DISTRIBUTED ENERGY PROGRAM **REPORT**

GTI Integrated Energy System for Buildings

Modular System Prototype

This document, which includes a "Laboratory Testing of Alpha Prototype" section, focuses on the market acceptability of integrated energy systems in commercial buildings.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

DISTRIBUTED ENERGY PROGRAM **REPORT**

GTI Integrated Energy System for Buildings

Modular System Prototype

Gas Technology Institute

January 2006

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

01/17/06 Version

GTI Integrated Energy System for Buildings

Modular System Prototype

Prepared by:

Greg Rouse
Marek Czachorski
Patrick Bishop
Jignesh Patel

Reviewed by: William R. Staats

Approved by: John F. Kelly

Gas Technology Institute
1700 S. Mount Prospect Rd.
Des Plaines Illinois 60018-1804

GTI Project 15357/65118

January 2006

Acknowledgement

The authors wish to thank Ron Fiskum of the U.S. Department of Energy and Tim Theiss, Bob DeVault, Patti Garland, and Steve Fischer of the Oak Ridge National Laboratory for their support and helpful comments in the development of this report. We also thank Bill Ryan of the University of Illinois, Joe Sinclair of Ballard Engineering, Bill Plzak and Vikas Patnaik of Trane, Monte McCormick and John Peffer of Waukesaha, and Tom Smith of Equity Office Partners for their significant contributions to this research.

Notice

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

This report was prepared by Gas Technology Institute (GTI) as an account of its R&D. Neither GTI, members of GTI, or any person acting on their behalf:

a. Makes any warranty or representation, express or implied with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

b. Assumes any liability with respect to the use of, or for any and all damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Reference to trade names or specific commercial products, commodities, or services in this report does not represent or constitute an endorsement, recommendation, or favoring by GTI of the specific commercial product, commodity, or service.

Executive Summary

DOE and GTI agree that the market acceptability of integrated energy systems (IES) in commercial buildings would improve if these systems were available to consumers as factory-assembled modules rather than being purchased as components, site engineered, and site assembled. This manufactured packaged system approach will accelerate distributed energy system sales by:

- Lowering engineering and installation costs through standardization and minimizing site work.
- Improving the likelihood that the components would optimally match one another and, therefore, the IES would perform more efficiently and reliably.
- Improving in-service reliability, by establishing a manufacturer with responsibility for design, quality construction, warranty, and maintaining the entire system.

The premise of the project was that an entire IES could be manufactured, using quality standards, as a single module or set of modules, so it could be transported to the customer's premises and connected to the customer's electrical and thermal systems with very little advance engineering and custom installation.

The purpose of Phase 1 of this project was to:

- Develop an advanced, highly efficient, and reliable modular IES package that has an overall efficiency of at least 70% and an installed cost 20% lower than currently available systems.
- Build, test, and evaluate the performance of an alpha prototype.
- Using the test results, identify design improvements for Phase 2.
- Identify a commercialization path.

The team developed, built and tested an advanced 600-kW IES package that has an efficiency of over 70%. The two-module system requires only seven connections in the field, lowering installation costs and reducing total installed cost (including the absorption chiller) from nearly $2,500 to less than $2,000 per kW – a 25% reduction. The system included a Waukesha 615 kW engine-generator, GE switchgear, a Trane absorption chiller, and Cain heat recovery equipment. Ballard Engineering developed the control system.

The IES design provides controls to vary engine jacket water outlet temperature. This feature provides for a 40% increase in the production of chilled water when called for.

Trane built a new 90-125 RT (refrigeration ton) single-stage absorption chiller, based on its Horizon™ series for this project. Trane designed the prototype chiller specifically for the low activation temperatures available from IC engine recoverable heat.

Trane targeted the chiller design for operation over the wide range of 207 to 237ºF thermal energy available from a gas engine, rather than the 270ºF source temperature usually used for hot-water-fired absorption chillers. Performance testing verified the design output of 90 RT at a coefficient of performance (COP) of 0.7 when operated with 207ºF hot water supply and produced slightly more than 130 RT at 0.7 COP with 237ºF water supply.

Performance tests of the alpha prototype demonstrated that it exceeded the goal of 70% overall efficiency. The electric power output and efficiency were flat over a range of intake air temperatures up to 104ºF, and NO_x emissions were well below the manufacturer's specification of 2 g/bhp. The measured engine-generator power output of 612 kW met expectations. The total estimated parasitic power consumption of the cogeneration module was 22 kW and the parasitic consumption of the chiller module was 47 kW.

Evaluation and testing of the alpha prototype identified a number of design improvements that will be addressed in Phase 2. They include:

- Develop and integrate an intelligent operator to improve system reliability.
- Increase modularization to facilitate transportation of the equipment to installation sites and enable greater flexibility in configuring installations.
- Base the beta prototype on a smaller engine to increase the range of applicable buildings.

GTI expanded and updated the initial design economic analysis and IES optimization in early 2005 to account for changing market conditions. The updated optimization revealed that an IES capacity in the range of 350 kW, with a 96-RT hot-water-fired single-effect absorption chiller would provide optimal performance – highest applied energy efficiencies and lowest simple paybacks – for the most significant commercial markets. Multiples of the IES (700 kW and 1,050 kW) could serve some of the larger commercial buildings. In Phase 2, GTI intends to design, optimize, and demonstrate a nominal 350-kW system and a 1,100-kW system based on a new ARES engines.

Effective commercialization requires a packaging partner that can fabricate, market, warrant, and service a suite of high-quality IES systems. GTI' initially pursued Waukesha as the manufacturer for the packaged system. However, competing priorities and markets made it difficult for Waukesha to divert resources from its core business – reciprocating engines. As a result, GTI shifted its commercialization strategy, seeking an experienced engine-generator set packager that is willing to expand its scope of supply to include heat recovery and chilled water. GTI identified Enercon Engineering, Inc. as such a commercialization partner and created a partnership with Enercon Engineering to design, manufacture, warrant, and sell a line of IES packages with nominal capacities of 300 to 1,100 kW. Enercon Engineering will leverage the existing manufacturer distributor sales and maintenance networks.

Contents

List of Figures

List of Tables

Introduction

Background

The Department of Energy embarked on an innovative program to develop and deploy integrated energy systems (IES) for providing electricity and thermal energy for space conditioning to commercial buildings. Integrated energy systems can help meet growing demand for electric power and reduce summer peak loads while improving energy efficiency and avoiding energy losses inherent in the current electric power supply system. This GTI project, under the DOE program, is developing modularized integrated energy systems that will cost less to install because they will not need custom system design and installation for each building. These factory-integrated systems would have higher overall energy efficiencies, significantly improved reliability, and lower life-cycle costs.

Furthermore, if a modular system were supplied and warranted by a manufacturer that also provides maintenance services, users could be more confident that the system would perform as intended and not require user oversight. Building as much of the system as possible at the factory, rather than in the field, would improve quality control and ensure that the components of the system are properly matched. Modular systems would also avoid the problem of users not knowing which vendor to contact when operating problems occur.

The IES program supports a potentially significant consumer need – lower cost electricity – and a significant public need – higher energy use efficiency. These needs and the market forces that prevent their fulfillment have been identified in a number of thorough analyses, including a study for Oak Ridge National Laboratory by Resources Dynamics Corporation[1] and a GTI study for the gas industry of barriers to distributed generation.[2]

Project Objectives and Goals

The overall project objective was to develop IES package system technology that would improve the market penetration of combined heat and power systems. The approach is to reduce the installed costs and improve the reliability of integrated energy systems by modularizing them to reduce the expenses currently incurred in one-of-a kind engineering and installation projects. Although the higher efficiency of IES offers lower energy costs to many consumers, the high first cost of installed IES systems and lack of diversified product lines and system experience is limiting the widespread adoption of IES.

---

[1] LeMar, Paul, Resource Dynamics Corporation, "Integrated Energy Systems (IES) for Buildings: A Market Assessment," Report Prepared for Oak Ridge National Laboratory, ORNL/SUB/409200, September 2002.

[2] Berry, C. and Wrobel, J. "Strategy for Breaking Down DG Barriers in New England – A Look at the Future of Distributed Energy in New England," Gas Research Institute Report GRI-03/0173, November 2003.

The modular IES would be a platform for near-term engine improvements, such as those being developed under the DOE Advanced Reciprocating Engine System (ARES) Program. An ARES engine, with 50% efficiency rather than the 35-40% (LHV) efficiency of current engines[3] would broaden the applicability of IES systems to include applications that do not have enough thermal requirements to use all of the byproduct heat of a conventional engine. A more efficient engine would produce a higher ratio of electric power to byproduct heat.

The ARES engine would also cost less to operate and have very low NO_x emissions, further broadening IES markets to include locations where current engines cannot meet air emissions requirements without expensive add-on emissions control equipment.

Goal 1 – Overall Efficiency

Central electric power plants generate electric power at approximately 35% efficiency, and the remaining 65% of the input energy is wasted in the form of heat rejected to the environment. Local IES offers customers the opportunity to use the byproduct heat from power generation to offset their thermal needs for space and process heating, hot water supply, and space cooling with absorption chillers. A goal of this project was to develop a system that can use current engine-generator technology to provide an overall efficiency of more than 70%. One aspect of achieving this goal is to develop an absorption chiller that can efficiently use the relatively low-temperature waste heat available from an engine. Another goal was to improve the summer performance of the IES by raising the temperature of the available heat from the engine to improve the chiller output.

Goal 2 – Installed Cost

Installed first cost of IES systems is the greatest obstacle to their widespread adoption, and the cost of engineering and installing the systems is a major contributor to the installed cost. For systems in the 300- to 1,000-kW range, installation costs are more than 50% of the total installed cost of IES.[4] A goal of this project was to reduce engineering and installation costs by 50%, thereby decreasing IES total installed costs by 20%. This goal was to be achieved by developing a complete modular power plant with on-board cooling and heating, capable of automatic operation and grid paralleling.

Goal 3 – Applicability

In order to be widely applicable, the modular IES would have to be highly flexible and adaptable to a variety of building types and thermal demand requirements without significant custom site-specific engineering.

---

[3] National Renewable Energy Laboratory, "Gas-Fired Distributed Energy Resource Technology Characterizations," NREL/TP-620-34783, Chapter 2, Table 2, November 2003.

[4] National Renewable Energy Laboratory, "Gas-Fired Distributed Energy Resource Technology Characterizations," NREL/TP-620-34783, Chapter 2, Table 4, November 2003.

Goal 4 – Reliability

When an IES installation does not work, users often have to deal with several equipment vendors because no single vendor has responsibility for the system's performance. A goal of this project was to establish a reputable manufacturer to package the IES and take responsibility for specifying all components and selling and servicing the entire system. Because the IES would be factory-assembled rather than site-assembled, and the choice of system components centralized, the quality control would be better, resulting in fewer installation delays and out-of-service incidents.

Goal 5 – Market Identification and Characterization

For an IES to provide energy cost savings that justify its purchase, the system should be sized to maximize the recovery of the available thermal energy, while at the same time, appealing to a significant market. This project identified significant commercial building markets that can effectively on an annual basis, make use of the thermal energy and quantified the market potential of the most promising applications.

Work Scope

This project was to design, develop, and demonstrate, through laboratory testing and eventual field demonstration, an integrated modular system for supplying electricity, hot water for building and domestic water heating, and chilled water for air conditioning. A necessary part of this work included the design, development, and demonstration of an absorption chiller that could effectively use the relatively low-temperature heat available from reciprocating engines.

A future phase of the project would be a field demonstration of the technology to characterize its costs and performance in an actual application at a customer's site.

Design of Alpha Prototype of Integrated Energy System

Engine Selection Decision Factors

A Waukesha engine was selected for the alpha prototype early in the project to expedite the design and analysis activities. The selection decision was based on the following factors:

Market Applicability

Based on the initial 2001 IES system analysis for the selected markets, the 300 to 1,000 kW range would provide the highest heat recovery factors and greatest economic returns. In this size range, Waukesha is a leader and the only manufacturer of rich burn engines and they are developing an advanced lean burn engine to improve efficiency and emissions. The project team selected the nominal 870-bhp Waukesha model VGF 36GLD engine (615 kW), as representing this size range.

Infrastructure

Waukesha Engine is an established international reciprocating engine manufacturer, headquartered in Waukesha, Wisconsin. At the outset of this project, Waukesha Engine was the only U.S. manufacturer with system packaging capability co-located with its engine manufacturing capability. Waukesha subsequently closed the packaging facility to focus on its core engine business. Waukesha has an expansive and effective sales and service network of regional and national distributors who interface with the end users for sales, projects, and service. Waukesha is the only U.S. manufacture that focuses solely on the design and manufacture of gas-fueled (natural gas, digester gas, landfill gas, and propane) industrial-type reciprocating engines for stationary use in the power generation and oil and gas markets.

The major members of the project team (GTI, Trane, Waukesha, and Ballard) were most experienced with Waukesha engines and had existing business relationships with the factory.

Manufacturer Commitment

Waukesha agreed to develop fabrication drawings and manufacture the alpha unit at its now-closed manufacturing facility. Due to a workers' strike and several competing projects, Waukesha outsourced fabrication to Professional Power Products, Inc. In late 2004, Waukesha declined to move forward with IES design and fabrication responsibilities in the near term. Waukesha cited the ARES engine development and the acquisition of a Wartsilla engine line as competing business priorities that limited its near-term resources. As a result, GTI identified and secured Enercon Engineering, a leading U.S. packager of engine-generator sets and switchgear, as the manufacturer and commercialization partner.

Initial Cost

The VGF 36GLD model engine is a lean-burn engine and produces 615 kW gross electrical output. The rich-burn version of the VGF 36 engine-generator set has a rated output of 570 kW with a nearly identical cost. Therefore, the initial cost of the lean-burn version per unit of output power is lower than the rich-burn version.

Maintenance Cost

The maintenance cost of the VGF 36GLD per kWh is lower than that of the comparable rich-burn VGF 36GSID, partly because of its higher power output.

Permit Requirements in Midwest

GTI expected that the eventual field demonstration would be in the Midwest. The lean-burn VGF 36GLD has an emissions profile that is acceptable for permiting in the Midwestern states without exhaust gas after-treatment. The specified NO_x emission level for this engine is 2.0 g/bhp/hr. Waukesha is developing an ARES engine for locations that require lower emissions.

Chiller Selection Decision Factors

Market Applicability

Trane developed and built a new 90- to 125-RT chiller for this project, based on its advanced Horizon™ line development experience. Prior to this program Trane's smallest Horizon unit was 500 RT. GTI and DOE were seeking to expand the absorption chiller suppliers for IES systems. Thermally activated space cooling is critical to maximizing IES system efficiency because of the large space-cooling needs of many commercial buildings. Trane optimized the chiller design for operation on the 200 to 230ºF thermal energy available from a gas engine rather than the 270ºF source temperature usually used for hot-water-fired single-effect absorption chillers. Performance testing verified the chiller design output of 90 refrigeration tons (RT) at a coefficient of performance (COP) of 0.7 when operated on a 207ºF hot water supply and slightly more than 130 RT at COP 0.7 on a 237ºF water supply.

Infrastructure

Trane is a leading global provider of indoor comfort systems with current annual sales approaching $5 billion. Among other HVAC products, its offerings include thermally activated absorption cooling systems. Trane has been manufacturing absorption chillers for over 50 years. Trane's present Horizon™ line of single-stage absorption chillers is designed for operation on 12-psig steam or 270ºF hot water, with capacities from 500 to 1350 RT. The Horizon design was amenable to modification to accommodate the lower capacities and supply temperatures needed for this project.

The newest line, the Trane Horizon® two-stage steam-fired absorption water chiller is the only line of two-stage absorption chillers designed, built, and supported in the U.S.A. Trane provides complete absorption chiller development, manufacturing and test capability. Its absorption chillers are built in an ISO-9001-certified facility.

Manufacturer Commitment

Trane committed to developing and supplying an advanced line of smaller, nominally 150-RT, single-effect absorption chillers for IES applications, contingent upon the IES market developing to a reasonable size.

Initial Cost

Trane is competitive in the single-effect absorption chiller market, with mass-produced product lines.

Maintenance Cost

Maintenance costs in the 150-RT size range for single-effect units can be as low as $15/RT/yr, which is close to the costs for an electric unit.

The Modular Integrated Energy System

Figure 1 shows the concept of a modular system in which all components would be skid-mounted to facilitate transporting them to the installation sites and to simplify connection to the site's utilities. The initial concept was to have the entire IES mounted on one skid, however, a single skid design is too large to ship and maneuver. Therefore, the following two-skid design was developed:

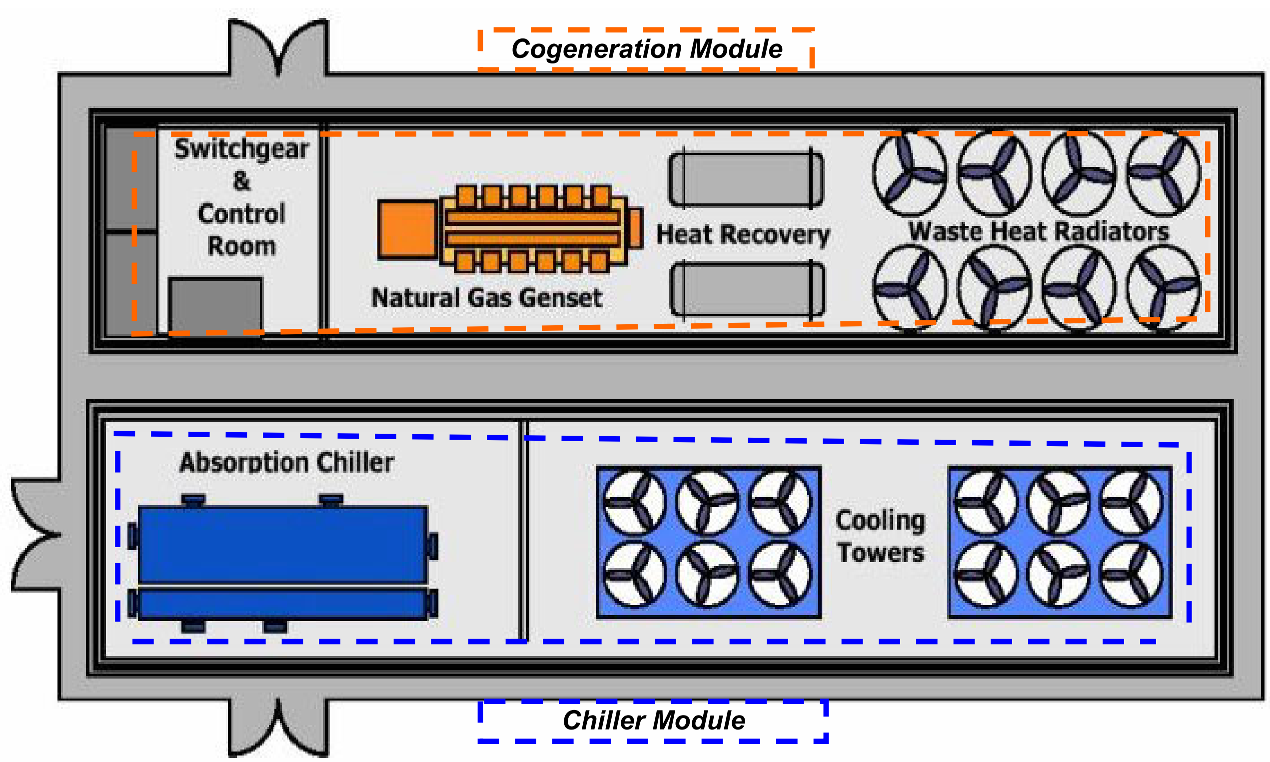


Figure 1: Integrated Energy System

The two-module configuration provides flexibility in the design of the building or enclosure to meet customer and city zoning requirements.

It was originally intended to design the modules to be shipped in standard ISO railroad ("piggy-back") containers, but the size of the engine and the desire to allow enough room in the module for convenient maintenance of the equipment would not accommodate a ISO container. The team designed a structure to house the two modules that meets maximum size requirements for over-the-road shipping. The cogeneration module is 51 feet long, 8-1/2 feet wide, and 10 feet high; and it weighs 58,000 lbs (29 tons). The absorption chiller module is 50 feet long, 8-1/2 feet wide, and 10 feet high. The chiller itself weighs 14,280 lbs (7.1 tons). The complete chiller module was not weighed.

The IES consists of two factory-fabricated modules that can be shipped to a site, installed on a flat concrete slab, and interconnected to the owner's facility. A free-standing, pre-engineered, insulated panel enclosure/building, selected to the customer's color and texture specifications, with access doors, lighting, and fixed and motorized dampers would be erected on-site around the modules.

Design of the control system was based on the sequence of operations developed for both interconnection to the grid and various electrical and thermal modes of operation to meet the requirements of the commercial building market. Because IES installations can have broader market applicability where electric power demand charges are high, the system can be operated in parallel with the electric utility grid in peak-shaving mode. However, it is also designed for and capable of continuous operation. Without modification to the system components, the system can also be programmed to operate in automatic black-start mode for standby power applications. For standby applications, additional equipment and engineering would be required to ensure isolation from the grid and management of generator loading.

The Cogeneration Module

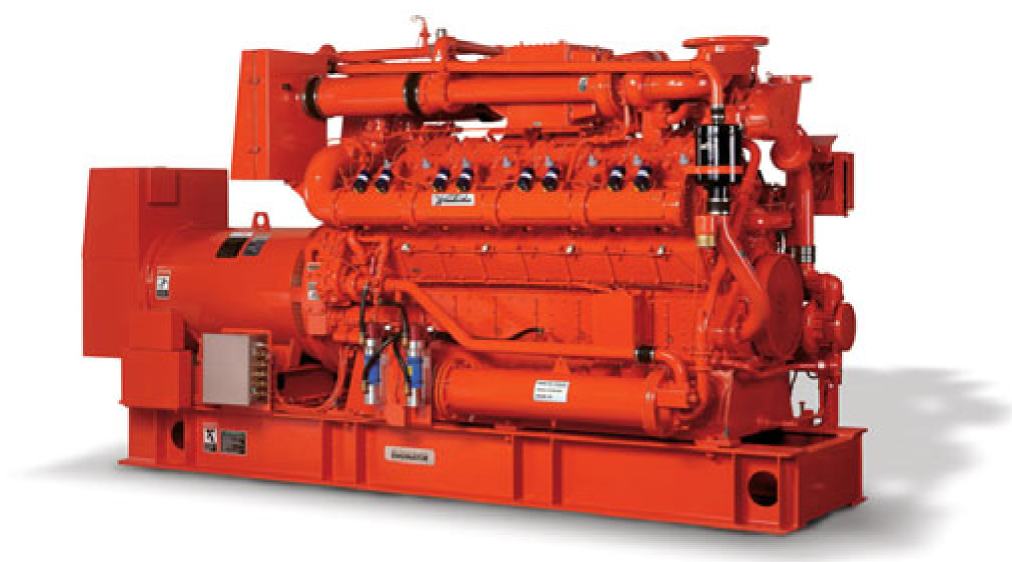


Figure 2: Waukesha VGF Series Enginator® Engine-Generator Set

Engine

The Waukesha VGF 36GLD is a high-speed industrial spark-ignited lean-burn engine that can operate on a variety of gaseous fuels. The specifications for the engine are as follows:

- Output: 867 bhp continuous duty
- Speed: 1800 rpm
- Compression ratio: 11:1
- BMEP: 176 psi
- Jacket coolant temperature: 230ºF
- Intercooler coolant temperature: 130ºF
- Allowable overload: 5% for 2 hours every 24 hours

The engine is provided with a 24-Vdc starting motor, powered from the battery-operated engine starting system, which also powers the switchgear and master control system. Figure 2 is a picture of the engine/generator set.

Generator

The generator is a single-bearing 3-phase synchronous machine rated at 615 kW continuous duty at 480 Volts, 1800 rpm, and a 0.8 power factor.

Engine Cooling and Heat Recovery System

The cogeneration module is designed for commercial building applications, where hot water is typically used for space heating and hot water. Reasons for using a hot water system, rather than a steam system, are:

- The cogeneration module is intended for commercial building applications, not for industrial applications, where steam use is more prevalent.
- The engine selection is based on recommendations from Waukesha and Ballard Engineering. The engine chosen did not lend it self to ebullient cooling or to a high-temperature forced circulation system, although GTI did get permission from Waukesha to allow coolant temperatures above the VGF 36GLD's normal coolant temperature limit of 190ºF.
- The team members' experience suggested that steam systems are more costly to design, build, and operate.
- The team members were also concerned that steam systems have more code and insurance issues than hot water systems.
- Hot-water systems are adaptable to both retrofit and new heating systems.
- The hot-water system chosen offers a greater range of output temperatures than steam would, increasing the number of potential applications of a single design.

The prototype heat recovery system is designed to deliver hot water whose temperature can be varied from approximately 120 to 240ºF. The heat recovery system uses engine exhaust heat to boost the temperature of the coolant leaving the engine jacket by 11ºF, of which 4ºF is lost in the heat exchanger that separates the engine coolant from the hot water supplied to the building. Typically, the hot water supply for commercial buildings would be for heating during winter months and for space cooling by an absorption chiller during the summer.

Temperatures of 240ºF are not always needed or optimal for building thermal requirements, and temperatures near the higher end of the range increase engine wear and maintenance costs. Therefore, the absorption chiller prototype was developed to operate on 207ºF hot water to be compatible with the 200ºF jacket coolant commonly provided by engines. With engines, such as the Waukesha VGF 36GLD, that can, if desired deliver 230ºF jacket coolant, the chiller can provide 40% more cooling during times of peak building cooling loads. When cooling loads are lower, the jacket coolant temperature can be reduced to 200ºF to prolong engine life and improve engine efficiency.

Figure 3 shows the three heat-recovery circuits (engine jacket, high-temperature heat recovery, and auxiliary coolant).

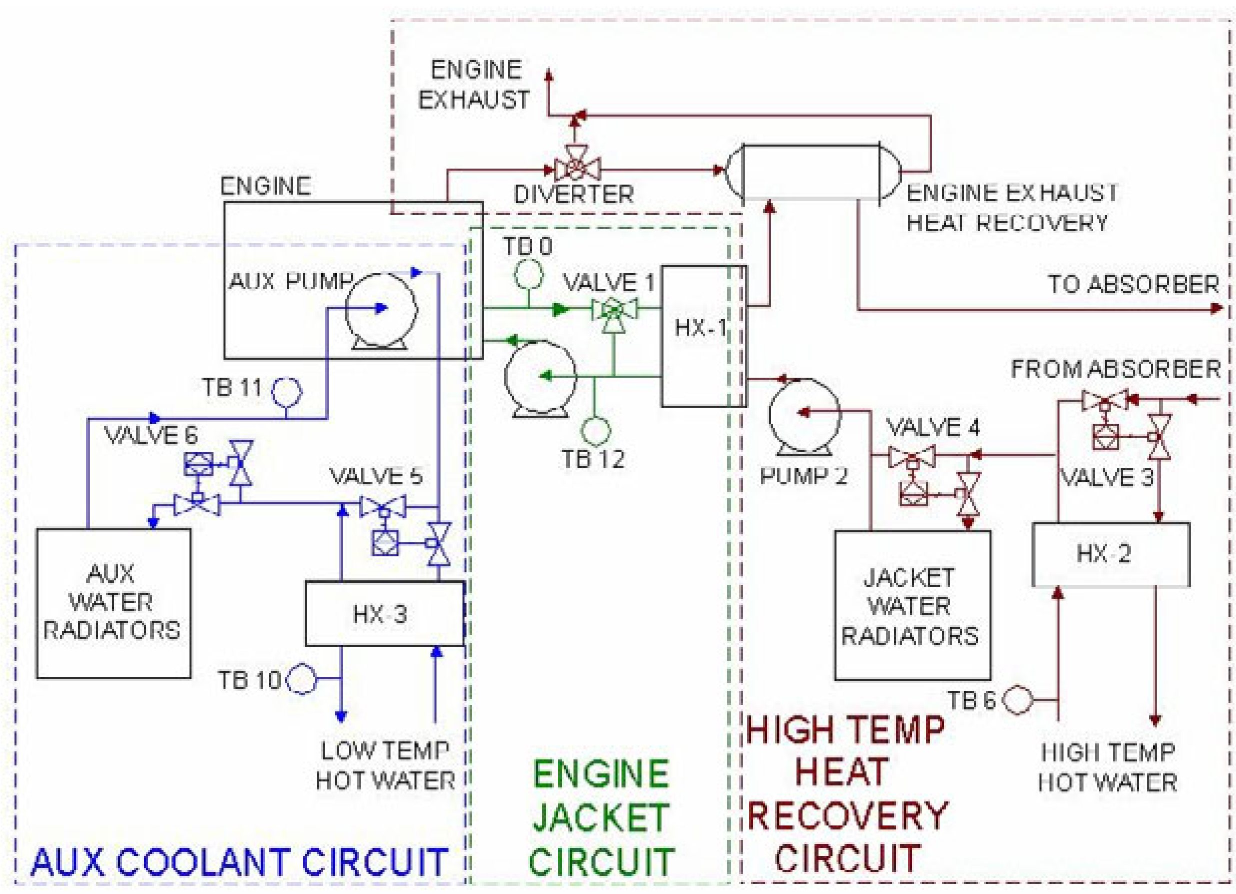


Figure 3: Heat Recovery Circuits

The hot engine coolant in the engine jacket circuit supplies heat to the high-temperature heat recovery circuit through a heat exchanger (HX1). The hot water in the high-temperature heat recovery circuit, after leaving HX1, passes through the exhaust heat exchanger, where it is heated further by the engine exhaust. Then the hot water is routed to the absorption chiller module. The heat from the water returning from the chiller is used to meet any hot water needs (HX2). If the water is still too hot to cool the engine jacket adequately, the excess heat is dissipated to the atmosphere through the jacket-water radiators.

The auxiliary coolant circuit is used to cool the engine turbocharger and lube oil circuit. The hot coolant is used to heat hot water for building services, or its heat is dissipated through radiators when there is not enough demand for hot water.

Engine Jacket Circuit Control

Engine-jacket coolant (50% ethylene glycol in water) flows from the engine outlet to a three-way temperature control valve (Valve 1) that has an adjustable setpoint on the master control computer touch-screen. This valve serves to maintain the desired engine outlet temperature (TB0) by modulating flow either to the plate heat exchanger (HX1) for fluid cooling or to the off-engine motor-driven jacket coolant pump (Pump 1) suction for return to the engine. This valve and all other three-way valves in the system were modified after initial testing to include PID controllers in order to gain superior temperature control. The jacket coolant circuit has a bladder-type pressurized expansion tank and a low-pressure alarm to detect fluid leaks. Figure 4 shows the user interface screen of the master controller for the jacket coolant circuit.

High-Temperature Heat Recovery Circuit Control

This fluid circuit provides hot water to drive the absorption chiller module, and it provides other heating services to the building through a plate heat exchanger (HX2). The circuit rejects heat that is not required by the building through the radiator to the atmosphere to maintain the required engine temperature. A constant-speed centrifugal electric-motor-driven pump (Pump 2) circulates the fluid through the heat recovery system.

Valve 3, in conjunction with temperature sensor TB6, the exhaust heat recovery unit, and the exhaust modulating diverter valve control the customer-side fluid temperature. If the customer thermal demand at HX2 is not sufficient to decrease the temperature of the coolant exiting HX2, and, subsequently, the jacket coolant engine inlet temperature at TB12, valve 4 diverts flow through the jacket coolant radiators to reject the unused heat and allow the engine-generator to operate independently of thermal demand. The jacket coolant radiator core is served by four fans, each programmable to start and stop to maintain an appropriate engine jacket coolant temperature at TB12.

When the building thermal demand exceeds the heat available solely from the engine jacket coolant circuit (indicated by an inability to maintain the setpoint temperature at TB6 with radiators fully bypassed), the modulating exhaust diverter valve actuates to pass engine exhaust through the air-to-coolant heat exchanger and increase the temperature of the fluid supplied to the absorption chiller.

Figure 5 is the user interface screen of the master controller for the heat recovery system.

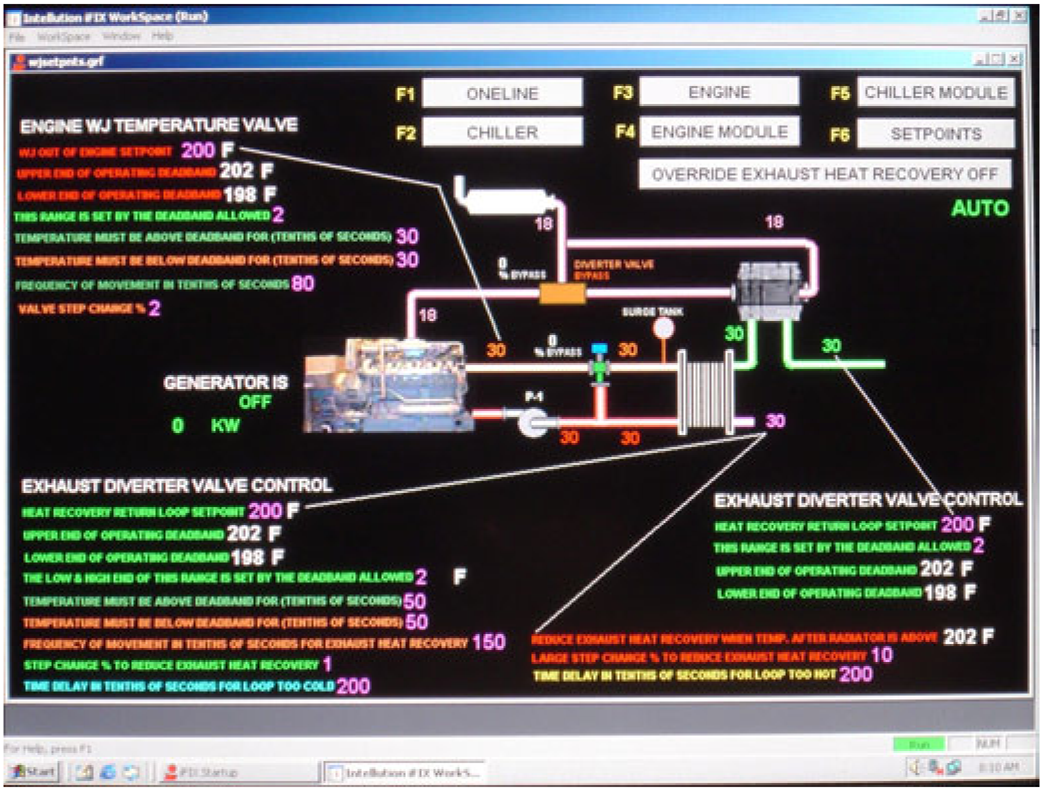


Figure 4: User Interface Screen for Jacket Coolant Circuit Master Control

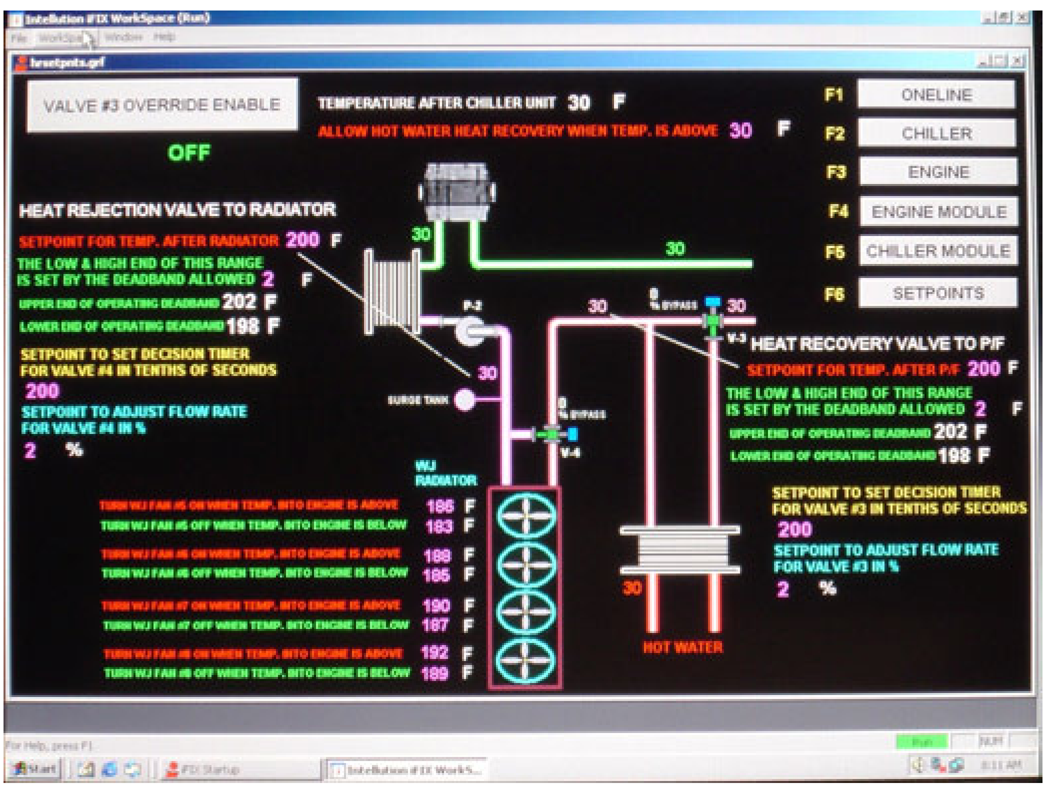


Figure 5: User Interface Screen for Heat Recovery System Master Control

<u>Auxiliary Coolant Circuit Control</u>

The auxiliary coolant leaves the engine at approximately 150ºF and 62 gpm. The circuit is driven by the engine-mounted circulating pump and is designed to maintain a constant inlet temperature to the turbocharger intercooler. The coolant's heat is made available to the customer's facility through plate heat exchanger HX3 and controlled by valve 5, based on the temperatures at TB10 and TB11. When the thermal demand for domestic hot water at HX3 is insufficient to reduce the return coolant temperature to the engine, valve 6 modulates flow through the auxiliary radiator to maintain the temperature setpoint at TB11. Just as with the jacket coolant radiator, the auxiliary coolant radiator is served by four fans, each programmable to start and stop to maintain the appropriate turbocharger intercooler temperature.

