes is measured by the flow of the fluid through the heat exchanger and the temperature drop of that fluid across the heat exchanger. There are two important metrics used to describe useful waste heat recovery: heat recovery per unit capacity and heat recovery per unit of fuel input.

Heat recovery per unit of capacity provides the amount of waste heat harnessed for every kilowatt of installed electricity generating capacity. This metric allows for comparisons between different cogeneration systems on their ability to provide useful heat. Heat recovery per unit of fuel input essentially represents the thermal efficiency of the installed system in capturing and harnessing useful heat recovery. Both of these metrics are presented below by technology.

Microturbines

Range of Useful Waste Heat Recovery at SGIP Microturbine Facilities

Microturbines in the SGIP exhibit a wide range of useful heat recovery. Table 3-1 provides some key summary statistics of both the heat recovery per unit of capacity and the heat recovery per unit of fuel input.

Table 3-1: Useful Waste Heat Recovery at SGIP Microturbine Facilities (n=18)

	Minimum	Maximum	Median	Average	Weighted Average
Useful Waste Heat Recovery Per Unit Capacity (kBtuh/kW)	0.94	8.26	3.22	3.85	5.34
Heat Recovery Per Unit Fuel Input ($kBtu_{heat}/kBtu_{fuel}$)	0.04	0.52	0.22	0.25	0.34

As the table indicates, there is significant variation in both the amount of useful waste heat recovery per unit of installed capacity and the efficiency of useful waste heat recovery. In addition, the difference between the arithmetic average and the weighted average suggests a trend towards higher heat recovery with larger systems. To examine this, Itron plotted both metrics against installed capacity. Figure 3-1 illustrates the useful waste heat recovery per unit of electrical generation capacity by site for all sites reported. Figure 3-2 shows the variation of useful heat recovery per unit fuel input by site. Both Figure 3-1 and Figure 3-2 are sorted by system size, from left to right.

Figure 3-1: Useful Waste Heat Recovery Per Unit Capacity by Site for Microturbines

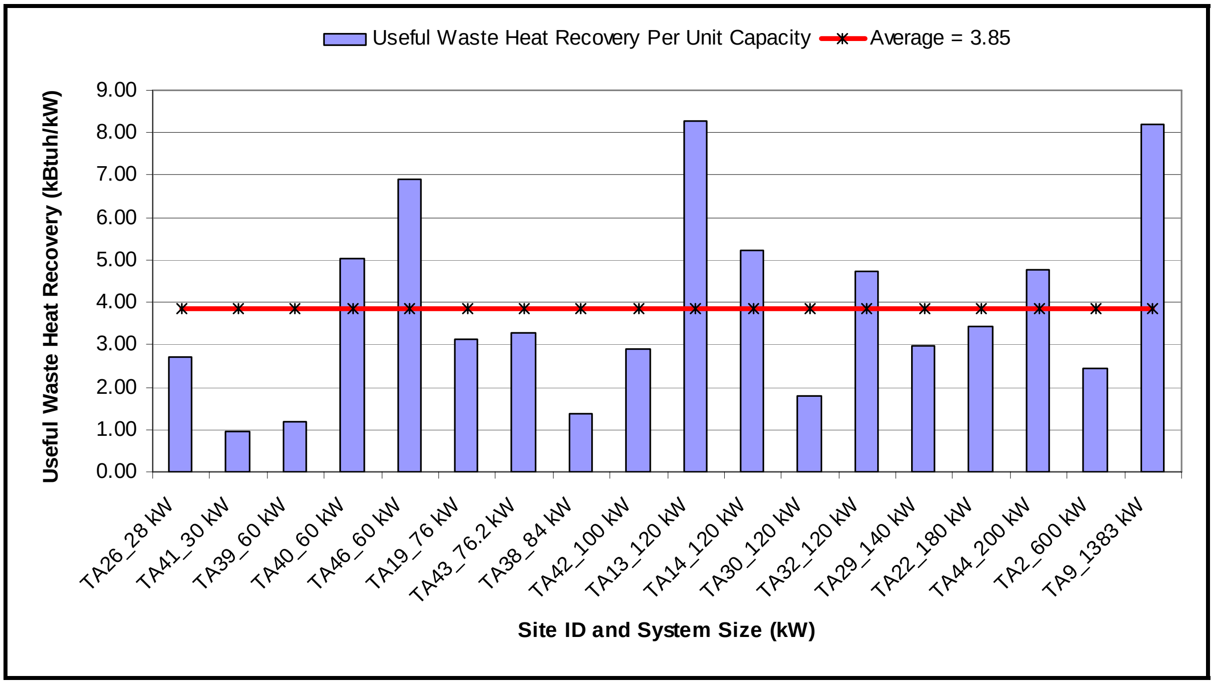
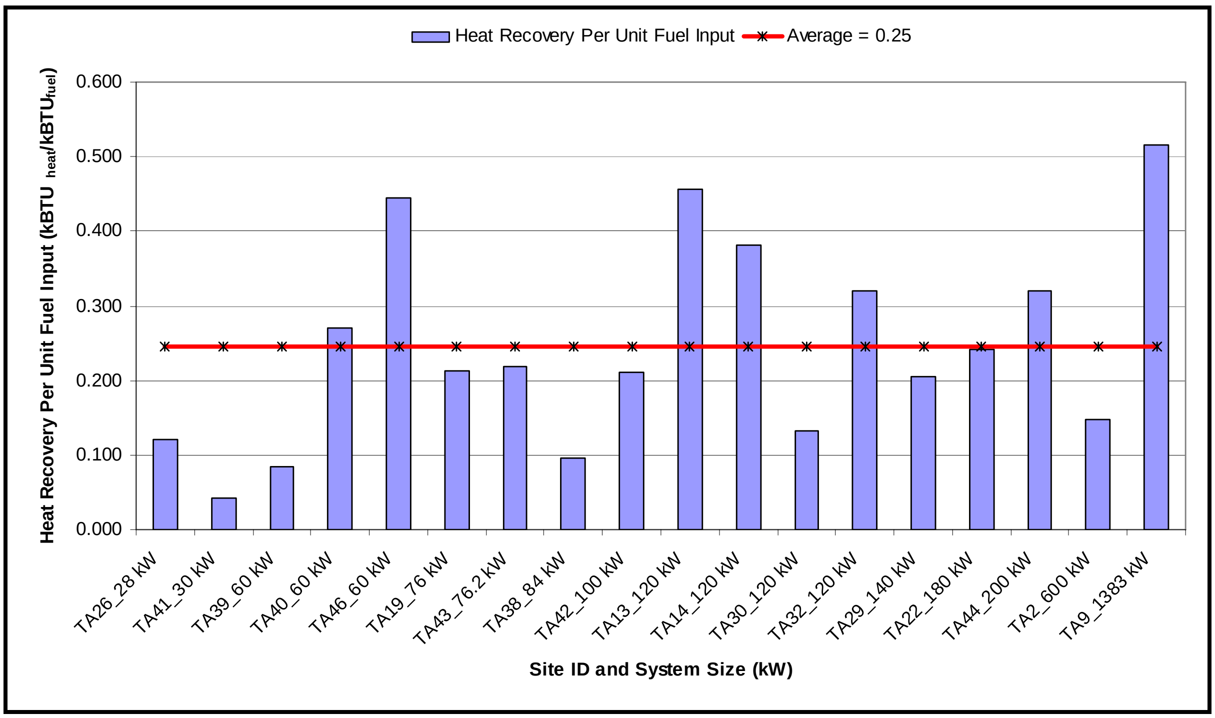


Figure 3-2: Microturbine Useful Heat Recovery Per Unit Fuel Input Versus System Size



In general, microturbines installed under the SGIP and examined during the 2003-2005 operating period show an average of 3,850 Btu/hr of recovered useful heat per kilowatt of installed capacity, and a capacity weighted average of 5,340 Btu/hr of recovered useful heat per kilowatt of installed capacity. In addition, these same facilities show an average recovered waste heat efficiency of approximately 25%. Although there is only a weak correlation between size and useful heat recovery, it is notable that the lowest three useful heat recovery metrics occur in the smaller half of systems. This may be attributable to the relatively greater amount of front-end feasibility analysis present in larger systems.

Compliance with Federal Requirements/Guidelines

Cogeneration systems participating in the SGIP are required to meet recovered waste heat levels specified by Public Utility Code (PUC) 218.5. This requirement was cited earlier and is summarized in Table 3-2 for quick reference below. PUC 218.5 (a) differs from the heat recovery rate identified in Table 5-1 in that it compares recovered waste heat to the total energy output from both the thermal and electricity generation contributions.

Table 3-2: Program Required PUC 218.5 Minimum Performance

Element	Definition	Minimum Requirement
218.5 (a)	Proportion of facilities' total annual energy output in the form of useful heat	5.0%
218.5 (b)	Overall system efficiency (50% credit for useful heat)	42.5%

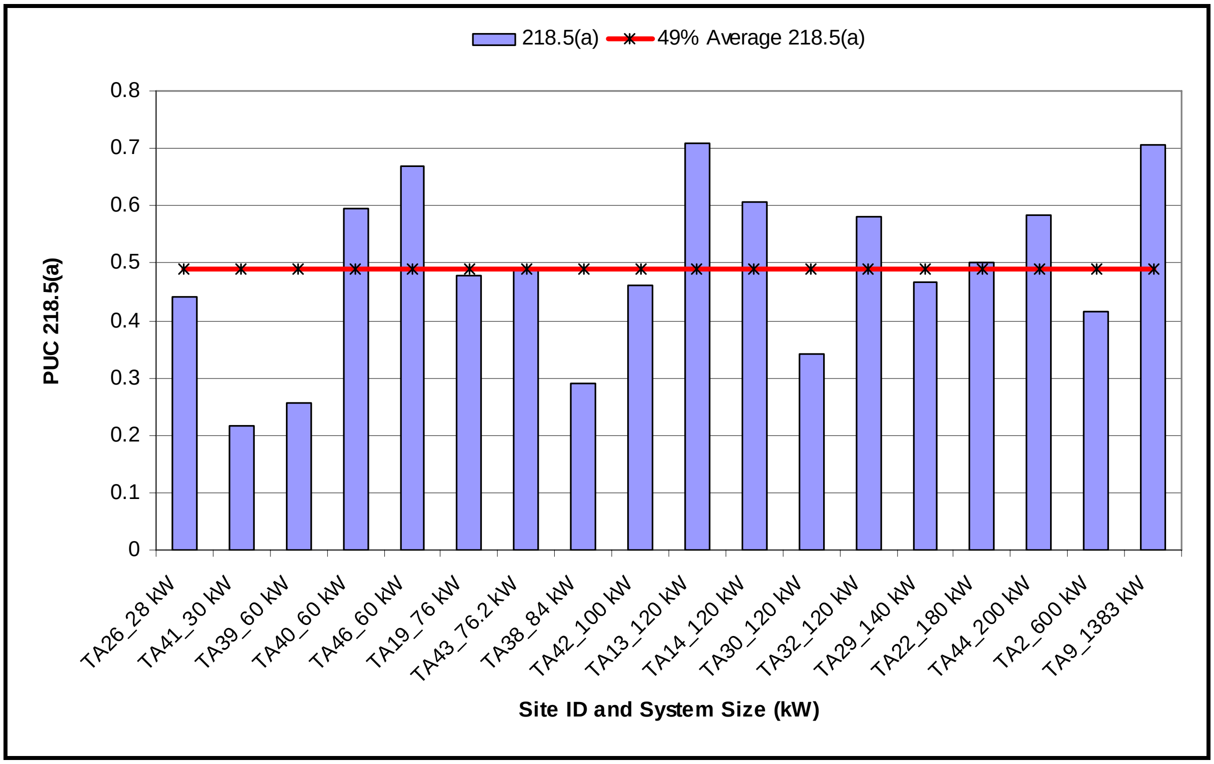
Previous impact evaluations have indicated possible problems in some SGIP cogeneration systems minimally meeting PUC 218.5(a) requirements. Given the Federal Energy Regulatory Commission's (FERC) concern over facilities that are only minimally meeting this requirement, it is important to better understand how SGIP facilities examined for PY03 and PY04 impact reports met the requirements. Estimates were updated to include monitoring data for 2005 and are presented in Table 3-3, below. Of the 18 microturbines examined, all met PUC 218.5(a) requirements. In addition, the minimum 218.5 (a) level observed was 22% and the average was 49%, indicating that the examined SGIP cogeneration facilities had no problems complying with the state or federal 218.5 (a) requirements.

Table 3-3: Summary Statistics for Microturbine PUC 218.5(a) Efficiencies

	Minimum	Maximum	Median	Average	Weighted Average
218.5(a)	0.22	0.71	0.49	0.49	0.57

As the difference between the arithmetic and weighted averages in the above table suggests, there is a slight improvement in efficiency with system size. This is caused by the largest project having the highest PUC 218.5(a) result and may be explained by the additional design-stage engineering involved in larger (both in capacity and financially) projects. Figure 3-3 illustrates the variation of 218.5(a) efficiencies by system size.

Figure 3-3: Microturbine PUC 218.5(a) Efficiencies Versus System Size



<u>Problems Encountered with Waste Heat Recovery</u>

Although all systems achieved PUC 218.5 (a) requirements, evaluation of waste heat recovery showed that some systems had significantly lower waste heat recovery than others. A detailed analysis of these “poorer” performing systems was conducted to explore why they were exhibiting lower waste heat recovery efficiencies. It was discovered that many of these poorer performing systems’ calculations used at the design stage had significant flaws in assumptions that overstated the achievable efficiency. To better identify the types of incorrect assumptions that could be impacting PUC 218.5 (a) and (b) efficiencies, Itron analyzed the Waste Heat Utilization Worksheet (WHUW). This worksheet is used by SGIP project developers in the SGIP application process to demonstrate that their proposed projects comply with PUC 218 requirements.

The following are some examples of “bad” assumptions that had significant impacts on the PUC efficiencies and which were more commonly made.

- Hours of operation of the proposed SGIP system were routinely overstated, and
- Information provided in the WHUW did not quantify the coincidence of electrical demand with thermal demand. As a result, some applications assumed coincident power generation and thermal energy recovery and use. This resulted in a mismatch of load and generation and possibly resulted in over-sizing of equipment.