The auxiliary coolant circuit has an expansion tank and low-pressure alarm to detect leaks. Figure 6 is the user interface screen of the master controller for the auxiliary coolant system.

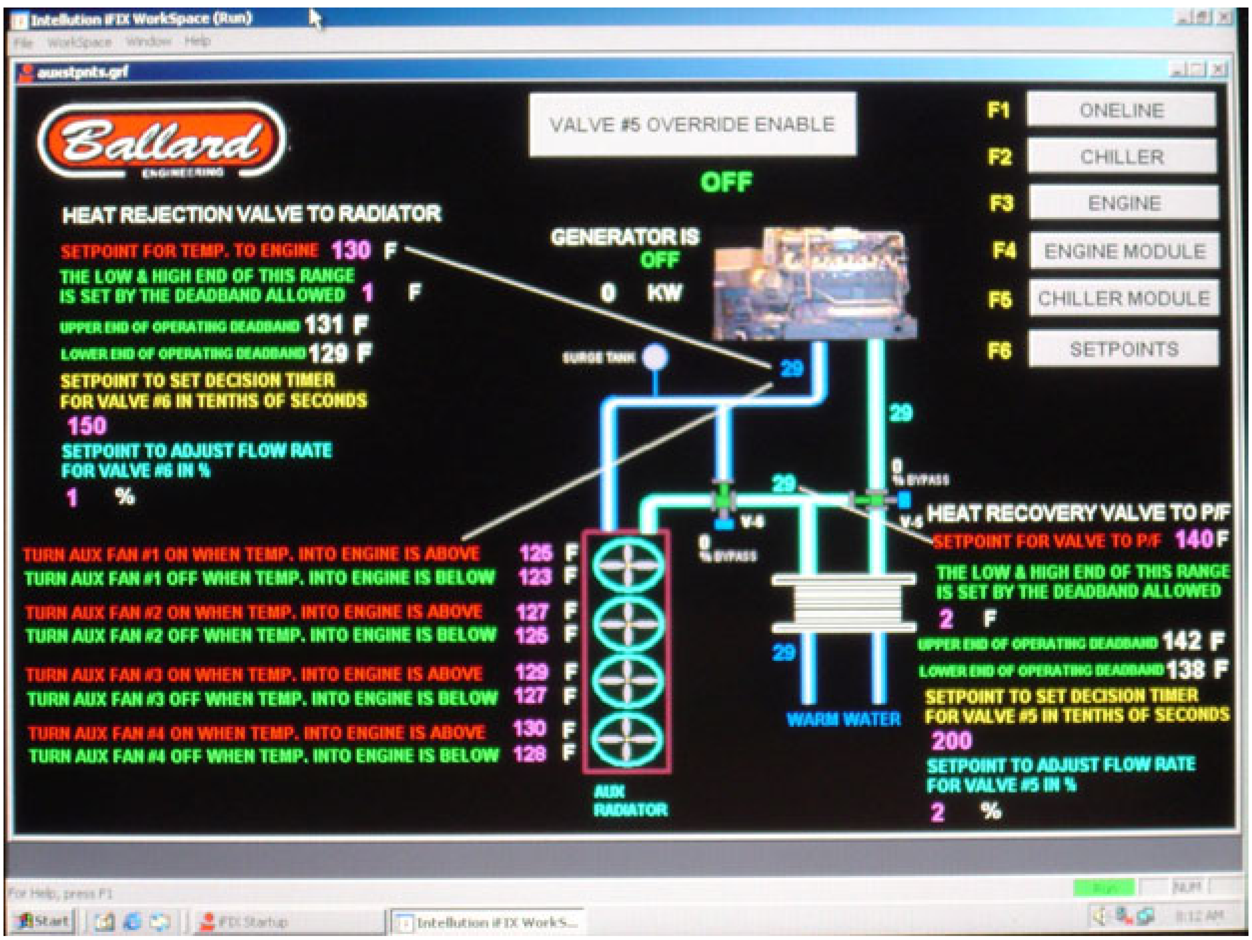


Figure 6: User Interface Screen for Auxiliary Coolant Circuit Master Control

Summary of Design Heat Flows

Table 1 describes the design conditions for the three heat recovery circuits, and Table 2 shows individual design parameters for each heat exchanger. These design parameters were given to various heat exchanger manufacturers to quote applicable heat exchangers for the system. Their performance is expected to be compatible with the expected performance shown in Table 1.

Table 1 and Table 2 show design conditions for 200ºF jacket coolant. The engine performance data are based on 77ºF ambient temperature.

Table 1: Design Conditions for Heat Recovery Modules (200ºF Jacket Coolant)

	Jacket Coolant Circuit (Customer Side of HX1)	**High-Temperature Coolant Circuit**	**Auxiliary Coolant Circuit**
Fluid	50% ethylene glycol in water	50% ethylene glycol in water	50% ethylene glycol in water
Flow rate, gpm	218	218	62
Temperature at circuit inlet, ºF	181	196	130
Temperature at circuit outlet, ºF	196	207	150
Heat delivery capacity, Btu/hr	1,509,000	1,106,000	609,000

Package Temperature Control

The air temperatures in the engine compartment and the controls area of the cogeneration module are managed with a heat pump/air conditioner unit and ventilation fans. Their operation is programmable on the master control touch-screen, based on local temperature sensors.

Table 2: Heat Exchanger Design Parameters (200ºF Jacket Coolant)

	HX1	HX2 (If all heat is diverted to HX2)	HX3	Exhaust Heat Recovery
Hot side inlet temperature, ºF	200	207	157	849
Hot side outlet temperature, ºF	184	180	130	348
Cool side inlet temperature, ºF	181	168	124	196
Cool side outlet temperature, ºF	196	195	151	207
Type	Brazed plate	Brazed plate	Brazed plate	Shell & tube
Heat transfer area, ft^2	281.65	250	250	460
Heat duty, Btu/hr	1,540,000	2,564,000	722,000	1,084,000

Interconnection Switchgear and Controls

The paralleling and synchronizing switchgear (PSG) is designed to provide the control and monitoring necessary to parallel the generator to the local utility source automatically, in accordance with UL891. The switchgear line-up contains the generator circuit breaker, system tie breaker, engine speed and load controls, engine protection, grid protective relaying, utility metering provisions, and customer system interconnection for powering of auxiliaries. The PSG provides for automatic and manual operation of the generator system, according to defined sequences of operation. The controller programming can be changed to modify the sequence of operations to meet specific site requirements.

Primary control of the Waukesha VGF 36GLD engine-generator is via a Woodward digital synchronizer and load controller (DSLC) with interface to a Woodward 2301A load-sharing and speed controller (LSSC). The DSLC and LSSC work in conjunction with a generator programmable logic controller (PLC) to provide automatic control of the generator. The generator protective relay provides primary AC protection of the alternator. Modbus and SNP networks are used to consolidate generator status information into the generator PLC.

A 12-inch color master interface panel serves as both system operator interface (for system-related settings and adjustments) and an operator interface for the generator control. Figure 7 and Figure 8 show examples of the operator interface. A main interface panel (MIP) with a touch-screen interface was designed into the switchgear lineup to provide the following information and functionality:

- Breaker status (Figure 7)
- Generator summary (Figure 8)
- Metering screens for generator and bus
- System control
- Load shed/add control
- System alarm indication
- Real-time trending of system parameters

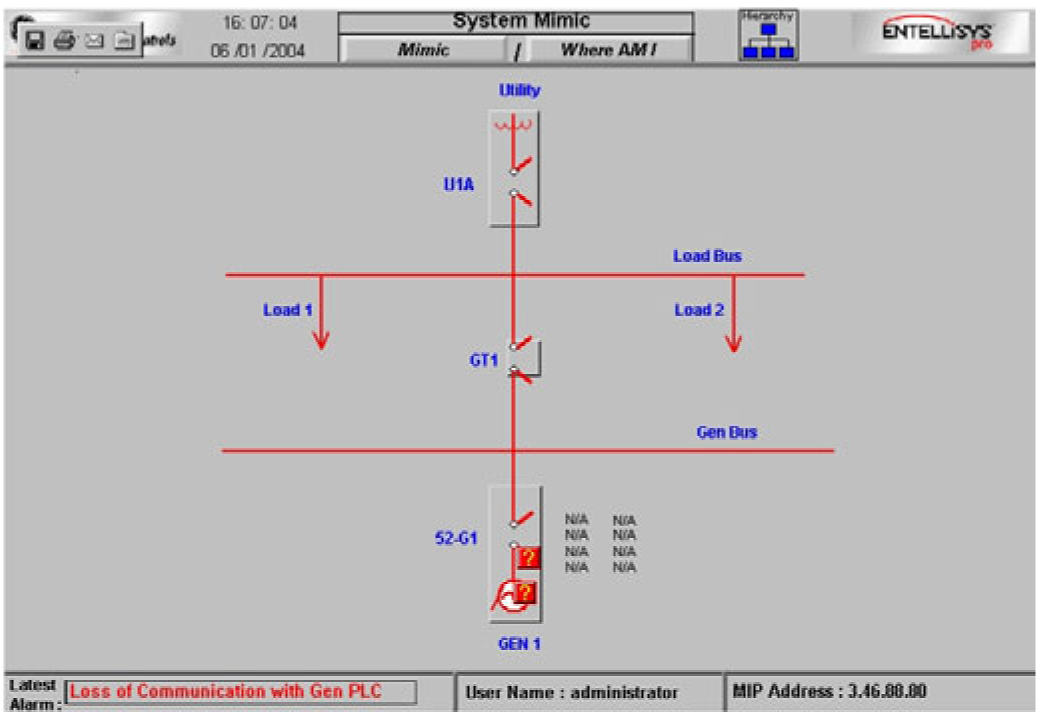


Figure 7: System One Line/Mimic Diagram

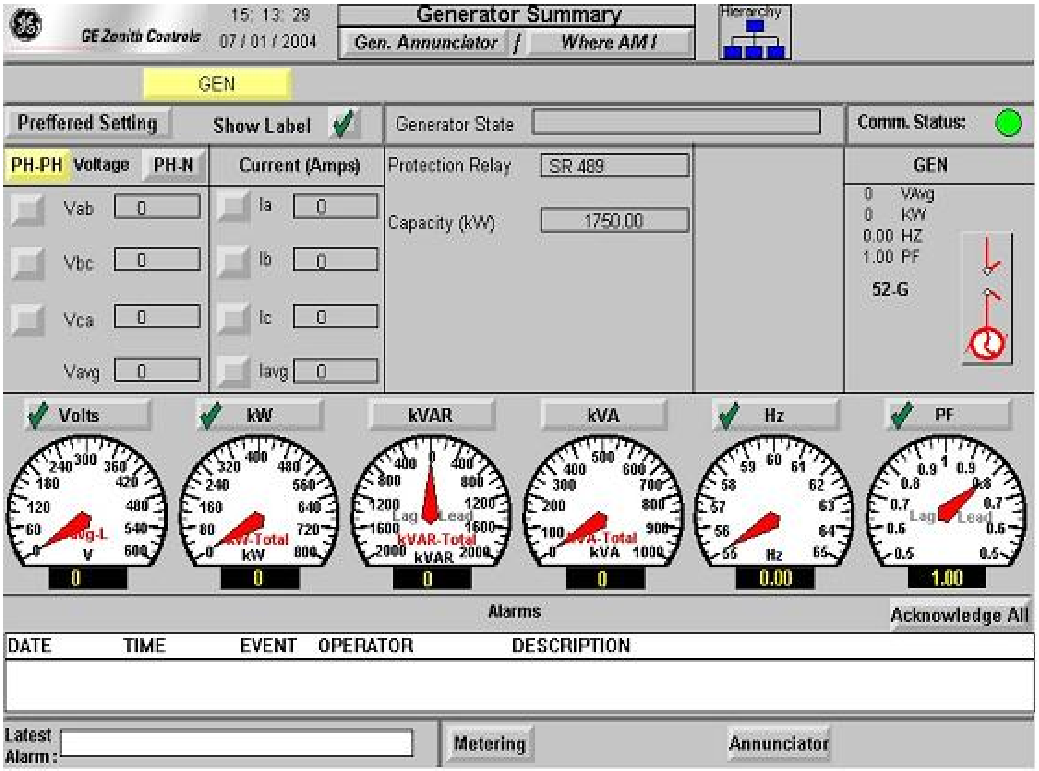


Figure 8: Generator Summary Screen

Figure 9 is a photograph of the cogeneration unit as it is being offloaded for testing at GTI, and Table 3 specifies the connection characteristics needed for installing the unit at a customer's site.

Figure 9: Offloading of Cogeneration Module

Table 3: Customer Connections

System	Nominal Size	Quantity	Comments
Natural gas	2-inch pipe	1	8 in. w.c. minimum gas pressure at cogeneration module inlet
High-temperature heat recovery	4-inch pipe	2	240°F maximum, site specific circulating pump required
Low-temperature heat recovery	2-inch pipe	2	160°F maximum, site specific circulating pump required
Electrical	4-inch conduit	1	480V, 3ϕ, 600 amp nominal
Sewer/sanitary	4-inch pipe	1	110°F, cooling tower blow-down
Makeup-water (cooling tower)	1-inch pipe	1	Soft water
Chilled water	5-inch pipe	2	40°F minimum, site-specific circulating pump required

The Absorption Chiller Module

The cooling module is an experimental prototype absorption chiller designed and fabricated by Trane Company. Hot water from the high-temperature heat recovery circuit is delivered to the absorption chiller through field-installed piping.

Prototype Chiller Design and Development

The hot water temperature needed to drive a conventional indirect-fired single-effect absorption chiller is about 270°F (leaving the chiller's generator at about 230°F). Entering temperatures below 270ºF (for a given water flow rate) would reduce the cooling capacity. If a certain cooling capacity were required with a hot water entering temperature of 200°F, a significantly oversized conventional chiller would have to be employed. The prototype single-effect water-lithium bromide absorption chiller developed under this project is designed for the lower-temperature heat (205°F to 240°F) available from reciprocating engines. The lower mean temperature difference available in the generator required larger heat-transfer surface areas.

The chiller was initially sized for a nominal 90-RT (refrigeration ton) output, given the temperatures and flow rates available from the cogeneration module. The initial design hot water supply temperature for the chiller was 207ºF, based on an engine jacket coolant temperature of 200ºF. Later in the project, Waukesha raised the allowable jacket-water temperature to 230ºF, enabling a 237ºF hot water supply temperature.

The chiller was tested in two modes: 90- and 125-RT modes. The differences between the modes were the hot water, chilled water, and cooling flow rates that were scaled according to the operating mode. Trane designed the 90-RT mode to operate with 175 gpm of 207ºF hot water supply. The 125-RT mode did not require any physical modifications to the chiller. In this mode, to accommodate the greater heat input from a 600-kW engine providing 237ºF hot water, the hot water supply was scaled up to 231 gpm, and the chilled water and cooling tower flow rates were also scaled up to maintain 2.4 & 3.6 gpm/ton, respectively, per ARI Standard 560-

2000. Because the higher supply temperature will increase engine maintenance requirements and decrease engine life, the higher temperature should be only used at times of peak demand for space cooling such as during the summer months.

An optimized chiller design would be one that yields the lowest first cost within certain operating constraints. Variable elements such as the cost of tubes (which depends on number, length, etc.) and shell material cost (which depends on the girth of the bundle, steel plate thickness, etc.) comprise the first cost, i.e. chiller cost, which varies with bundle size and aspect ratio. Minimizing this cost via bundle manipulation, while recognizing the interdependence (non-linearity) of heat/mass exchanger performance, was the objective of the optimization. The operating constraints consisted of equality constraints, such as capacity and crystallization margin, and inequality constraints, such as pressure losses. A comprehensive optimization algorithm, based on a modified dynamic programming technique previously developed by Trane, was used to optimize tube surface area distribution for the lower heat-source temperature. A different tube surface area distribution among the component tube bundles was indicated. The generator bundle would have to be much larger than that of conventional single-effect chillers for a given tube diameter. Commensurate with the greater tube count is a greater number of passes, to keep the inside water velocities (and hence, heat transfer coefficients) at the desired level. In addition to the augmented generator, the chiller would employ a highly effective solution heat exchanger and novel solution flow-handling and plumbing.

The major reallocations of tube surface area among the four major components are shown in Table 4. The generator would have to be 115% larger for a given tube design and flow rate per tube. The absorber and condenser would also have to be significantly larger. As the chiller testing progressed, Trane modified the chiller to help hold certain internal design parameters to their targets. Key modifications are described in the results section for the chiller.

Table 4: Comparison of Component Area Requirements of Conventional and Low-Source-Temperature Absorption Chillers

Component	*% Size Increase*
Absorber	*36%*
Evaporator	*8%*
Condenser	*31%*
Generator	*115%*

Even though its components would have to be much larger, the new chiller would still be a better solution than merely derating a conventional Trane absorption chiller. Figure 10 shows Trane's comparison of the estimated cost of the new design to the cost of a down-rated conventional chiller. A conventional chiller sized to deliver the same cooling capacity with a 207ºF hot water supply would cost one-third more than the new chiller design.

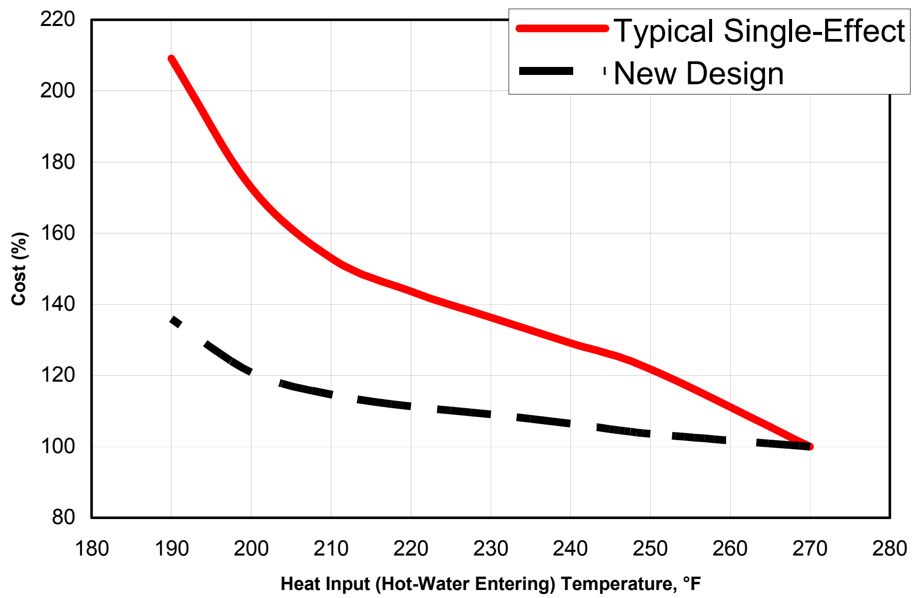


Figure 10: Comparison of the Cost of the New Chiller Design to that of a Conventional Absorption Chiller

Trane built a full-scale prototype chiller for testing. Figure 11 is an isometric drawing. Figure 12 and Figure 13 are photographs. The unit is 140 inches long, 54 inches wide, and 65 inches high. Its dry weight is 9,500 pounds, and it weighs 14,280 pounds when fully loaded with fluids.

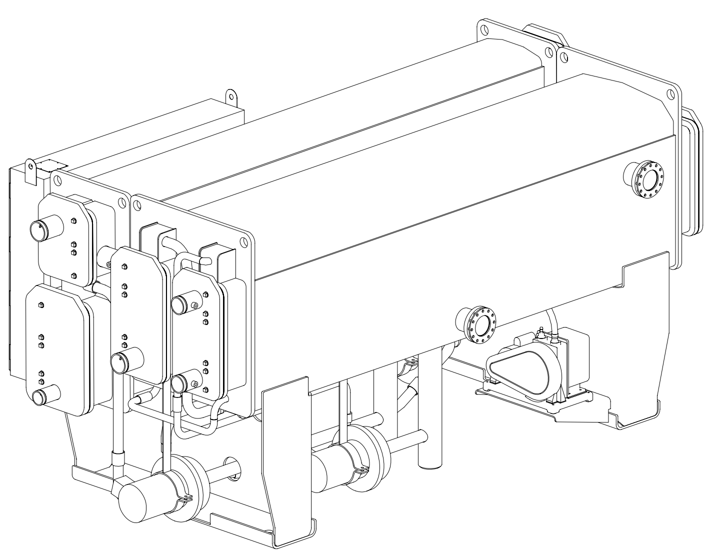


Figure 11: Rear Isometric View of Prototype Chiller

Figure 12: Photograph of Prototype Chiller (Front View)

Figure 13: Photograph of Prototype Chiller (Side View)

Condenser Cooling Water System

The absorption chiller module contains two cooling towers (combined rating of 117 RT) that supply water to cool the absorption chiller's condenser, a condenser water circulating pump, and the appropriate flow control valves needed to maintain required fluid temperatures.

The two cooling towers are manifolded together. Operation of the individual cooling towers is controlled by the master controller, which maintains the desired chiller condenser supply water temperature. The cooling water system is equipped with an automatic treatment system to maintain proper water chemistry to minimize scaling and fouling of the chiller condenser tubes.

Figure 14 is the user interface screen on the system master controller for operating the absorption chiller system.

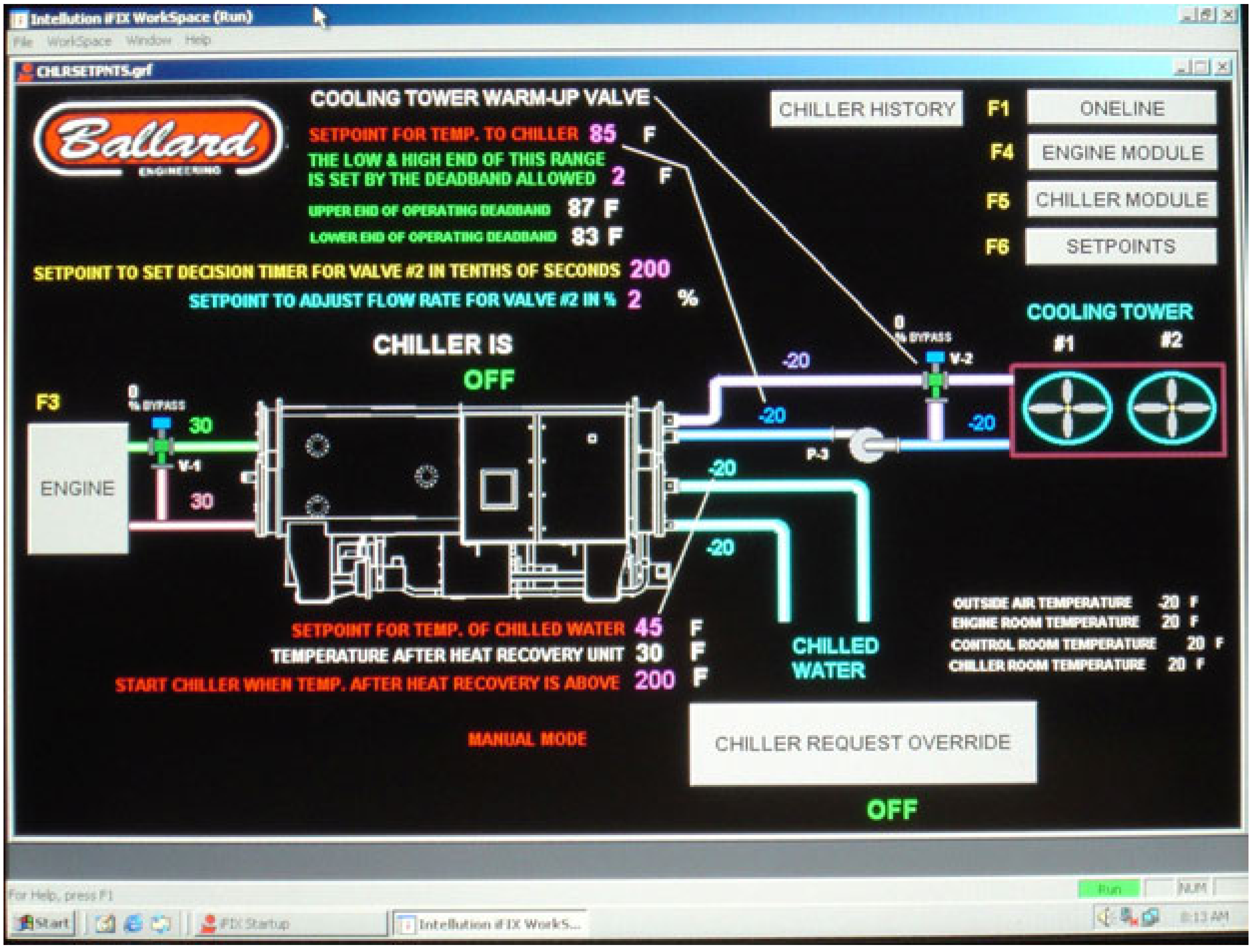


Figure 14: User Interface Screen for Chiller

Laboratory Testing of Alpha Prototype

The laboratory testing performed under the project consisted of two distinct tests to assess key performance characteristics and validate the system and individual component designs. The cogeneration module was tested at GTI's Distributed Energy Technology Center in Des Plaines, Illinois, and the absorption chiller was performance-tested at Trane's factory laboratory test facility in La Crosse, Wisconsin.

The tests fully mapped the separate thermal performance of the cogeneration module and the chiller. These test results were used to predict the overall IES performance without incurring the cost of repeating these tests with the units joined together.

Cogeneration Module Testing

Test Purpose

The purpose of laboratory testing was to verify proper system operation and performance, as well as verify design assumptions to the greatest extent possible. Testing focused on measuring the operating parameters necessary for evaluating electrical and thermal output and efficiency, and exhaust gas emission levels in all operating modes.

GTI performed these tests under the ASERTTI (draft) distributed generation performance testing protocol and its requirements for stability and uncertainty of measurements. The purposes of testing under the ASERTTI protocol were to verify that the newly drafted protocol was feasible and to improve data quality. One exception to the protocol was that noise measurements were not made because the walls for the modular enclosure were not yet selected. The intent was to select the walls based on conditions at a to-be-determined field site. The testing performed under ASERTTI protocols was done from January to April 2005. GTI also took performance data on the unit in September 2004 to support an earlier draft of this report. Several of the 2004 data points were taken hastily to meet schedule goals and did not meet the stability criteria outlined in the ASERTTI protocols. The initial (2004) test points were re-measured in 2005 and found to be of lesser quality, so they are not included in this report.

The fuel mass-flow rate measurements made in 2005 still did not quite meet the stability requirements of the ASERTTI protocol. GTI will recommend that the protocol may need to be revised to loosen the fuel flow rate stability requirements. The mass flow measurements were made with a Coriolis meter, which is the most accurate flow meter currently available. The fuel flow rate measurement would have met the protocol if the stability requirement had been ±3% instead of ±2%. Appendix A lists the stability requirements as well as the maximum uncertainty constraints of the protocol and test matrix, with complete descriptions of each test.

Test Setup Overview

The cogeneration module was tested in the Distributed Energy Technology Center (DETC) at GTI from January through April 2005.

The test bay in which the module was tested chamber is approximately 35 feet long, 18 feet wide, and 20 feet high. The module was situated in the building to allow the engine heat rejection radiators to be outdoors, as they would be in actual installations. Engine combustion intake air was supplied via the DETC's environmental control system to maintain the specified intake air temperatures. The engine exhaust discharged into an exhaust test section, where exhaust flow, emissions, temperature, and pressure were measured. The auxiliary coolant circuit that will provide warm water was connected to the DETC cooling tower. The high-temperature circuit (jacket coolant) was connected to an external flow meter and routed through the cogeneration module's own radiators. Figure 15 is a piping and instrumentation diagram for the test configuration and serves as the mechanical boundary diagram for these tests.

Figure 16 is an electrical boundary diagram of the test setup. The system boundary includes parasitic loads, such as the radiator fans, battery charger, engine controls, and coolant pumps. Net electrical output is the power that crosses the boundary. Net electrical output efficiency is the calculated fuel-to-electricity conversion efficiency of the system, based on the net power output and the fuel energy required to operate the system. Specific parasitic loads included in the net electrical output are noted for each test in the appropriate section.

Performance Test Results from Cogeneration Module

GTI conducted a series of performance tests to determine or validate the electric and thermal output and efficiency of the system. Appendix A contains a detailed description of the test facility, instrumentation, data collection methods, and test program.

Exhaust System Back-Pressure Tests

The purpose of these tests was to verify the system's ability to operate within the allowable 15 in. w.c. back-pressure, as measured at the turbocharger exhaust outlet, and to determine the effect of increased back-pressure on engine performance. In these tests, the system was tested at zero back-pressure and 6.5 in. w.c. back-pressure, measured at the module exhaust outlet flange, which corresponded to 8.5 in. w.c. and 15 in. w.c., respectively, at the turbocharger exhaust. For these tests, the unit was loaded to full power, while the intake air temperature was maintained at 59ºF. A manual exhaust damper was used to vary the exhaust back-pressure. There was no discernable difference in unit efficiency with increased back-pressure at either of these test points.

In field installations of this unit, any connections made to the module's exhaust outlet connection at the customer site must be limited to a maximum pressure of 6.5 in. w.c. at the product boundary interface.