In addition to flawed design assumptions, there are cases of equipment failures that contributed to poor performance. In some cases, the failure causes complete system shutdown, which does not impact PUC 218.5 calculations. Other times, only part of the system is disabled (e.g., the heat recovery loop) and the generator continues to produce electricity without recovering heat, causing PUC 218.5 efficiencies to plummet. Some examples of mechanical equipment problems are presented below.

- The heat exchanger fails due to unexpected reactions with working fluids.
- The gas compressor fails.
- The absorption chiller fails.

Possible Ways to Promote Improved Useful Waste Heat Recovery

Possible improvements are divided into SGIP process improvements that affect future applicants and site-specific improvements that affect past applicants. Both require careful thought before implementation and the suggestions here are only a starting point for further investigation. Site-specific suggestions are in no way intended to be actionable items without further engineering.

Process Improvements to the SGIP Application

Documentation for Load Profile and Hours of Operation. Electric and thermal load profiles should be developed as part of the application process and used in the WHUW. These are key indicators of the success of the cogeneration system but are often times estimated using assumptions and estimates without documentation.

Design to Minimum of Electrical and Thermal Loads. Coincident electrical and thermal loads are imperative for successful cogeneration system performance. Without a coincident electric and thermal load, the cogeneration system should be downsized to meet the minimum of the electric or thermal load. This would ensure full-load operation of the microturbine.

Internal Combustion Engines

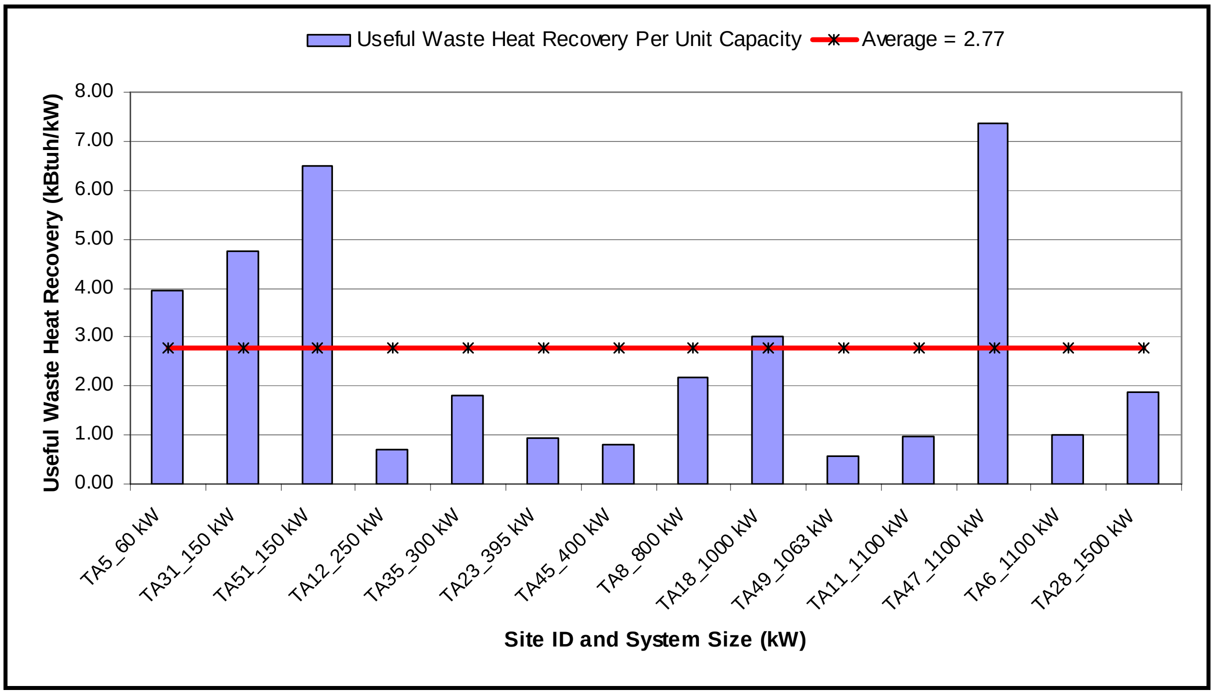
Internal combustion engines (ICEs) in the SGIP exhibit a more predicable and consistent range of useful heat recovery than microturbines. Table 3-4 provides some key summary statistics of both the heat recovery per unit of capacity and the heat recovery per unit of fuel input.

Table 3-4: Useful Waste Heat Recovery at SGIP ICE Facilities (n=27)

	Minimum	Maximum	Median	Average	Weighted Average
Useful Waste Heat Recovery Per Unit Capacity (kBtuh/kW)	0.58	7.36	2.10	2.77	2.61
Heat Recovery Per Unit Fuel Input ($kBtu_{heat}/kBtu_{fuel}$)	0.05	0.45	0.21	0.23	0.20

As the table indicates, there is significant variation in both the amount of useful waste heat recovery per unit of installed capacity and the efficiency of useful waste heat recovery. Figure 3-4 illustrates this variation by site for all sites reported.[1]

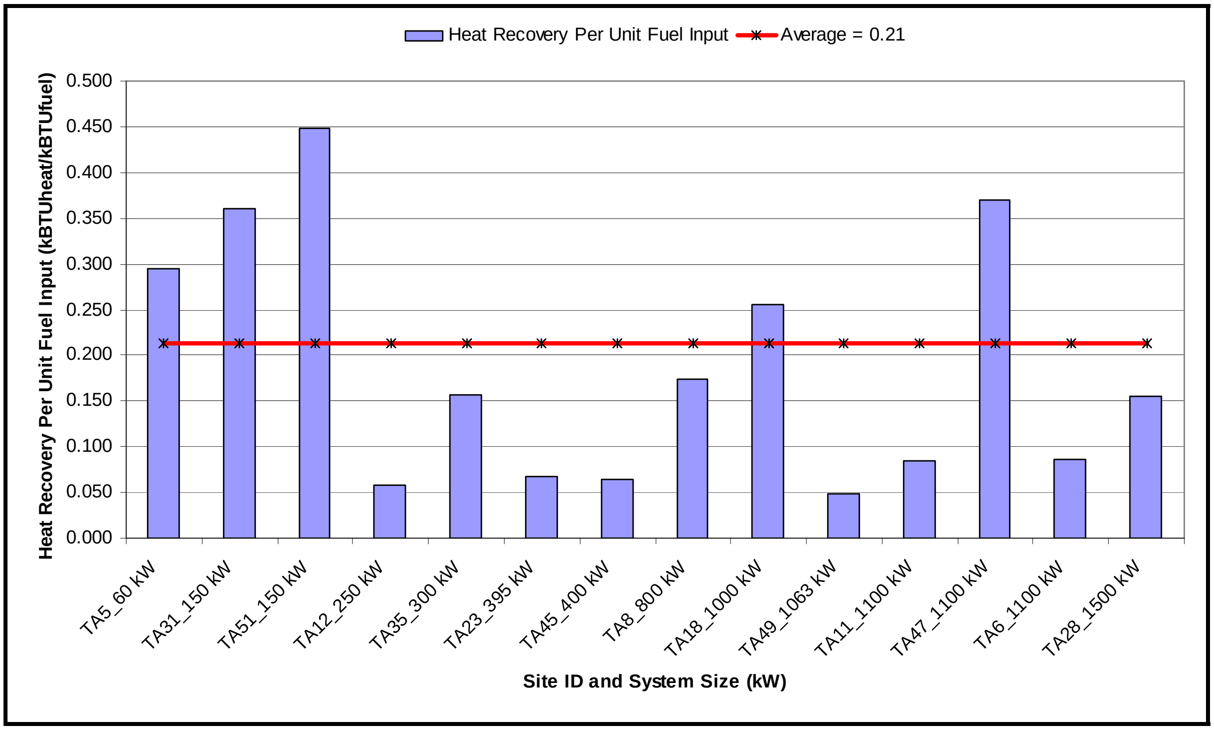
Figure 3-4: Thermal Efficiency by Site for ICEs (n=14)



[1] There are 13 sites for which monitoring data exists but confidentiality agreements with data providers prevent releasing site-specific data. Data for these sites is reported in all summary statistics but removed from site-specific statistics.

An interesting observation for ICEs is that for both the useful waste heat recovery and the heat recovery rate, the weighted averages are lower than the averages. This suggests that larger systems do not perform as well as smaller systems. Figure 3-5 illustrates the variation of useful heat recovery rate by system size.

Figure 3-5: ICE Useful Heat Recovery Per Unit Fuel Input Versus System Size



Compliance with Federal Requirements/Guidelines

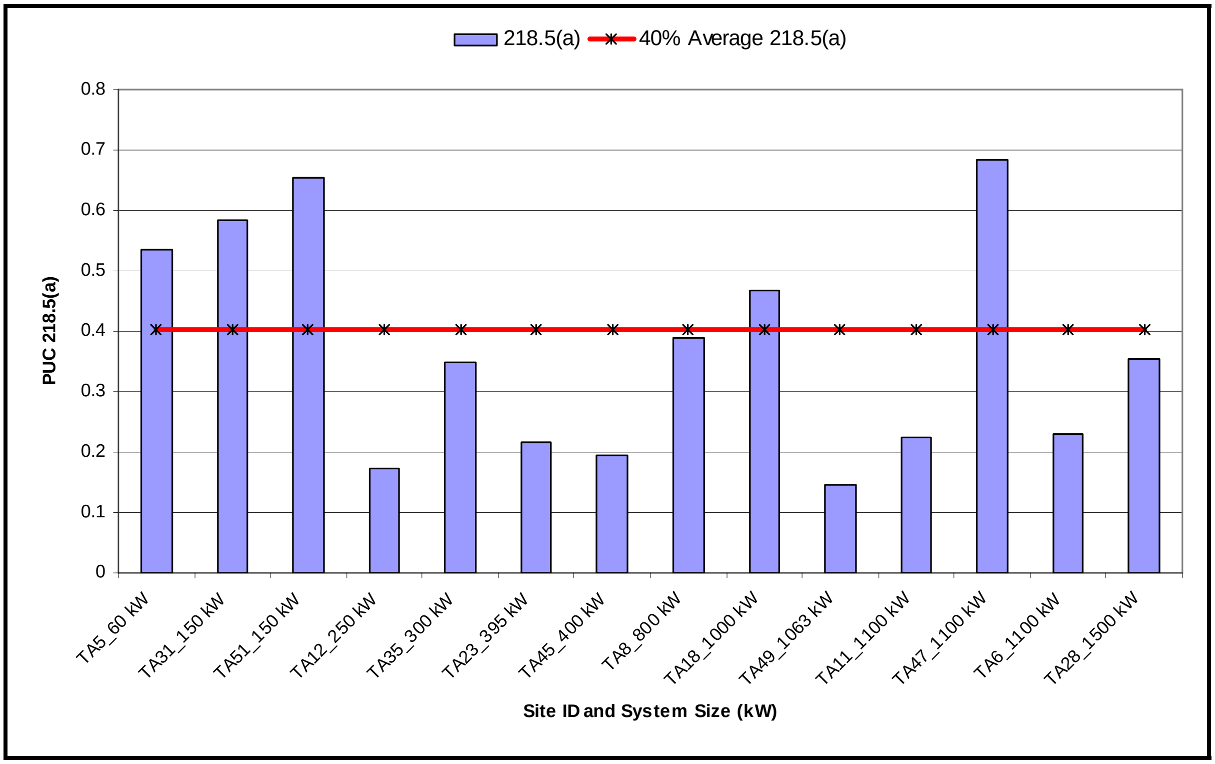
As with microturbines, estimates of compliance with PUC 218.5 (a) requirements have been updated to include recent monitoring data and are presented in Table 3-5. Of the 27 ICEs examined, all met PUC 218.5(a) requirements.

Table 3-5: Summary Statistics for ICE PUC 218.5(a) Efficiencies

	Minimum	Maximum	Median	Average	Weighted Average
218.5(a) efficiency:	0.15	0.68	0.38	0.40	0.39

As the above table suggests, there is a slight decrease in efficiency with system size. Figure 3-6 shows the variation of 218.5(a) efficiencies by system size.

Figure 3-6: ICE PUC 218.5(a) Efficiencies Versus System Size



Problems Encountered with Waste Heat Recovery

As with microturbines, not all ICEs provided the same degree of waste heat recovery. A detailed analysis of poor performing systems was conducted to explore why they were not meeting design efficiencies. Similar to the situation seen with microturbines, many times the calculations at the design stage had significant flaws that overstated the achievable efficiency. As before, we analyzed the WHUW for assumptions that do not represent actual operation. Some examples are presented below.

- Hours of operation are routinely overstated, and
- The WHUW does not quantify the coincidence of electrical demand with thermal demand. This results in a mismatch and possibly over-sizing of equipment.

In addition to flawed design assumptions, there are cases of equipment failures that contributed to poor performance. In some cases, the failure causes complete system shutdown, which does not impact PUC 218.5 calculations. Other times, however, only part of the system is disabled (i.e., heat recovery loop) and the generator continues to produce electricity without recovering heat, causing PUC 218.5 efficiencies to plummet. Some examples of mechanical equipment problems are presented below.

- The heat exchanger fails due to unexpected reactions with working fluids.

- The engine cylinder head fails.
- The absorption chiller fails.

Possible Ways to Promote Improved Useful Waste Heat Recovery

Possible improvements are divided into SGIP process improvements that affect future applicants and site-specific improvements that affect past applicants. Both require careful thought before implementation and the suggestions here are only a starting point for further investigation. Site-specific suggestions are in no way intended to be actionable items without further engineering.

Process Improvements to the SGIP Application

Documentation for Load Profile and Hours of Operation. Electric and thermal load profiles should be developed as part of the application process. These are key indicators of the success of the cogeneration system but are often times estimated using assumptions and estimates without documentation.

Design to Minimum of Electrical and Thermal Loads. Coincident electrical and thermal loads are imperative for successful cogeneration system performance. Without a coincident electric and thermal load, the cogeneration system should be downsized to meet the minimum of the electric or thermal load. This would ensure full-load operation of the ICE.

3.2 Electrical and Overall System Efficiency

Electrical system efficiency is defined as electrical output divided by fuel input. Overall system efficiency is the sum of the electrical output and the useful waste heat recovery divided by the fuel input. Various technologies in the SGIP have trends in operational efficiencies as presented in Section 2. Data collected for this evaluation yield a different result as presented below.