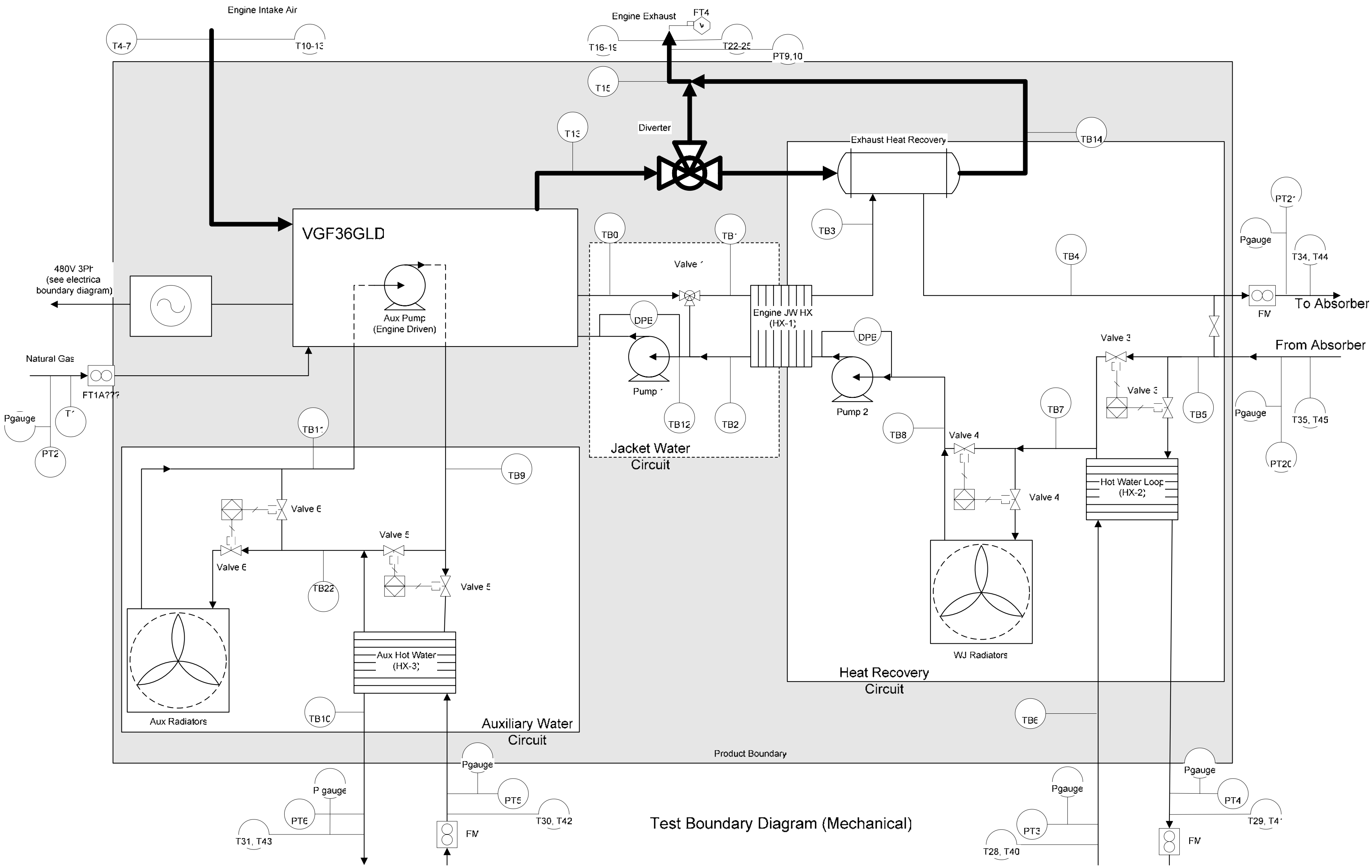
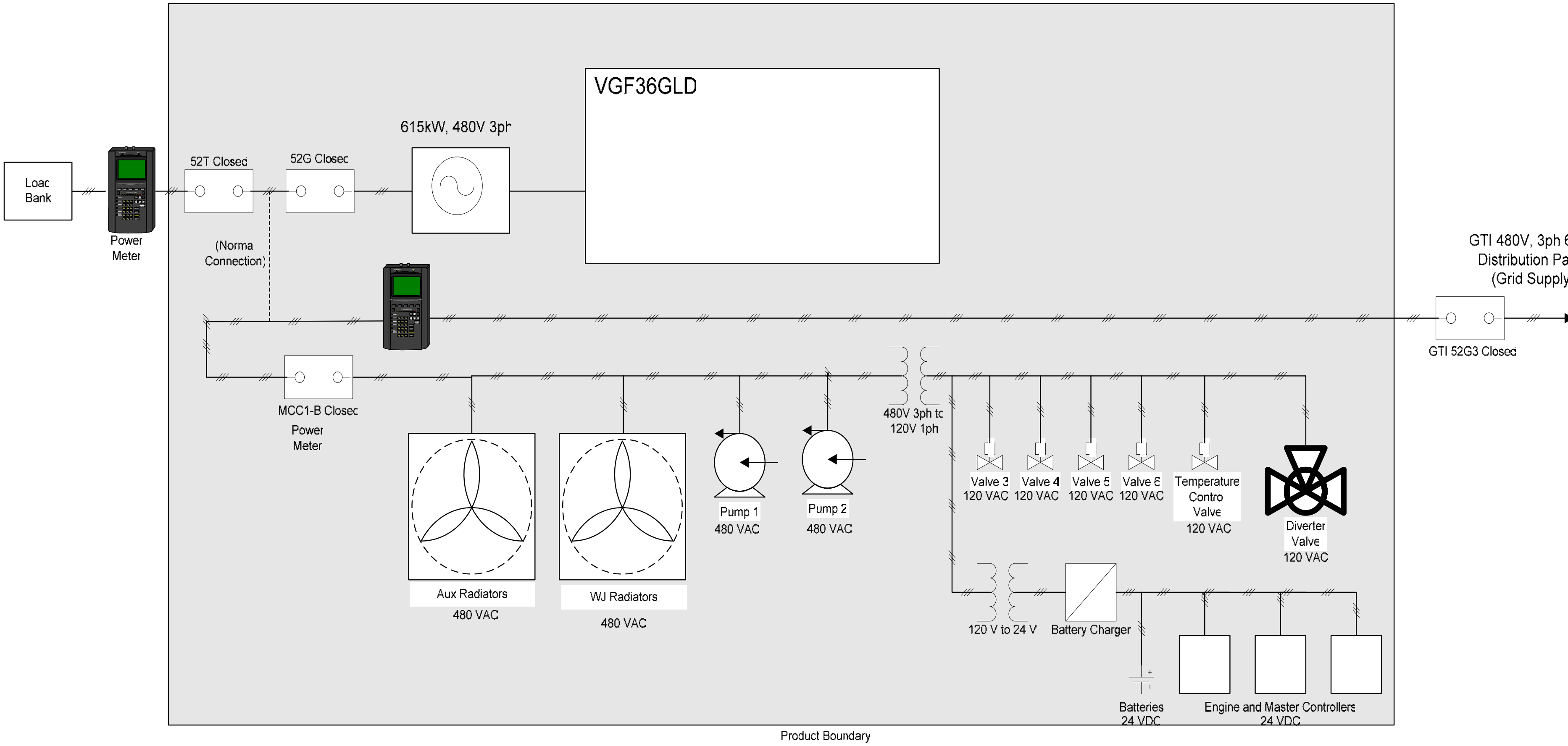


Figure 15: Mechanical Module Boundary Diagram



Test Boundary Diagram (Electrical) - As Tested, Island Mode

Figure 16: One-Line Schematic of Electrical Subsystem and Electrical Boundary Diagram

Ambient Air Temperature, Electric Efficiency, and Electric Power Output Tests

Tests were conducted at ambient air temperatures of 59°F (15°C), 77°F (25°C), and 104°F (40°C) and at 50%, 75%, and 100% of rated electrical output. The purpose of these tests was to evaluate the system's electrical output without heat recovery and to verify that the equipment worked satisfactorily within this temperature range. Tests were conducted at 59ºF because this temperature is representative of an ISO standard day. Chiller rating is normally performed at 95ºF, such as in ARI 560, so this temperature was included in the test matrix as well. Tests at 104ºF were included to determine how the engine would respond to temperatures above 95ºF. It appeared that the delivered power started to drop off at 104ºF.

The engine was not tested below 50% rated electrical output, because most manufacturers recommend not operating engines below this power level due to engine life issues. These data were taken assuming that the system was operated in an electric-only mode, meaning that the system did not recover any thermal output. Heat generated by the engine was rejected through the radiator fans or out of the exhaust stack.

GTI did not assess the effect of fuel inlet pressure, as this would have required changes to the factory fuel control settings.

Table 5 compares the system's design parasitic loads to those actually measured. However, net power output and efficiency can vary, depending on operating conditions. For example, on a warm day, more radiator fans would be used, increasing the parasitic load and decreasing the net electric efficiency. The electrical efficiency in electric-only mode is expected to be lower than in the heat recovery mode, because more radiator fans will be operating in the electric-only mode to dissipate the heat generated by the system. Both modes require that the same number of pumps be operating.

The cogeneration module can be installed with sidewalls and a wall separating the engine from the controls. In this configuration, engine compartment ventilation fans would be used to keep the engine at proper operating temperatures. In addition, a heat pump/air conditioning unit was specified to keep the control components within their respective operating temperature limits. The walls and the heat pump/air conditioner were not installed or operating during the tests. Table 6 shows the ventilation and heat pump parasitic loads that would potentially be included in the system parasitic loads, depending on ambient temperatures. The ventilation fans, space heating, and space cooling would be switched on and off by the master control system, depending on the ambient temperature, engine power level, solar radiation, and number of radiator fans turned on at the site. It would be difficult to calculate the exact thermal load for each test condition, but the worst-case impact of these loads can be gauged by assuming that all of the ventilation fans are turned on, along with either the controls space heater or cooler. The worst-case sum of these loads is 8.6 kW.

Table 5: Parasitic Power – Electric-Only Tests

Parameter/Component	Design, Full Load	Actual, Full Load	Design, 50% Load	Actual, 50% Load
Fuel input (LHV), MMBtu/hr	6.10	6.10	No data available	3.65
Generator power output, kW	615	615	308	308
Jacket coolant and high-temperature heat recovery pumps, kW	9.7	9.5	9.7	9.5
Auxiliary coolant circuit pump, kW	2.2	3.1	2.2	3.1
Jacket coolant radiator fans, kW	3.7/fan	4/fan	3.7/fan	4/fan
Auxiliary radiator fans, kW	3.7/fan	3/fan	3.7/fan	3/fan
Controls and battery charger, kW	No data available	5	No data available	5

Table 6: Potential Parasitic Loads Not Included in Test Results

Parameter/Component	Design Load
Control room heat pump (heating mode)	4.1kW
Control room heat pump (cooling mode)	~ 4.1kW
Three ventilation fans	1.5kW each
Worst case: Full ventilation (3 fans) + heating or cooling	**8.6 kW**

The results of the intake air temperature, efficiency, and electrical output tests are shown in Table 7, Figure 17, and Figure 18. Net and gross output and efficiency are presented, based on both higher heating value and lower heating value. The efficiency results are similar to efficiency results for other lean-burn natural gas engines and to Waukesha's specifications for this engine. Ambient air temperature has a minimal effect on the electrical efficiency, as shown in the table and figures, although some power de-rating may have started to occur at 104ºF, as the full-load power output dropped from 614 kW to 602.8 kW.

Table 7: Electrical Efficiency as a Function of Engine Intake Air Temperature and Power Output[5]

Setpoints		Higher Heating Value		Lower Heating Value	
Power Output	Intake Air Temperature	Gross Electrical Efficiency	Net Electrical Efficiency	Gross Electrical Efficiency	Net Electrical Efficiency
(kW)	(˚F)	(%)	(%)	(%)	(%)
309.7	59.5	26.1	23.9	29.0	26.5
462.6	58.1	29.1	27.4	32.3	30.4
615.3	58.3	30.9	29.5	34.3	32.8
308.4	77.2	26.0	23.8	28.8	26.4
459.6	77.8	29.0	27.3	32.1	30.3
609.5	78.0	30.7	29.4	34.1	32.7
310.9	95.7	26.4	24.0	29.2	26.7
462.8	95.1	29.3	27.5	32.5	30.6
614.0	95.0	31.0	29.7	34.4	32.9
310.9	103.7	26.4	24.0	29.3	26.7
462.6	104.3	29.3	27.6	32.5	30.6
602.8	104.4	31.0	29.6	34.3	32.8

[5] Net power in the "electric-only" tests includes the auxiliary and jacket-water radiator fans; the auxiliary-coolant, jacket-water, and heat-recovery pumps; controls; and battery charger. Module ventilation and space heating or cooling loads were not included in the net power or net efficiency calculations.

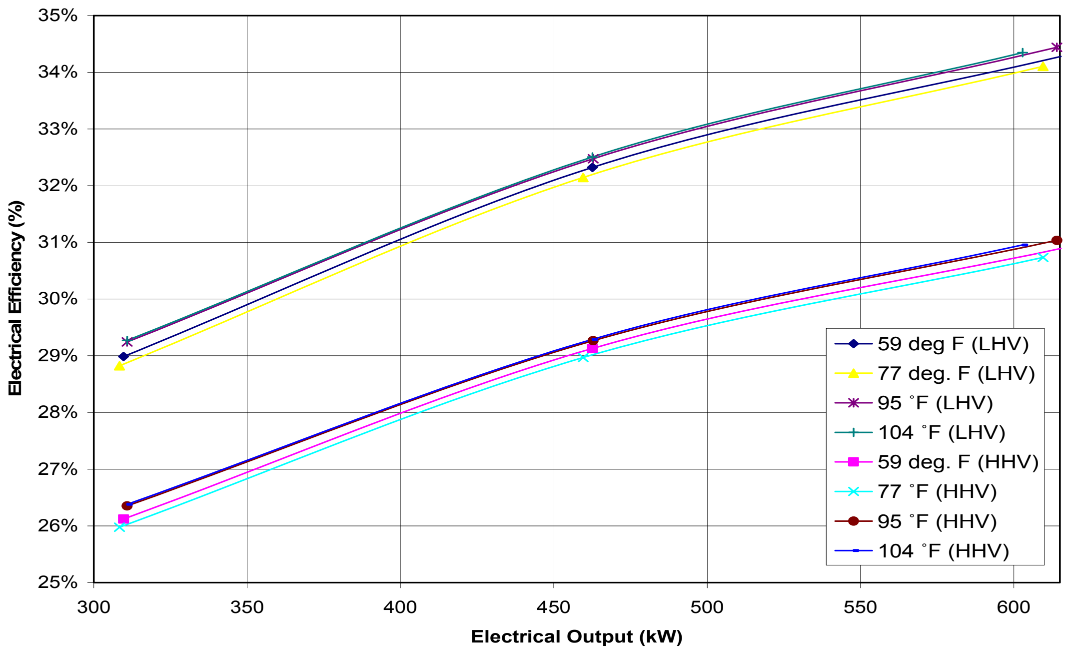


Figure 17: Gross Electric Efficiencies as Functions of Output

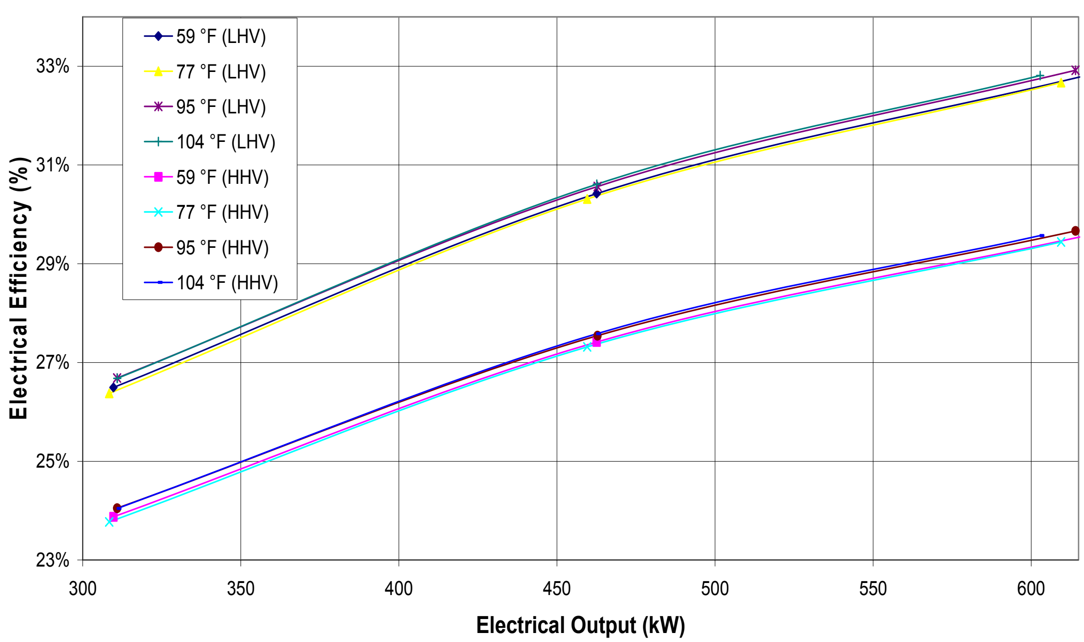


Figure 18: Net Electric Efficiencies as Functions of Output

Exhaust Gas Emissions

Steady-state exhaust gas emissions were measured during testing at the previously stated operating conditions (electric only). The results are presented in Figure 19. The air/fuel ratio controller was adjusted during setup to maintain an excess oxygen level in the exhaust at the nameplate setting of 7.8% at the unit's full power output.

Table 8 lists the minimum, maximum, and mean emissions output in multiple units and at power output levels of 308, 461, 550, and 615 kW. The levels of emissions fluctuated at the various power output levels, as the oxygen level was being maintained by the air/fuel ratio controller.

The measured NO_x emissions level at full load (1.24 g/bhp-hr) is typical of lean-burn engines in this size range. It is well below the 2.0 g/bhp-hr specified by Waukesha, but the performance of this new engine may degrade with time. The emissions are an order of magnitude higher than the goal of the ARES program.

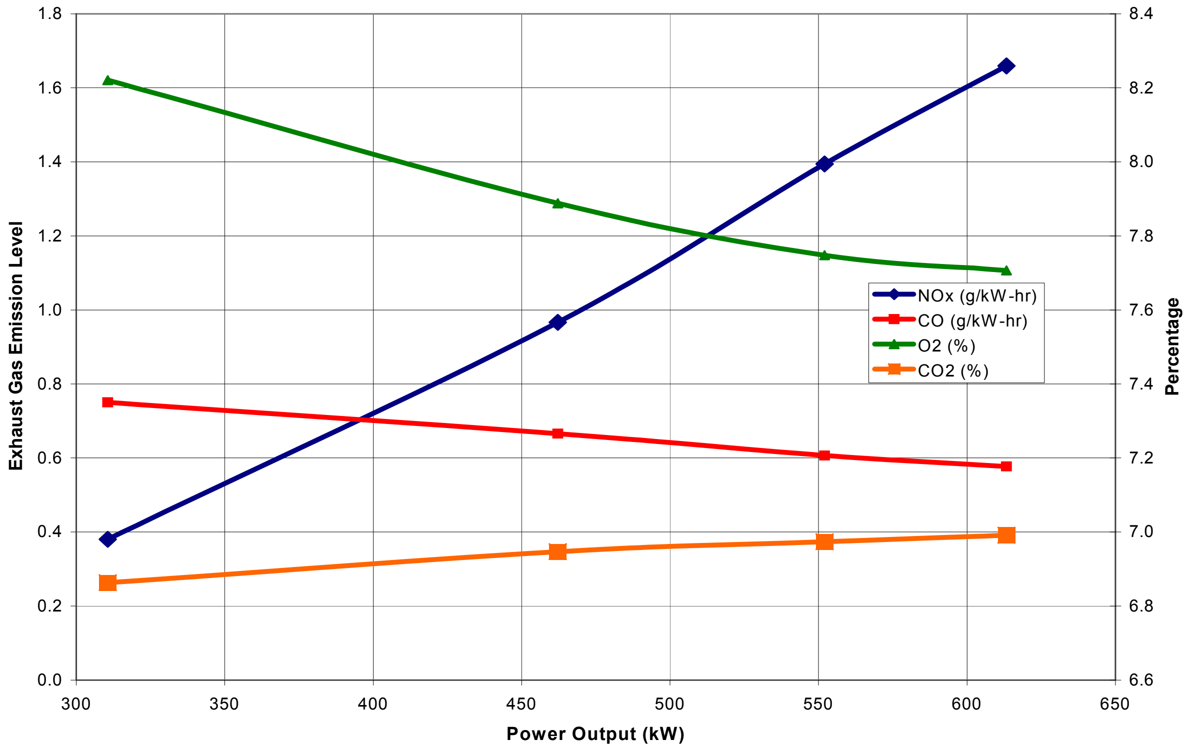


Figure 19: Exhaust Gas Emissions as Functions of Output

Table 8: Emissions Levels as Functions of Power Output

Set-Point	Point	Power Output	NO_x	CO	CO_2	O_2	NO_x				CO			
		kW	ppm	ppm	%	%	lb/hr	g/bhp-hr	g/kW-hr	lb/MW-hr	lb/hr	g/bhp-·hr	g/kW-hr	lb/MW-hr
308 kW, 77˚F	Average	310.6	55.3	346.3	6.86	8.22	0.26	0.28	0.38	0.84	1.52	0.75	1.65	4.89
	Min	309.9	51.4	343.6	6.83	8.16	0.23	0.26	0.34	0.76	1.46	0.72	1.59	4.71
	Max	311.4	59.4	349.3	6.90	8.29	0.29	0.32	0.42	0.93	1.59	0.78	1.73	5.10
461 kW, 77˚F	Average	462.1	161.0	352.4	6.95	7.89	0.98	0.72	0.97	2.13	2.01	0.67	1.47	4.34
	Min	460.8	152.3	350.0	6.92	7.85	0.91	0.67	0.90	1.98	1.96	0.65	1.44	4.24
	Max	463.2	170.3	354.5	6.98	7.92	1.02	0.74	1.00	2.20	1.97	0.65	1.44	4.26
550 kW, 77˚F	Average	552.0	248.9	344.0	6.97	7.75	1.70	1.04	1.39	3.07	2.18	0.61	1.34	3.95
	Min	550.8	235.8	341.8	6.94	7.71	1.56	0.96	1.29	2.84	2.11	0.59	1.30	3.83
	Max	553.2	266.3	346.3	7.00	7.79	1.86	1.14	1.52	3.36	2.25	0.62	1.38	4.07
615 kW, 77˚F	Average	613.3	303.4	335.1	6.99	7.71	2.24	1.24	1.66	3.66	2.31	0.58	1.27	3.76
	Min	612.0	287.2	333.0	6.96	7.67	2.08	1.15	1.54	3.40	2.25	0.56	1.24	3.67
	Max	614.8	320.7	337.8	7.02	7.47	2.37	1.30	1.75	3.85	2.32	0.58	1.28	3.78

Transient Load Testing

The purpose of these tests is normally to verify that the unit can accept load changes within the manufacturer-specified limits. However, Waukesha does not provide written guidance on the transient capabilities of its engines in terms of recovery time and frequency and voltage drop with respect to the applied load. The testing performed (25% load increments every 10 seconds) was in accordance with tests performed by Waukesha and with Waukesha distributor's recommendations. The test matrix is in Appendix A. Based on these recommendations, building applications for black starts should be designed for block loading of no more than 150 kW at a time. Load-shedding breakers would be required to ensure that the unit would not attempt to take on more than a 150-kW load from a black start in power backup applications.

Load testing, utilizing a resistive load bank, was performed to assess the system's ability to accept and recover after application of block loads. The test is intended to simulate grid-isolated operation for black-start applications. The power analyzer measured the voltage and frequency deviation and recovery time during successive applications of 25% of the generator's rated output. The test results indicate that the engine could handle 25% load blocks with minimal effect on voltage and frequency transients. The voltage traces during the tests are displayed in Figure 20 through Figure 22 for each of the three power phases.

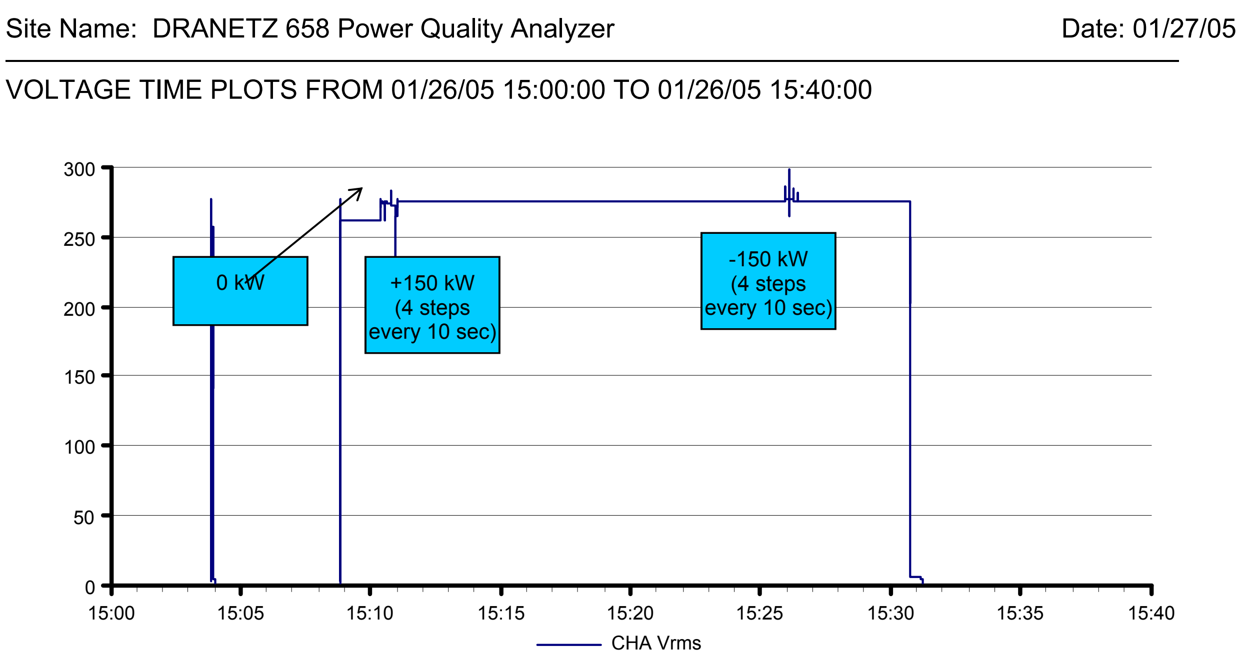


Figure 20: Voltage-Time Plots for Transient Load Testing – Phase A

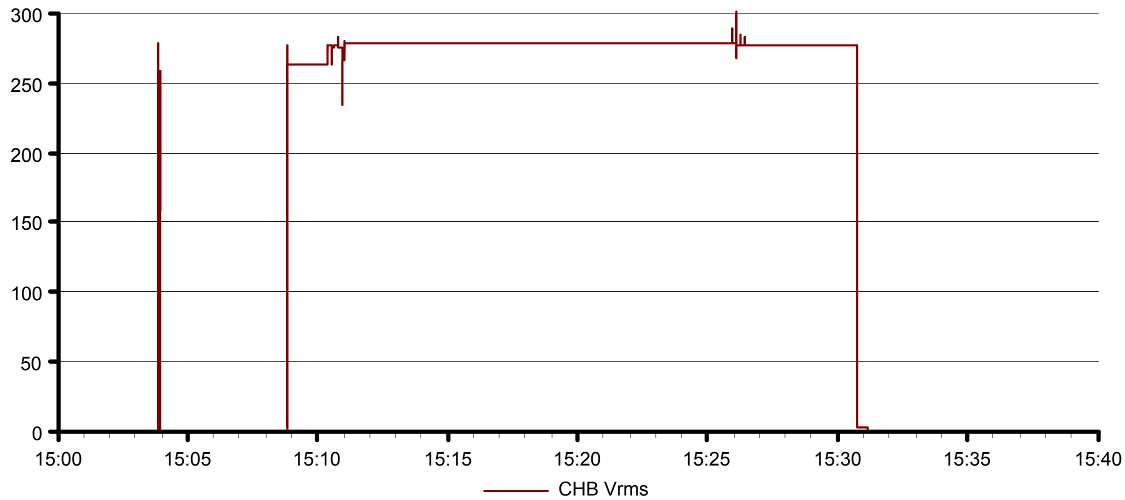


Figure 21: Voltage-Time Plot for Transient Load Testing – Phase B

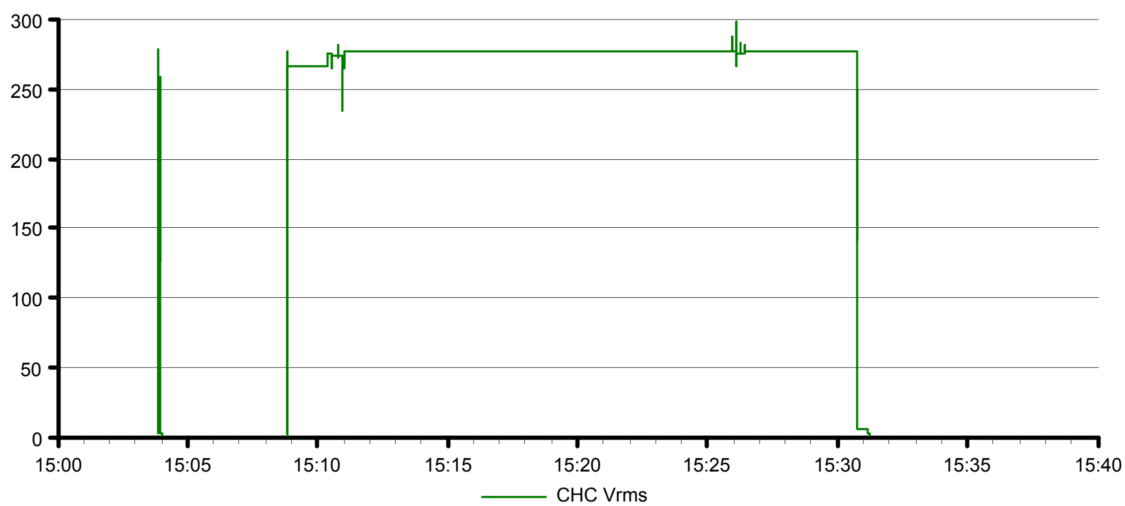


Figure 22: Voltage-Time Plot for Transient Load Testing – Phase C

As indicated in the three figures above, there was a voltage sag (a momentary decrease in the rms voltage magnitude) on all three phases during the last load step. The voltage fell to 233 V for at least one second in all three phases. This generator response during grid-isolated operation could harm equipment that is sensitive to transient voltages.

Figure 23 indicates that there were three voltage sags during the test period.

Site Name: DRANETZ 658 Power Quality Analyzer Date: 01/27/05

VOLTAGE SAGS FROM 01/26/05 15:00:00 TO 01/26/05 15:40:00

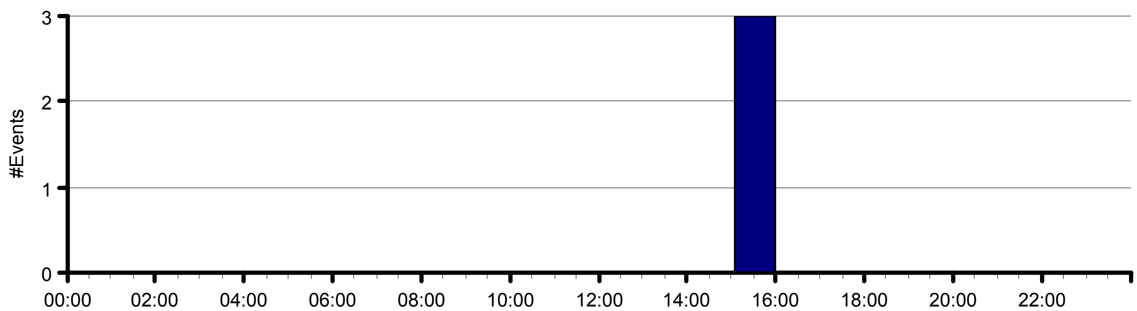


Figure 23: Number of Voltage Sags during Transient Load Testing

Table 9 shows that all three voltage sags were momentary disruptions in voltage, not continuous events. There were no voltage swells during transient loading. Voltage swells are increases in the rms ac voltage, at the power frequency, for durations from a half-cycle (8 milliseconds) to a few seconds. There were no voltage interruptions (complete losses of voltage) during testing.

Table 9: Worst-Case Transient Load Summary

Site Name: DRANETZ 658 Power Quality Analyzer Date: 01/27/05

Of 3 total VOLTAGE SAGS Occurring from 01/26/05 15:00:00 TO 01/26/05 15:40:00

CRITERIA	PHASE	CATEGORY	DATA	DATE/TIME
Lowest Magnitude	A	MOMENTARY	232.7V, 1.060 sec	01/26/05 at 15:10:56.30
	C	MOMENTARY	233.8V, 1.000 sec	01/26/05 at 15:10:56.36
	B	MOMENTARY	234.7V, 1.050 sec	01/26/05 at 15:10:56.26
Longest Duration	A	MOMENTARY	232.7V, 1.060 sec	01/26/05 at 15:10:56.30
	B	MOMENTARY	234.7V, 1.050 sec	01/26/05 at 15:10:56.26
	C	MOMENTARY	233.8V, 1.000 sec	01/26/05 at 15:10:56.36
Most Energy Missing	B	MOMENTARY	234.7V, 1.050 sec	01/26/05 at 15:10:56.26
	A	MOMENTARY	232.7V, 1.060 sec	01/26/05 at 15:10:56.30
	C	MOMENTARY	233.8V, 1.000 sec	01/26/05 at 15:10:56.36

Table 9 shows that the voltage dropped to 233 to 234 volts on all three phases during the last load step of 150 kW for one second. This voltage drop was not sustained, but it could damage voltage-sensitive equipment.

Heat Recovery Testing

The purpose of these tests is to determine the quantity and quality (temperature) of the heat available from the system. Thermal output was measured at intake air temperatures of 59ºF and 95ºF. Since the thermal testing is time-consuming, the test matrix was reduced to these two points when Waukesha left the project. As mentioned previously, 59ºF represents ISO standard day conditions. To simplify test conditions, GTI used 59ºF to approximate operation when only heat output but no cooling would be required. Data were taken at 95ºF, since this is the typical rating temperature for chillers. The thermal data at 95ºF can be used to give an indication of thermal output at high intake air temperatures for thermal uses at the site or for driving the absorption chiller module.

It was intended to test the thermal output between 200ºF and 230ºF jacket coolant temperatures. However, during testing, the engine thermostat did not allow the engine to operate above 220ºF jacket coolant temperature. The jacket coolant temperature was controlled at TB0 (see Figure 15), but the engine thermostat that protects the engine and the limit control would shut the engine down when TB0 was set for 230ºF. The engine distributor was asked to re-adjust the engine thermostat, but the technician used an infrared gun when making the adjustment. After the technician left, the problem persisted. GTI recommends using a more reliable method of calibrating the thermostat such as an oil bath, but decided not to test the system beyond 220ºF because of time and budget considerations.

Testing at an air intake temperature 59ºF was intended to represent conditions requiring hot water heating. Table 10 shows the heat output in the form of hot water from the cogeneration module. In the table, HT HW refers to the heat output of the heat recovery circuit, and HT AW refers to the heat output of the auxiliary coolant circuit (see Figure 15). The unit was able to obtain net system efficiencies[6] (net electrical + thermal output divided by HHV fuel input) ranging from 62.2% to 67.4% while in hot-water heat-recovery mode.

The first two columns in Table 10 and Table 11 are in italics because they represent system setpoints rather than measurements.

Testing at 95ºF was intended to represent conditions requiring thermal output for firing an absorption chiller. Table 11 shows the heat output from the cogeneration module in the form of hot water. This hot water could be supplied to the chiller module or to other thermal loads in the building. The expected chiller capacity, based on the hot water delivered from the cogeneration module, is described in a later section. The unit was able to obtain net system efficiencies (net

---

[6] Net efficiency includes the effects of the following parasitic loads: auxiliary water pump, high-temperature heat recovery pump, jacket coolant pump, controls, and battery charger. Radiator fan loads were excluded from parasitic loads because these fans would not be operated during conditions of maximum thermal demand by the building. All thermal output would be absorbed by the building loads. Parasitic loads do not include the module's ventilation fans or space heating or cooling for reasons discussed in a previous section. If these loads were included for maximum ventilation and space heating, they would add a maximum 8.6 kW of additional parasitic load which would translate to 0.4% electric or system efficiency points. These results do not include parasitic loads associated with the chiller modules. Those loads will be covered in a later section.

electrical + thermal output divided by HHV fuel input) ranging from 60.1% to 74.1% while in hot-water heat-recovery mode.

Table 10: Cogeneration Module Performance for Hot Water Heat Recovery (59ºF Intake Air Temperature Setpoint)

Power Output Setpoint	*Engine Jacket Coolant Setpoint*	Engine Jacket Coolant Outlet Temperature (TB0)	Design HT Heat Output[7]	HT HW Output	LT AW Output	Net Electrical Efficiency (HHV)[6]	Net System Efficiency (HHV)
(kW)	*(˚F)*	(˚F)	(Btu/hr)	(Btu/hr)	(Btu/hr)	(%)	(%)
308	*200*	199.3		1,569,160	242,342	23.5	67.4
	210	209.6		1,506,703	167,259	24.0	64.6
	220	218.4		1,412,149	82,069	24.0	60.5
461	*200*	200.8		1,867,096	300,579	27.6	67.4
	210	209.7		1,781,713	303,531	27.6	66.0
	220	219.0		1,737,262	246,745	27.6	64.3
615	*200*	198.9	2,564,000	2,259,960	249,230	29.2	65.7
	210	207.9	2,527,000	2,227,421	312,377	29.1	66.4
	220	219.5	2,486,000	2,138,266	121,220	29.2	62.2

As expected, the auxiliary coolant thermal output was much higher at 95ºF than at 59ºF air intake temperature, because more heat has to be rejected from the turbocharger after-cooler at 95ºF. The auxiliary coolant temperature was regulated to be 150ºF, so the auxiliary coolant thermal output was largely a function of intake air temperature. The decrease in auxiliary coolant thermal output with decreasing intake air temperature is the primary reason that the overall efficiency at 59ºF was lower than at 95ºF. The effect of the declining thermal output reduced the net system efficiency by approximately 6 percentage points.