Microturbines

Range of Electrical and Overall System Efficiencies at SGIP Microturbine Facilities

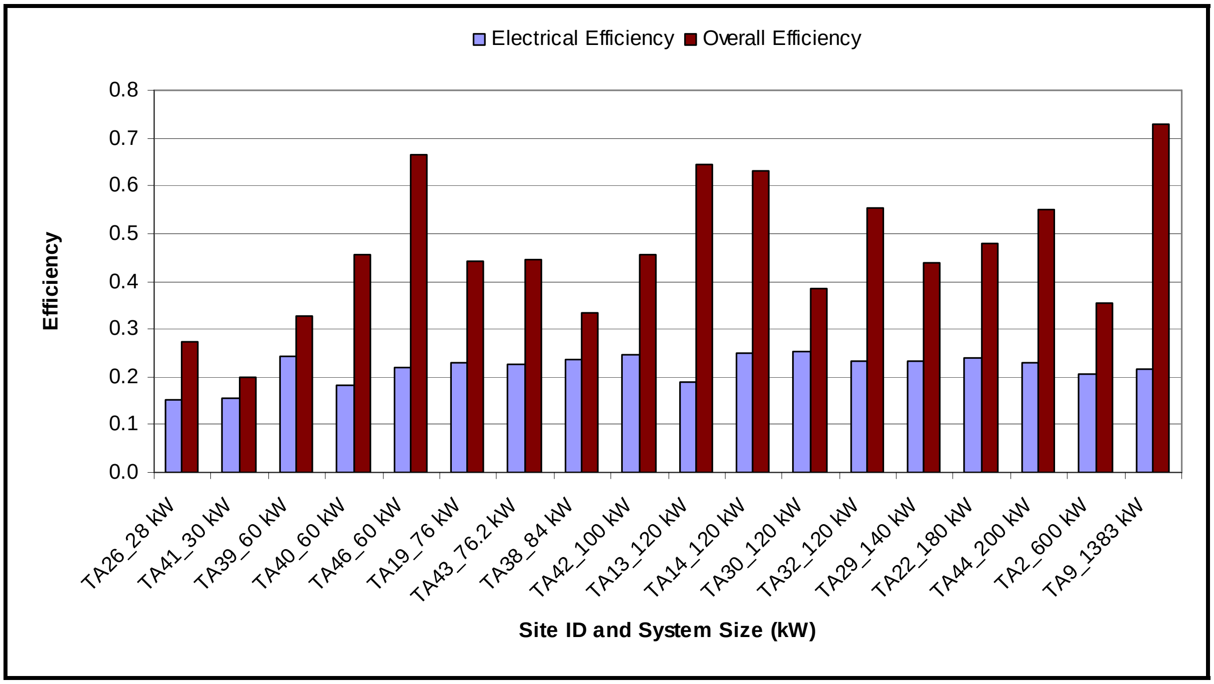
Electrical system efficiencies for microturbines are significantly below manufacturer claims but are very consistent. Table 3-6 presents summary statistics for electrical and overall system efficiencies. The results of this evaluation are significantly lower than manufacturer’s claims of approximately 30%.

Table 3-6: Electrical and Overall System Efficiencies at SGIP Microturbine Facilities

	Minimum	Maximum	Median	Average	Weighted Average
Electrical Efficiencies	0.15	0.25	0.23	0.22	0.22
Overall System Efficiencies	0.20	0.73	0.45	0.46	0.56

Figure 3-7 shows the variation of electrical and overall system efficiencies of microturbine systems by system size. An interesting observation from this figure is the relatively flat electrical efficiencies with widely distributed overall system efficiencies, showing that the source of variation is not on the electrical conversion side but rather on the useful waste heat recovery.

Figure 3-7: Microturbine Electrical and Overall System Efficiencies by System Size



Compliance with CPUC 218.5 (b) Requirements/Guidelines

Microturbines in the SGIP do not typically comply with PUC 218.5(b). As shown in Table 3-7 below, the average PUC 218.5(b) level achieved was only 34% and the minimum level achieved was only 18%.

Table 3-7: PUC 218.5(b) Summary Statistics for Microturbines

	Minimum	Maximum	Median	Average	Weighted Average
218.5(b) efficiency:	0.18	0.47	0.34	0.34	0.39

Examination of the two components of the PUC 218.5(b) calculation is provided in Table 3-8. Even if the electrical efficiencies were increased to manufacturer's claims, our analyses indicate many systems would fall below the required 42.5% levels required by PUC 218.5(b). This indicates that there are operational issues on both sides of the cogeneration system.

Table 3-8: Breakout of Electrical and Thermal Components of PUC 218.5(b) for Microturbines

Elec. Eff	Waste Heat	218.5(b)
21.90%	12.28%	34.18%

<u>Problems Encountered with Engine Electrical Efficiencies</u>

A detailed analysis of poor performing systems was conducted to explore why they were not meeting design efficiencies. Many times the calculations at the design stage had significant flaws that overstated the achievable efficiency. The WHUW, the tool for demonstrating compliance, was analyzed for assumptions that do not represent actual operation. Several examples are presented below.

- Generator output often does not account for parasitic loads, thereby overstating electrical output.
- Electrical conversion efficiencies are routinely overstated.
- Fuel may be reported in HHV rather than LHV.
- Hours of operation are routinely overstated.
- The WHUW does not quantify the coincidence of electrical demand with thermal demand. This results in a mismatch and possibly over-sizing of equipment.

In addition to flawed design assumptions, many cases of equipment failures are contributed to poor performance. In some cases, the failure causes complete system shutdown, which does not impact overall efficiency calculations. Other times, however, only part of the system is disabled (i.e., heat recovery loop) and the generator continues to produce electricity without recovering heat, causing overall system efficiencies to plummet. Some examples of mechanical equipment problems are presented below.

- The heat exchanger fails due to unexpected reactions with working fluids.
- The recuperator fails causing poor electrical power output.

- The gas compressor fails.
- The absorption chiller fails.
- Poor fuel quality leads to part-load operation (this applies to renewable-fueled projects but has a significant negative impact on operations).
- Operating temperature has an effect on system electrical efficiency.
- Regular maintenance is required to maintain good efficiency.

Possible ways to Promote Improved Electrical and Overall System Efficiencies

Possible improvements are divided into SGIP process improvements that affect future applicants and site-specific improvements that affect past applicants. Both require careful thought before implementation and the suggestions here are only a starting point for further investigation. Site-specific suggestions are in no way intended to be actionable items without further engineering.

Process Improvements to the SGIP Application

Require Actual Electrical Efficiency. To date, many entries involve a nameplate value that does not adequately account for parasitic loads or part-load operation.

Require Documentation for Load Profile and Hours of Operation. Electric and thermal load profiles should be developed as part of the application process. These are key indicators of the success of the cogeneration system but are often times estimated using assumptions and estimates without documentation.

Design to Minimum of Electrical and Thermal Loads. Coincident electrical and thermal loads are imperative for successful cogeneration system performance. Without a coincident electric and thermal load, the cogeneration system should be downsized to meet the minimum of the electric or thermal load. This would ensure full-load operation of the Microturbine.

Internal Combustion Engines

Range of Electrical and Overall System Efficiencies at SGIP ICE Facilities

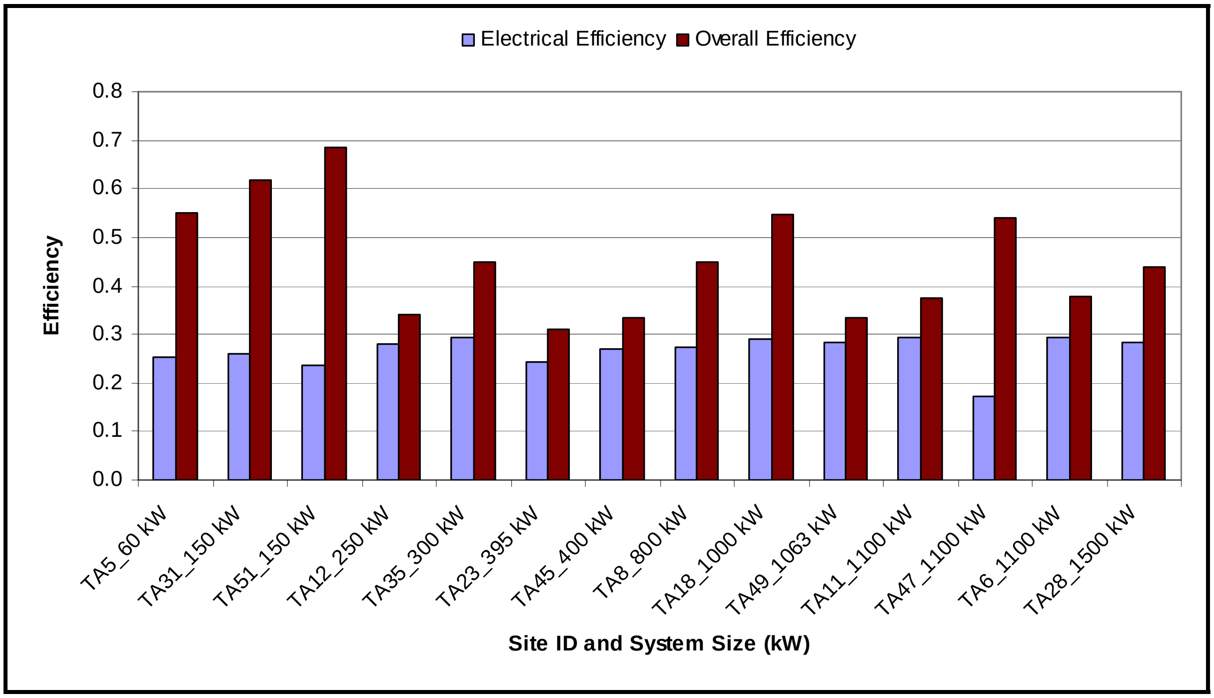
ICE cogeneration systems generally have higher electrical efficiencies than microturbine systems. This may be attributable to the relative longer history of ICEs as many of the issues discovered during product development have been encountered and resolved prior to the SGIP. Unexpectedly, there is a wider range of electrical efficiencies present in the program, as indicated in Table 3-9.

Table 3-9: Electrical and Overall System Efficiencies at SGIP ICE Facilities

	Minimum	Maximum	Median	Average	Weighted Average
Electrical Efficiencies	0.17	0.34	0.26	0.27	0.27
Overall System Efficiencies	0.31	0.69	0.47	0.49	0.47

Figure 3-8 shows the variation of electrical and overall system efficiencies of ICEs by system size. As expected from the similarity of average and weighted average above, there is no correlation between efficiency and system size.

Figure 3-8: ICE Electrical and Overall System Efficiencies by System Size



<u>Compliance with CPUC 218.5 (b) Requirements/Guidelines</u>

In general, ICE cogeneration systems perform closer to PUC 218.5(b) than microturbine systems. This is in part due to the way PUC 218.5(b) is calculated, in that electrical efficiency counts twice as much as thermal efficiency. That being said, ICEs overall do not meet PUC 218.5(b). As shown in Table 3-10, the average PUC 218.5(b) level achieved was only 38%, and the minimum level achieved was only 28%.

Table 3-10: PCU 218.5(b) Summary Statistics for ICEs

	Minimum	Maximum	Median	Average	Weighted Average
218.5(b) efficiency:	0.28	0.48	0.37	0.38	0.37

Table 3-11 provides the components that make up PUC 218.5(b) for ICEs.

Table 3-11: Breakout of Electrical and Thermal Components of PUC 218.5(b) for ICEs

Elec. Eff	Waste Heat	218.5(b)
27.25%	10.63%	37.88%

Problems Encountered with Engine Electrical Efficiencies

A detailed analysis of poor performing systems was conducted to explore why they were not meeting design efficiencies. Many times, the calculations at the design stage had significant flaws that overstated the achievable efficiency. The WHUW was analyzed for assumptions that do not represent actual operation. Several examples are presented below.

- Generator output often does not account for parasitic loads, thereby overstating electrical output.
- Electrical conversion efficiencies are routinely overstated.
- Fuel may be reported in HHV rather than LHV.
- Hours of operation are routinely overstated.
- The WHUW does not quantify the coincidence of electrical demand with thermal demand. This results in a mismatch and possibly over-sizing of equipment.

In addition to flawed design assumptions, there are many cases of equipment failures that contributed to poor performance. In some cases, the failure causes complete system shutdown, which does not impact overall efficiency calculations. Other times, however, only part of the system is disabled (i.e., heat recovery loop) and the generator continues to produce electricity without recovering heat, causing overall system efficiencies to plummet. Some examples of mechanical equipment problems are presented below.

- The heat exchanger fails due to unexpected reactions with working fluids.
- The recuperator fails causing poor electrical power output.
- The gas compressor fails.
- The absorption chiller fails.

- Poor fuel quality leads to part-load operation (this applies to renewable-fueled projects but has a significant negative impact on operations).
- Operating temperature has an effect on system electrical efficiency.
- Regular maintenance is required to maintain good efficiency.

Possible ways to Promote Improved Electrical and Overall System Efficiencies

Possible improvements are divided into SGIP process improvements that affect future applicants and site-specific improvements that affect past applicants. Both require careful thought before implementation and the suggestions here are only a starting point for further investigation. Site-specific suggestions are in no way intended to be actionable items without further engineering.

Process Improvements to the SGIP Application

Require Actual Electrical Efficiency. To date, many entries involve a nameplate value that does not adequately account for parasitic loads or part-load operation.

Require Documentation for Load Profile and Hours of Operation. Electric and thermal load profiles should be developed as part of the application process. These are key indicators of the success of the cogeneration system but are often times estimated using assumptions and estimates without documentation.

Design to Minimum of Electrical and Thermal Loads. Coincident electrical and thermal loads are imperative for successful cogeneration system performance. Without a coincident electric and thermal load, the cogeneration system should be downsized to meet the minimum of the electric or thermal load. This would ensure full-load operation of the ICE..

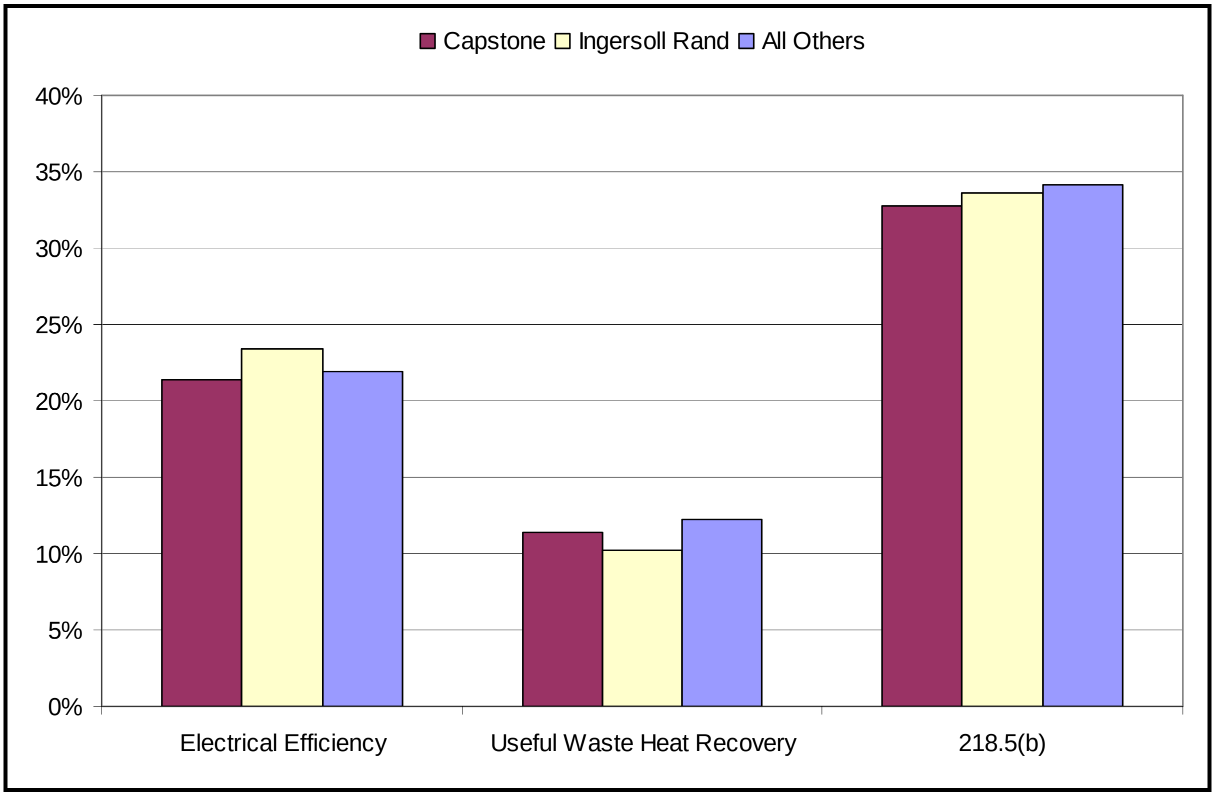
3.3 Manufacturer Comparative Results

Within each technology, two to three manufacturers represent most of the microturbine or ICE capacity within the SGIP. For microturbines, Capstone and Ingersoll Rand systems represent over 70% of the installed capacity. Similarly, Waukesha, Hess Microgen, and GE Jenbacher represent over 48% of the installed capacity for ICEs within the SGIP. Summary statistics were developed to examine performance by manufacturer. Due to the nature of participation, the most prevalent manufacturers were compared to the combination of all other manufacturers in the program.

Comparison of Microturbine Systems

Figure 3-9 compares the key efficiency metrics for Capstone and Ingersoll Rand against all other microturbine manufacturers. In general, there appear to be only marginal differences in performance between systems from the two most common manufacturers and from other manufacturers. The marginally lower results for Capstone units are likely due to two significant findings. First, Capstone provides turnkey packages of equipment that typically contain more components of the system than their competitors, such as heat exchangers, controls, etc. These additional components draw a parasitic load from the electrical generation of the microturbine that may not be captured in the monitoring data of the non-Capstone microturbines. This has the effect of lowering the electrical efficiency and the 218.5(b) efficiency. Second, early generation Capstone units had some equipment problems that compromised the operational performance of the units. Most participants with equipment problems claim that Capstone has replaced the equipment under warranty. As these units are replaced, a time-series comparison may produce higher efficiency results.

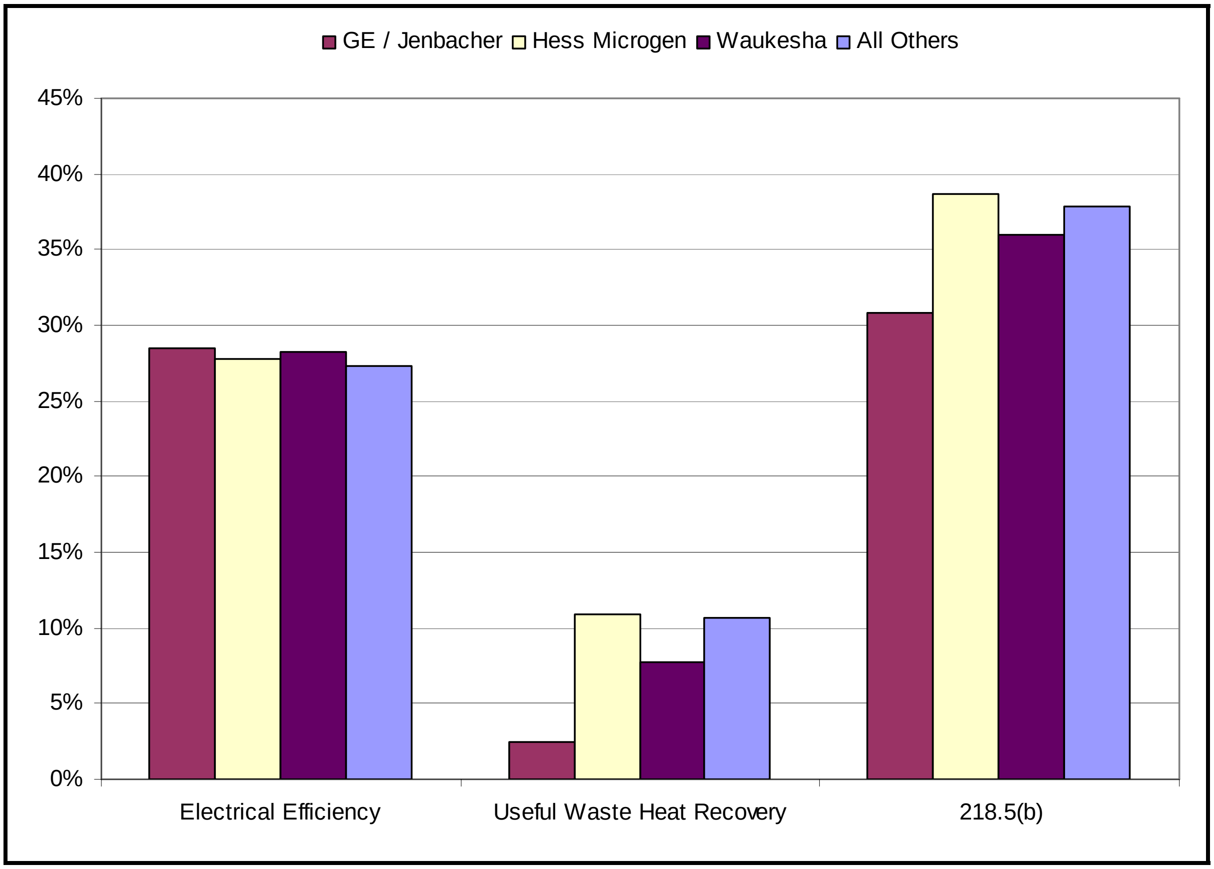
Figure 3-9: Comparative Statistics for Microturbines



Comparison of ICE Systems

Figure 3-10 compares the key efficiency metrics for Waukesha, Hess Microgen, and GE Jenbacher against all other ICE manufacturers. In general, the Hess units are performing better than their competitors are. One possible explanation for this performance is that a relatively large equipment installer/operator routinely provides service along with operation. As a result, the Hess equipment not only operates more efficiently, it also operates at a higher capacity factor. Conversely, one site with poor waste heat utilization significantly reduces the thermal and 218.5(b) performance for GE/Jenbacher.

Figure 3-10: Comparative Statistics for ICEs



3.4 Comparative Results (Microturbines and ICEs)

While conducting this analysis several interesting comparisons were drawn to assess the presence of trends. While many were rejected because they did not show a clear difference in operating characteristics, two items are worth noting.

Table 3-12 provides summary statistics for average capacity factors by technology. Capacity factor represents the percent of time the prime mover is available at the rated capacity. By average, this is the average capacity factor over the entire date range of valid monitoring data per site. What is interesting about this table is that microturbines have a higher average capacity factor than ICEs but operate at a lower efficiency. In essence, this means that while microturbines have a greater percentage of time operating at capacity than ICEs, the amount of work available from that capacity is less than from ICEs.

Table 3-12: Capacity Factor by Technology

	Minimum	Maximum	Median	Average	Weighted Average
MT	0.10	0.81	0.41	0.43	0.52
ICE	0.07	0.71	0.28	0.37	0.40

Figure 3-11 presents a comparison of 218.5(b) efficiency by technology. As shown in the figure, thermal efficiency is similar across microturbines and ICEs. Most of the difference in efficiency is due to the difference in electrical efficiency.

Figure 3-11: Comparison of 218.5(b) Efficiency by Technology

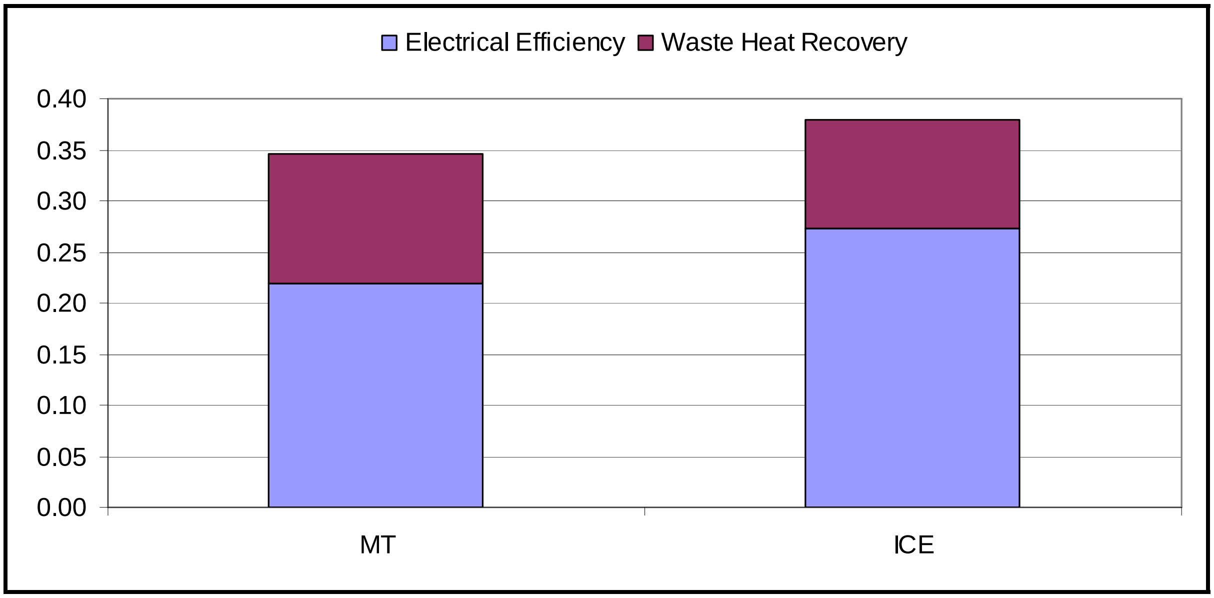
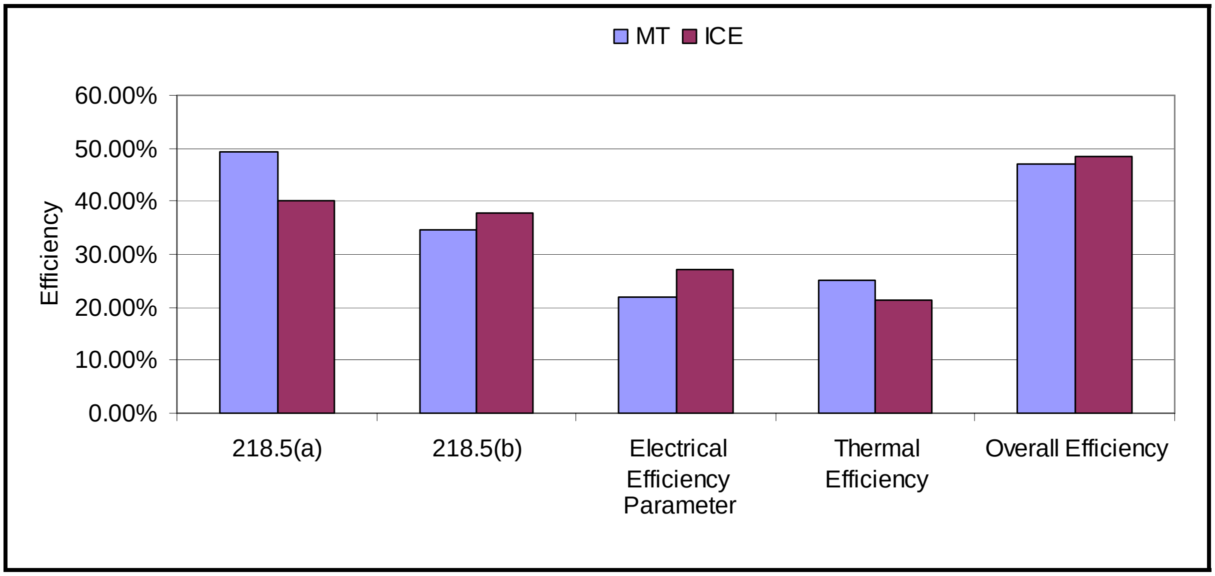


Figure 3-12 shows several important parameters that are used to assess cogeneration system performance.

Figure 3-12: Comparative Parameters for Microturbines and ICEs



As shown in the first two comparisons in Figure 3-12, microturbines generally have a higher PUC 218.5(a) value and a lower PUC 218.5(b) value. This is explained by the remaining three comparisons: electrical, thermal, and overall efficiency. Two general statements may be made regarding SGIP sites. First, ICEs typically have higher electrical efficiencies than microturbines (parameter 3 in Figure 3-12). Second, microturbines typically have higher thermal efficiencies than ICEs (parameter 4 in Figure 3-12). When taken together, these two statements help to explain the remaining parameters in Figure 3-12.