[7] Design performance was calculated for full load at 77ºF engine air intake temperature.

Table 11: Cogeneration Module Performance at 95ºF Intake Air Temperature

Power Output Setpoint	*Engine Jacket Coolant Setpoint*	Engine Jacket Coolant Outlet Temperature (TB0)	Design Heat HT Output[8]	HT HW Output	LT AW Output	Net Electrical Efficiency (HHV)[9]	Net System Efficiency (HHV)
(kW)	*(˚F)*	(˚F)	(Btu/hr)	(Btu/hr)	(Btu/hr)	(%)	(%)
308	*200*	193.3		1,018,986	378,172	25.3	60.1
	210	205.2		998,116	403,549	25.3	60.3
	220	215.6		1,040,475	421,039	25.3	62.0
461	*200*	199.5		1,845,315	526,403	28.4	72.5
	210	211.8		1,850,647	531,873	28.4	72.7
	220	220.1		1,760,152	555,904	28.5	71.7
615	*200*	201.4	2,564,000	2,307,616	668,184	30.1	74.1
	210	211.6	2,527,000	2,259,684	674,765	30.2	73.6
	220	221.3	2,486,000	2,202,365	709,261	30.2	73.1

The comparison of design performance with actual performance is only approximate, because the design conditions were based on 77ºF intake air temperature, while the actual heat recovery test measurements were made at 59ºF and 95ºF.

[8] Design conditions were calculated for full load at 77ºF air intake temperature.

[9] Net efficiency includes the effects of the following parasitic loads: auxiliary water pump, high-temperature heat recovery pump, jacket coolant pump, controls, and battery charger. Radiator fan loads were excluded from parasitic loads since the radiator fans would normally be off during periods of maximum thermal output. Parasitic loads do not include ventilation fans or space heating or cooling. If these loads were included for maximum ventilation and space cooling, they would add a maximum 8.6 kW of additional parasitic load, which would translate to 0.4% electric system efficiency points. These results do not include parasitic loads associated with the chiller module, as these will be covered in a later section.

Table 12 and Table 13 summarize an energy balance comparison between design and test conditions for 200ºF jacket coolant, 130ºF auxiliary coolant inlet, and 100% power, simulating a situation where the building uses all of the heat generated by the cogeneration module. Table 12 describes the electrical energy balance, and Table 13 describes the thermal energy balance. Table 12 shows individual parasitic losses and net power output. All of the parasitic loads were connected to the MCC bus so the total parasitic load could be measured. During the tests, the radiator fans were used to reject the heat from the system. However, during conditions of maximum thermal demand by the building, the radiator fans would be off because all thermal output would be absorbed by the building loads. Therefore, the power consumption of the radiator fans was not included in the net power calculations.

In Table 13, the heat not accounted for is the difference between the thermal output plus known losses and the fuel input. The heat not accounted for is negative for the design case at 77ºF and at 95ºF, with the design data being more negative. This may indicate that the losses due to heat rejection to the lube oil, engine heat radiation, and generator heat radiation were overestimated in the design. Alternately, it may indicate that the heat recovery was overestimated. A possible reason for overestimation might be that no thermal losses were assumed for HX1. At 59ºF, the heat not accounted for was positive. This could indicate that some of the heat losses were higher than expected in the design.

Table 12: Electric Power Balance Summary for Heat Recovery Tests at 100% Rated Power[10]

	Design (at 77ºF)		Actual (at 59ºF)		Actual (at 94.5ºF)	
Fuel energy in (HHV)	6,841,000 Btu/hr	100%	7,000,000 Btu/hr	100%	6,777,000 Btu/hr	100%
Units	**kW**	**% of Fuel Energy Input**	**kW**	**% of Fuel Energy Input**	**kW**	**% of Fuel Energy Input**
Gross generator power output	615	30.7	613	29.9	612	30.8
Parasitic Losses						
Jacket coolant and heat recovery pumps	7.5	0.37	Not measured separately	Not measured separately	Not measured separately	Not measured separately
Auxiliary coolant pump	2.2	0.11	Not measured separately	Not measured separately	Not measured separately	Not measured separately
Instruments, controls, and other	6.6	0.33	Not measured separately	Not measured separately	Not measured separately	Not measured separately
Total parasitic load	16.3	0.81	14.8	0.72	13.3	0.67
Net Output						
Net IES power output	598.7	29.9	598.6	29.2	598.7	30.1

[10] Radiator fan loads were excluded from parasitic loads because the radiator fans would normally be off during periods of maximum thermal output to the building. Parasitic loads do not include the module's ventilation fans or space heating or cooling. If these loads were included, they would add a maximum 8.6 kW of additional parasitic load, which corresponds to 0.4% electrical or system efficiency points at full rated power. These results do not include parasitic loads associated with the chiller module, as these will be covered in a later section.

Table 13: Thermal Energy Balance Summary for Heat Recovery Tests at Full Rated Power

	Design (at 77ºF)		Actual (at 59ºF)		Actual (at 94.5ºF)	
	Btu/hr	% of Fuel Input	Btu/hr	% of Fuel Input	Btu/hr	% of Fuel Input
Fuel energy in (HHV)	6,841,000	100	7,000,000	100	6,777,000	100
Fuel energy equivalent of generated gross electric power	2,098,000	30.7	2,093,000	29.9	2,088,000	30.8
Heat generated by engine-generator	4,743,000	69.3	4,907,000	70.1	4,689,000	69.2
Useful Heat						
Heat to building from jacket coolant circuit	2,564,000	37.5	2,260,000	32.3	2,308,000	34.0
Heat to building from auxiliary coolant circuit	609,000	8.9	249,000	3.5	668,000	9.9
Total useful heat	3,173,000	46.4	2,509,000	35.8	2,976,000	43.9
Heat Not Recovered						
Sensible heat in engine exhaust[11]	668,000	9.8	789,000	11.3	686,000	10.1
Latent heat in engine exhaust	676,000	9.9	689,000	9.8	670,000	9.9
Radiation from equipment surfaces[12]	457,000	6.7	457,000	6.5	457,000	6.7
Heat not accounted for	-231,000	-3.4	463,000	6.6	-100,000	-1.5
Total heat not recovered	1,570,000	22.9	2,398,000	34.3	1,703,000	25.3
Efficiency						
Gross overall efficiency (HHV)		77.1%		65.7%		74.7%

---

[11] Exhaust flow rate was estimated from emissions test data at similar conditions.

[12] Estimate from Charles Equipment (Waukesha Distributor).

Figure 24 shows sensitivity of thermal output to engine intake air temperature. The total thermal output was based on the output from the low temperature and high temperature coolant circuits. Both total thermal output and net system efficiency increase with increasing intake air temperature. The net HHV system efficiency was calculated per note 13, so the values shown are slightly lower than those shown in Table 11.

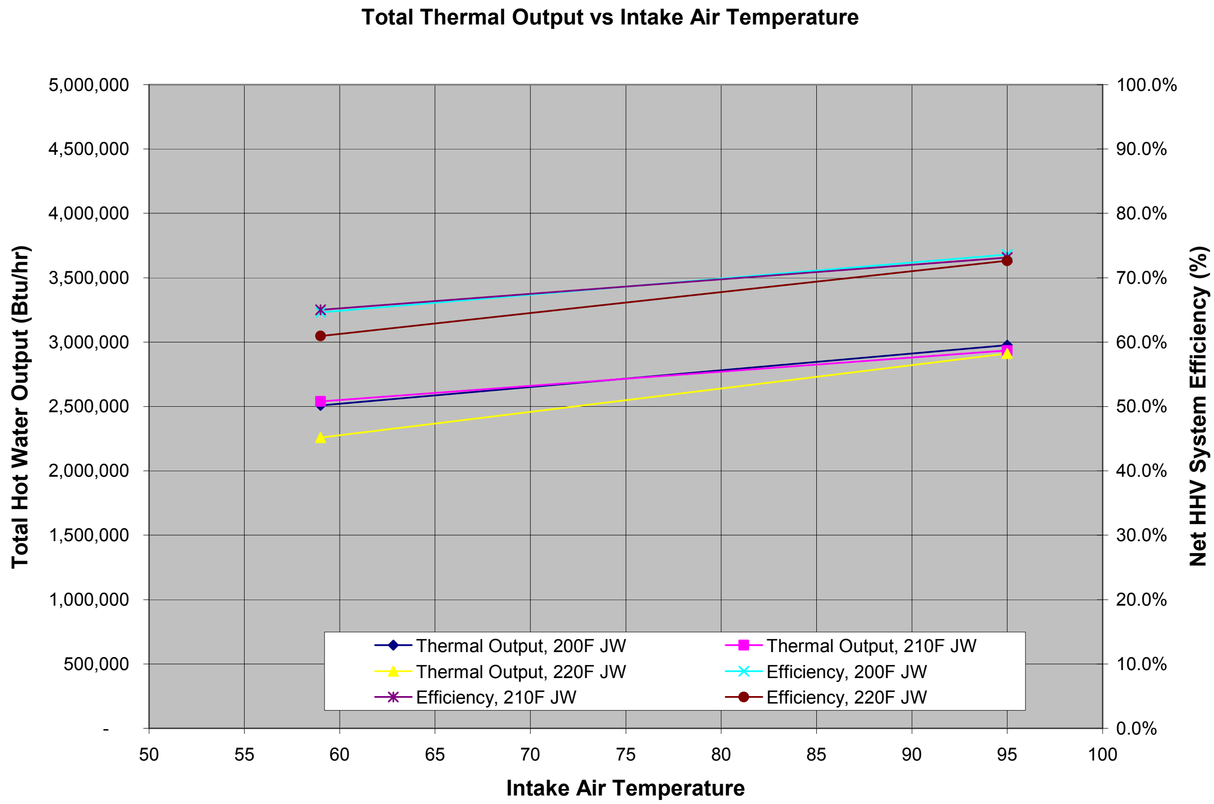


Figure 24: Sensitivity of Thermal Output to Engine Intake Air Temperature

Analysis of Heat Exchanger Performance

The cogeneration module was instrumented to determine the thermal output of the high-temperature and low-temperature coolant loops. The unit's control system was set up to monitor internal temperatures, but the instruments used for this purpose were not calibrated of verified per GTI's normal laboratory procedures because they were part of the product offering assembled by the subcontractors. However, post-test calibrations did not reveal any large discrepancies in either the laboratory or product instrumentation.

---

[13] Net system efficiency and net output include the effects of the following parasitic loads: auxiliary water pump, high-temperature heat recovery pump, jacket coolant pump, controls, battery charger, environmental control of the control room, and loads from the chiller module.

Table 14 compares estimates of the actual performance of heat exchanger HX1 to its expected performance. The design conditions are shown for 95ºF intake air temperature, 615 kW gross electrical output, and 200ºF jacket coolant temperature. The purpose of this table is to help identify performance shortfalls of the system. It is important to mention the experimental uncertainty when comparing the experimental data to the design conditions. Experimental uncertainty on the heat recovery was estimated to be on the order of plus or minus 20% and was largely influenced by the plus or minus 2ºF uncertainty from the temperature measurements. The majority of the temperature uncertainty was caused by the signal conditioning, not the RTDs themselves.

Since the measured fuel flow was less than design conditions, the expected heat exchanger performance was corrected for fuel input differences from values shown in Table 2 by multiplying the design heat exchanger duty by the ratio of the actual fuel flow to the design fuel flow. The duty calculated from the hot side of HX1 was higher than that calculated on the cooler side. This difference could have been caused by heat exchanger not being insulated and being in a cold outdoor environment (~45ºF) during testing. Experimental uncertainty may have also contributed to the difference. This heat exchanger was not insulated because it was difficult to insulate since the resulting insulation blanket would have several protrusions through it and because it would normally be contained in a much warmer environment inside the cogeneration module enclosure. In these calculations, the coolant flow rate on the hot side of HX1 was not measured, but was assumed to be at the design conditions. The short length of hot-side flow loop between the heat exchanger and engine did not allow space for installing a flow meter. Initial test energy balances indicated that the flow rate was approximately correct, so no further attempts were made to measure the flow rate on the hot side during testing. It is believed that the hot side flow rate is fairly close to the design flow rate, although small differences in this flow rate could cause the calculated duty on the hot side to be incorrect.

The 1.9% performance shortfall on HX1 was calculated as a shortfall in duty on the cold side of the heat exchanger. This shortfall is within the range of experimental accuracy, as a 1ºF error in temperature measurement would lead to a 6.7% error in the duty calculation. In addition to experimental error, this shortfall could have been caused by the heat exchanger not being insulated, the hot side flow rate being inexact, or the heat exchanger being undersized.

During testing, the cold side inlet temperature to HX1 had to be reduced to 177ºF in order to hold the jacket coolant outlet temperature to 200ºF. This is an indication that the heat transfer within HX1 was lower than expected. This low heat transfer may have been due to the flow rate on the engine side of HX1 being too low or the thermal output of the engine being higher than expected.

It is doubtful that the flow rate on the engine side of HX1 was off by a significant amount, since the expected and actual temperatures on the engine side were close to expectations. If the flow rate on the engine side had been too low, one would expect a wider range of temperature differences on the engine side. It also appears that the thermal output on the engine side was not off by very much since the cold side duty was fairly close to expectations. Although some of above effects may have been present, it is felt that the primary reason for the higher-than-expected pinch point is that the heat exchanger was undersized. Since HX1 is a brazed-plate exchanger, and therefore difficult to modify, the only way to improve its performance would be to replace it with a larger one.

Table 14: Estimated Performance of HX1

	Expected	Actual
Engine fuel flow (Btu/hr HHV)	6,841,000	6,777,000
HX1 hot side inlet temperature (ºF)	200	199.5
HX1 hot side outlet temperature (ºF)	185	184.4
HX1 hot side flow rate (lb/min)	1836	1836[14]
HX1 cold side inlet temperature (ºF)	181	177.4
HX1 cold side outlet temperature (ºF)	196	191.9
HX1 cold side flow rate (lb/min)	1836	1845
HX1 hot side duty (Btu/hr)	1,495,000	1,519,000
HX1 cold side duty (Btu/hr)	1,495,000	1,466,000
HX1 hot side/cold side difference	0.0%	3.5%
HX1 performance shortfall		1.9%

Table 15 compares the estimated performance of the exhaust heat exchanger to its expected performance. Note that the expected thermal output was corrected for fuel flow differences, just as it was for heat exchanger HX1. The actual exhaust temperatures and the exhaust temperature change across the heat exchanger were higher than expected. The exhaust flow rate was estimated from data taken during the emissions measurements 77ºF. There is probably a small difference in exhaust flow between data taken at 77ºF and 95ºF. However, this difference in exhaust flow would not account for the large unexpected drop in heat recovery on the cold side (water side) of the heat exchanger. The estimated heat transfer from the exhaust side of the heat exchanger was higher than expectations, and the calculated heat transfer on the water side was much lower than expectations. The shortfall in expected thermal output was more than 20%, and it is thought to be related to the large discrepancy (30%) between the calculated hot side and cold side heat exchange rates. Experimental measurement error may also have been a factor.

[14] The actual flow rate was not measured, but was assumed to be at design conditions for the purpose of these calculations.

Table 15: Estimated Performance of Exhaust Heat Exchanger

	Expected	Actual
Exhaust HX hot side inlet temperature (ºF)	849	922.5
Exhaust HX hot side outlet temperature (ºF)	349	373.8
Exhaust HX hot side flow rate (lb/min)	130.2	131.5
Exhaust HX cold side inlet temperature (ºF)	196	191.9
Exhaust cold side outlet temperature (ºF)	207	200.3
Exhaust cold side flow rate (lb/min)	1,836	1,845
Exhaust HX hot side duty	1,076,000	1,215,000
Exhaust HX cold side duty	1,076,000	848,000
Exhaust HX hot side/cold side difference	0.0%	30.2%
Exhaust HX performance shortfall		21.2%

There are several possible causes of the difference between the calculated hot side and cold side heat exchange rates, assuming that the mass flow assumptions are reasonably correct. It was suggested that a leaky diverter valve could have caused the apparent shortfall in thermal energy transferred to the water. However if this were the case, the final downstream exhaust temperature would have been much higher, somewhere in the neighborhood of 550ºF instead of the measured 374ºF. This would have been an unusually large error. The 30.2% discrepancy could have been caused by a 3ºF error in water temperature measurement. This is a possibility, because the total uncertainty of the measurement was on the order of plus or minus 2ºF. However, the indicated temperatures were confirmed by temperatures reported by the master controller PLC at other points in the system. The final exhaust outlet temperature downstream the mixing point from the flow through the heat exchanger and the flow bypassed by the exhaust diverter was also confirmed within a few degrees of the exhaust temperature measured by the data acquisition system. Other possibilities include an error in the exhaust temperature measurements upstream and downstream of the exhaust heat recovery heat exchanger. However, errors in exhaust temperature measurement would have to be very large to cause a 30% discrepancy.

A final possibility is that high thermal losses (due to cold weather) in the exhaust heat exchanger and instrumented exhaust tailpipe could have caused the heat transfer on the exhaust side to appear higher than it actually was. The exhaust heat exchanger was not insulated. Normally, it would be inside the enclosure, where insulation would not be necessary. During GTI's tests, the heat exchanger cogeneration module was not enclosed, and the heat exchanger was exposed to colder temperatures than normal. The final exhaust thermocouples were approximately twelve feet downstream of the exhaust silencer. These thermocouples were installed to determine exhaust properties at the point where the emissions measurements were taken, not for diagnostics, so the tailpipe was not insulated. Rough one-dimensional heat transfer calculations indicate that heat losses could be on the order of 100,000 Btu/hr, assuming an air temperature of 30ºF and a ten mile per hour wind. These heat losses can probably explain part of the thermal output discrepancy. The actual thermal output shortfall may be due to a combination of the heat losses and measurement errors related to the water temperature.

Table 16 compares of the high-temperature circuit thermal output to expectations. The expected thermal output was adjusted for fuel flow, so it does not match the design values shown in Table 11. The thermal output was lower than expected in terms of both temperatures and thermal output for 200ºF jacket coolant temperature. As discussed above, the outlet temperature is lower than expected and is hypothesized to be low due to the jacket water heat exchanger being too small and the thermal output of the exhaust heat recovery heat exchanger being too low. As mentioned above, the indication of low thermal output may have been due to the measurement uncertainty for the inlet and outlet temperatures.

Table 16: Analysis of Thermal Output

	Expected	Actual
High-temperature circuit outlet (ºF)	207	200.3
High-temperature circuit return (ºF)	181	177.4
High-temperature circuit flow (lb/min)	1836	1845
High-temperature thermal output (Btu/hr)	2,540,000	2,308,000
Thermal output difference		9.1%

Additional Testing Observations

- The unit had difficulty starting on the first attempt on days when the ambient temperature was below 40°F. There were at least 15 days of testing at these conditions, and the unit did not start on the first attempt on those days. This required a reset of the control alarms and a second attempt to start. The engine always started on the second attempt.

- After difficulties controlling the temperatures in the heat recovery circuits, GTI had proportional-integral-differential (PID) control loops added to all of the three-way valves in the fluid circuits. These PID loops tremendously improved temperature control. Without them, stable temperature control would not have been possible without continual operator intervention.
- The oxygen sensor in the engine exhaust had to be recalibrated during testing. From initial commissioning in September to the time that the oxygen sensor was recalibrated in March, the oxygen controller had changed from maintaining 7.8% oxygen to 7.1%. This decrease in oxygen concentration caused the unit to emit more NO_x. Units in the field may require periodic checks of the oxygen sensors to ensure that the unit is meeting emission requirements.
- The exhaust diverter in the unit, as received, was not installed correctly, which may have hurt the sealing characteristics of the valve. Care should be taken when installing these devices to avoid damaging them during commissioning.
- The oil delivery system for the makeup tank did not work in cold weather. Heat tape had to be installed on the delivery lines to keep the oil flowing to the fill chamber. The tank may need the addition of a heater in some installations to keep the lubricant flowing in cold weather.

Prototype Absorption Chiller Testing

Test Purpose

Performance testing of the prototype absorption chiller at Trane Company's laboratory in La Crosse, Wisconsin verified the low-temperature hot-water-fired chiller design. The test program was planned and conducted to verify operation and performance of the following components, features, and functions:

- Solution and refrigerant flow systems including pumps, piping, sprays, sumps, and heat exchangers.
- Vapor-liquid separation devices in the generator-condenser and evaporator-absorber.
- Heat and mass transfer performance of all tube bundles and the heat exchanger.
- Fully manual purge system.
- Overall chiller performance and operational range.
- All automatic and manually operated valves.
- Control system including soft-start, crystallization prevention, and heat input reduction to avoid generator carry-over.

Test Results

<u>Performance in the 90-RT Mode</u>

The nominal capacity of the chiller, based on ARI design reference conditions, is 90 RT when driven by 207ºF fluid heated by both the exhaust stream and jacket coolant of a nominal 400-kW gas engine (the original design capacity). Lab performance of the stand-alone chiller was close to expectations and was in reasonable agreement with model predictions.

Table 17 summarizes the full-load performance of the prototype when operating in the 90-RT mode, with heat supplied at 207ºF. Under Trane rating conditions, the expected performance was 90-RT versus 86.4-RT from the laboratory tests. Trane considered this to be within the range of acceptable performance, especially when considering experimental uncertainty.

Table 17: Prototype Chiller Performance Summary (90-RT Mode)

Parameter	Units	Performance at Trane Rating Conditions
Capacity	%	96%
Capacity	RT	86.4
COP		0.72
Chilled water flow rate	gpm	217
Chilled water leaving temperature	°F	44.1
Tower water flow rate	gpm	329
Tower water entering temperature	°F	85.0
Hot water flow rate	gpm	178
Hot water entering temperature	°F	207.1
Hot water leaving temperature	°F	190.4

Figure 25 shows the performance of the chiller as a function of the source heat input temperature, at design temperatures for chilled water delivery and cooling water supplied to the chiller. As expected, the chiller capacity increases steadily with source temperature. The COP is relatively constant and above 0.7 for hot water temperatures above 185ºF.

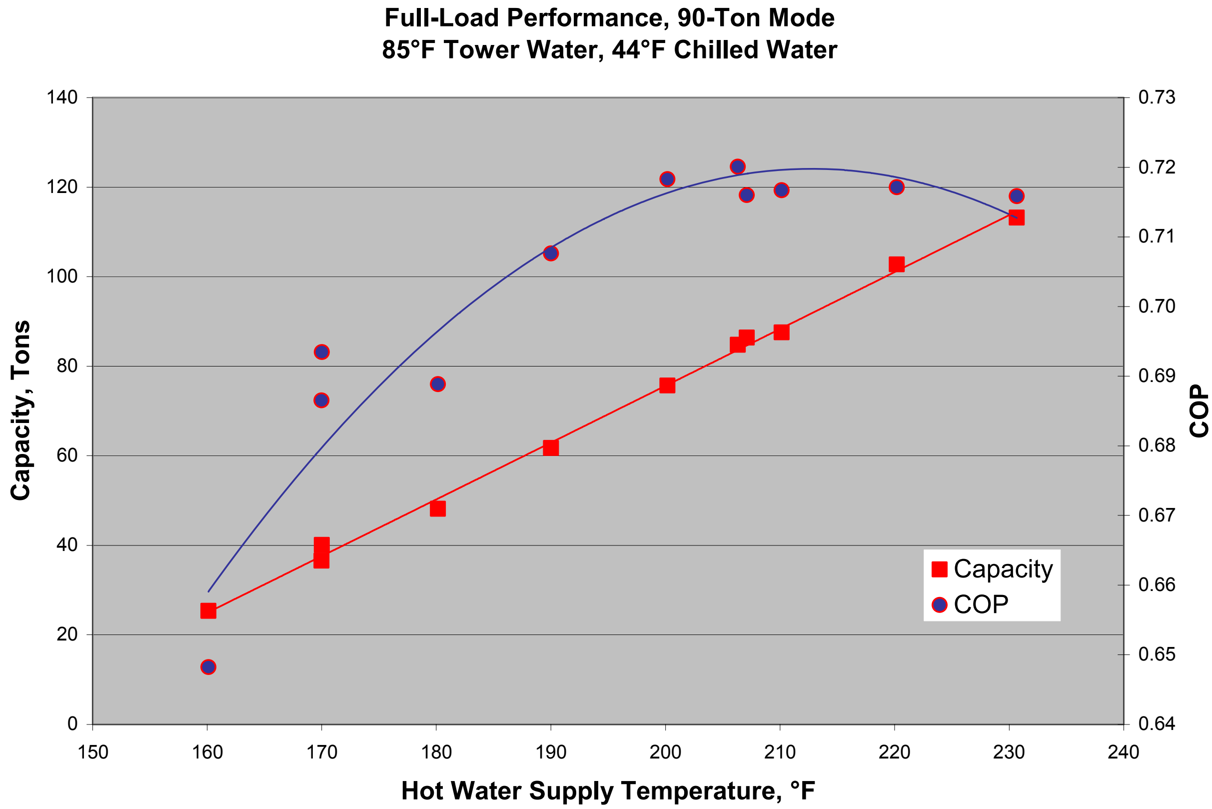


Figure 25: Chiller Performance as a Function of Hot Water Supply Temperature

Figure 26 and Figure 27 show the sensitivity of the capacity and COP, respectively, to off-design temperatures of the chilled water delivered by the unit.

Figure 28 and Figure 29 show the sensitivity of the capacity and COP, respectively, to off-design temperatures of the water returned from the cooling towers.

As would be expected, the COP declines sharply when trying to deliver colder-than-design water temperature or trying to accommodate poor cooling tower performance at lower-than-design heat input temperature.

Figure 30 shows part-load performance of the unit when operating at design temperatures of hot water supply, chilled water delivery, and cooling tower water. The unit capacity was modulated by regulating the hot water supply flow rate.

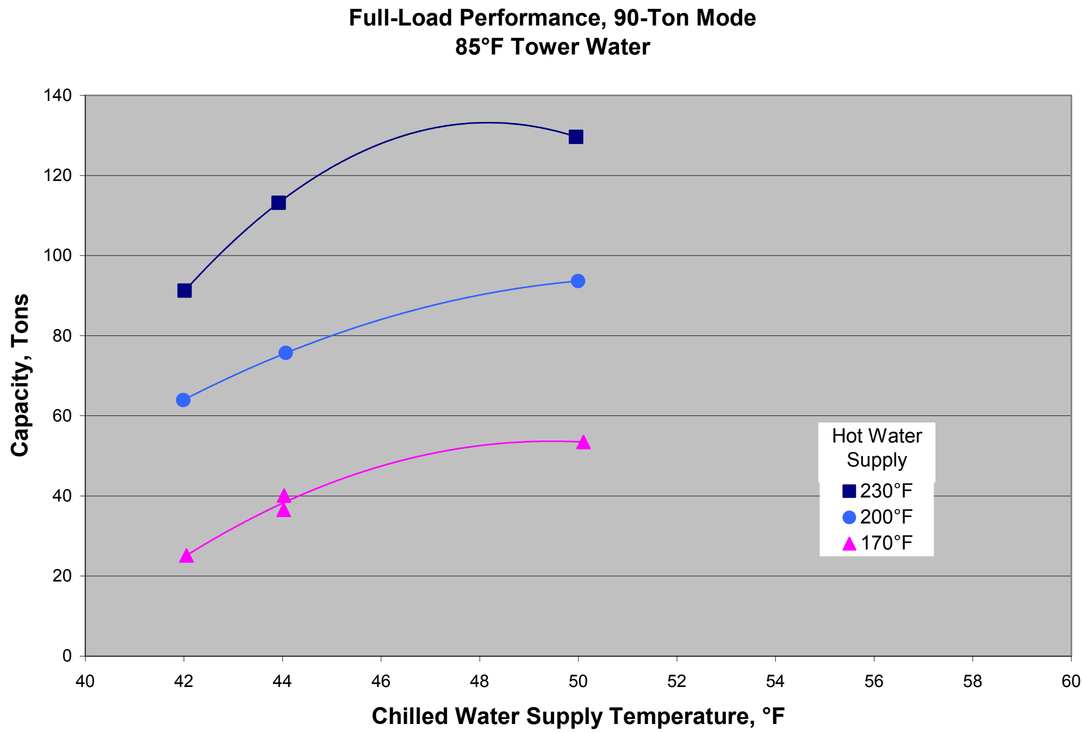


Figure 26: Effect of Chilled Water Delivery Temperature on Chiller Capacity

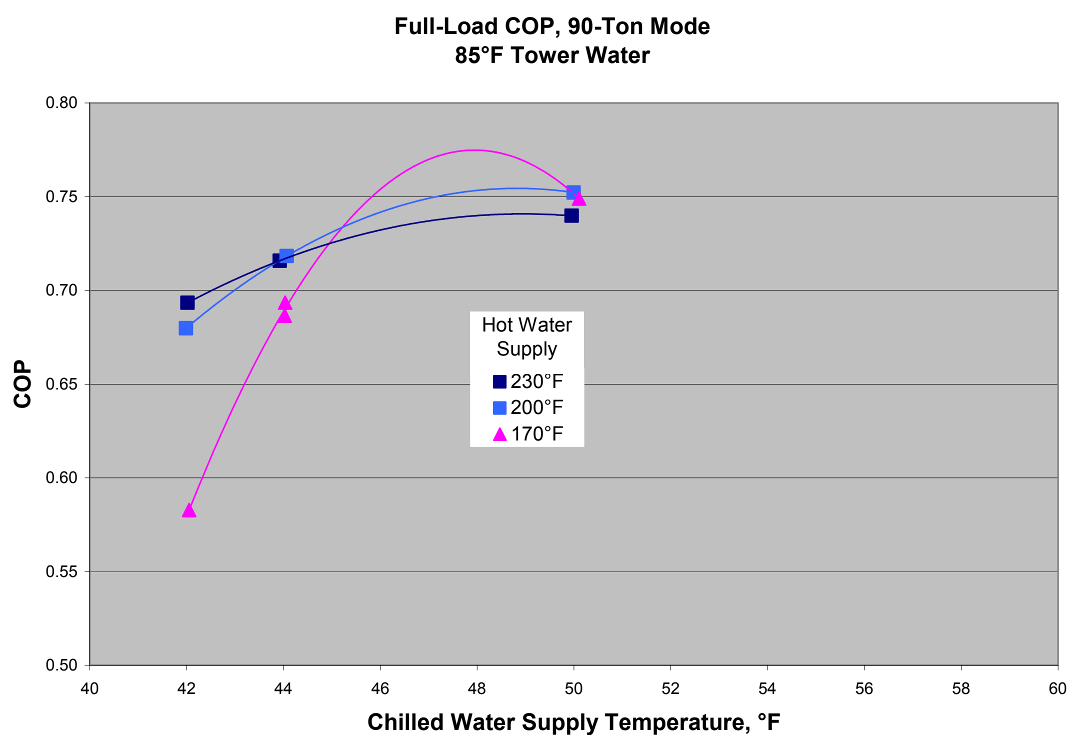


Figure 27: Effect of Chilled Water Delivery Temperature on Chiller COP

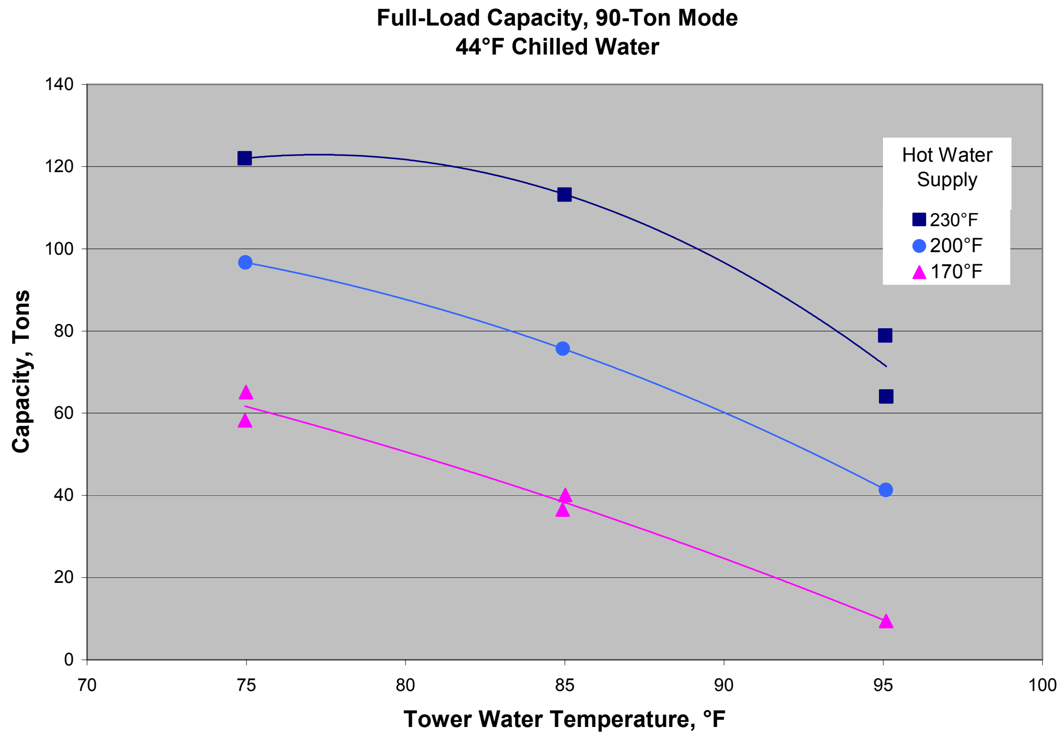


Figure 28: Effect of Tower Water Temperature on Chiller Capacity

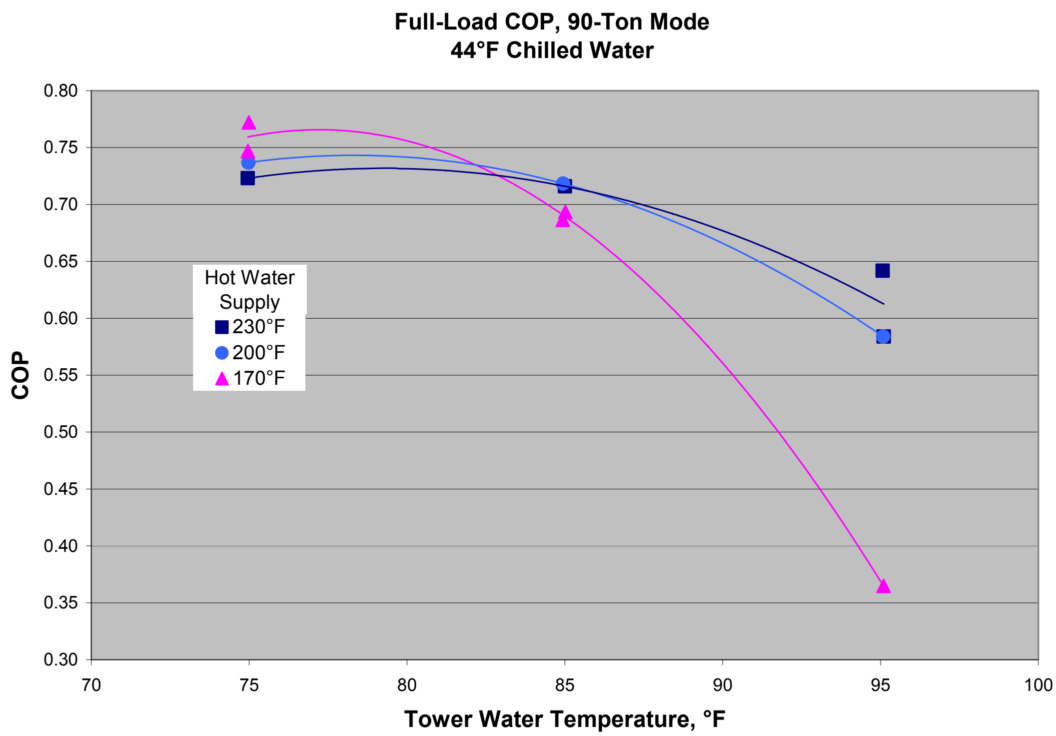


Figure 29: Effect of Tower Water Temperature on Chiller COP

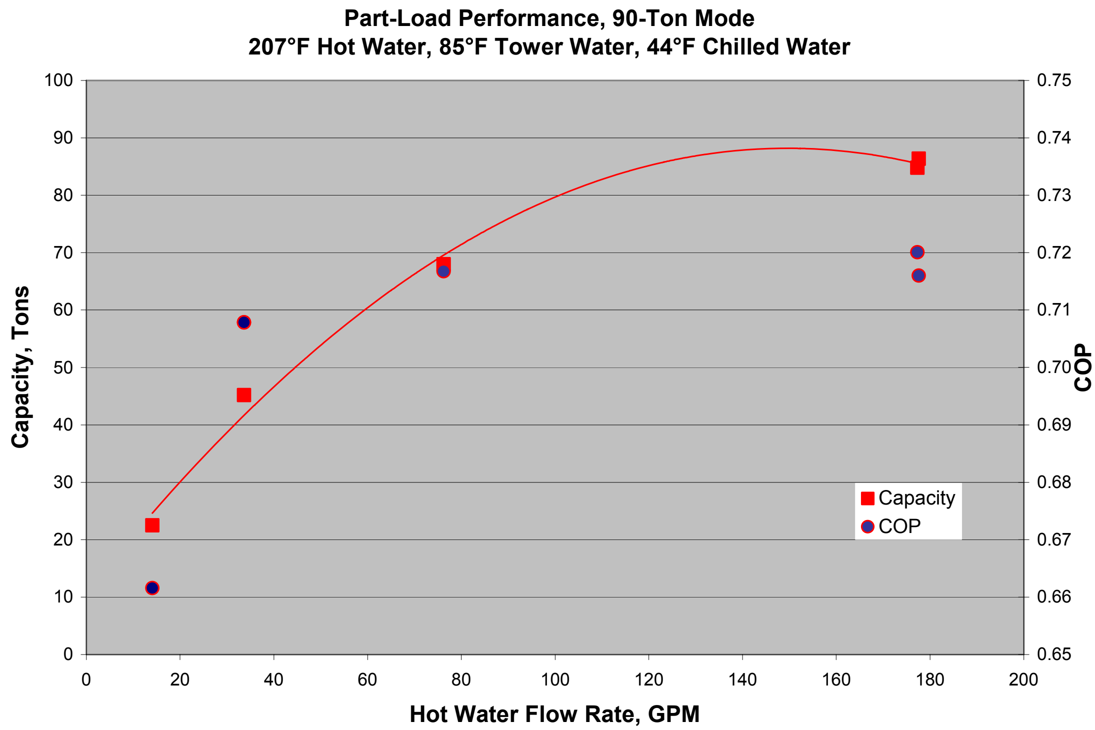


Figure 30: Part-Load Chiller Performance at Design Temperatures

<u>Performance in the 125-RT Mode</u>

Table 18 summarizes the performance when operating in the 125-RT mode, with heat supplied at 237ºF. The chiller output at the design condition was 131 RT and exceeded the expected 125-RT output.