As a reminder, PUC 218.5(a) states that at least 5% of energy production must be in the form of useful thermal energy. In practical application, this is the proportion of *total output* that is useful waste heat recovery. In other words, the useful waste heat recovery divided by the sum of the electrical output and the useful waste heat recovery. With lower electrical efficiency and higher thermal efficiency, microturbines clearly show a more favorable PUC 218.5(a) result.

A similar story may be told for PUC 218.5(b), which states that the sum of the electrical output and half of the thermal output divided by the fuel input must be greater than or equal to 42.5%. With higher electrical efficiencies, ICEs do not need to recover as much heat to comply with PUC 218.5(b).

Appendix A

Reciprocating Engines

Internal Combustion Engines

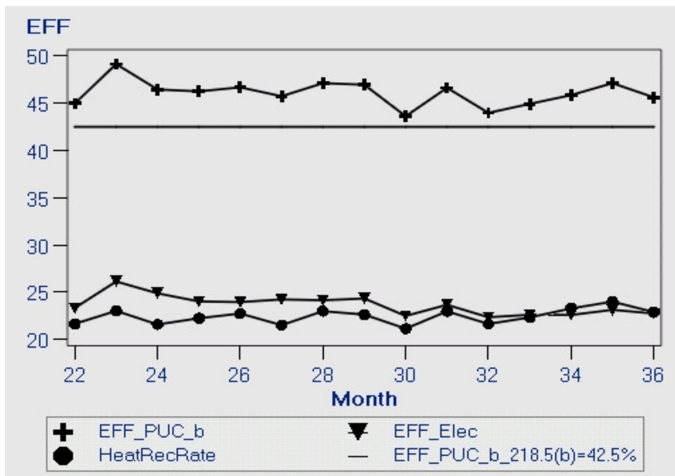
	IC Engine	**Good Performer**
Site ID for Thermal Analysis	**TA6**	
System Details:	ICE 150kW	
Manufacturer	Tecogen	
Model	CM-75	
Applications of recovered heat:	Domestic Hot Water Space Heating	
Is there an Absorption Chiller?	No	
Notes:	System is operating 24/7 with decent heat recovery rate	
Monitoring Start Date:	Oct-04	
Monitoring End Date:	Dec-05	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



Parasitic Loads:	**kW of Parasitic Loads**
Circulating Pump P1 & P2 Rated at 0.75 hp ea	1.19kW
Circulating Pump P3 & P4 Rated at 0.50 hp ea	0.75kW
Circulating Pump P5 Rated at 0.50 hp	0.37kW
Circulating Pump P6 Rated at 0.75 hp	0.56kW
Total	2.87kW

1. Is electrical efficiency correct based on technology? Low

Electrical Conversion Efficiency= 23.60%
PU 218.5 (a) Efficiency = 65.17%
PU 218.5 (b) Efficiency = 46.02%

Capacity Factors	
Waste Heat Utilization Worksheet (Estimated)	91.3%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	13.7%
Actual Capacity Factor in 2005	75.4%

Heat Recovery Rate(kBTU/kWh)	
Waste Heat Utilization Worksheet (Estimated)	6.5
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	5.9
Actual Heat Recovery Rate in 2005	6.6

2. Is thermal efficiency correct based on technology? Yes

3. Notes/anecdotal information

4. Conclusion Good Performer

	IC Engine	Good Performer
Site ID for Thermal Analysis	**TA16**	

System Details: ICE Hess Microgen 400kW
Manufacturer: Hess Microgen
Model: 200i

Applications of recovered heat: Recovered heat is used to run absorption chiller.

Is there an Absorption Chiller? Yes

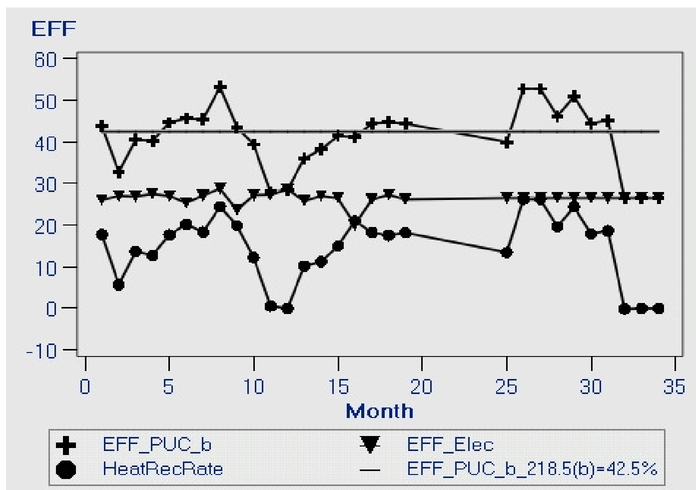
Notes: We do not have fuel data from Jan 2005. Assumed electrical efficiency for this period.
When the heat recovery is low, they are unable to meet the 218.5(b) efficiency standards

Monitoring Start Date: Jan-04
Monitoring End Date: Dec-04
Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Are there specific circumstances that lead to poor heat recovery?
Host has changed ownership since data receipt.
Operational information from Applicant is not site-specific.

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



Parasitic Loads:

1. Is electrical efficiency correct based on technology? Yes
Electrical Conversion Efficiency= 26.55%
PU 218.5 (a) Efficiency = 47.84%
PU 218.5 (b) Efficiency = 42.43%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	39.7%
Actual Capacity Factor in 2003	38.3%
Actual Capacity Factor in 2004	11.1%
Actual Capacity Factor in 2005	5.5%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	2.0
Actual Heat Recovery Rate in 2003	3.9
Actual Heat Recovery Rate in 2004	4.1
Actual Heat Recovery Rate in 2005	5.2

2. Is thermal efficiency correct based on technology? Yes

3. Notes/anecdotal information Host has changed ownership. Future of cogen operation is uncertain. System may be decomissioned.

4. Conclusion Good Performer

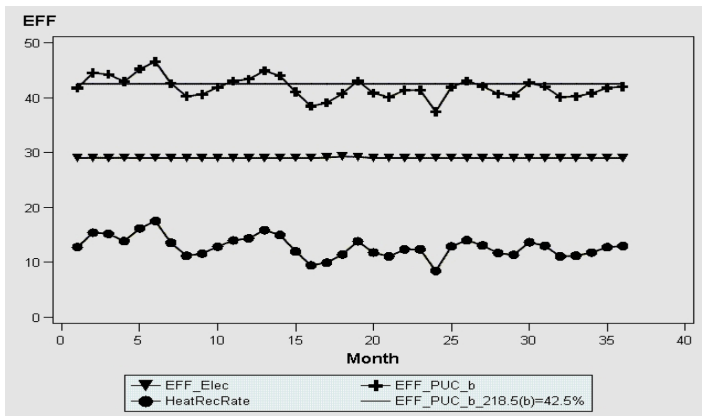
	IC Engine	Good Performer
Site ID for Thermal Analysis	**TA23**	
System Details:	ICE 1000 kW	
Manufacturer	Caterpillar	
Model	G3516B-LE	
Applications of recovered heat:	The existing plant has two York 450-on centrifugal chillers (CH 1, 2), a Trane 300-ton absorption chiller (ABS-1, served by the original cogeneration system) and two 16.7-MMBtuh Kewanne Boilers (BLR-1, 2).	
Is there an Absorption Chiller?	Yes	
Notes:	15 minute Fuel Data is estimated based on 15 minute ENGO data with an estimated electrical efficiency of 29%. (estimate is based on all ICE sites in the monitoring sample)	
Monitoring Start Date:	Jan-03	
Monitoring End Date:	Dec-05	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Yes
Electrical Conversion Efficiency= 29.00%
PU 218.5 (a) Efficiency = 35.43%
PU 218.5 (b) Efficiency = 42.15%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	100.0%
Actual Capacity Factor in 2003	50.5%
Actual Capacity Factor in 2004	31.4%
Actual Capacity Factor in 2005	64.3%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	2.2
Actual Heat Recovery Rate in 2003	3.3
Actual Heat Recovery Rate in 2004	2.8
Actual Heat Recovery Rate in 2005	2.9

2. Is thermal efficiency correct based on technology? Yes

3. Notes/anecdotal information Very steady heat recovery over the monitored period.

4. Conclusion Good Performer

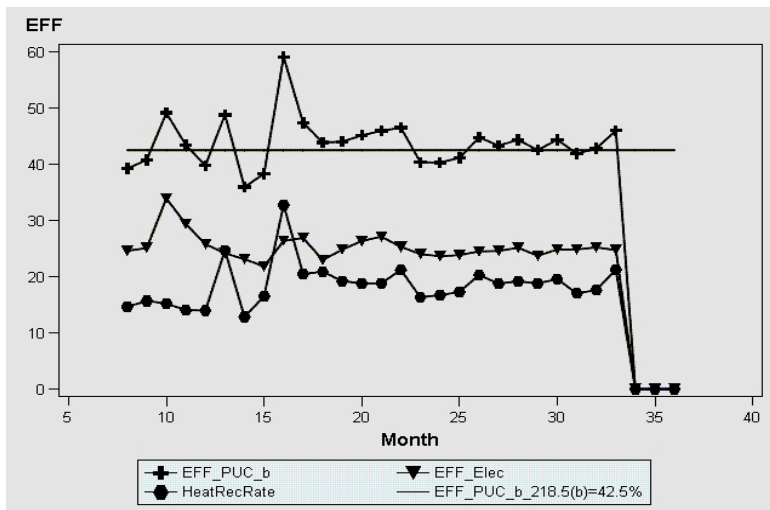
	IC Engine	Good Performer
Site ID for Thermal Analysis	**TA35**	
System Details:	Generac Utility DG50 ICN 150kW	
Manufacturer	Generac	
Model	Utility DG50	
Applications of recovered heat:	1.Space temperature is maintained by bare pipes running the length of the greenhouse buildings. The 2.Dirt is sterilized in a Van Dijk soil sterilizer that requires water temperature over 190℉	
Is there an Absorption Chiller?	No	
Monitoring Start Date:	Jun-03	
Monitoring End Date:	Nov-05	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Why was the system shut down? Is it because of the high gas prices or some kind of repairs?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



Parasitic Loads:

1. Is electrical efficiency correct based on technology?	Yes	
Electrical Conversion Efficiency=	25.84%	
PU 218.5 (a) Efficiency =	57.76%	
PU 218.5 (b) Efficiency =	43.51%	
Capacity Factors		
Waste Heat Utilization Worksheet (Estimated)		74.2%
Actual Capacity Factor in 2003		7.0%
Actual Capacity Factor in 2004		6.4%
Actual Capacity Factor in 2005		4.7%
Heat Recovery Rate(kBTU/kWh)		
Waste Heat Utilization Worksheet (Estimated)		3.3
Actual Heat Recovery Rate in 2003		3.7
Actual Heat Recovery Rate in 2004		5.1
Actual Heat Recovery Rate in 2005		5.5
2. Is thermal efficiency correct based on technology?	Yes	
3. Notes/anecdotal information	System is shut down in Nov 2005. Operations resumed in early 2006. The system has a very good heat recovery rate when running.	
4. Conclusion	Good Performer	

IC Engine **Good Performer**

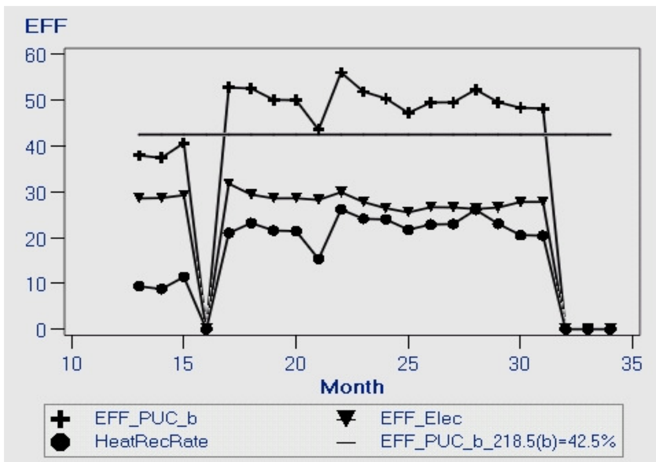
Site ID for Thermal Analysis	**TA50**
System Details:	Hess Microgen ICE 800kW
Manufacturer	Hess Microgen
Model	Hess 200
Applications of recovered heat:	190ton Absorption Chiller Supplement the existing hot water boiler for each building.
Is there an Absorption Chiller?	Yes
Notes:	Site was shut down from Aug 1 due to high natural gas prices. System has good heat recovery rate while operating.
Monitoring Start Date:	Jan-04
Monitoring End Date:	Dec-04

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology?	Yes	
Electrical Conversion Efficiency=		27.76%
PU 218.5 (a) Efficiency =		54%
PU 218.5 (b) Efficiency =		44.2%
Capacity Factors		
Waste Heat Utilization Worksheet (Estimated)		60.7%
Actual Capacity Factor in 2003		Not Available
Actual Capacity Factor in 2004		17.3%
Actual Capacity Factor in 2005		12.3%
Heat Recovery Rate(kBTU/kWh)		
Waste Heat Utilization Worksheet (Estimated)		2.7
Actual Heat Recovery Rate in 2003		Not Available
Actual Heat Recovery Rate in 2004		4.5
Actual Heat Recovery Rate in 2005		5.7
2. Is thermal efficiency correct based on technology?	Yes	
4. Conclusion	Good Performer	

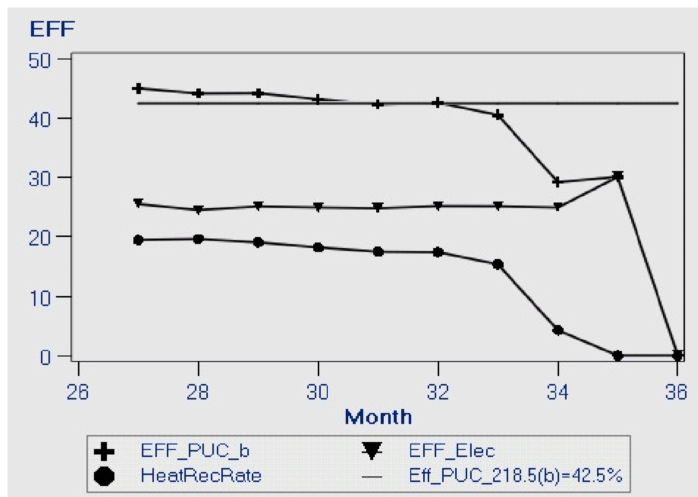
	IC Engine	Poor Performer
Site ID for Thermal Analysis	**TA51**	
System Details:	60 kW Recip. ICE	
Manufacturer	Tecogen	
Model	CM-60	
Applications of recovered heat:	This cogeneration unit produces hot water which is used for domestic uses and electricity to offset electricity purchases	
Is there an Absorption Chiller?	No	
Notes:	Heat recovery stopped in October 2005	
Monitoring Start Date:	Mar-05	
Monitoring End Date:	Dec-05	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:	What was the problem with heat recovery? Has it been resolved?	