Figure 31 shows the performance of the chiller as a function of the source heat input temperature at design conditions for chilled water delivery temperature and cooling tower water temperature. As expected, the chiller capacity increased steadily with source temperature. The COP is relatively constant and above 0.7 for hot water temperatures of 175 to 230ºF. It is interesting to note that the estimated performance of the chiller, based on a curve fit of the data, at 207ºF hot water supply temperature is 94 RT, which exceeds the measured performance in the 90-RT mode by approximately 8 RT. The increased performance was largely due to the higher hot water flows in the 125-RT mode

Figure 32 and Figure 33 show the sensitivity of the chiller performance to off-design chilled water and tower water temperatures, respectively.

Table 18: Prototype Chiller Performance Summary (125-RT Mode)

Parameter	Units	Performance at Trane Rating Conditions
Capacity	%	105
Capacity	RT	131.5
COP		0.68
Chilled water flow rate	gpm	300
Chilled water leaving temperature	°F	44.0
Tower water flow rate	gpm	447
Tower water entering temperature	°F	85.0
Hot water flow rate	gpm	231
Hot water entering temperature	°F	237.4
Hot water leaving temperature	°F	216.8

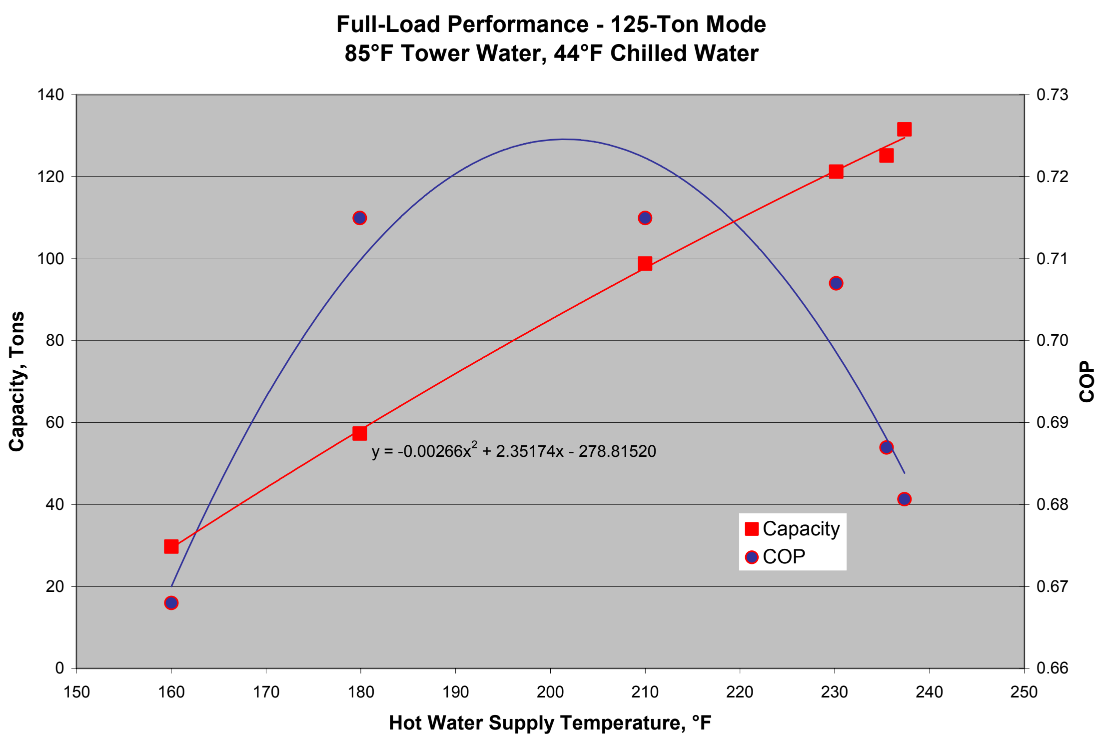


Figure 31: Sensitivity of Chiller Performance to Hot Water Temperature – 125-RT Mode

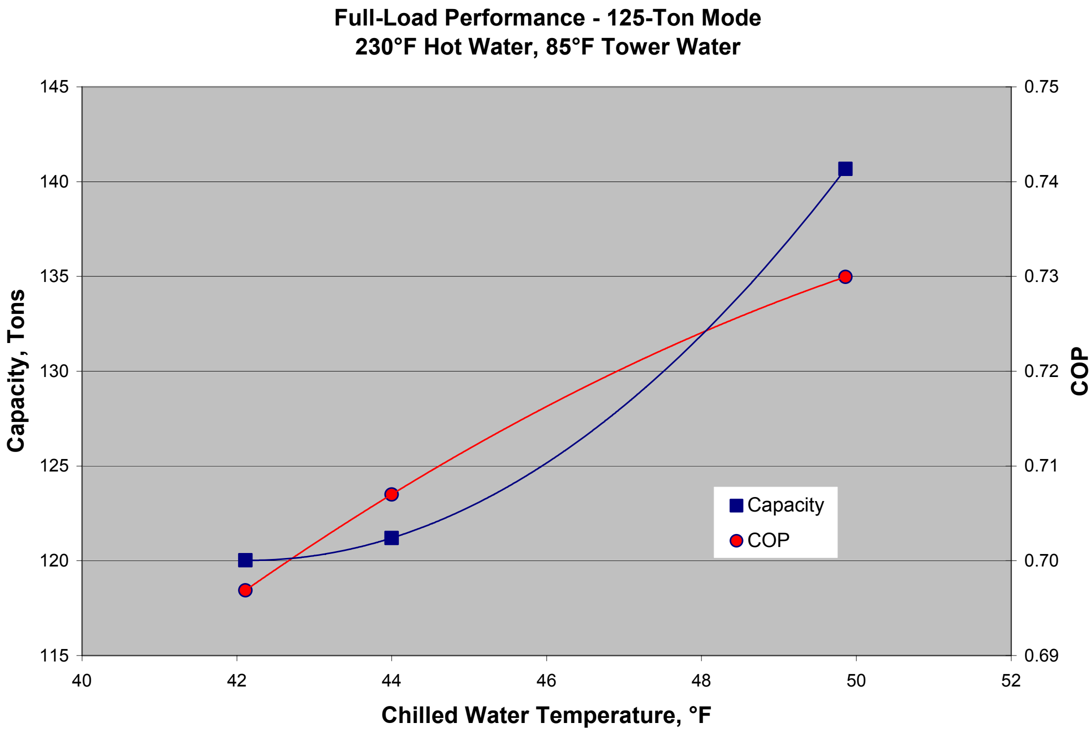


Figure 32: Sensitivity of Chiller Performance to Chilled Water Temperature – 125-RT Mode

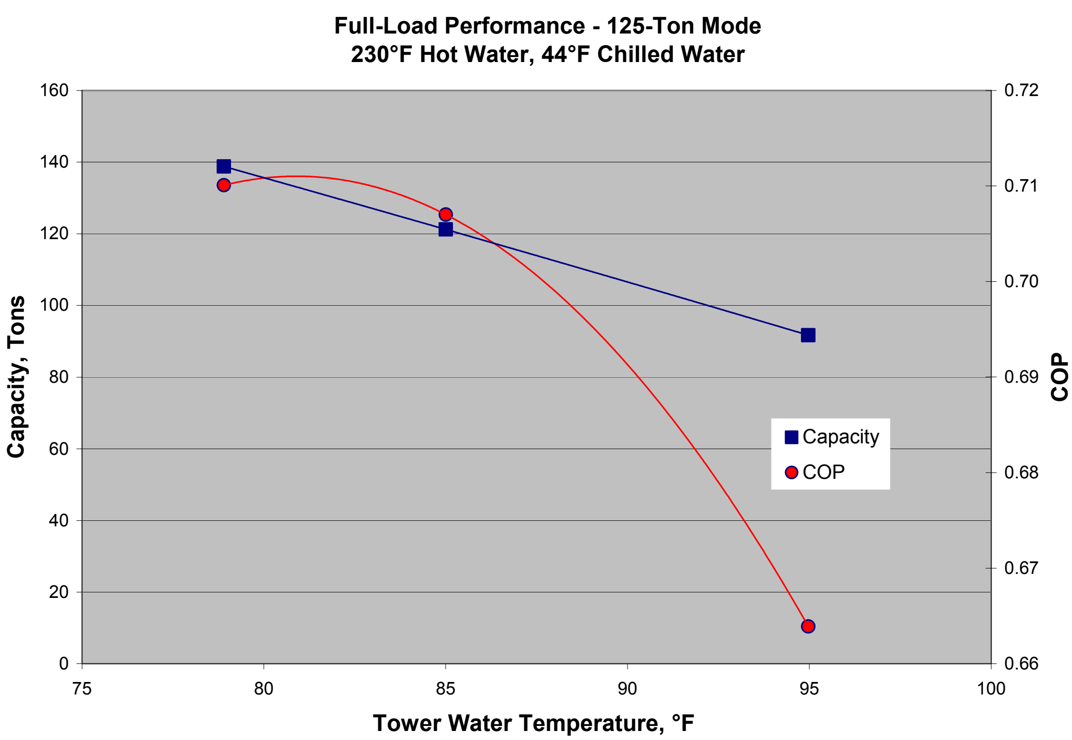


Figure 33: Sensitivity of Chiller Performance to Tower Water Temperature – 125-RT Mode

Modifications to the Chiller

In the initial stages of the testing, Trane engineers found that liquid refrigerant from the condenser was slinging back into the generator. As a result, they blocked some of the condenser tubes to reduce this effect. The condensate slinging effect was reduced, but not completely eliminated.

Trane also found that the flow rate out of the absorber was limited to less than the design value due to higher than expected pressure drop, possibly caused by an unexpected vortex in the solution outlet pipe. This was expected to have only a marginal effect on performance. Trane made other minor modifications to the chiller during the initial stages of testing.

Modeled Overall Performance of Combined System

Chiller output was modeled based on data taken from the cogeneration module and data taken by Trane on the absorption chiller. The chiller output calculation was based on an interpolation of the data taken in the 90- and 125-RT modes, based on the temperature and flow from the cogeneration module at 95ºF. The condenser return temperature and the chilled water outlet temperature were set at their design values of 85ºF and 44ºF, respectively.

Table 19 shows that, with its current configuration, the combined cogeneration/chiller module will generate 83 RT of cooling, rather than the design capacity of 90 RT, at 200ºF jacket coolant temperature. These results are based on curve fits of the data, as shown in Figure 25, Figure 30 and Figure 31. Most of this capacity shortfall can be attributed to lower-than-expected thermal output from the cogeneration module, as described in the cogeneration module test results section. Table 19 also compares the design and actual chiller inlet temperature and shows the results of curve fits for 90-RT and 125-RT mode capacities as functions of hot water supply temperature. As the hot water supply temperature increased, chiller performance improved.

Table 19: Calculated Chiller Output, 95ºF Engine Intake Air Temperature

Power Output Setpoint	*Jacket Coolant Setpoint*	*Design Chiller Inlet Temperature*	Chiller Inlet Water Temperature (TB4)	High-Temperature Circuit Output	Modeled Chiller Output 218 gpm HW flow	Expected (Curve Fit) Chiller Output 90-RT Mode 177 gpm HW flow	Interpolated Chiller Output 218 gpm HW flow	Expected (Curve Fit) Chiller Output 125-RT Mode 231 gpm HW flow
(kW)	*(˚F)*	*(˚F)*	(˚F)	(Btu/hr)	(RT)	(RT)	(RT)	(RT)
308	*200*	*Not tested*	193.3	1,018,986	Not tested	Not tested	Not tested	Not tested
	210		205.2	998,116				
	220		215.6	1,040,475				
461	*200*		199.5	1,845,315				
	210		211.8	1,850,647				
	220		220.1	1,760,152				
615	*200*	*207*	201.4	2,307,616	83	85	90	92
	210	*217*	211.6	2,259,684	96	97	103	104
	220	*227*	221.3	2,202,365	108	110	114	116
	230	*237*	Not tested			123	126	127

The chiller module also entails parasitic losses in addition to the losses in the cogeneration module. These losses were not measured during the testing at Trane, but were estimated, based on datasheet information for the related equipment at 218 gpm hot water flow rate. These estimated losses are shown in Table 20. Table 21, shows that these parasitic losses, together with the 16.3 kW loss in the cogeneration module and the 8.6-kW worst-case module and control room ventilation and space-conditioning load will reduce the net power output to 543 kW at the full 615-kW gross power rating point. Taking all of these parasitic loads into consideration, the combined net system efficiency[15] based on the thermal energy of the hot water and the electrical output was 71.2% at 95ºF intake air temperature and 200ºF jacket coolant temperature. The combined net system efficiency based on the thermal energy of the chilled water and the electrical output was 42.1% at 95ºF intake air temperature and 200ºF jacket coolant temperature.[16] At 220ºF jacket coolant temperature, the combined efficiency based on chilled water increased to 46.9%.

Table 20: Additional Parasitic Loads Associated with Chiller Module

Parameter/Component	Design Load
Chiller pumps and controls	9.7 kW
Cooling tower fans	11.2 kW each
Cooling tower pump	14.9 kW
Total chiller module parasitic losses	**47.0 kW**

[15] Net system efficiency and net output include the effects of the following parasitic loads: auxiliary water pump, high-temperature heat recovery pump, jacket coolant pump, controls, battery charger, environmental control of the control room, and loads from the chiller module.

[16] This calculated efficiency credits the cooling capacity of the chiller, rather than the heat input to the chiller.

Table 21: Combined System Net Energy Output and Efficiency at 95ºF Air Intake

	Design at 200ºF Jacket Coolant		Actual at 200ºF Jacket Coolant		Actual at 220ºF Jacket Coolant	
Fuel energy input (HHV Btu/hr)	6,841,000	100%	6,777,000	100%	6,784,000	100%
Units	**kW**	**% of Fuel Input**	**kW**	**% of Fuel Input**	**kW**	**% of Fuel Input**
Generator gross power output	615	30.7	612	30.8	612.8	30.8
Parasitic Losses						
Cogeneration module parasitic load	16.3	0.81	13.3	0.67	13.3	0.67
Chiller module parasitic load	47	2.3	47	2.3	47	2.3
Worst-case module and control room ventilation and space-conditioning load	8.6	0.4	8.6	0.4	8.6	0.4
Energy Output						
Net IES power output with control room ventilation[17]	543.1	27.1	543.1	27.3	543.9	27.4
Auxiliary coolant output (kW thermal)	178.5	8.9	195.8	9.9	207.9	10.5
High-temperature output from cogeneration module (kW thermal)[18]	751.5	37.5	676.3	34.0	645.5	32.5
Combined net electric power and thermal output	1,473	73.5	1,415	71.2	1,397	70.3
Chiller output (kW cooling)[19]	316.5	15.8	293.3	14.8	379.1	19.1
Combined net power and cooling output[20]	868.2	43.3	836.4	42.1	931.6	46.9

Figure 34 shows the sensitivity of estimated chiller output to engine jacket coolant temperature. Both chiller output and net system efficiency increase with increasing jacket coolant temperature. Net HHV system efficiency was calculated per footnotes 16 and 19.

---

[17] See footnote 15.

[18] See footnote 15.

[19] Calculated on the basis of 1 RT = 12,000 Btu/hr and 1 kW = 3,412 Btu/hr.

[20] See footnotes 16 and 19.

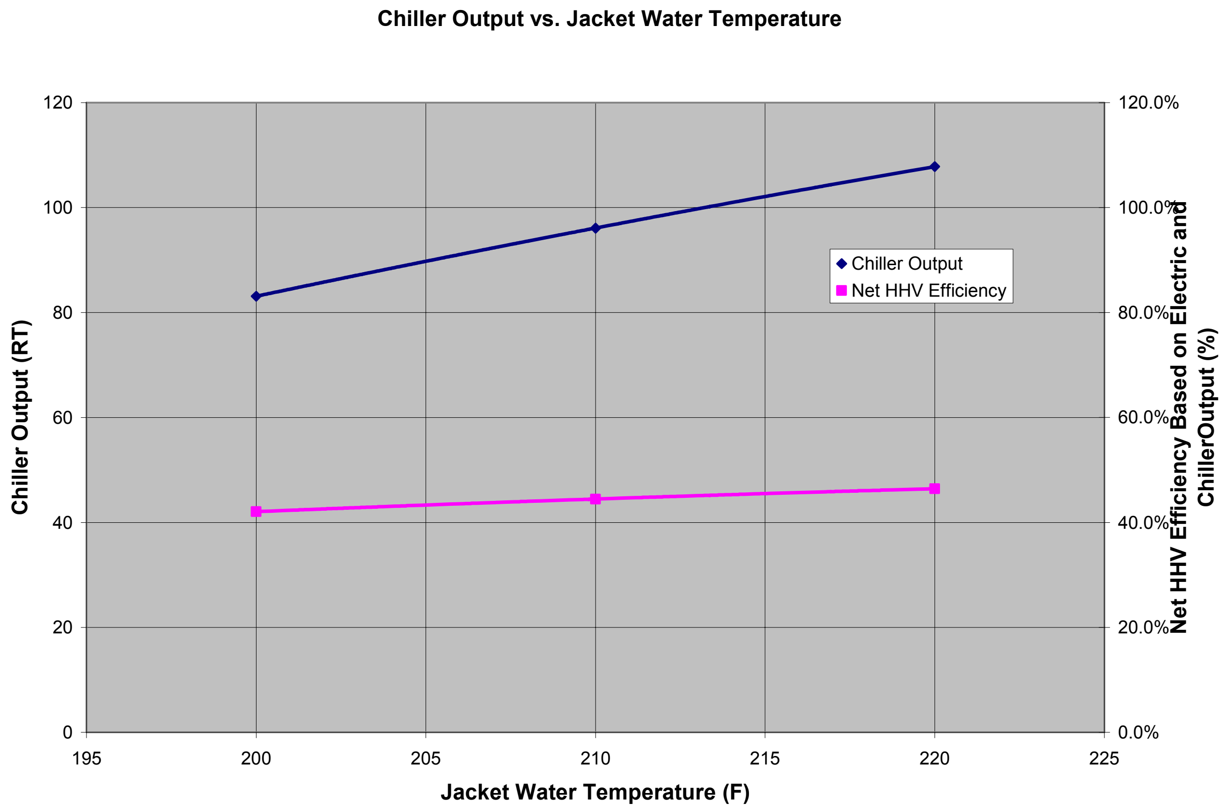


Figure 34: Sensitivity of Chiller Output to Engine Jacket Coolant Temperature

Assessment of Potential IES Markets

In industrial applications, IES can provide heat for a variety of process uses, but in commercial buildings, the uses are mainly limited to space heating, cooling, and water heating. As a result, climate (and, therefore, geographical location) will influence IES economics. Location also influences economics because electric rates in various states or cities differ significantly. Economics will also be influenced by the type of building and its use. Some segments of the commercial building sector will be more amenable to IES than other segments. Segment size, building size, and balances between the needs for electrical energy and thermal energy are important factors.

Best Locations

The potential application for integrated energy systems should be based on the competing cost of conventionally supplied electricity and should focus on locations where the commercial building market is large and growing dynamically.

Figure 35 shows the ten states with a combination of the highest average electric power rates and the largest power consumption in commercial buildings.

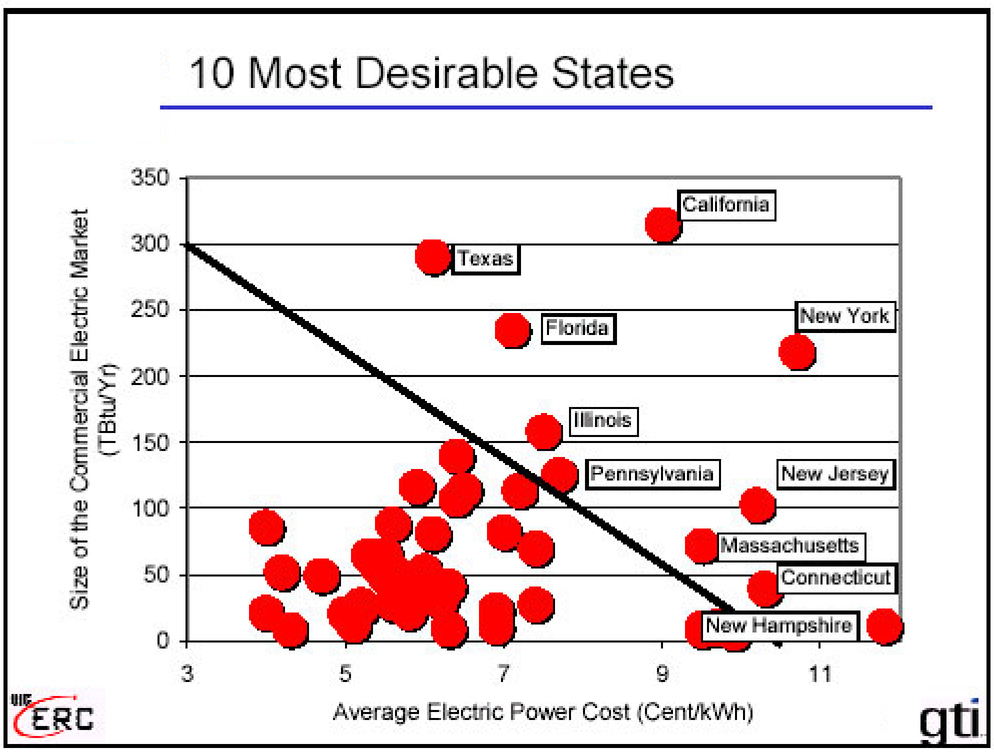


Figure 35: States with High Electric Power Rates and High Commercial Building Energy Needs

As described later in this report, the economic analysis revealed that, although Illinois, Massachusetts, and Florida represent large potential markets with high electric power rates, the rates in Chicago, Boston, and Miami are not now high enough to make those cities good candidates for initial IES marketing efforts. Economically viable locations would have to have average electric power costs of 8-9 cents/kWh or more. As shown in Figure 35, New York Massachusetts, Connecticut, New Jersey, New Hampshire, and California meet this criterion. However, the Northeastern states shown in the lower right-hand corner of the figure are not suitable because they have punitive interconnect and standby rate policies and smaller commercial markets. Therefore, a second economic analysis, based on more flexible IES sizing, focused on New York City and San Diego.

> Because of their high electric rates, New York and California are the best states for initial entry of IES for commercial buildings

Best Market Segments

The following large market segments were ranked, based on their total energy use, and are shown in descending order.

1. Office*
2. Retail*
3. Food Sales
4. Lodging*
5. Education*
6. Food Service
7. Health Care*
8. Warehouse
9. Public Assembly
10. Houses of Worship

From this list, the food sales (supermarkets, grocery stores, etc.) and food service segments (restaurants, carryouts, etc.) were not selected for analysis because individual establishments in these segments are usually too small for economical application of engines. After removing those two applications from the ranked list, the five largest remaining applications (marked with asterisks) were selected for further analysis.

To refine the selection, the size of the facility was matched to 300- to 800-kW engine-generators, typical of the range of economical engine-driven systems. The results of this analysis determined the general size of the targeted facilities and narrowed the range of promising application sizes to those shown in Table 22 or larger. This report refers to these applications as market sub-segments.

Table 22: Sub-Segments of the IES Market Consistent with Engine-Driven IES

Sub-segment	Application Size
Large Office	142,000 SF (square feet)
Large Retail	125,000 SF
Large Hotel	220,000 SF
Large Educational	120,000 SF (Predominantly secondary schools)
Health Care	125,000 SF (Typically large nursing care facilities)

Recommended Marketing Strategies

Summary

The market study examined different market segments and sub-segments to identify the market potential for IES application. Factors considered included:

- Segment size.
- Energy intensity (per square foot).
- Potential for operating cost savings.
- Market concentration (to enable reaching a large part of the segment through a small number of owners).
- Existence of desirable sub-segments within a segment.
- Attractiveness of IES to decision-makers within the segment.
- Potential growth of the segment.

The characteristics of the five market sub-segments are compared in Table 23, summarized in the paragraphs that follow Table 24, and described in detail in Appendix B.

Table 23: Sub-Segment Advantages and Disadvantages for IES Marketability

Segment	Advantages for IES Acceptance	Disadvantages
Large hotel	24/7 operation Good electric/thermal ratio Good national chain concentration	High rise central system sub-segment only – a relatively small sub-segment
Hospital and other healthcare	24/7 operation Large maintenance staff (hospitals) Backup power implications	High electric/thermal ratio Limited maintenance staff (nursing care facilities)
Large office	Large market On-peak operating hours Some market concentration	Short operating hours Sizable fraction are rental facilities (Tenants pay the energy costs)
Large retail	Large, well-defined market Long operating hours Good electric/thermal ratio	Sizable fraction are rental facilities (Tenants pay the energy costs) Require short payback times
Large (K-12) school	Institutional owner- will accept longer payback times Level Thermal Load	Limited maintenance staff Low summer use

The markets shown in Table 24 are highly focused, consisting of specific sub-segments. The purpose of this tight focus is to identify the best introductory markets that could be addressed with minimum marketing effort and cost. Particular emphasis was placed on sub-segments that: 1) dominate the segment in sales or revenues, 2) have a limited number of major players who could be identified, and 3) best fit the power, heating, and cooling outputs of engine-driven IES equipment.

Table 24: Electric Load Size of the Selected Market Sub-Segments

Segment	Existing Market Size, GW	Notes
Large hotels	4.65	Facilities with more than 150 rooms
Medium-size healthcare facilities	10.9	Facilities from 50,000 to 150,000 SF
Large offices	12.5	Buildings using between 100 and 1,000 kW
Large retail stores	6.45	Retail stores larger than 65,000 SF
Large schools	11.9	Schools over 400 kW
Total	46.4	Equivalent to 90,000 500-kW systems

Appendix B includes the following detailed information for each market segment:

- Size.
- Pros and cons for IES, by segment.
- Best economic regions for IES overall.
- Structure, size, occupancy, and operating schedule of typical buildings.
- HVAC equipment and fuel types currently used.
- The major equipment decision-making processes.
- Division of the market into new construction and existing building retrofit opportunities.
- Major market players.
- Ownership concentration.
- Determination and characterization of the most practical sub-segments, where applicable.
- Summary of market size by number of buildings and overall electric demand and use.
- Suggested marketing strategy.

Lodging

Lodging is a highly concentrated market, with 50 chains (identified in the Appendix B) dominating the market. However, some of these chains have a large number of small motel-type facilities, which would not be appropriate for IES in the 300-800 kW size range and are not usually equipped to use the centralized hot and chilled water provided by an IES. Therefore, 24 of the chains that featured average facility sizes above 300 rooms were selected. The 24 operators identified in the report control over 1,600 of the 6,000 domestic large hotels (as well as running 1,500 large hotels overseas). The overall retrofit market potential is 4.65 GW for domestic large hotels with 300+ rooms each.

Marketing strategy:

- Initially focus on the 24 chains identified.
- Make an economic case, based on the unusual thermal load profile in large lodging establishments, which is characterized by daily patterns of fluctuation.
- Target high-electric-cost states, due to the concentration of the hotel industry in those states.
- Include the backup power features, particularly for overseas locations.
- Include the potential for stand-alone operation for remote resort locations.

Medium-Size Medical and Healthcare Facilities

In the medical facility market, medium-size facilities were chosen to correspond to the size range of the packaged systems. In general, for larger hospital facilities in the 2+ MW range, a custom-applied system would be more cost-effective than using numerous packaged systems.

Medium-size medical facilities are a diverse market, including small hospitals, nursing care facilities, community nursing homes, and medical office buildings. The most concentrated sub-segment was found to be large, privately owned nursing care facilities, which often belong to multi-site systems or chains. These facilities have appropriate power usage for IES. The most common heating and cooling systems are centralized boilers and chillers, making these facilities a good retrofit opportunity for IES.

There is also the potential for IES to be used as emergency power equipment in these facilities, providing both power and cooling during power blackouts, thereby avoiding potentially life-threatening evacuations.

The overall retrofit market potential is 10.9 GW, concentrated in large, privately owned nursing care facilities with central hydraulic cooling and heating systems.

Marketing strategy:

- Focus on large, privately owned nursing care facilities.
- Make the case for backup power, keying on the difficulty of evacuating patients.
- Show how IES provides operating cost reductions and backup power and cooling for critical business operations in one package.

Office

Office buildings represent one of the largest applications in terms of occupied floor space. An office building may operate 3,500 to 4,500 hours per year, rather than 24/7 operation or 8,760 hours per year, but most of the electric load is during peak hours when electric prices are highest. This makes IES for office building economically attractive in states such as New York and California, where peak electric rates are high.

There are over 705,000 office buildings in the United States, but only 57,000 of them have electric demand of 100-500 kW, and 12,000 have electric demand of 500-1,000 kW. The overall retrofit market potential is 12.5 GW.

Key to this market is that many large office buildings need some back-up power, and some need 24/7 space cooling for their computer servers and data centers. An IES system can provide some back-up service while also reducing energy costs.

Marketing strategy:

- Target 4-5 large commercial real estate firms, such as Equity Office Properties, Boston Properties, and Vornado Realty Trust.
- Provide IES with some back-up power capability for critical loads.
- Apply a multiple-engine approach for higher reliability and better load-following capability.
- Show how IES reduces energy costs and can provide energy security.
- Initially concentrate on areas that have high electric costs to have better economics in spite of the current high gas prices.

Retail

The retail market segment was focused down into the large general-merchandise sub-segment, which dominates all retail sales with a small percentage of all stores. The large general-merchandise sub-segment comprises less than 1% of all retail stores but comprises over 47% of all retail stores with individual site sales of over $25 million per year. The peak demand for stores of this size will be in the 400-700 kW range, which is an excellent match for engine-driven IES. The overall retrofit market potential is 6.45 GW. Because retail stores have limited needs for backup power, IES packages will have to be sold largely on economics.

Marketing Strategy:

- Focus effort on large general merchandising chains (identified in Appendix B).
- Focus the marketing effort on fewer than 12,000 sites in the identified chains.
- Focus on operating-cost advantages.

Schools

Although educational facilities have been pioneers in IES usage, this has largely been through large systems serving college campuses. College applications are generally too large for packaged integrated energy systems in the 300-800 kW range. Many secondary schools are in the appropriate size range.

About 10% of existing schools have backup generation. One element in this use of power backup is schools that serve as community emergency storm shelters, summer cooling shelters, or winter warming shelters in the event of weather or other emergencies, generally leading to or caused by power outages.

There are more than 91,000 schools nationwide, comprising a very small segment of the overall 4.6 million commercial buildings. The peak electric demand of these buildings is 25,580 MW.

However, many of these facilities are smaller than would be desirable for most IES. Engine-driven IES produce better payback with loads of at least 300 kW. Fifty percent of schools have electric demands in the range of 200-400 kW, and 40% of schools have electric demands greater than 400 kW. Although 88% of elementary and middle schools have electric demands less than 400 kW, 45% of high schools have electric demands greater than 400 kW.

The target market for IES should be the 17,400 schools that have electric demands greater than 400 kW. This represents a retrofit market potential of 11.9 GW. The most amenable buildings for IES are buildings with central cooling and heating and natural gas available at the site. Almost 50,000 schools have gas available, and, of those 50,000, only 14,000 have central cooling/heating, and only 2,000 use absorption cooling.

Secondary (9-12) schools should be an attractive growth market for CHP systems. Unlike other sectors of the commercial buildings market, ownership and continued use of school buildings is extremely stable, leading to a willingness to undertake longer-term investments like IES. In addition, back-up power is a significant benefit in buildings that house children, are becoming more computer-intensive, and often serving as emergency shelters. The ability of IES to supply surplus heat affordably to power desiccant dehumidification of ventilation air or to heat large quantities of ventilation air is also a plus in buildings where indoor air quality can be a major public concern. Systems used in larger school buildings today lend themselves to integration with CHP systems.

Marketing strategy suggestions:

- Steer product information toward high-school applications.
- First target districts on the 50 Largest Districts Lists in high-power-cost states.
- Target district engineering or facility management staff at the district headquarters level. There is no need to market to individual schools. In many cases, the key influencer may be the engineering consultant for the district rather than district employees.
- The backup power and heating/cooling capability of IES may be additional benefits.
- Make the economic case first for high schools that have partial- or full-day summer school programs, noting that even partial-day summer operation triggers high summer demand rates.

Schools are a technically attractive target market for IES. Their payback hurdles are often not as demanding as other commercial sites. However, in its efforts to identify a candidate site for an IES demonstration, GTI found that there are institutional hurdles that will make it difficult to market to schools. The concentration of ownership is very low. Each school district is autonomous, often requiring school board approval of each sale.

Economic Assessment of Selected Applications of IES

The first economic analysis was based on a 615-kW IES system corresponding to the 615-kW alpha prototype that was built and tested under this project. The purpose of the analysis was not to design an IES for a given building, but merely to characterize which building types and locations would represent promising IES market opportunities.

The practicality of IES depends on the timing and amount of typical electric and thermal loads in buildings. For economically favorable applications, the thermal and electrical loads typically coincide in order to effectively use the waste heat. Therefore, energy use patterns in typical buildings for these five sub-segments were analyzed on an hourly basis. The fraction of the available heat that could be recovered and used over a year's time was found to depend strongly on both building type and climate.

The effectiveness and economic benefit of utilizing this natural-gas-driven IC-engine-generator were examined, assuming heat recovery for typical commercial building heating and domestic hot water loads and for satisfying a portion of building cooling loads. The analysis assessed, hour by hour, the potential for heat requirements that would be coincident with the electric power requirements of the typical commercial buildings.

A recoverable-heat-driven BCHP-90 Trane prototype absorption chiller was used to generate chilled water. A maximum reached chiller capacity of 112 RT was determined by the maximum temperature of hot water available from the IC engine. The target buildings were selected, based on the methodology described in the Market Potential Assessment chapter of this report, using criteria of high energy density, total number of buildings, and electric demand that can be satisfied or supported with a 615-kW system. Building Energy Analyzer (BEA), a commercial software/engineering tool utilizing the DOE2.1E hour-by-hour computational engine, was used to generate 8760-hour-per-year load profiles (cooling, heating, and electric and gas consumption by end use) for the analyzed buildings. GTI developed a separate program to model the engine, generator, heat recovery system, and absorption chiller integration with the building HVAC and utility systems, using load profiles developed in the first stage of the modeling process.

Detailed economic analyses were conducted for four market sub-segments (applications), at five large cities (Boston, Chicago, Miami, New York, and San Diego), in geographical locations representing a range of climates. Local electric rates were used, and simple payback periods were calculated, based on targeted installed costs ($/kW) and annual energy cost savings. The modeling assumptions, charts showing calculated payback periods, and details of the analysis are described in Appendix C.

Based on this assessment, the following changes were made, followed by a second economic analysis:

- Initial sensitivity analysis indicated that the 615-kW prototype was not optimal for the target markets. A second analysis was based on a smaller 336-kW unit. In addition, a number of virtual IES units having performance characteristics identical to the 336-kW unit but having capacities ranging from 136 kW to 936 kW were analyzed for each application to find the best size/capacity match.

- The updated analysis was based on the climate conditions and updated (current as of May 2005) electric rates and for two geographical locations. New York and San Diego were selected, because they were indicated by the first study to be the most favorable for initial market entry of new IES products.
- To help identify optimal system size, in addition to the simple payback analysis used previously, we did a more practical total present worth (TPW) analysis, based on life-cycle cost savings.

As during the first assessment, the optimal IES operating strategies were determined for each application in both cities. Three operating strategies were considered:

- Operating only during the on-peak demand hours specified by the utility.
- Operating only during periods of on-peak energy costs.
- Operating whenever the application needs electric power.

The optimal operating strategy was based on maximizing building annual energy cost savings. For all three strategies, the generator was only operated when the electric power demand was higher than 35% of generator capacity. (It is not practical to operate the engines below this level.)

No consideration was given to operating the IES to supply heating or absorption cooling service when electric power was not needed. With the current high costs of natural gas, the economics of IES are driven primarily by the value of the electric power they produce.

Nomenclature and Abbreviations

The following nomenclature is used throughout this chapter:

- 24/7 – Available 8,760 hours per year
- AC – Air conditioning
- BEA – Building Energy Analyzer
- CFM – Cubic feet per minute
- CHP – Cooling, heating, and power generation
- COP – Coefficient of performance
- DHW – Domestic hot water
- Overall Efficiency – ((Generated kWh * 3412) + recovered heat)) / generator fuel heating value input (HHV), %
- Heat Recovery Effectiveness – Recovered heat / recoverable heat, %
- HVAC – Heating, ventilation, and air conditioning
- IC – Internal combustion
- kW – Thousand watts
- MMBtu – Million Btus

- O&M – Operation and maintenance
- RT – Refrigeration ton (12,000 Btu/hour)
- SCFM – Standard cubic feet per minute
- SF – Square feet

Characteristics of the Typical Buildings

Five different building types were evaluated: large hotel, nursing home, large office, large retail store, and large school. Table 25 shows the assumed attributes of the selected building applications.

Table 26 summarizes the HVAC equipment characteristics in each typical type of building, and the following text provides more detail. The HVAC characteristics were selected to represent widespread practice for each building type. Figures 36 through 40 show the floor plans assumed in the analysis for each building type.

Table 25: Basic Parameters of Analyzed Buildings

	Application				
Attribute	**Nursing Home**	**Large School**	**Large Office**	**Large Hotel**	**Large Retail**
Typical floor space, SF	125,000	110,000	142,000	220,000	125,000
Number of buildings	16,000	48,000	38,000	6,000	30,000
Operating schedule, hours	24/7	0700 to 1800 hours Mon.-Fri. and 1000 to 1300 hours Sat.**	0700 to 1800 hours Mon.-Fri.	24/7	0600 to 2400 hours Mon. - Sat. and 0700 to 2200 hours Sun.
Typical* annual electric consumption, kWh	1,692,378	1,412,817	1,617,239	3,605,393	2,573,888
Typical* annual demand, kW	~550	~700	~633	~900	~700
Typical* annual gas consumption, MMBtu	10,411	10,414	1,859	17,518	7,240

* Based on Chicago, IL location

** Limited-operation summer schedule July to September

Table 26: Basic HVAC Parameters of Analyzed Buildings

	Application				
Attribute	**Nursing Home**	**Large School**	**Large Office**	**Large Hotel**	**Large Retail**
Cooling equipment type	Electric screw, cooling tower	Electric screw, cooling tower	Electric centrifugal, cooling tower	Electric centrifugal, cooling tower	Electric Screw, Cooling Tower
Chiller design capacity,* RT	242	516	391	489	384
Chiller energy rating, kW/RT	0.78	0.78	0.68	0.68	0.78
Heating equipment type	Natural gas boiler	Natural gas boiler	Natural gas boiler	Natural gas boiler	Natural gas boiler
Heating design capacity, MMBtu/hr*	4.1	11.8	7.7	6.9	6.9
Boiler energy efficiency, %	82	82	82	82	82
Outside air, SCFM	25,084	78,000	12,720	58,030	37,510
Thermal Economizer	No	Yes	Yes	No	No
Active humidity control	No	No	No	No	No

* Based on Chicago, IL location

Hotel

The typical large hotel characteristics are:

- Slab on grade construction with interior corridors. Lobby and meeting rooms on first floor; guest rooms on upper floors (four-story building).
- 40% wall glazing, 0º North orientation, and 10-foot floor height.
- Comfort control settings, schedules, and internal loads and ventilation values apply to 154,000 SF of guest rooms.
- Building construction materials are: walls; 10-inch HW concrete + 3-inch R-10 insulation, windows; double-pane tinted, roof; 6-inch LW concrete + 5.5-inch R-17 insulation, roof color - dark.
- Constant-volume chilled-water air-handling system using two water-cooled chillers; electric centrifugal chiller with inlet-vane control (0.68 kW/RT) each sized at 60% of building ASHRAE design point cooling capacity.

- System configured without economizer.
- Cooling tower uses 1-speed fan with fixed temperature control at 85ºF.
- System does not use relief air heat recovery, direct-cooling option is not engaged, gas energy is used for heating.

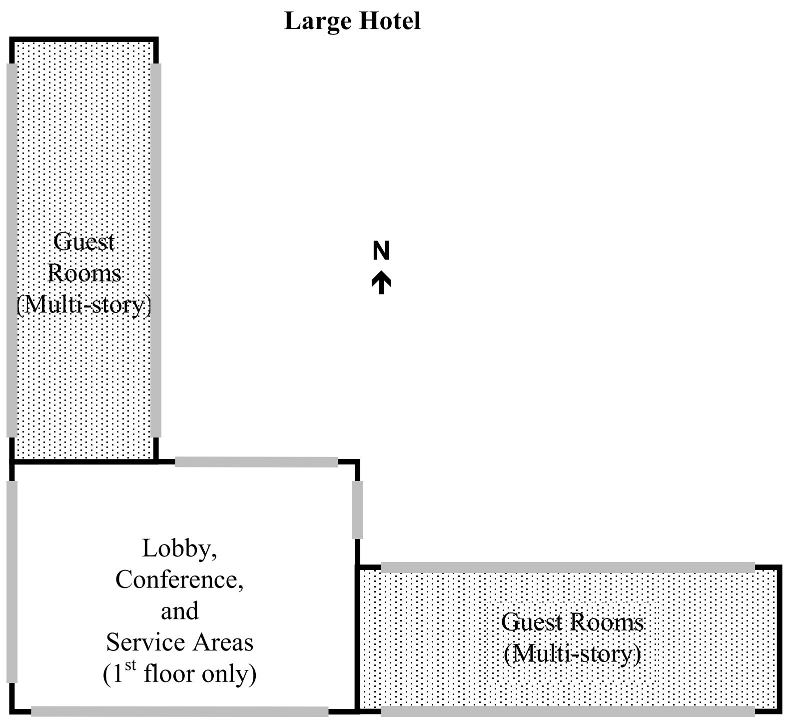


Figure 36: Layout of Typical Large Hotel

Nursing Home

The typical nursing home characteristics are:

- 1-story slab on grade construction with attic and three independently controlled zone types (patient rooms, common areas, kitchen, and laundry).
- 25% wall glazing, 0º North orientation, and 8-foot floor height.
- Dehumidification system serves only ventilation air for the patient wings (56% of total floor area).
- Humidity control air treatment can be applied independently in each zone to cover up to 125,000 SF of the entire building.
- Each zone has separate profiles of internal loads, ventilation, and infiltration.

- Building construction materials are: walls; (default) - frame + 3.5-inch R-12 insulation, windows; (default) - single-pane tinted, roof; (default) - plywood + 6-inch R-19 insulation, roof color - dark.
- Constant-volume chilled water air-handling system using three types of air-cooled chillers: A) One electric screw (0.84 kW/RT) sized at 40% of building ASHRAE design point cooling capacity, B) One electric screw (0.84 kW/RT) sized at 40% of building ASHRAE design point cooling capacity, C) One electric screw (0.84 kW/RT) sized at 40% of building ASHRAE design point cooling capacity.
- System configured without economizer.
- System does not use relief air heat recovery, direct-cooling option is not engaged, gas energy used for heating.

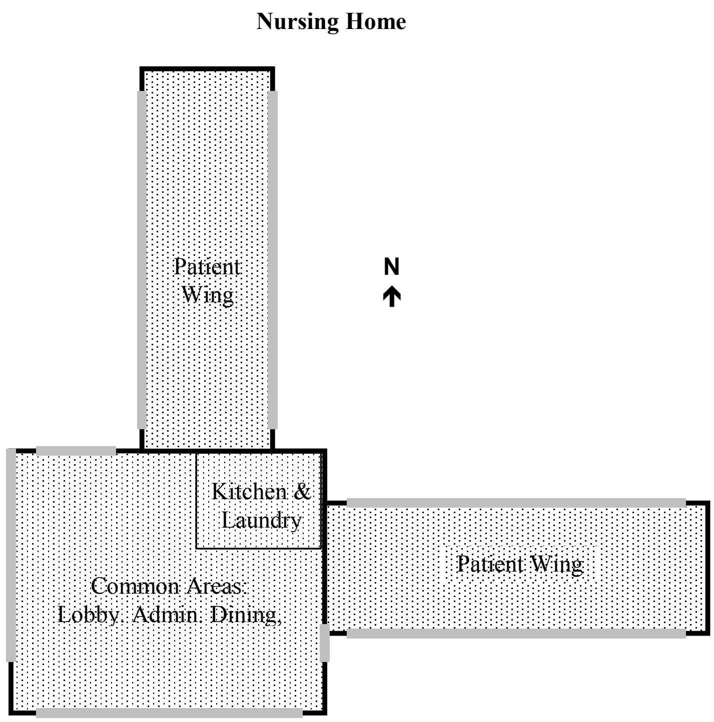


Figure 37: Layout of Typical Nursing Home

Office

The typical large office building (high-rise) characteristics are:

- Five-story (plus basement) window-wall construction.
- 75% wall glazing, 0º North orientation, and 10-foot floor height.
- Comfort control settings, schedules, and internal loads and ventilation values apply to 127,800 SF floor area.

- Building construction materials are: walls; 1-inch stone + 3-inch R-10 insulation, windows; double-pane tinted, roof; 4-inch LW concrete + 5.5-inch R-17 insulation, roof color - dark.
- Variable-volume chilled-water air-handling system using three water-cooled chillers; electric centrifugal inlet-vane control (0.68 kW/RT) each sized at 40% of building ASHRAE design point cooling capacity.
- System configured with temperature economizer.
- Cooling tower uses 1-speed fan with fixed temperature control at 85ºF.
- System does not use relief air heat recovery, direct-cooling option is not engaged, gas energy is used for heating.

Office – High-Rise

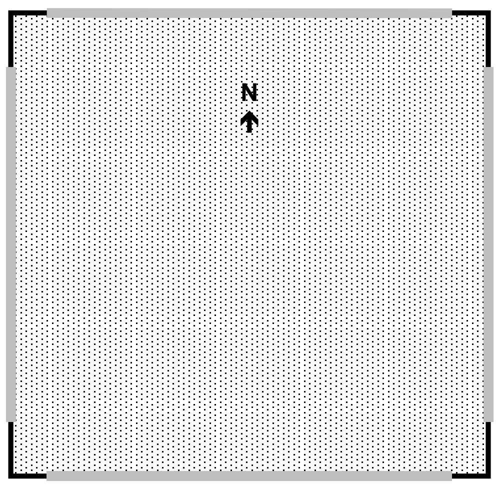


Figure 38: Layout of Typical Large Office Building

Retail

The typical large retail store characteristics are:

- One-story slab-on-grade construction, typical of a national-chain discount department store.
- 8% wall glazing, 0º North orientation, and 25-foot floor height.
- Comfort control settings, schedules, and internal loads and ventilation values apply to 125,000 SF floor area.
- Building construction materials are: walls; (default) – 4-inch brick + 2.5-inch R-7.5 insulation, windows; double-pane tinted, roof; plywood + 6-inch R-19 insulation, roof color – dark.

- Constant-volume chilled- air-handling water system using two water-cooled chillers: electric screw (0.84 kW/RT) each sized at 60% of building ASHRAE design point cooling capacity.
- System configured without economizer.
- Cooling tower uses 1-speed fan with fixed temperature control at 85ºF.
- System does not use relief air heat recovery, direct-cooling option is not engaged, gas energy used for heating.

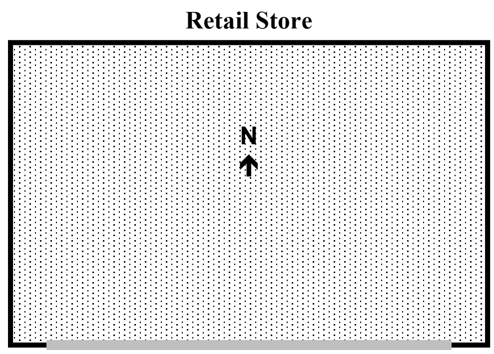


Figure 39: Layout of Typical Large Retail Store

School

The typical school characteristics are:

- Single-story slab-on-grade construction, typical of suburban secondary schools.
- 20% wall glazing, 0º North orientation, and 10-foot floor height.
- Building construction materials are: walls; 8-inch MW concrete + 3-inch R-10 insulation, windows; double-pane clear, roof; (default) plywood + 6-inch R-15 insulation, roof color - dark.
- Constant-volume chilled-water air-handling system using two water-cooled chillers: electric screw (0.84 kW/RT) each sized at 60% of building ASHRAE design point cooling capacity.
- System configured with temperature economizer.
- Cooling tower uses 1-speed fan with fixed-temperature control at 85ºF.
- System does not use relief air heat recovery, direct-cooling option is not engaged, gas energy used for heating, humidifier not used.

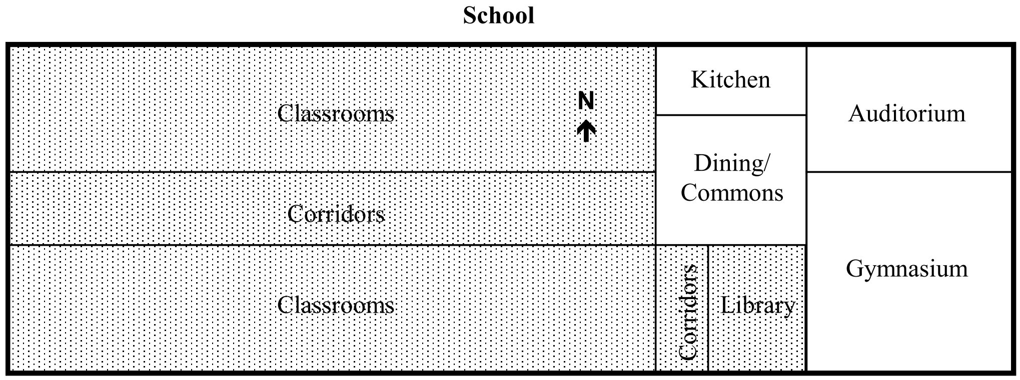


Figure 40: Layout of Typical School

The Conceptual Beta IES System

Sensitivity analysis of the data from the updated economic analysis indicated that a 615-kW IES would be too large to have satisfactory economics in a wide range of buildings in the market sub-segments being considered. It appeared that, in most applications, an optimal IES should be sized at about 50% to 75% of the peak electric demand of the targeted application. After analysis of the characteristics of various engine-generators, a Cummins 336-kW engine-generator was found to have optimal characteristics for use as a model for a second evaluation of IES economics.

A mass and heat balance of this new IES system was performed to determine the best match in absorption chiller hardware, allowing maximum recovery of available waste heat. Figure 41 is a diagram of the IES, showing placement and capacity of components, critical fluid and energy flows, and temperatures.

The engine characteristics fixed many of the IES design variables. To cool the engine adequately, the jacket coolant leaving the engine cannot be higher than 203ºF with a fixed flow of 69.7 lb/hr. Consequently, to remove engine heat, the returning water jacket coolant must be no hotter than 191ºF. Based on that and, assuming 4ºF water heat exchanger temperature approach, the hot water leaving the chiller can be no hotter than 187ºF.

An investigation of the performance characteristics and cost of absorption chillers suggested that the best option would be to use a conventional single-effect multi-pass absorption chiller. The chiller had to be derated to 62% of its rated capacity because it would be operated on 205ºF hot water rather than its 260ºF rated capacity activation temperature. (See Figure 42.)

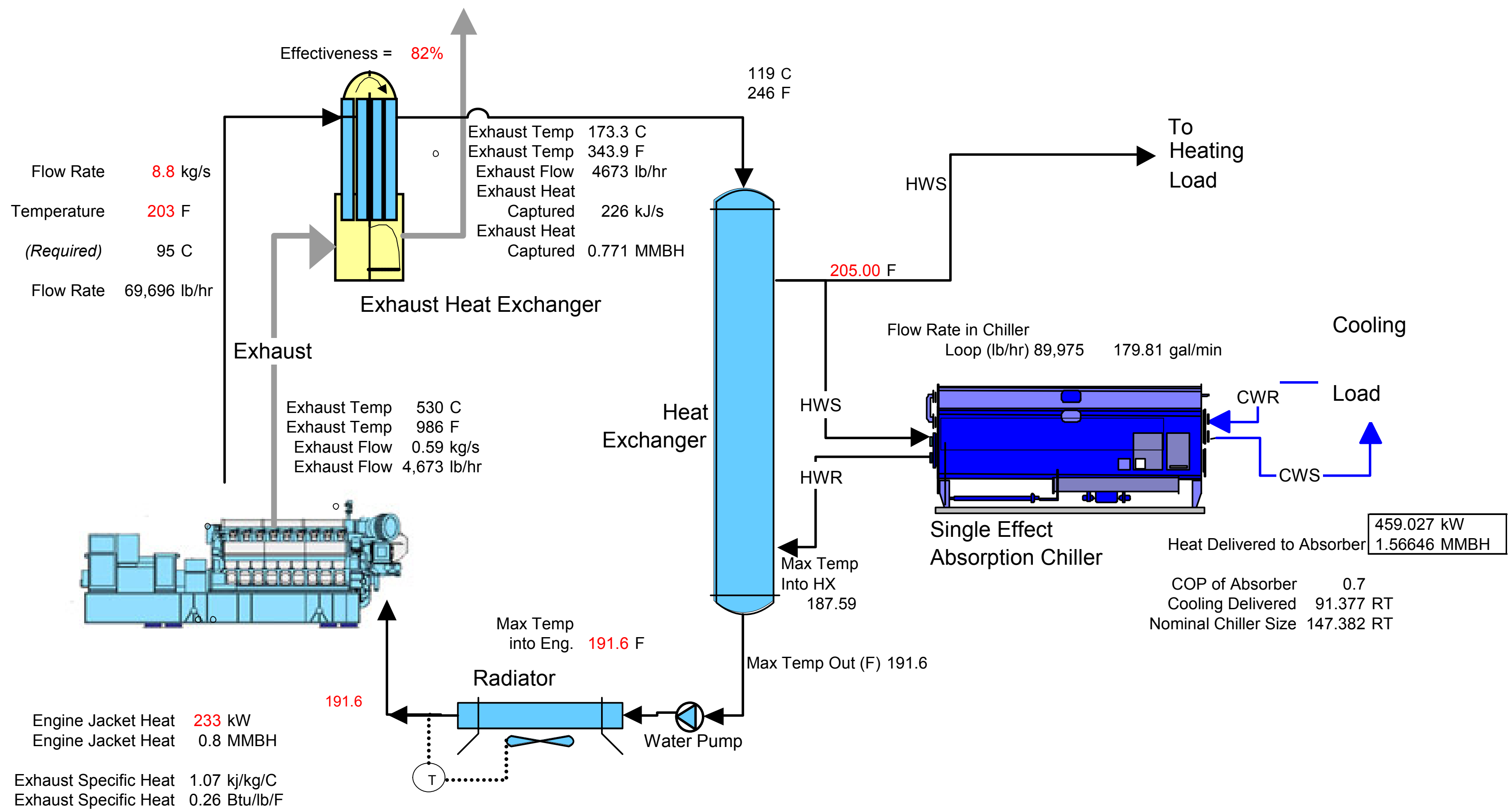


Figure 41: IES Concept Diagram

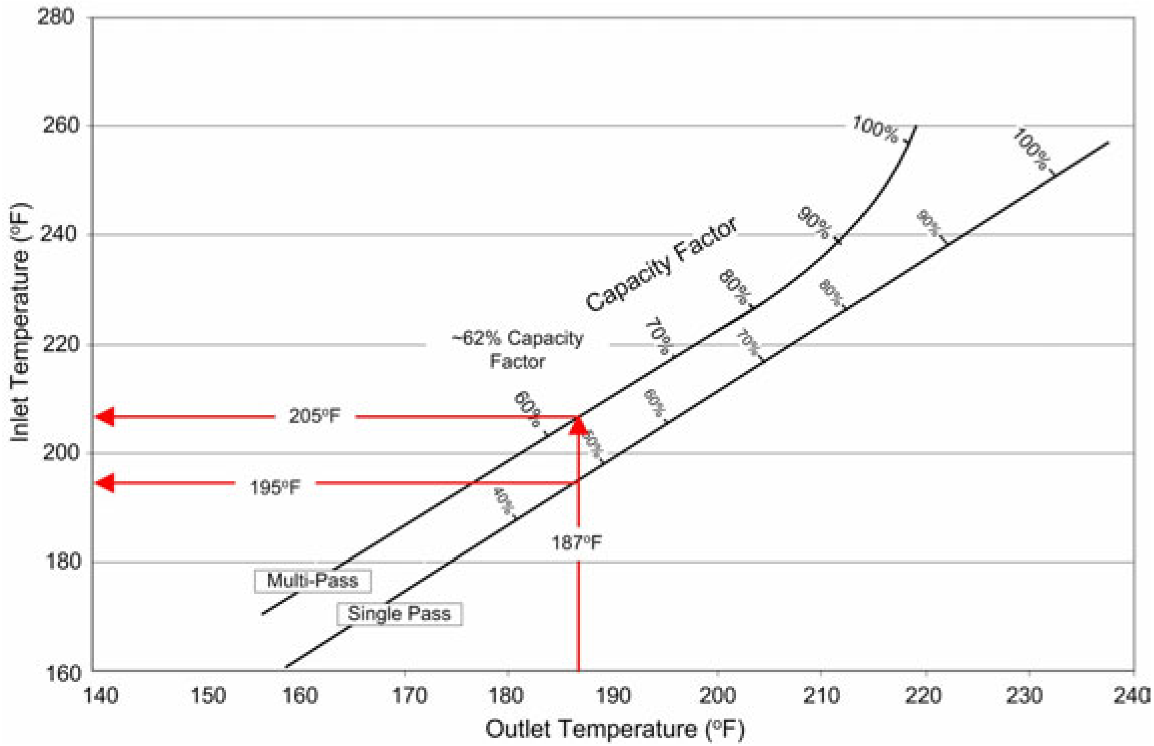


Figure 42: Typical Capacity De-Rating Factor for Single and Multi-Pass Single-Effect Absorption Chillers

These characteristics fixed the relationship between the capacities of the engine-generator and the chiller. A chiller matched to the 336-kW engine-generator would produce ~92 refrigeration tons (RT) of cooling. To accommodate the 62% derating, the chiller's rated capacity would have to be 147 RT. Based on these requirements, a commercially available York 155-RT unit was selected as one that was closest to the required nominal capacity of 147 RT. Its characteristics were used to model the IES chiller.

The chiller parasitic losses of chilled water, tower water, and hot water circuit pumps were modeled, using manufacturer's data (York Catalog Form 155.16-EG1).

Marley cooling tower model AV6231 performance and parasitic electric losses were modeled based on data from the manufacturer (Marley AV Series Cross-Flow Cooling Tower Engineering Data Catalog TECH-AV-01).

Cummins 336-kW engine-generator performance was modeled, using manufacturer-provided data (Cummins Gen-set Designation 334GFBA Data Sheet, 2004).

For modeling purposes, the following was assumptions were made as shown in Table 27:

Table 27: Engine-Generator Electrical Efficiency

Load, %	Electric Efficiency HHV, %	Fuel Heat Input, Btu/kW
100	31.08	10,978
75	30.35	11,242
50	28.19	12,104

Engine Generator Heat Recovery Effectiveness

- High-temperature recovery stream: 42.47% of total engine fuel heat input at 205ºF
- Low-temperature recovery stream: 6.5% of total engine fuel heat input at 118ºF

IES Electric Parasitic Power

- York 155-RT absorption chiller, 5.9 kW
- Cooling tower water pump, 15 ft H_2O, 3.6 gpm/RT, 82% efficient pump.
- Cooling tower fans, 15 HP, 87%-efficient motor, serving 91 RT from de-rated 1A2 155-RT absorption chiller.
- One 6-HP heat recovery system pump, operating continuously.

Costs

To evaluate the economic benefits, a set of estimated first/installed costs of the equipment was developed, based on updated information from equipment manufacturers. Figure 43 shows the specific cost of single-stage absorption chillers, including the costs of piping and cooling towers. Table 28 shows the aggregated installed costs of IES with and without an absorption chiller. The cost includes selective catalytic reduction emissions controls sufficient to meet emissions standards for California and New York.

O&M cost was $ 0.011 per kWh, including O&M for the emissions control system.

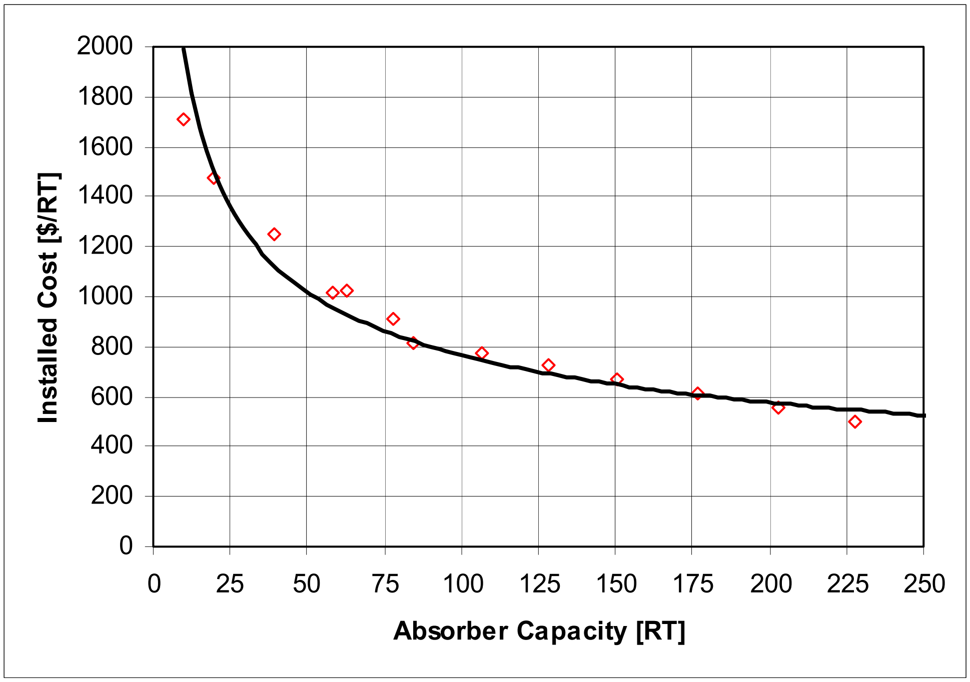


Figure 43: Specific Cost of a Single-Stage Absorption Chiller, Including Costs of Piping and Cooling Tower

Table 28: Installed Cost of IES Components

IES Capacity, kW	Cost of Engine/ Generator/ Heat Recovery	Cost of Chiller	Total Installed Cost
136	$322,886	$46,976	$380,475
236	526,318	62,278	604,872
336	700,950	71,110	793,278
436	846,782	75,473	947,918
536	963,814	76,414	1,069,954
636	1,052,046	74,579	1,160,106
736	1,111,478	70,408	1,218,862
836	1,142,110	64,222	1,246,579
936	1,143,942	56,263	1,243,524

Modeling

Modeling of the energy requirements of the five typical buildings in both New York and San Diego was based on the TMY2 Weather Database (DOE2.1E). Depending on the application's electric demand, up to nine IES capacities (136, 236, 336, 436, 536, etc kW) were modeled for each of the 10 building-location combinations.

For each combination of building type, location (climate), and IES capacity, an optimal balance between purchased power and self-generated power capacity was calculated, and an optimal IES operational control strategy was determined.

The modeled generator deployment control strategy was to follow the application's electric load profile. A generator could follow the electric load down to a minimum of 35% of the generator's nominal installed capacity.

The generator operating hours were optimized to achieve the highest annual energy cost savings for the building. Consequently, the generator operating hours varied, depending on the location, local utility rates, and the type of application being modeled. Several different generator control strategies were examined for each modeled case:

- Generating electricity during the electric utility energy on-peak hours.
- Generating electricity during the electric utility demand on-peak hours.
- Generating electricity during the electric utility energy on-peak and mid-peak hours.
- Generating electricity during all hours that the building operated and the electric demand exceeded generator minimum part load capacity of 35% of nominal IES installed kW.

Three configurations of engine heat recovery were considered. Heat was recovered for space heating, domestic hot water heating, and for driving a single-stage absorption chiller. The three heat-recovery configurations were:

- Recovery for space heating, domestic hot water heating, and for driving a single-stage absorption chiller (HT+DHW+ABS). Heat recovered from the IC engine was passed to a single-stage absorption chiller if a cooling load was present, then to the space heating/reheating load and the domestic hot water load. Unused heat was rejected to the atmosphere. The absorption chiller was sized to match the recoverable heat from the engine at full rated electrical output. Only that portion of the recoverable heat that was available at temperatures higher than the minimum required for driving single-stage absorption, was used to size and drive the chiller. The actual cooling capacity of the absorption chiller depended on the available recoverable heat. If needed, the remaining building cooling load was satisfied by a standard electric AC system comprised of either a 0.68 kW/RT centrifugal chiller, or a 0.84 kW/RT screw compressor chiller (depending on the application).
- Recovery for space heating and domestic hot water only (HT+DHW). Recovered heat offset the heating load that would otherwise have been satisfied by an 82%-efficient natural gas heater/boiler. Unused heat was rejected to the atmosphere.
- No heat recovery from the IES (NO HEAT REC.). All heat was rejected to the atmosphere.

York YIA-ST 1A2 absorption chiller performance was modeled using manufacturer-provided performance data. The system was modeled assuming the hot water temperature entering the chiller to be 205ºF. Chiller rating point cooling capacity and cooling COP as functions of cooling tower water temperature were modeled using the test data presented in Figure 44.