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



Parasitic Loads:	**kW of Parasitic Loads**
Dump Radiator Fan rated 1 hp	0.75 kW
Jacket Water Pump rated 3/4 hp (internal)	0.56 kW
2 Circulating pumps, 1@1/4 hp and 1@1/3 hp	0.43 kW
Total	1.74 kW

1. Is electrical efficiency correct based on technology?	Yes
Electrical Conversion Efficiency	25.49%
PU 218.5 (a) Efficiency	35.98%
PU 218.5 (b) Efficiency	40.23%

Capacity Factor

Waste Heat Utilization Worksheet (Estimated)	58.3%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	Not Available
Actual Capacity Factor in 2005	21.4%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	4.5
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	Not Available
Actual Heat Recovery Rate in 2005	3.9

2. Is thermal efficiency correct based on technology?	Yes
3. Notes/anecdotal information	Low heat recovery from sep 2005 resulted in 218.5(b) efficiency to fall below 42.5%
4. Conclusion	Host states issue resolved. Site inspection proved operational heat recovery equipment. Site should meet 218.5(b) efficiency in 2006.

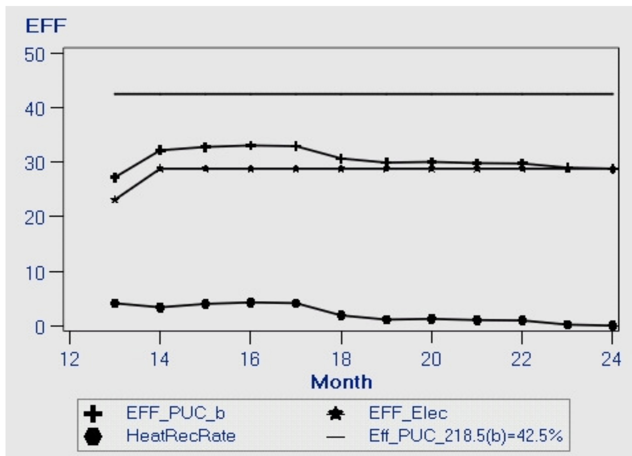
	IC Engine	Poor Performer
Site ID for Thermal Analysis	**TA5**	
System Details:	1063 kW ICE generator	
Manufacturer	GE / Jenbacher	
Model	JGC 320 GS-N.L.	
Applications of recovered heat:	Heat for absorption chiller	
Is there an Absorption Chiller?	Yes	
Notes:	15-minute ENGO data is estimated using monthly ENGO data and 15-minute FUEL data with an estimated average electric efficiency of 28.45% (estimate is based on all ICE sites in the monitoring sample)	
Monitoring Start Date:	Jan-04	
Monitoring End Date:	Dec-04	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Why is the heat recovery low?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



Parasitic Loads:	**kW of Parasitic Loads**
Circulation Pump rated 10hp	6.6 kW

1. Is electrical efficiency correct based on technology? Yes (But the estimated electrical efficiency in WHUW of 36% is high for an IC engine.)

Electrical Conversion Efficiency= 28.45%
PU 218.5 (a) Efficiency = 7.03%
PU 218.5 (b) Efficiency = 30.87%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	95.0%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	55.6%
Actual Capacity Factor in 2005	Not Available

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	1.2
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	0.6
Actual Heat Recovery Rate in 2005	Not Available

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information

4. Conclusion

System could not meet 218.5(b) efficiency because of low heat recovery rate. Problem with the absorption chiller that spread to cogen system.

When Chiller went down the temporary loss of chiller capacity was not an issue. The problem was that chiller failure caused the generator to trip off. The plant's electrical system is not robust enough to tolerate this and would cause power outages in the plant. The solution was to run the chiller at part load so it would not trip off.

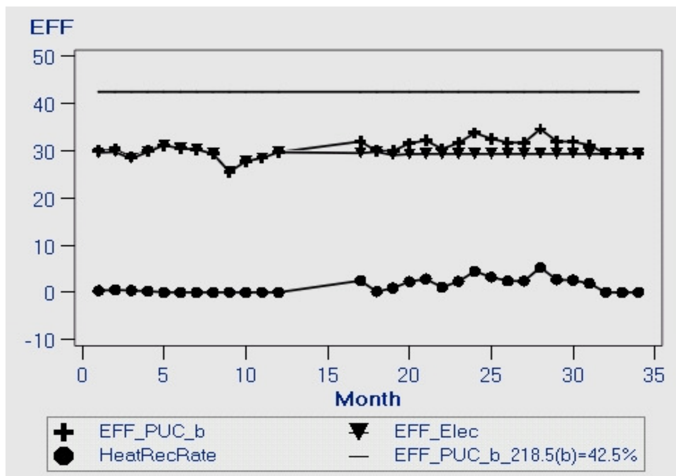
	IC Engine	Poor Performer
Site ID for Thermal Analysis	**TA7**	
System Details:	Hess Microgen 200s, 800 kW Total	
Applications of recovered heat:	1. Part of the heat energy recovered from the generators is used to displace purchased steam for space heating 2. Another part of the energy recovered is used to operate an absorption chiller, which will provide pre-cooling for existing electric chillers	
Is there an Absorption Chiller?	Yes	
Notes:	Heat recovery is very low…almost zero. WHUW Review shows 110-Ton Thermax Abs Chiller with 68.1% conversion efficiency. 54/44	
Monitoring Start Date:	Jan-03	
Monitoring End Date:	Oct-06	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:	Why is the heat recovery down? Was the heat exchanger broken? Are the units supplied the correct units (Btu per 15-min period)?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Yes

Electrical Conversion Efficiency= 29.35%
PU 218.5 (a) Efficiency = 3.54%
PU 218.5 (b) Efficiency = 30.66%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	41.4%
Actual Capacity Factor in 2003	49.5%
Actual Capacity Factor in 2004	19.8%
Actual Capacity Factor in 2005	24.8%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	2.8
Actual Heat Recovery Rate in 2003	0.0
Actual Heat Recovery Rate in 2004	0.5
Actual Heat Recovery Rate in 2005	0.7

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information Attempts to obtain site-specific information from applicant unsuccessful. System has recently changed owners. Future attempts may be more successful after workload decreases. Still suspect HEAT unit error.

4. Conclusion System could not meet 218.5(b) efficiency because site was not recovering heat.

	IC Engine	Poor Performer
Site ID for Thermal Analysis	**TA28**	

System Details: ICN Caterpillar 395kW
Manufacturer: Caterpillar
Model: 63412 SITA

Applications of recovered heat: Reciprocating engine used to provide hot water to an absorption chiller.
Used for process heating.

Is there an Absorption Chiller? Yes

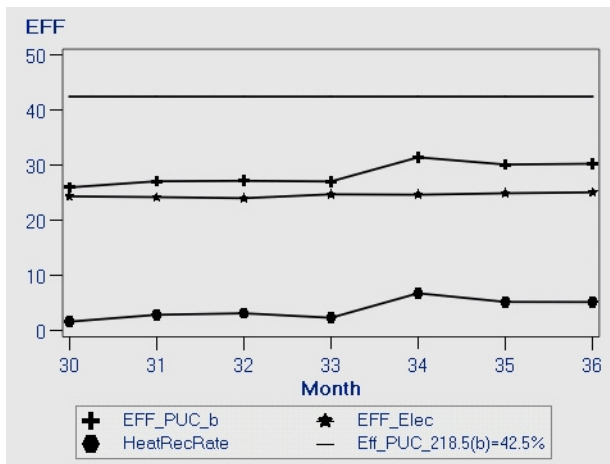
Notes: Aquamar is unable to meet 218.5(b) efficiency because of low heat recovery.
They recover 28% of the total heat that is available.
They dump excess heat through heat dump radiator.
From Dec 2005, Heat recovery rate is zero.

Monitoring Start Date: Jun-05
Monitoring End Date: Jan-06
Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Why is the heat recovery low compared to the estimated thermal load.
Was the heat exchanger broken?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Yes(Little low)
Electrical Conversion Efficiency= 24.42%
PU 218.5 (a) Efficiency = 5.49%
PU 218.5 (b) Efficiency = 27.77%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	85.8%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	Not Available
Actual Capacity Factor in 2005	32.1%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	6.4
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	Not Available
Actual Heat Recovery Rate in 2005	0.9

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information

4. Conclusion System could not meet 218.5(b) efficiency because of low heat recovery. They recover only 28% of the total waste heat available.
System was recently repiped and per HOST should perform better in future. This should be verified.

	IC Engine	**Poor Performer**
Site ID for Thermal Analysis	**TA31**	
System Details:	Waukesha L7042GHI, 600kW	
Manufacturer	Waukesha	
Model	L7042GHI	
Applications of recovered heat:	Load 1: Absorption Chiller Load 2:Space Heating Load 3: Domestic Hot water	
Is there an Absorption Chiller?	Yes	
Monitoring Start Date:	Jun-03	
Monitoring End Date:	Oct-04	

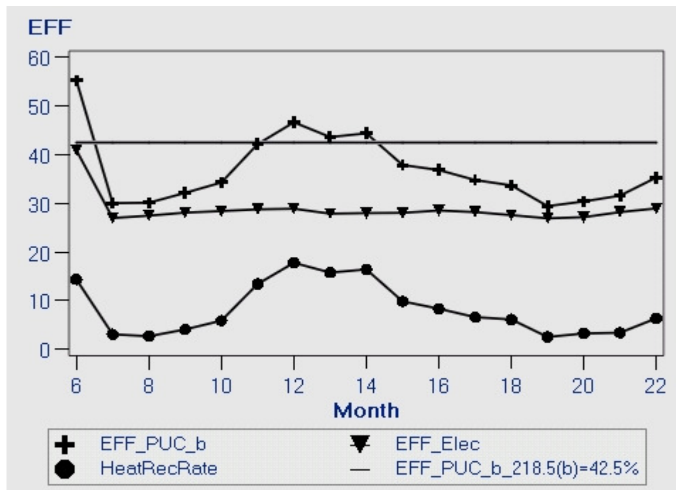
Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Notes:

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Yes

Electrical Conversion Efficiency= 28.27%
PU 218.5 (a) Efficiency = 4.90%
PU 218.5 (b) Efficiency = 30.02%

Capacity Factors	
Waste Heat Utilization Worksheet (Estimated)	73.5%
Actual Capacity Factor in 2003	34.0%
Actual Capacity Factor in 2004	51.5%
Actual Capacity Factor in 2005	Not Available

Heat Recovery Rate(kBTU/kWh)	
Waste Heat Utilization Worksheet (Estimated)	2.4
Actual Heat Recovery Rate in 2003	1.8
Actual Heat Recovery Rate in 2004	1.9
Actual Heat Recovery Rate in 2005	Not Available

2. Is thermal efficiency correct based on technology? Yes

3. Notes/anecdotal information

4. Conclusion System meets 218.5(b) efficiency only if they completely recovery waste heat.

IC Engine **Poor Performer**

Site ID for Thermal Analysis	**TA36**
System Details:	Hess Microgen 200i, 400kw
Manufacturer	Hess Microgen
Model	200i
Applications of recovered heat:	Load 1: A 115-ton Century absorption chiller provides chilled water supply (CHWS) to the facility's chilled water distribution loop. This unit receives heat in the form of high-temperature water from the cogeneration system's thermal distribution loop. The cogeneration system is the only source of thermal energy for the absorption chiller.
Is there an Absorption Chiller?	Yes
Monitoring Start Date:	Jan-03
Monitoring End Date:	Oct-05

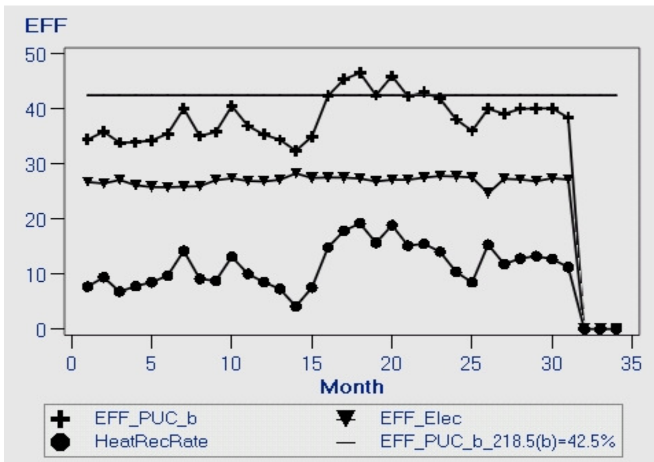
Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Notes:

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology?
1. Is electrical efficiency correct based on technology? Yes (But the estimated electrical efficiency in WHUW of 36% is high for an IC engine.)

Electrical Conversion Efficiency= 26.86%
PU 218.5 (a) Efficiency = 34.90%
PU 218.5 (b) Efficiency = 38.08%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	46.0%
Actual Capacity Factor in 2003	33.9%
Actual Capacity Factor in 2004	24.5%
Actual Capacity Factor in 2005	12.8%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	2.8
Actual Heat Recovery Rate in 2003	2.4
Actual Heat Recovery Rate in 2004	3.4
Actual Heat Recovery Rate in 2005	3.0

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information

4. Conclusion System meets 218.5(b) efficiency only if they completely recover waste heat. Electrical conversion efficiency was largest discrepancy.