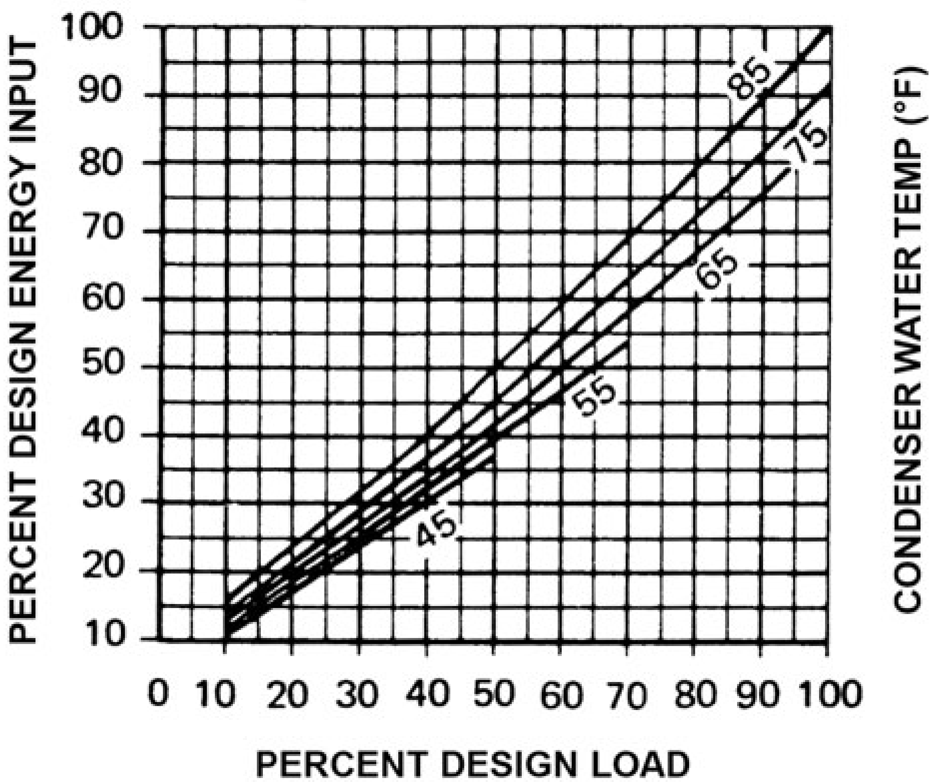


Figure 44: Part-Load Performance Characteristics of Modeled Absorption Chiller

Local electric rates for San Diego and New York were used, and a fixed natural gas price of $6/MMBtu was used for all analyses. Later, sensitivity to a range of gas prices ($5, $7, and $9/MMBtu) was calculated. Actual gas prices have been volatile. According to data published by the Energy Information Administration,[21] industrial market gas prices in California averaged $7.19/MCF in 2003 and $7.95/MCF in 2004[22], and were $8.75/MCF in May 2005. Industrial market gas prices in New York averaged $7.35/MCF in 2003 and $8.68/MCF in 2004, and were $10.34/MCF in May 2005.

These high gas prices are retarding the adoption of integrated energy systems, but this situation is, hopefully, temporary. Projections by the Energy Information Administration[23] indicate that

---

[21] www.eia.gov/emeu/states/ngprices/

[22] These figures are based on gas rates to industrial customers, in keeping with EIA's classification of self-generation and CHP as industrial uses.

[23] Energy Information Administration, "Annual Energy Outlook 2005," Table A3.

gas prices are moderating and will return to the $5/MMBtu level within the next five years, as shown in Table 29. Many gas companies now recognize the benefits of IES to their load-leveling efforts, since demand for gas by IES systems is highest when overall demands for natural gas are lowest. In one example, the New York Public Service Commission has mandated that IES installations receive favorable rate treatment by gas companies.[24]

Table 29: EIA Projection of Gas Costs to Industrial Gas Consumers (2002$)

Year	Gas Cost, $/MCF
2002	3.89
2003	5.86
2010	4.37
2015	4.82
2020	5.23
2025	5.47

Realistic equipment installed costs were used to calculate simple payback times and life-cycle cost savings.

Electric Rates

San Diego, California

One electric rate, SDG&E AL-TOU_DER + EECC (1/22/04) was used during analysis of the San Diego location. (See Table 30.) Because the engine is clean-burning, there is no standby rate.

The optimal IES control strategy was to run it 24/7, whenever the application's electric power requirements exceeded 35 % of the generator's rated capacity.

[24] State of New York Public Service Commission, Case 02-M-0515 Order Providing for Distributed Generation Gas Service Classifications, Issued and Effective April 24, 2003.

Table 30: Electric Rate for San Diego

	SDG&E AL-TOU_DER + EECC 01/22/2004	
	Summer Months	Winter Months
	05 to 09 (inclusive)	10 to 04 (inclusive)
	Time (on-peak, mid-peak, off-peak)	
On-peak	11 to 18	17 to 20
Mid-Peak	6 to 11 and 18 to 22	6 to 17 and 20 to 22
Off-Peak	22 to 6	22 to 6
	Energy Cost $/kWh	
On-peak	0.10786	0.10691
Mid-Peak	0.08143	0.08145
Off-Peak	0.08071	0.08074
	Demand Charges $/kW	
On-peak	5.59	3.83
Mid-Peak	0	0
Off-Peak	0	0
Standby	0	0
**Non-Coincident	11.58	
	Customer Charge $/meter/month	
	48.52 (<500kW) and 194.06 (>500kW)	

**Higher of Actual or Ratcheted 50% from last 12 months

(NOTE - No standby charge – based on Ultra Clean DG. Cost of emission control should be included in the first/installed cost)

** Applied to the customer's loads served by the customer's generator, as measured by the generator net output meter.

New York, New York

Two different electric rates ConEd SC9 Rate 1 (<1500 kW, 5/1/2005) and ConEd 14-RA Standby (<1500 kW, 5/1/2005), were used. (See Table 31 and Table 32.)

The optimal IES control strategy was to run it 24/7, whenever the application's electric power requirements exceeded 35% of the generator's rated capacity.

Table 31: Electric Rate for New York Baseline Runs

	ConEd SC9 Rate I (<1500 kW)	
	Winter Months	Summer Months
	11 to 4 (inclusive)	5 to 10 (inclusive)
	Energy Cost $/kWh	
	0.1053	0.1053
	Demand Charges $/kW	
First 900 kWs	21.36	24.04
Over 900 kW	20.06	22.74
	Customer Charge $/meter/month	
	0.00	

(NOTE – ConEd SC 9 rate energy cost changes slightly from month to month and is not published for the entire year ahead of time. The above May 2005 energy cost structure was used uniformly for all 12 months of the simulation process.

Table 32: Electric Rate for New York DG Alternative Runs

	ConEd SC14 Standby Service SC9 Rate I (<1500 kW)	
	Winter Months	Summer Months
	11 to 4 (inclusive)	5 to 10 (inclusive)
	Energy Cost $/kWh	
	0.1053	0.1053
	Demand Charges $/kW	
Contract $/kW	3.89	3.89
8am to 6pm*	0.0000	0.2893
8am to 10pm**	0.3454	0.5736
	Customer Charge $/meter/month	
	62.88	

*As-used daily Monday - Friday only (Transmission)

**As-used daily Monday - Friday only (Distribution)

(NOTE – ConEd SC 14 rate energy cost changes slightly from month to month and is not published for entire year ahead of time. The above May 2005 energy cost structure was used uniformly for all 12 months of the simulation process.

Results of the Analysis

Figure 45 through Figure 84 show the results of the modeling of economic performance of typical buildings for the five modeled applications in San Diego and New York. Each page contains four charts, showing:

- Total present worth of the IES to the customer, based on life-cycle cost savings.
- Predicted use of thermal energy by the typical building, as a percentage of the total heat available from the IES. The prediction is based on the building's modeled energy requirements.
- Simple payback, based on a natural gas cost of $6.00/MMBtu.
- Sensitivity of simple payback to natural gas prices.

The independent parameter in all four charts is the IES capacity.

The first chart in each series of four charts shows the total present worth of an IES installation as a function of IES capacity.

The life-cycle cost analysis used the following parameters:

- Study period 10 years
- Depreciation period* 10 years
- Finance period 7 years
- % financed 80%
- Financing interest rate 8%
- Cost of capital 8%
- Tax rate 15%
- Electric rates inflation 2%/year
- Gas rates inflation 2%/year
- O&M cost inflation 2%/year

* Straight-line depreciation for both book and tax purposes.

In the chart legends, the following abbreviations are used:

- NO HEAT REC: A distributed generation system with no heat recovery.
- HT + DHW: Heat recovered only for space heating and domestic hot water.
- HT + DHW + ABS: Heat recovered for space heating, domestic hot water heating, and powering an absorption chiller.

Payback time is often used as an indication of whether an IES project is economically feasible, but payback time is only a very preliminary screening value, and the choice of optimum IES capacity for an installation would normally be based on a present worth calculation. For example, although Figure 47 indicates that a 336-kW IES system with a chiller would have the shortest payback time for a typical hotel in San Diego, Figure 45 shows that the maximum total present worth of a 536-kW IES would be $160,000 higher than that of a 336-kW IES.

The second chart in a series shows the annual heat recovery effectiveness as a function of IES capacity. The effectiveness is the amount of heat that would be recovered for use in the building divided by the total amount of heat generated by the IES when the IES is operating to fulfill the power needs of the building. The annual heat recovery effectiveness gives an indication of the extent to which the application makes use of the available heat from the IES. For example, Figure 46 shows that a typical San Diego hotel would use nearly all of the heat provided by any size of IES equipped with a corresponding absorption chiller, while it would use relatively little of the heat if it were not equipped with a chiller.

The third chart in each series shows how estimated simple payback time depends on IES capacity. The figure headings show the annual electric power demand (kW) of the building. For example, the San Diego hotel has an annual demand of 736 kW. It is not surprising that Figure 47 shows long payback times for an 836-kW IES, because the IES is clearly oversized.

The fourth chart in each series shows the sensitivity of simple payback time to natural gas prices in the range of $5 to $9/MMBtu.

The Value of Using Absorption Chillers

Figure 45 through Figure 84 show that equipping IES systems with absorption chillers improves their economics for all five typical buildings in San Diego. Table 33 summarizes this observation for San Diego sites, showing the total present worth[25] (TPW) of an optimal-size IES with an absorption chiller and comparing it to the TPW of an IES used only for space and water heating. Table 34 shows comparable information for New York. The tables show that the TPW of optimal-size IES in the typical New York buildings is much higher than in San Diego. However, there is much less inducement to add absorption chillers in New York. The difference between the two cities reflects the difference in electric power rates and relatively lower air conditioning loads in New York.

[25] Total present worth calculations are based on natural gas costs of $6.00/MMBtu.

Table 33: Financial Value of Adding an Absorption Chiller to an IES in San Diego

Typical Building	IES Capacity, kW	TPW, No Chiller, $K	TPW with Chiller, $K	Improvement Due to Chiller, %
Large hotel	536	531	871	64
Nursing home	236	115	204	77
Large office	436	117	354	203
Large retail	336	62	305	392
Large school	336	126	202	60

Table 34: Financial Value of Adding an Absorption Chiller to an IES in New York

Typical Building	IES capacity, kW	TPW, no Chiller, $K	TPW with Chiller, $K	Improvement Due to Chiller, %
Large hotel	636	2,317	2,471	7
Nursing home	236	766	809	6
Large office	336	996	1,062	7
Large retail	436	1,209	1,350	12
Large school	336	1,098	1,058	-4

Value of Heat Recovery

The charts for New York (Figure 65 through Figure 84) show clearly that payback period alone should not be used to select an optimal IES capacity. Although the charts indicate that the smallest systems have the shortest payback times, the maximum cost savings (TPW) are much higher for larger IES capacities.

The New York charts appear to show that there is little sensitivity to gas prices. However, this is a visual effect. The relative increases in payback time with increasing gas price are nearly the same in New York and San Diego.

All charts show that adding an absorption chiller to an IES would substantially increase its annual heat recovery effectiveness (and, therefore, its overall energy efficiency).

Table 35 and Table 36 compare the total present worth and simple payback time of IES with an absorption chiller to distributed generation systems with no heat recovery. The improvement in total present worth due to heat recovery is higher in New York than in San Diego.

Table 35: Financial Value of Heat Recovery to DG Systems in San Diego[26]

	DG, No Heat Recovery			IES with Chiller		
Typical Building	**Optimal Capacity, kW**	**TPW, $K**	**Simple Payback, Years**	**Optimal Capacity, kW**	**TPW, $K**	**Simple Payback, Years**
Large hotel	550-650	200-300	7	450-650	820-840	5
Nursing home	--	<0	9	200-280	170-200	7
Large office	400-550	100-120	8	380-480	320-350	6.5
Large retail	330-470	50-80	8	300-420	270-300	6.5
Large school	300-400	<10	8.5	260-430	150-200	7

Table 36: Financial Value of Heat Recovery to DG Systems in New York[26]

	DG, No Heat Recovery			IES with Chiller		
Typical Building	**Optimal Capacity, kW**	**TPW, $K**	**Simple Payback, Years**	**Optimal Capacity, kW**	**TPW, $K**	**Simple Payback, Years**
Large hotel	550-750	1,700-1,800	3.5	450-750	2,400-2,500	3
Nursing home	200-350	480-500	5	200-300	750-800	4
Large office	250-450	900-950	4	200-450	1,000-1,050	4
Large retail	450-650	1,00-1,020	4.5	350-650	1,200-1,350	4
Large school	150-350	900-950	3	150-400	1,050-1,l00	3

Source Energy Savings

Table 37 and Table 38 Show the source energy (fuel used at the building and fuel used to generate central electric power) savings that would occur if optimal-size IES, with absorption chillers, were installed in the typical buildings. The data show the considerable source energy savings that would result from successful implementation of typical integrated energy systems. Savings would be even greater with ARES engine performance.

[26] Based on a natural gas price of $6.00/MMBtu.

By all of the measures shown in Table 35 through Table 38, total present worth, simple payback, and source energy conservation, of the five typical building types, large hotels offer the best prospects for IES, in both San Diego and New York.

Table 37: Performance of Optimally Sized IES in San Diego

Typical Building	Optimal Capacity	Annual Heat Recovery Effectiveness	Utilized Recoverable Heat	Source Energy Used without IES	Source Energy Used with IES	Source Energy Savings	Source Energy Savings
	kW	%	Thousand Btu/SF/year				%
Large hotel	536	96	154	219	196	23	10
Nursing home	236	93	61	197	182	15	8
Large office	436	94	62	156	145	11	7
Large retail	336	66	67	239	233	6	3
Large school	336	91	47	181	168	13	7

Table 38: Performance of Optimally Sized IES in New York

Typical Building	Optimal Capacity	Annual Heat Recovery Effectiveness	Utilized Recoverable Heat	Source Energy Used without IES	Source Energy Used with IES	Source Energy Savings	Source Energy Savings
	kW	%	Thousand Btu/SF/year				%
Large hotel	636	95	161	253	215	38	15
Nursing home	236	95	63	241	213	28	12
Large office	336	71	42	157	150	7	4
Large retail	536	65	78	278	250	28	10
Large school	236	90	36	247	223	24	10

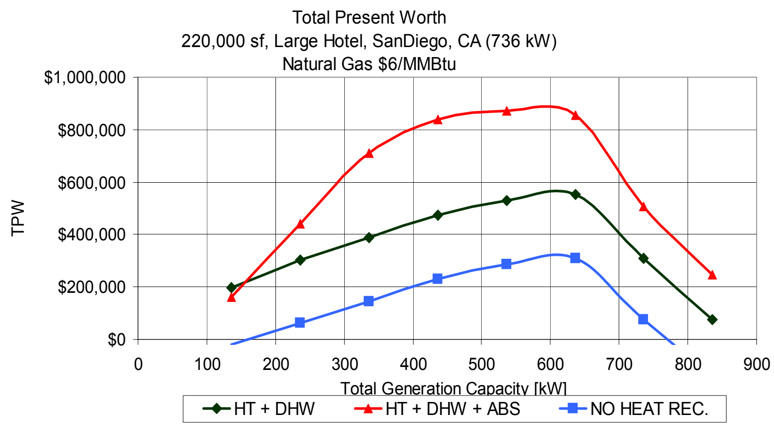


Figure 45: Total Present Worth – Large Hotel in San Diego

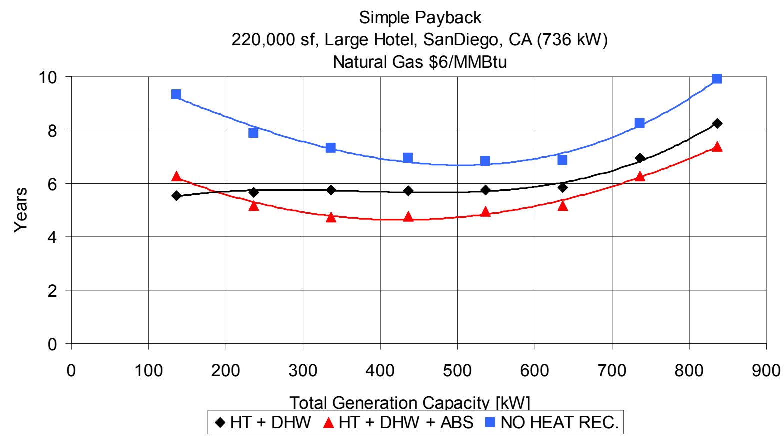


Figure 47: Simple Payback – Large Hotel in San Diego

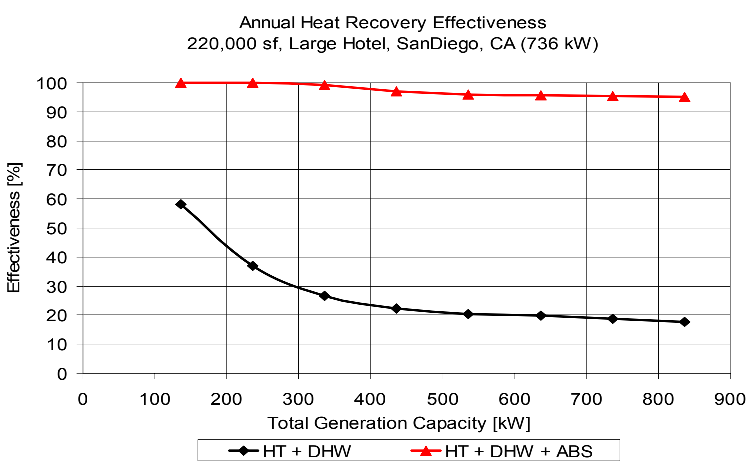


Figure 46: Annual Heat Recovery Effectiveness – Large Hotel in San Diego

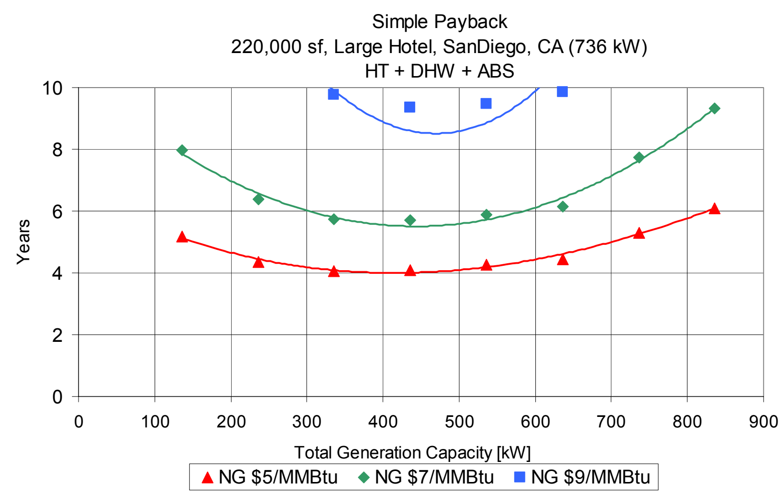


Figure 48: Gas Price Sensitivity – Large Hotel in San Diego

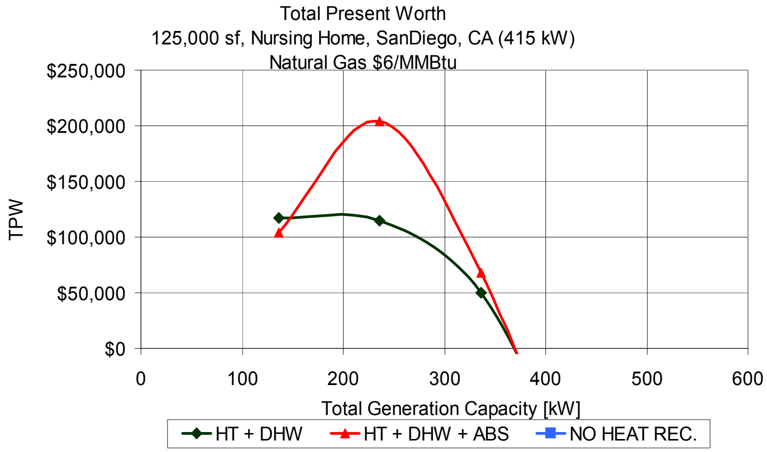


Figure 49: Total Present Worth– Nursing Home in San Diego

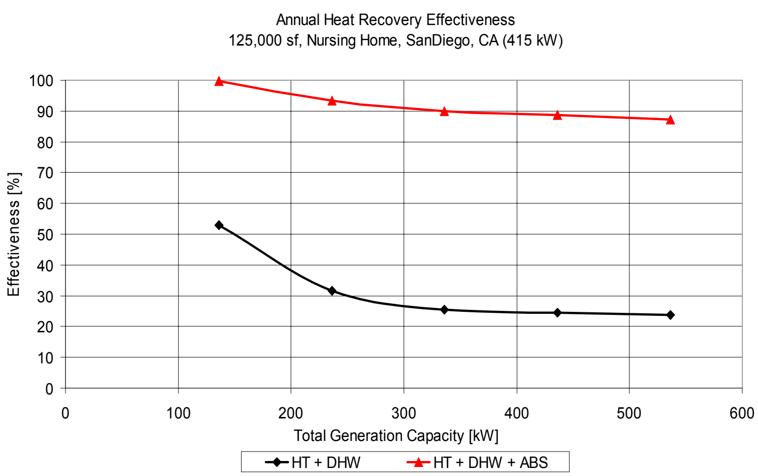


Figure 50: Annual Heat Recovery Effectiveness – Nursing Home in San Diego

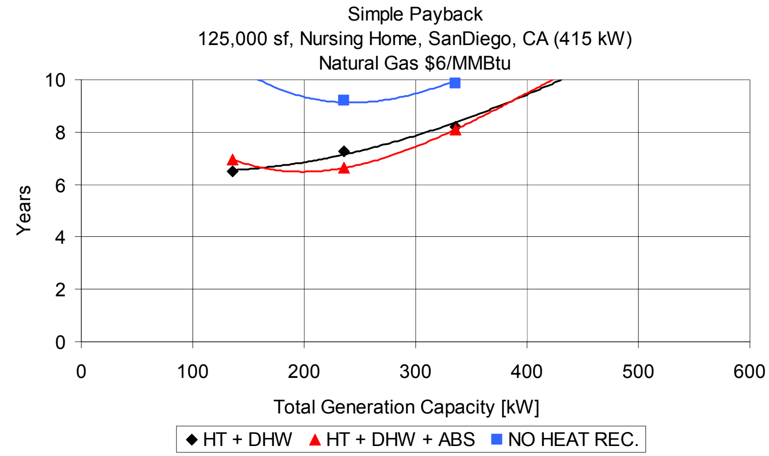


Figure 51: Simple Payback – Nursing Home in San Diego

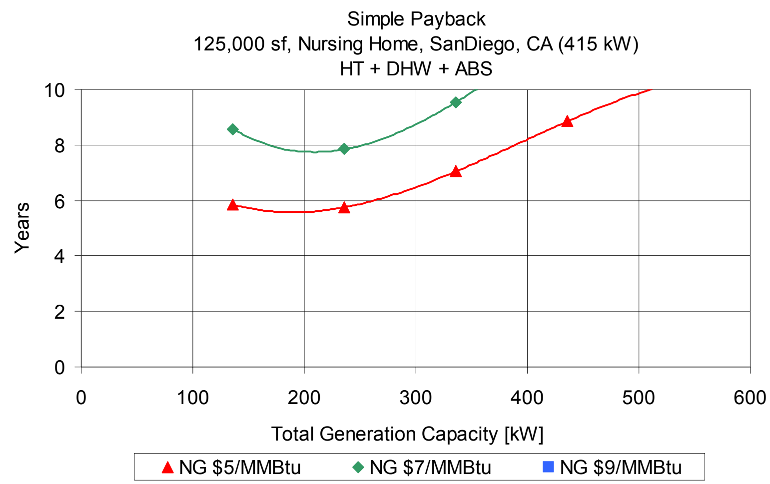


Figure 52: Gas Price Sensitivity – Nursing Home in San Diego

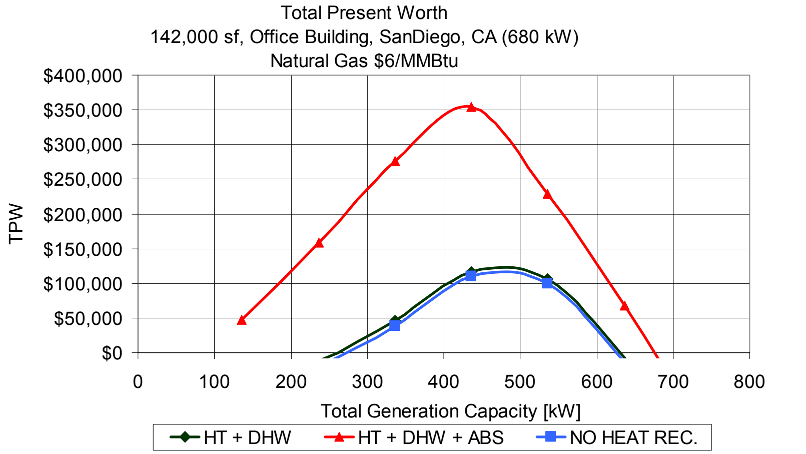


Figure 53: Total Present Worth – Large Office Building in San Diego

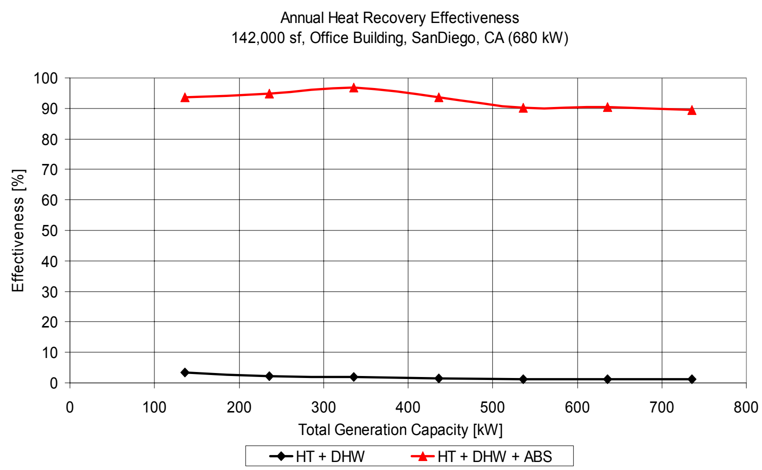


Figure 54: Annual Heat Recovery Effectiveness – Large Office Building in San Diego