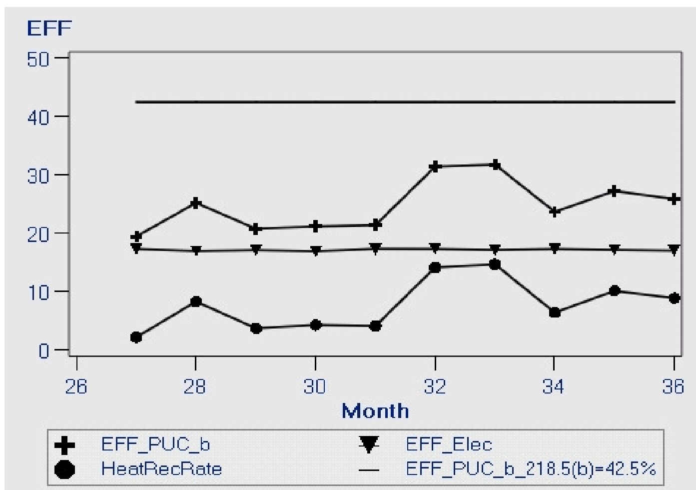
	IC Engine	Poor Performer
Site ID for Thermal Analysis	**TA49**	
System Details:	ICE 1100kW	
Manufacturer	Cummins	
Model	QSV81-G	
Applications of recovered heat:	No Monitoring Plan	
Is there an Absorption Chiller?	N/A	
Notes:	Low electric efficiency. Apparent high heat recovery rate likely due to unrebated generator driving absorption chiller.	
Monitoring Start Date:	Jan-05	
Monitoring End Date:	Dec-05	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Why is the electrical efficiency low? (nearly 17%)

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Low

Electrical Conversion Efficiency= 17.14%
PU 218.5 (a) Efficiency = N/A
PU 218.5 (b) Efficiency = 22.50%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	91.3%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	Not Available
Actual Capacity Factor in 2005	59.2%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	2.5
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	Not Available
Actual Heat Recovery Rate in 2005	

2. Is thermal efficiency correct based on technology? Yes

3. Notes/anecdotal information This is a mixed-status site. The site has an unrebated generator feeding absorption chiller. New host operator still coming up to speed on cogen operation

4. Conclusion System could not meet 218.5(b) efficiency because of low electrical efficiency and low heat recovery rate

Microturbines

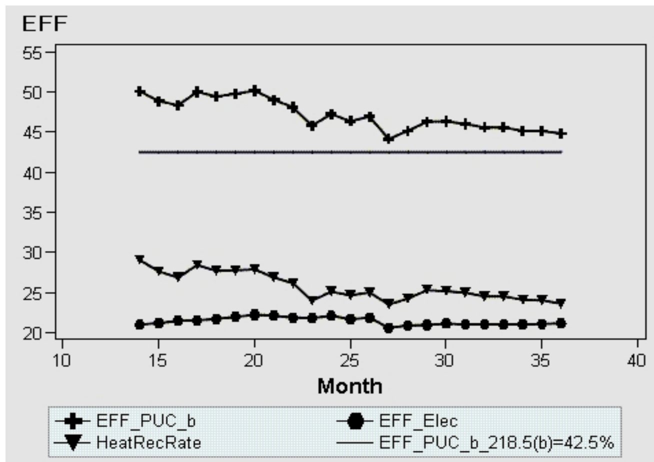
	Microturbine	**Good Performer**
Site ID for Thermal Analysis	**TA9**	
System Details:	MT Kawasaki GPB15X 1383kW	
Manufacturer	Kawasaki	
Model	GPB15X	
Applications of recovered heat:		
	All of the steam produced by the system is injected into oil wells to improve their production All of the energy recovered is from the exhaust stream passing through the waste heat recovery boiler.	
Is there an Absorption Chiller?	Yes	
Notes:	Heat recovery rate for this site is really high resulting in high 218.5(b) efficiency	
Monitoring Start Date:	Jan-04	
Monitoring End Date:	Dec-04	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



Parasitic Loads:	**kW of Parasitic Loads**
Turbine Housing Cooling Fan rated at 15 hp	11.2kW
Lube Oil Cooling Fan rated at 3 hp	2.2kW
Oil Demister Unit rated at 1 hp	0.7kW
Gas compressor rated at 60 hp	44.8kW
Boiler Feed Water Pump rated at 100 hp	74.6kW
Peak parasitic load	133.5kW
Average parasitic load =	0.8 x Peak = 106.8 kW or 7.6% of system capacity

1. Is electrical efficiency correct based on technology? Yes

Electrical Conversion Efficiency=	21.45%
PU 218.5 (a) Efficiency =	66.03%
PU 218.5 (b) Efficiency =	47.24%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	97.0%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	67.8%
Actual Capacity Factor in 2005	70.2%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	7.9
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	8.5
Actual Heat Recovery Rate in 2005	7.9

2. Is thermal efficiency correct based on technology? Yes

3. Notes/anecdotal information

4. Conclusion Good Performer. Mainly because of constant heat requirement.

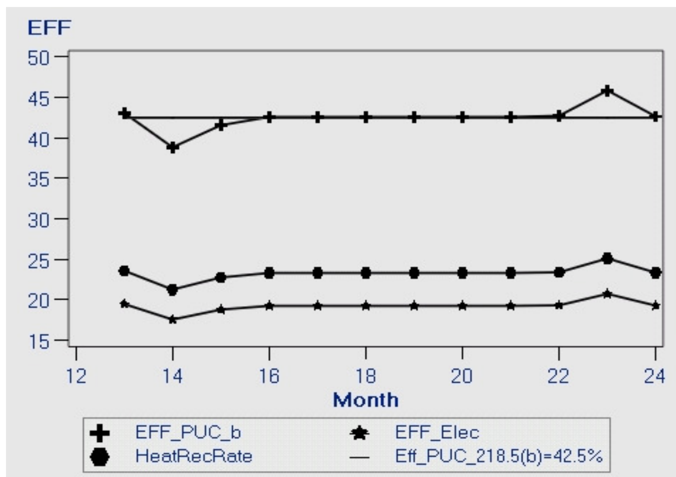
	Microturbine	Good Performer
Site ID for Thermal Analysis	**TA13**	
System Details:	MT 120kW	
Manufacturer	Capstone	
Model	C60	
Applications of recovered heat:	Adsorption Chiller Building Heating Glycol Heating	
Is there an Absorption Chiller?	Yes	
Notes:	Average ENGO production (32.25kW) is way less than the system size. System is running on part load most of the time.	
Monitoring Start Date:	Jan-04	
Monitoring End Date:	Dec-04	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:
1. Is FUEL splatted
2. Why is the electric efficiency low?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology?	Yes
Electrical Conversion Efficiency	18.84%
PU 218.5 (a) Efficiency	70.03%
PU 218.5 (b) Efficiency	41.65%

Capacity Factor

Waste Heat Utilization Worksheet (Estimated)	18.8%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	30.1%
Actual Capacity Factor in 2005	Not Available

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	4.2
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	8.3
Actual Heat Recovery Rate in 2005	Not Available

2. Is thermal efficiency correct based on technology?	Yes
3. Notes/anecdotal information	Heat data from 3rd party is cumulative and was transformed to 15-minute data using ENGO data and several assumptions.
4. Conclusion	System meets 218.5(b) efficiency. 2nd generation MT technology and use of heat for both heating and cooling help efficiency.

	Microturbine	**Poor Performer**
Site ID for Thermal Analysis	**TA29**	
System Details:	Ingersoll Rand, 70LM, 140kw	
Manufacturer	Ingersoll Rand	
Model	70LM	
Applications of recovered heat:	The facility uses hot water produced by the cogeneration system to offset natural gas consumption in the existing 200 HP (8,639 MBTUH input) steam boiler. The cogeneration module serves the hot water process loop storage tank, which provides 145°F water to the facility.	
Is there an Absorption Chiller?	No	

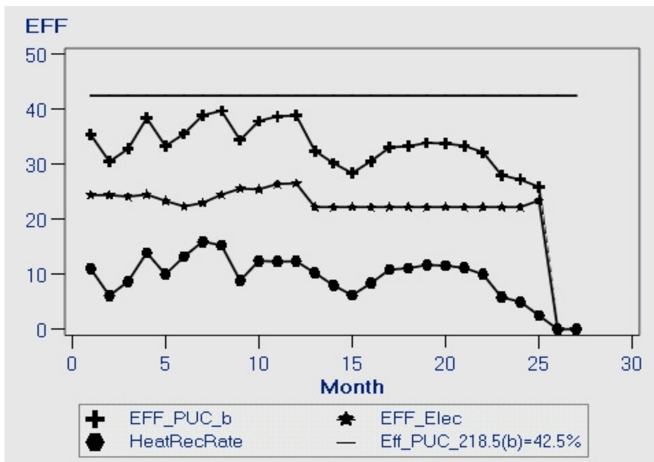
Notes:

Monitoring Start Date: Feb-03
Monitoring End Date: Mar-04
Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Is the system shut down from Feb 2005?
Yes, it was.

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? low
Electrical Conversion Efficiency= 23.43%
PU 218.5 (a) Efficiency = 53.33%
PU 218.5 (b) Efficiency = 36.82%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	48.7%
Actual Capacity Factor in 2003	26.9%
Actual Capacity Factor in 2004	23.3%
Actual Capacity Factor in 2005	0.3%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	3.9
Actual Heat Recovery Rate in 2003	3.2
Actual Heat Recovery Rate in 2004	2.7
Actual Heat Recovery Rate in 2005	0.7

2. Is thermal efficiency correct based on technology? low

3. Notes/anecdotal information

4. Conclusion System could not meet 218.5(b) efficiency because of low electrical efficiency.
System is no longer operational.

	Microturbine	**Poor Performer**
Site ID for Thermal Analysis	**TA30**	
System Details:	Capstone C60, 120kW	
Manufacturer	Capstone	
Model	C-60	
Applications of recovered heat:	Domestic hot water load	
Is there an Absorption Chiller?	No	

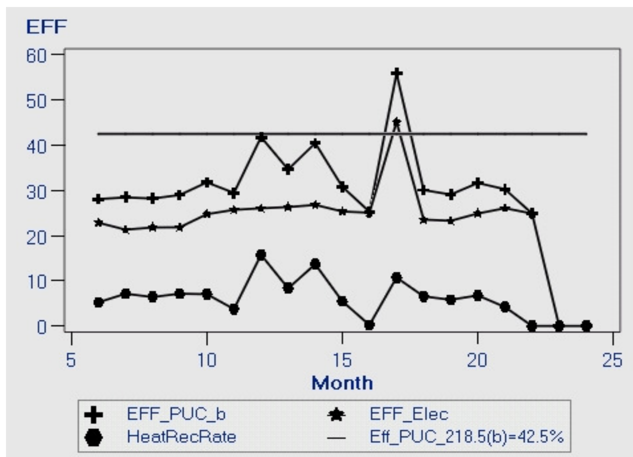
Notes:

Monitoring Start Date: Jun-03
Monitoring End Date: Mar-04
Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



Parasitic loads: The only parasitic load on the system is a natural gas compressor rated at 1/2 hp. This load is minimal relative to the generation capacity of the system and therefore was ignored in the calculations.

1. Is electrical efficiency correct based on technology? Yes

Electrical Conversion Efficiency= 25.28%
PU 218.5 (a) Efficiency = 16.78%
PU 218.5 (b) Efficiency = 31.86%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	100.0%
Actual Capacity Factor in 2003	41.6%
Actual Capacity Factor in 2004	65.2%
Actual Capacity Factor in 2005	Not Available

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	3.8
Actual Heat Recovery Rate in 2003	2.2
Actual Heat Recovery Rate in 2004	1.5
Actual Heat Recovery Rate in 2005	Not Available

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information

4. Conclusion System could not meet 218.5(b) efficiency because of low heat recovery rate.

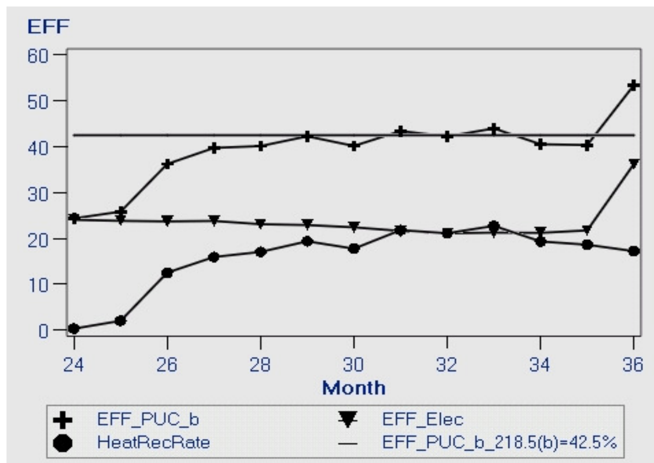
	Microturbine	**Poor Performer**
Site ID for Thermal Analysis	**TA32**	
System Details:	120kW Micro Turbine	
Applications of recovered heat:	Absorption chiller	
Is there an Absorption Chiller?	Yes	
Notes:	System is running 24 hours and is recovering heat all the time.	
ENGO	Applicant and utility data are similar…we are using utility data	
HEAT	Reasonable heat recovery rate……lines up with system capacity	
FUEL	Utility fuel data did not pass validation checks. Secondary fuel data from applicant passed validation checks and was utilized.	
Monitoring Start Date:	Dec-05	
Monitoring End Date:	Dec-04	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Why was the heat recovery low in Jan and Feb 2005?
Was the system broken?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



Parasitic Loads:
2 Natural Gas compressors 480 Volts / 3 phase 4 kW

Note: The natural gas compressors are considered integral components of the “microturbines” rather than electric parasitic loads that would cause net generator output to be different from gross generator output..

1. Is electrical efficiency correct based on technology? Low

Electrical Conversion Efficiency= 23.22%
PU 218.5 (a) Efficiency = 48.99%
PU 218.5 (b) Efficiency = 39.25%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	100.0%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	3.0%
Actual Capacity Factor in 2005	58.1%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	5.7
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	0.1
Actual Heat Recovery Rate in 2005	5.0

2. Is thermal efficiency correct based on technology? Yes

3. Notes/anecdotal information

4. Conclusion System meets 218.5(b) efficiency only if they completely recover waste heat. Heat recovery was low in Jan and Feb 2005 because of failed refrigerator pump in absorption chiller.

	Microturbine	Poor Performer
Site ID for Thermal Analysis	**TA39**	

System Details: MT Capstone 60kW
Manufacturer: Capstone
Model: 60R

Applications of recovered heat: Domestic hot water
Is there an Absorption Chiller? No

Notes: From 12/29/04 - 05/25/05 there was no heat recovery. Heat exchanger was broken so datalogger is recording zeros. From May 2005, datalogger has been recording very low heat recovery, consistent with data prior to heat exchanger failure.

Monitoring Start Date: Aug-04
Monitoring End Date: Dec-05
Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

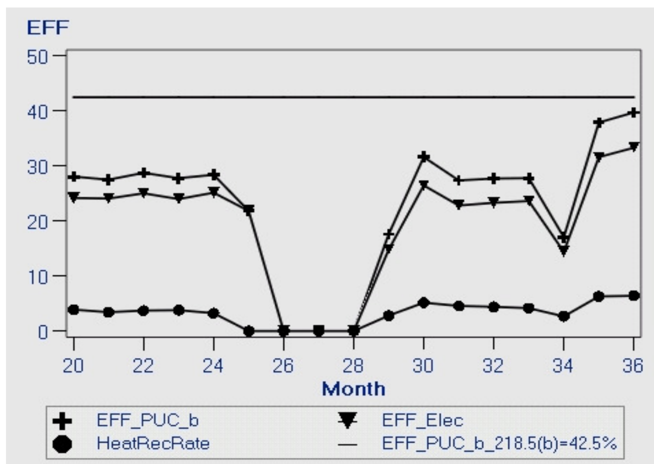
Site Specific Questions:

Was the heat exchanger fixed in May 2005? Yes

Heat recovery rate is very low even after fixing the heat exchanger. Are there any other issues?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Yes; 23-25% is in line with manufacturer claims
Electrical Conversion Efficiency= 23.41%
PU 218.5 (a) Efficiency = 11.13%
PU 218.5 (b) Efficiency = 27.26%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	22.8%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	31.1%
Actual Capacity Factor in 2005	47.9%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	4.9
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	1.0
Actual Heat Recovery Rate in 2005	1.2

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information Thermal load does not seem to be sufficient to utilize cogen to its fullest potential

4. Conclusion System could not meet 218.5(b) efficiency because of low heat recovery rate. Failure of heat exchanger exacerbated the issue.

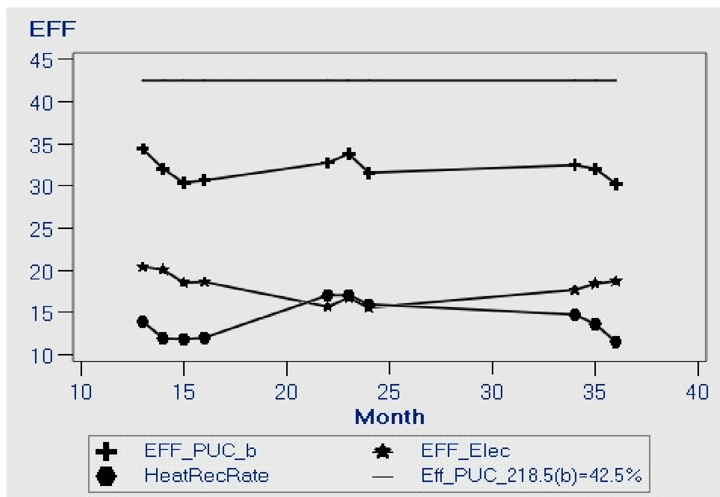
	Microturbine	Poor Performer
Site ID for Thermal Analysis	**TA40**	
System Details:	60kW MicroTurbine	
Manufacturer	Tecogen	
Model	CM-60	
Applications of recovered heat:	Hot water from the Unifin heat exchanger is used to heat the swimming pool.	
Is there an Absorption Chiller?	No	
Notes:	Heat exchanger is in repair frequently. Issue may be chemicals from pool water.	
Monitoring Start Date:	Jan-05	
Monitoring End Date:	Dec-06	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Has the heat exchanger been fixed?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Low

Electrical Conversion Efficiency= 18.37%
PU 218.5 (a) Efficiency = 47.44%
PU 218.5 (b) Efficiency = 31.91%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	45.7%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	Not Available
Actual Capacity Factor in 2005	Not Available

2. Is thermal efficiency correct based on technology?

Thermal Efficiency (kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	4.3
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	Not Available
Actual Heat Recovery Rate in 2005	Not Available

2. Is thermal efficiency correct based on technology? Yes

3. Notes/anecdotal information Recent discussion with host revealed that ENGO data may be inaccurate. Resolution from host is pending. Data will be revisited once issue is resolved.

4. Conclusion System could not meet 218.5(b) efficiency because of low electrical efficiency.

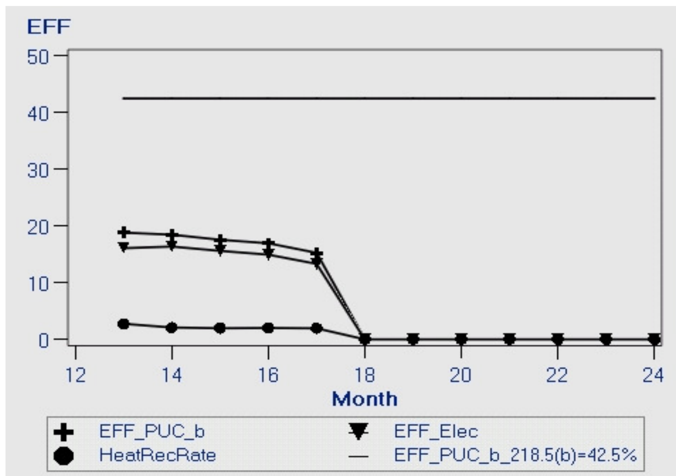
	Microturbine	**Poor Performer**
Site ID for Thermal Analysis	**TA41**	
System Details:	30kW MicroTurbine Capstone	
Manufacturer	Capstone	
Model	N/A	
Applications of recovered heat:	Hot water is used for laundry and domestic hot water uses.	
Is there an Absorption Chiller?	No	
Notes:	System was shut down from mid of Jun2004	
Monitoring Start Date:	Jan-04	
Monitoring End Date:	Dec-04	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions: Why was the system shut down?
Is there any mechanical failure?

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Low

Electrical Conversion Efficiency= 15.62%
PU 218.5 (a) Efficiency = 2.27%
PU 218.5 (b) Efficiency = 17.76%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	91.3%
Actual Capacity Factor in 2003	Not Available
Actual Capacity Factor in 2004	13.2%
Actual Capacity Factor in 2005	Not Available

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	5.2
Actual Heat Recovery Rate in 2003	Not Available
Actual Heat Recovery Rate in 2004	0.9
Actual Heat Recovery Rate in 2005	Not Available

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information

Host changed owenership and cogen was shut down in June 2004. As of June 2006 the system is still down. However, the new host indicated that they were working with a contractor to resume operation of the cogen unit.

4. Conclusion

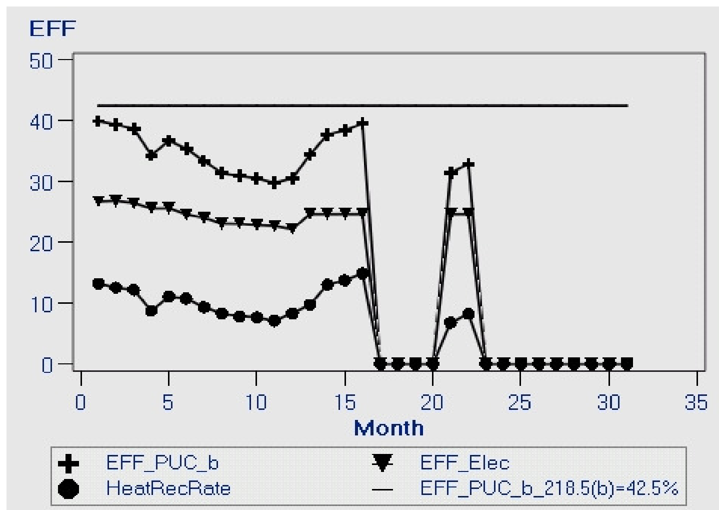
System could not meet 218.5(b) efficiency because of low electrical efficieny and low heat recovery rate. System is shut down from June 2004 and we have only 3-4 months of valid data.

	Microturbine	**Poor Performer**
Site ID for Thermal Analysis	**TA42**	
System Details:	100kW Micro Turbine	
Manufacturer	Turbec	
Model	T100 CHP system	
Applications of recovered heat:	Domestic Hot Water	
Is there an Absorption Chiller?	No	
Notes:	System is shut down from 2005. It was shut down for some part of 2004.	
Monitoring Start Date:	Jan-03	
Monitoring End Date:	Jul-05	

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Low

Electrical Conversion Efficiency= 24.68%
PU 218.5 (a) Efficiency = 19.68%
PU 218.5 (b) Efficiency = 35.20%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	91.3%
Actual Capacity Factor in 2003	38.6%
Actual Capacity Factor in 2004	10.1%
Actual Capacity Factor in 2005	Not Available

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	3.20625
Actual Heat Recovery Rate in 2003	2.8
Actual Heat Recovery Rate in 2004	2.9
Actual Heat Recovery Rate in 2005	Not Available

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information

4. Conclusion During operating periods, system could not meet 218.5(b) efficiency because of low electrical efficieny and low heat recovery rate.

Microturbine **Poor Performer**

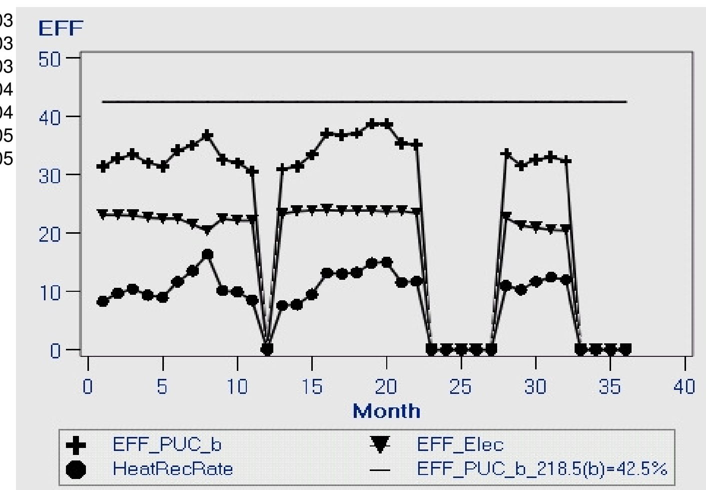
Site ID for Thermal Analysis	**TA43**
System Details:	Bowman Turbogen TG80CG MTN 76.2kW
Manufacturer	Bowman
Model	Turbogen TG80CG
Applications of recovered heat:	The system provides hot water to the laundry boiler The system provides hot water to the domestic hot water system.
Is there an Absorption Chiller?	No
Notes:	
Monitoring Start Date:	Feb-03
Monitoring End Date:	Dec-05

Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Yes(Little low)

Electrical Conversion Efficiency= 22.67%
PU 218.5 (a) Efficiency = 21.17%
PU 218.5 (b) Efficiency = 33.60%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	91.3%
Actual Capacity Factor in 2003	69.7%
Actual Capacity Factor in 2004	52.6%
Actual Capacity Factor in 2005	26.9%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	6.1
Actual Heat Recovery Rate in 2003	3.0
Actual Heat Recovery Rate in 2004	3.4
Actual Heat Recovery Rate in 2005	3.8

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information They have thermal load for around 4380 hrs annually whereas the cogen system operates 8000 hrs.

4. Conclusion System could not meet 218.5(b) efficiency because of low electrical efficieny and low heat recovery rate. Low heat recovery rate is due to system design problem.

Microturbine **Poor Performer**

Site ID for Thermal Analysis **TA44**

System Details: MT 200kW Turbec T100
Manufacturer Turbec
Model T100

Applications of recovered heat: Laundry
Domestic Hot Water (DHW)
Pool & Spa
Space Heating

Is there an Absorption Chiller? No

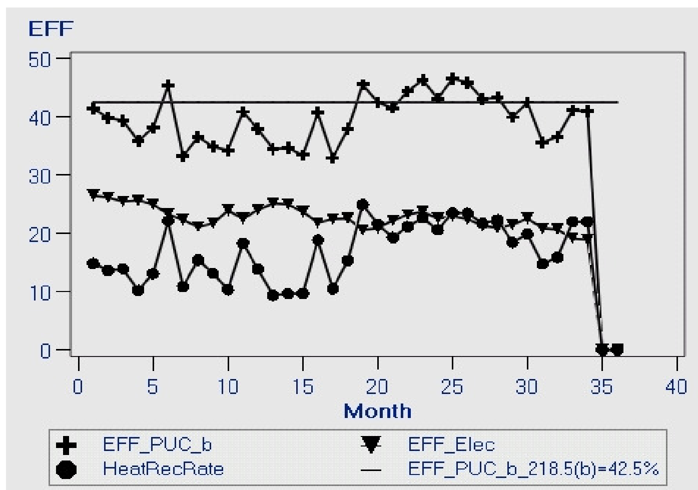
Notes:

Monitoring Start Date: Feb-03
Monitoring End Date: Dec-05
Monitoring start and end date indicates the period where ENGO, HEAT and FUEL data are available.

Site Specific Questions:

Graphical Representation of Efficiencies

Month 1 --- Jan 2003
Month 6 --- Jun 2003
Month 12 --- Dec 2003
Month 18 --- Jun 2004
Month 24 --- Dec 2004
Month 30 --- Jun 2005
Month 36 --- Dec 2005



1. Is electrical efficiency correct based on technology? Yes
Electrical Conversion Efficiency= 23.04%
PU 218.5 (a) Efficiency = 25.69%
PU 218.5 (b) Efficiency = 39.15%

Capacity Factors

Waste Heat Utilization Worksheet (Estimated)	91.3%
Actual Capacity Factor in 2003	38.9%
Actual Capacity Factor in 2004	34.3%
Actual Capacity Factor in 2005	29.5%

Heat Recovery Rate(kBTU/kWh)

Waste Heat Utilization Worksheet (Estimated)	3.4
Actual Heat Recovery Rate in 2003	3.9
Actual Heat Recovery Rate in 2004	4.9
Actual Heat Recovery Rate in 2005	6.1

2. Is thermal efficiency correct based on technology? Low

3. Notes/anecdotal information

4. Conclusion System meets 218.5(b) efficiency only if they completely recover waste heat. Waste heat utilization is good; capacity factor is very low.