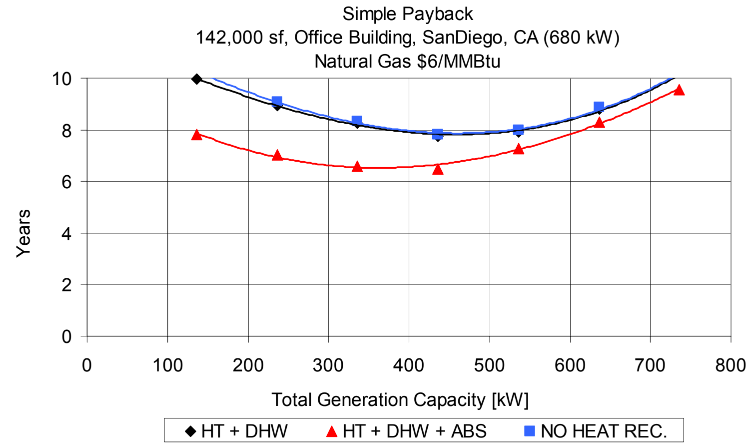


Figure 55: Simple Payback – Large Office Building in San Diego

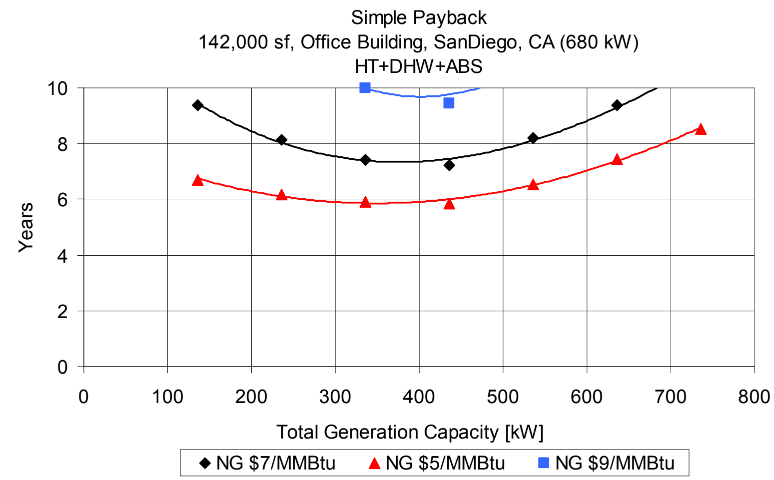


Figure 56: Gas Price Sensitivity – Large Office Building in San Diego

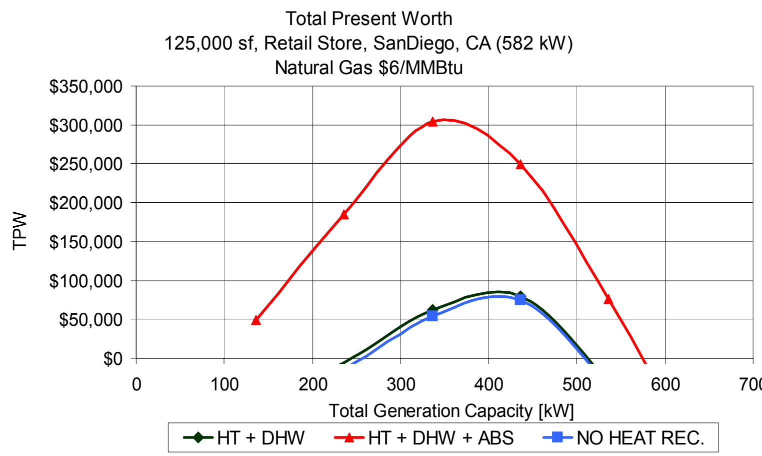


Figure 57: Total Present Worth – Large Retail Store in San Diego

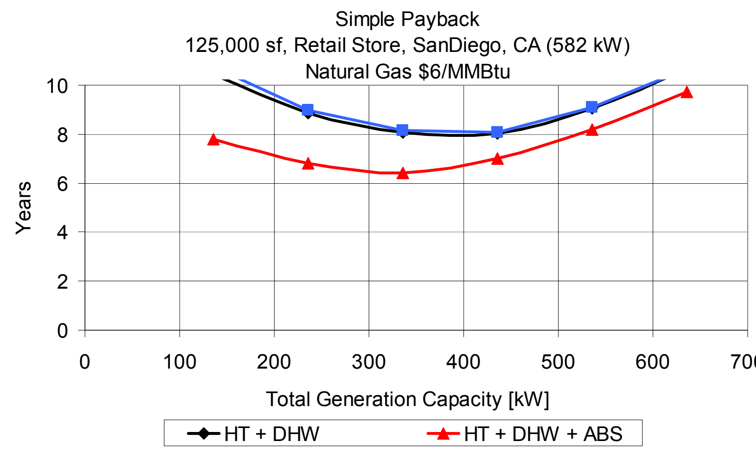


Figure 59: Simple Payback – Large Retail Store in San Diego

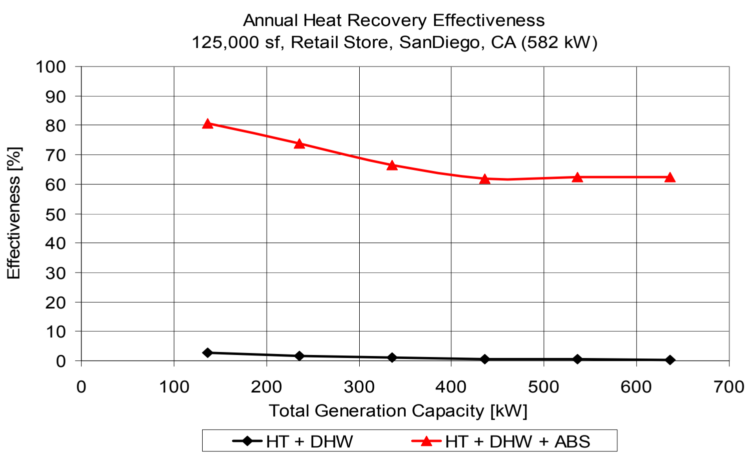


Figure 58: Annual Heat Recovery Effectiveness – Large Retail Store in San Diego

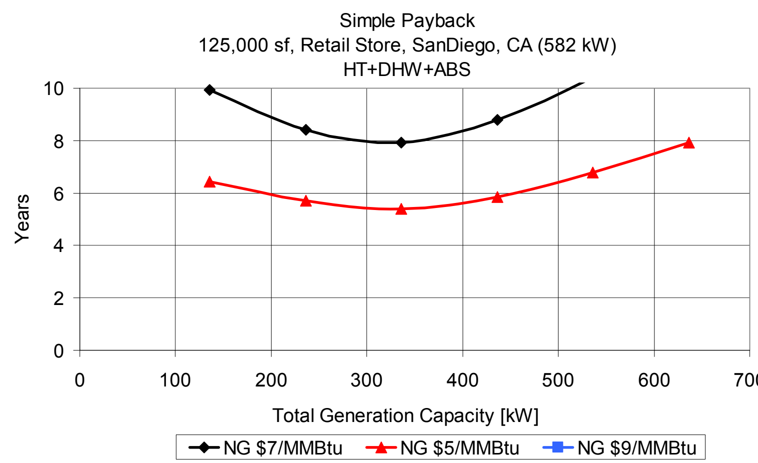


Figure 60: Gas Price Sensitivity – Large Retail Store in San Diego

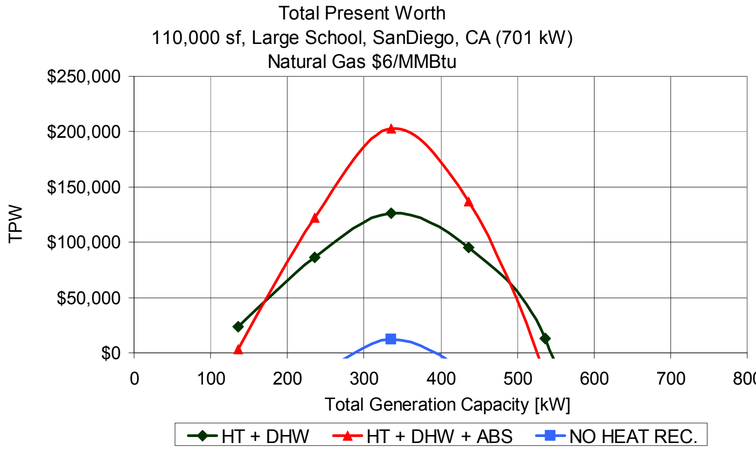


Figure 61: Total Present Worth – Large School in San Diego

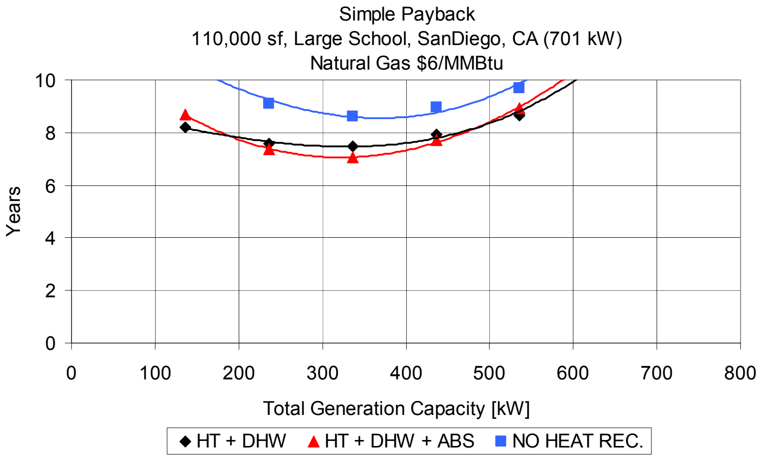


Figure 63: Simple Payback – Large School in San Diego

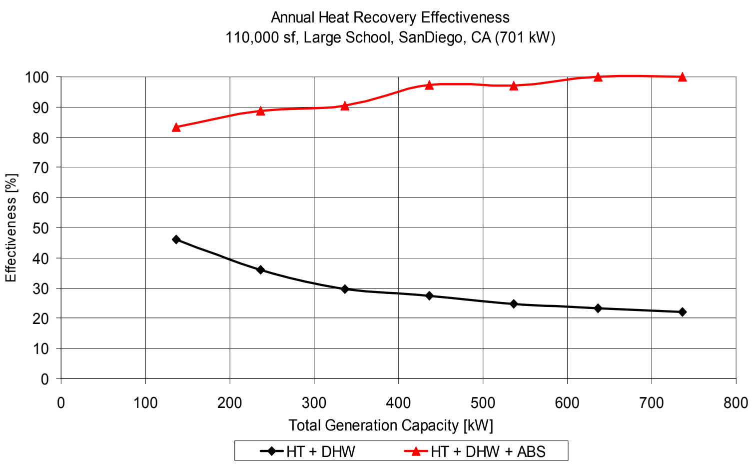


Figure 62: Annual Heat Recovery Effectiveness – Large School in San Diego

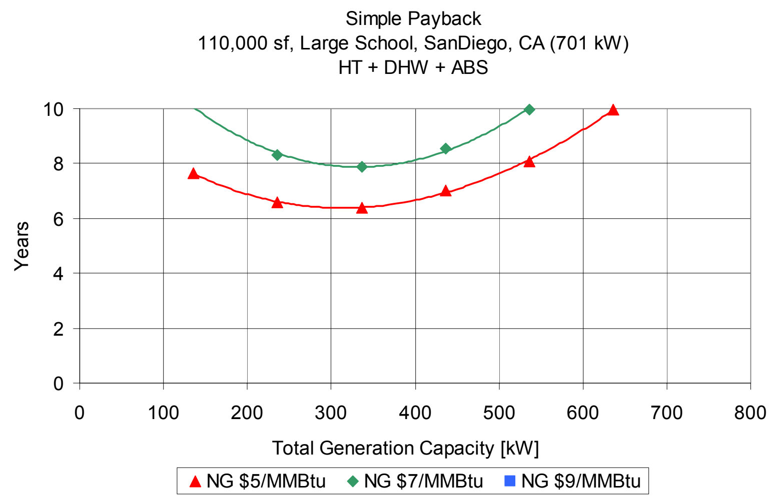


Figure 64: Gas Price Sensitivity – Large School in San Diego

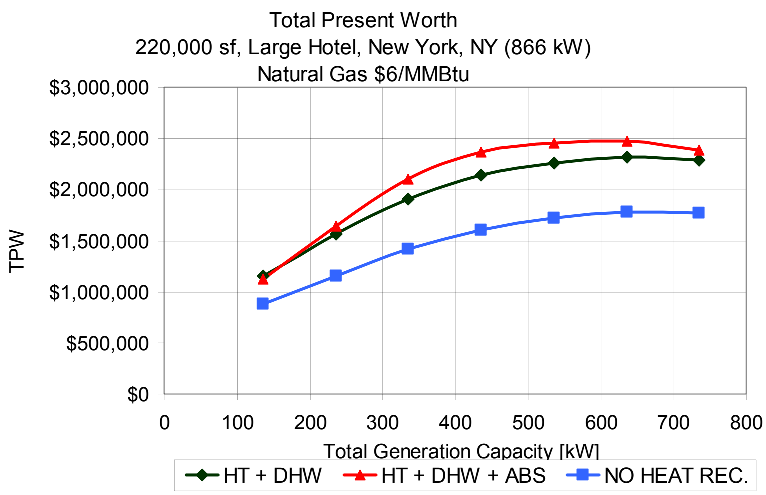


Figure 65: Total Present Worth – Large Hotel in New York

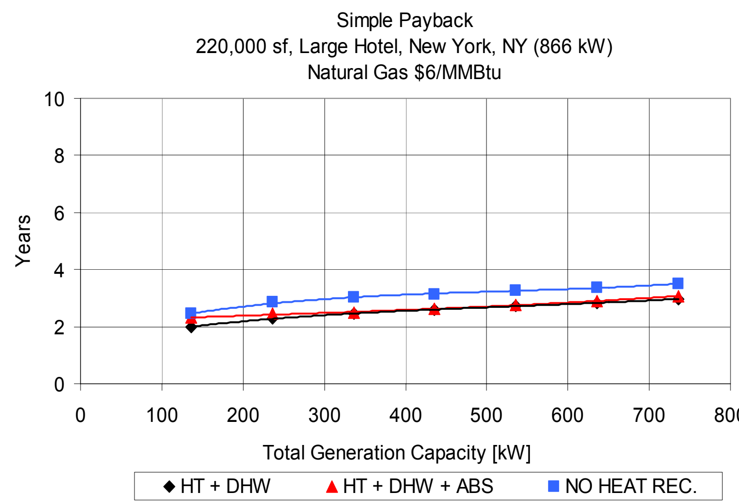


Figure 67: Simple Payback – Large Hotel in New York

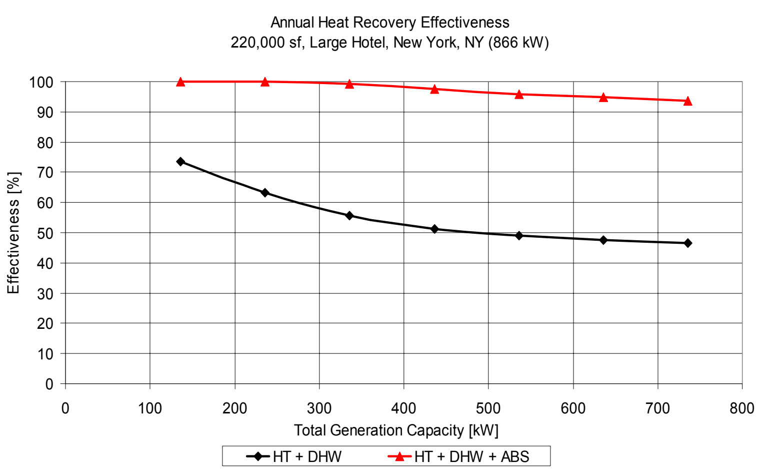


Figure 66: Annual Heat Recovery Effectiveness – Large Hotel in New York

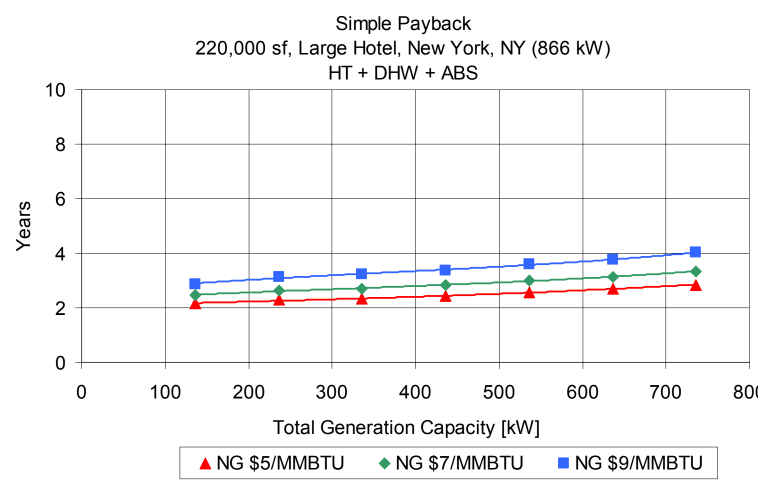


Figure 68: Gas Price Sensitivity – Large Hotel in New York

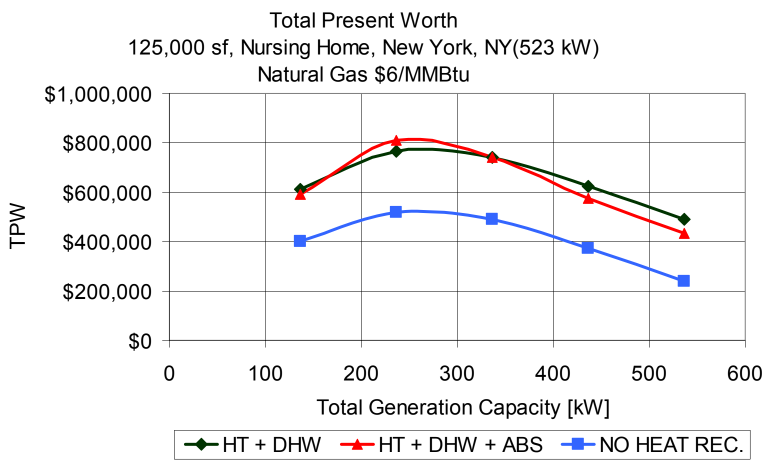


Figure 69: Total Present Worth – Nursing Home in New York

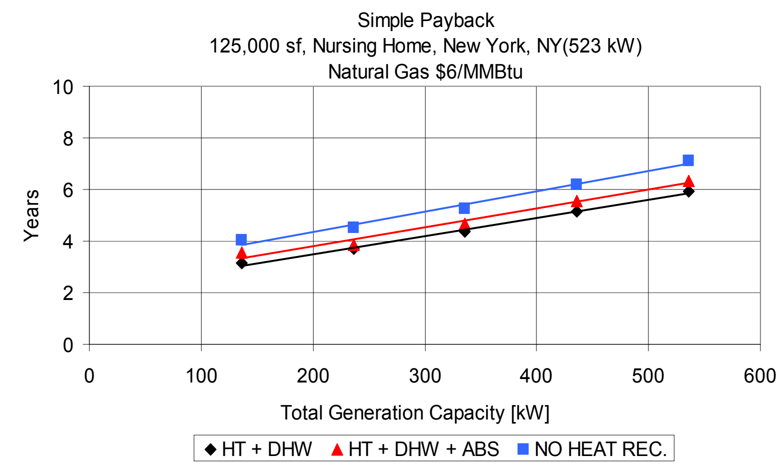


Figure 71: Simple Payback – Nursing Home in New York

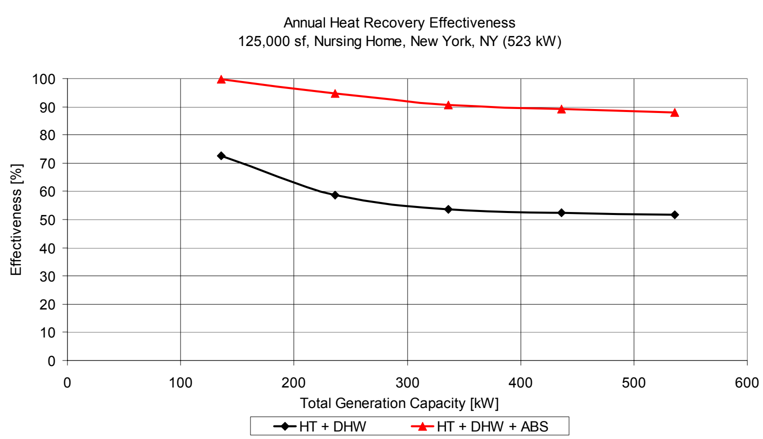


Figure 70: Annual Heat Recovery Effectiveness – Nursing Home in New York

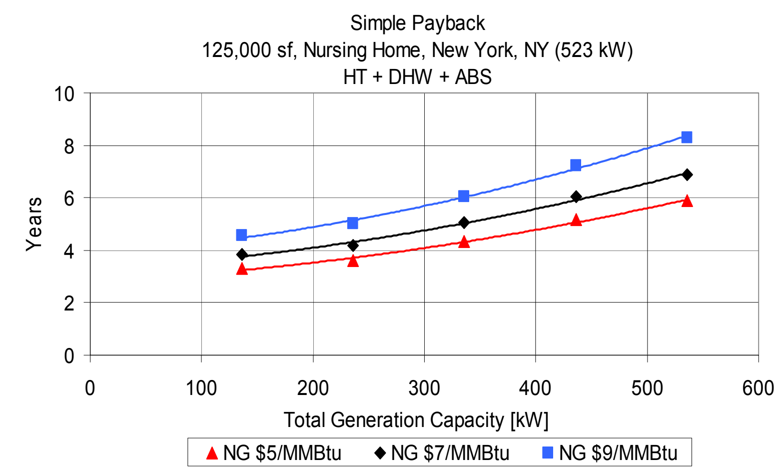


Figure 72: Gas Price Sensitivity – Nursing Home in New York

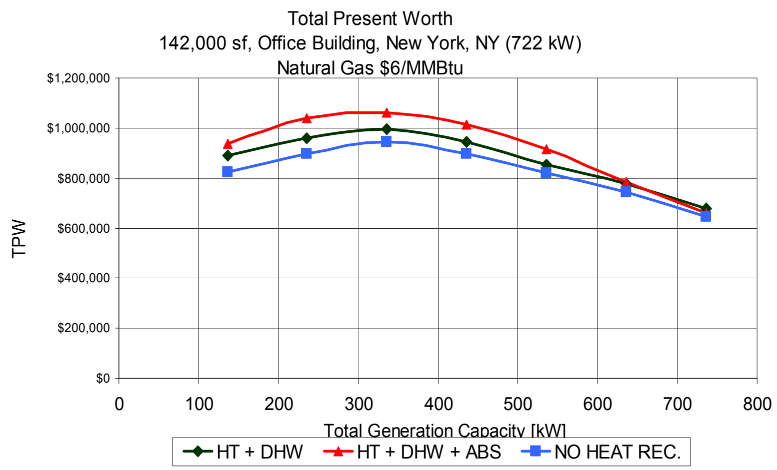


Figure 73: Total Present Worth – Large Office Building in New York

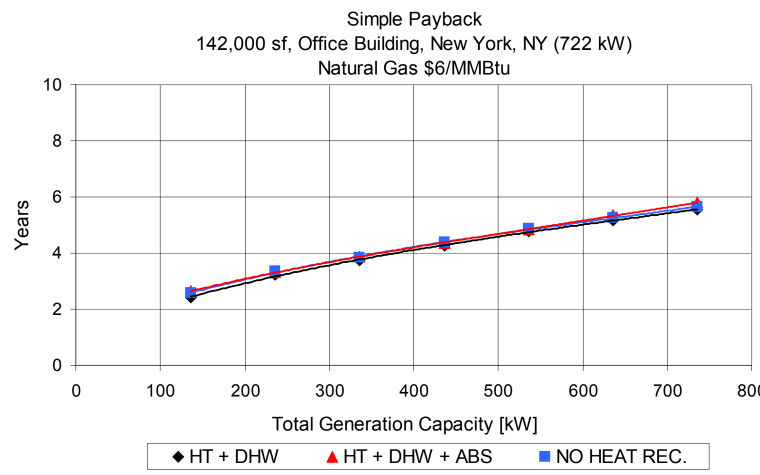


Figure 75: Simple Payback – Large Office Building in New York

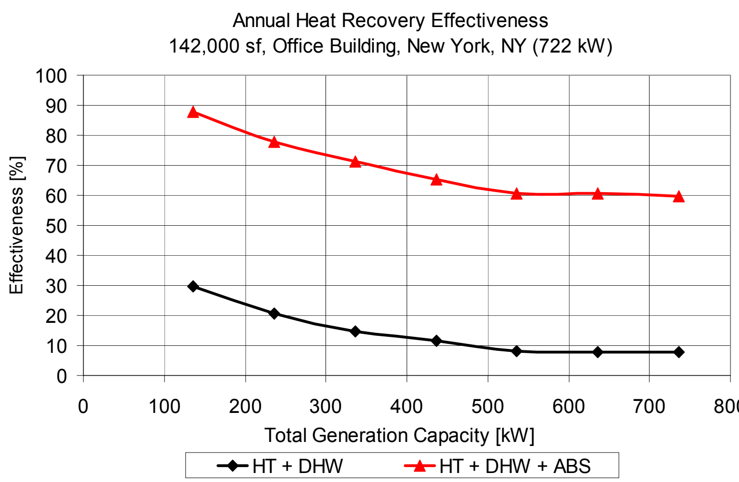


Figure 74: Annual Heat Recovery Effectiveness – Large Office Building in New York

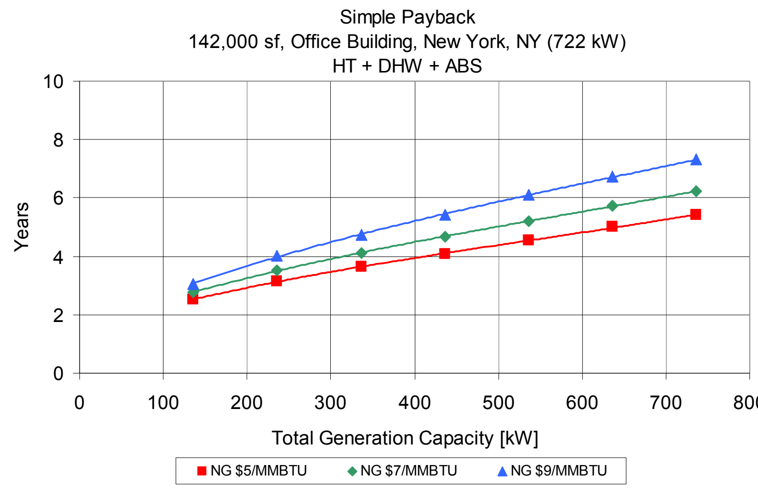


Figure 76: Gas Price Sensitivity – Large Office Building in New York

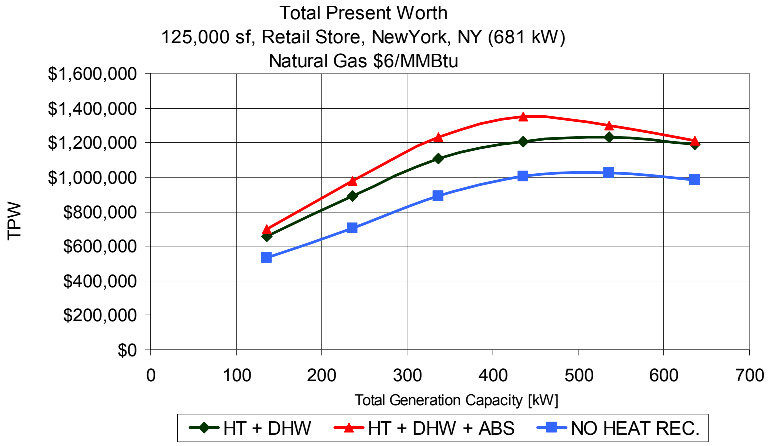


Figure 77: Total Present Worth – Large Retail Store in New York

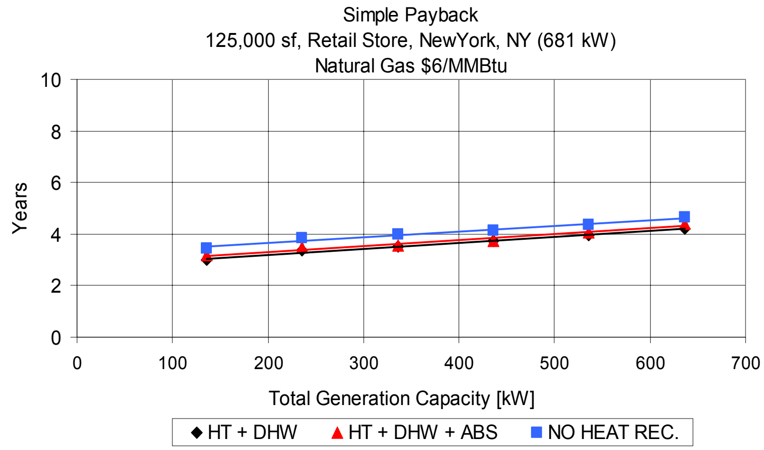


Figure 79: Simple Payback – Large Retail Store in New York

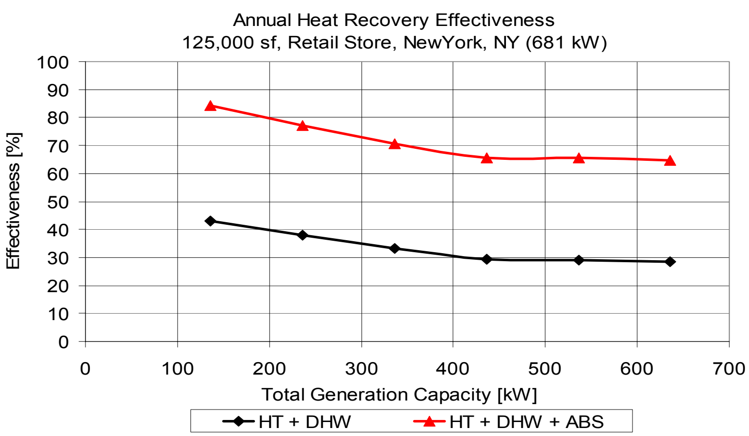


Figure 78: Annual Heat Recovery Effectiveness – Large Retail Store in New York

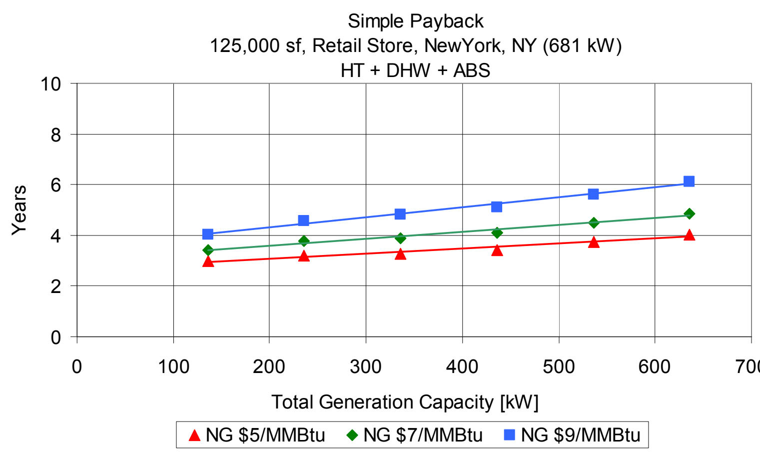


Figure 80: Gas Price Sensitivity – Large Retail Store in New York

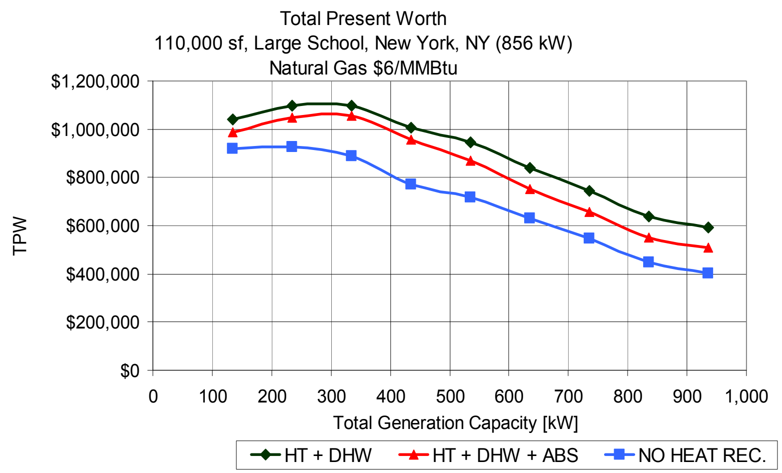


Figure 81: Total Present Worth – Large School in New York

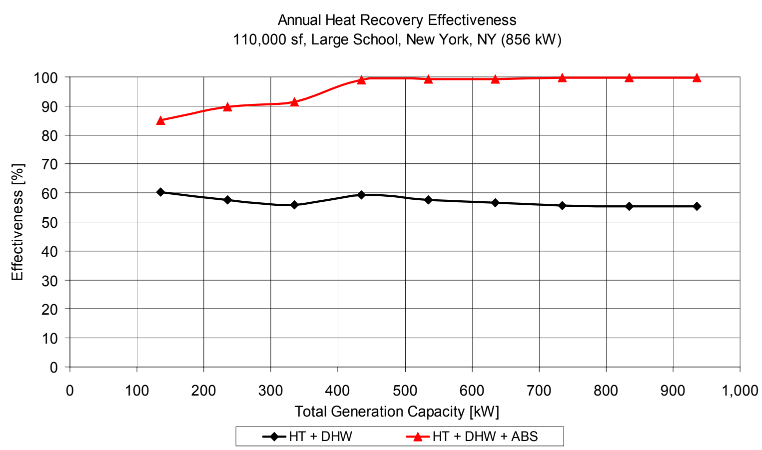


Figure 82: Annual Heat Recovery Effectiveness – Large School in New York

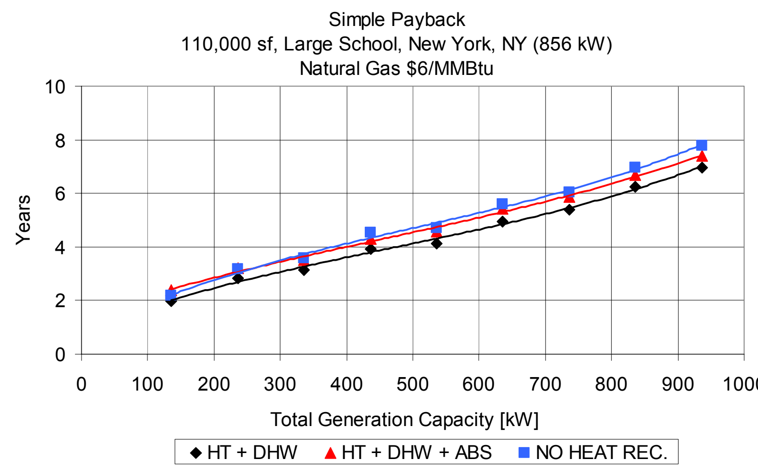


Figure 83: Simple Payback – Large School in New York

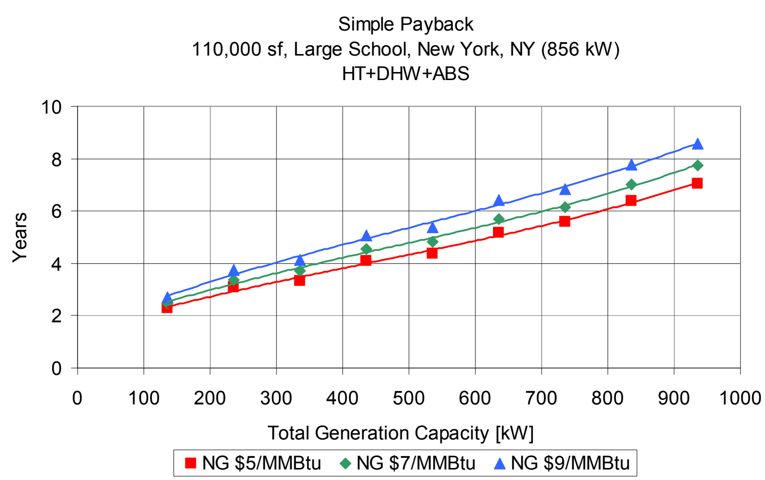


Figure 84: Gas Price Sensitivity – Large School in New York

Summary of Results

Goal 1 – Overall Efficiency Greater Than 70%

The system met the stated goal of achieving 70% thermal overall efficiency (based on higher heating value, HHV). The design called for 73.5% efficiency, which included a margin above the 70% efficiency goal. The tests results demonstrated a system efficiency of 71.2% when the engine was operated with a jacket coolant temperature of 200ºF and 70.3% with the jacket coolant at 220ºF. The measured thermal output was 6.2% lower than the design output, but 1.2% above the 70% goal.

Measured engine electric and thermal output and efficiency data were very close to manufacturer specifications, certainly within the measurement accuracy of the equipment. Exhaust back-pressure, within the manufacturer's specified range, had very little effect on performance. The electric power and efficiency were flat over a range of intake air temperatures. Measured NO_x levels were 1.24 g/bhp, compared to the manufacturer's specification of 2 g/bhp. The engine thermostat did not allow the jacket coolant temperature to exceed 225ºF.

Space cooling is often an important need that can be met with the heat recovered in an integrated energy system by using the heat to power an absorption chiller. Conventional absorption chillers are typically designed to be powered by heat at higher temperatures (270ºF) than normally available from engines. This project developed a prototype chiller that was optimized for a 207ºF hot water supply, which can be provided by most engines. This chiller achieved a measured full-load coefficient of performance of 0.7.

Performance testing of the chiller indicated that the chiller output at 200ºF engine jacket coolant temperature would be 83 RT, rather than the design intent of 90 RT. This performance shortfall was primarily due to the thermal output of the high-temperature coolant circuit of the cogeneration module being lower than expected. This will be corrected by using larger heat exchangers and incorporating other improvements into the heat recovery loop.

Goal 2 – 50% Reduction in Installation Cost

The project developed a modular system that can be transported to a customer's site and installed with very little custom engineering design and field work – significantly reducing the installation costs. Because each installation is unique, it is not possible to predict accurately how much this modularization will reduce installation costs in every case; but Table 39 shows our best estimates for typical installations. The goal of 50% site-related cost savings was achieved for the alpha unit, which is to be installed for approximately $300,000 or 40% of typical system installation costs.

Table 39: Estimated Cost Savings from Modularizing IES

	Baseline 600 kW	Alpha R&D Results	R&D Target
Equipment			
Engine/generator	$219,000	$219,000	$219,000
Heat recovery and rejection	94,000	94,000	94,000
Switchgear and controls	113,000	113,000	113,000
Chilled water system	153,000	153,000	102,000
Package	0	130,000	130,000
Emission controls	0	0	0
Subtotal	579,000	709,000	658,000
Module Assembly Costs			
Labor	0	198,000	100,000
Site Costs			
Installation and interconnect	750,000	300,000	300,000
Risk and warranty	200,000	100,000	100,000
Subtotal	950,000	400,000	400,000
Total	**$1,529,000**	**$1,307,000**	**$1,158,000**

Notes: Equipment costs include shipping and startup costs.

As important as first costs, the packaged systems will also have lower maintenance, repair, and standby costs.

Equity Office Partners provided actual average project costs from completed IES projects as the baseline.

Goal 3 – Adaptability to a Variety of Building Types and Thermal Demand Requirements

The project successfully designed a modular IES to provide appropriate performance and flexibility for the target commercial building market segments. A full-scale prototype cogeneration module was built and tested in GTI's Distributed Energy Technology Center. It performed nearly as well as expected. There was a 6.2% shortfall in the amount of recoverable heat (compared to the design value), but this should be correctable with better coordination between the engine jacket coolant limit control and the temperature setpoint sensor and by improving the sizing of the heat exchangers.

The project developed a prototype low-source-temperature absorption chiller to match the heat recovery capacity of the cogeneration module. The chiller was tested by its manufacturer, Trane, and met its performance goals of 90 RT capacity and 0.7 COP when powered by 207ºF water.

The project encouraged Waukesha to raise the allowable jacket coolant temperature of the engine used in the prototype cogeneration module to 230ºF to enable a low-source-temperature absorption chiller to meet peak cooling demands when necessary. A flexible control system was developed to take full advantage of the different jacket coolant temperatures and a full range of variation in a customer's varying thermal needs. The system provides a controlled variable hot water supply temperature of 200 to 237ºF (Only 220º was achieved, but this shortfall is correctable.) to meet a wide range of customer heating needs without modification, while minimizing engine maintenance requirements by operating at the lowest coolant temperature required.

The optimization analysis, when updated in early 2005, identified an optimal system size of 300 to 400 kW (highest applied efficiency and shortest payback). The optimization analysis also identified potential improvements over the heat recovery system.

Goal 4 – Reliability

One of the reasons for developing a modular IES was to improve system reliability through appropriate integration of all system components into a standardized manufactured product. This would help avoid incompatibility of components, which often delays the installation and startup of conventional integrated energy systems and sometimes causes persistent problems in operating the systems. Better system integration would include advanced system controls and monitoring equipment. The availability of standardized components and system designs would reduce package design costs, improve manufacturing quality control and quality assurance, and facilitate the incorporation of lessons learned into the manufacturing process.

GTI hosted workshops on February 8 and 9, 2005 and May 9 and 10, 2005 to identify reliability issues. They were attended by representatives from GTI, IES system operators, and one IES system manufacturer. The purposes of the workshops were to document lessons learned from operating and maintaining IES systems throughout the U.S. and to recommend changes that could mitigate unplanned outages.

The meetings illustrated the prime importance of IES reliability and identified a host of problems that have occurred in the field, mainly caused by inappropriate engineering or installation. The causes include inappropriate material selection, excessive vibration, exhaust noise, inadequate design ambient temperature, inconvenient locations of piping connections, interfaces with building energy system controls, lack of capability to send key operating data to the building maintenance staff and the energy system manager, inadequate insulation of heat recovery and exhaust piping, inadequate protection of sensitive components from high temperature and from maintenance activities, and inability to warn operators when emissions control is out-of-compliance. Many of these problems can be addressed by improvement in system design specifications, improved engineering, and quality control during the manufacturing process. However, some will require R&D. R&D needs include:

- Intelligent operating systems.
- Low cost Btu-measurement devices.
- Low cost flow sensors.
- Improved vibration dampers.
- Low cost cylinder monitoring.
- Low cost continuous emission monitoring.
- Adaptation of exhaust gas emissions monitoring systems to ensure compliance with air quality regulations.
- Fuel injection systems for natural gas engines for better control of engine performance and emissions.
- Long-life spark plugs.

The participants agreed that IES equipment could be more reliable if it were modular, comprised of standardized factory-assembled subsystems or modules that could be easily connected to one another at a customer's site. Modules that might be considered are:

- Engine/generator.
- Electric utility interconnection – standard subsystem designs for each major utility.
- Heat recovery modules – various options to meet building requirements.
- System master controls.
- A menu of standard options of pre-engineered and factory-assembled components, such as:
  - Standard switchgear panel for utility metering and utility protection.
  - Gas pressure boosters.
  - Circuit breakers.
  - Vapor-phase heat recovery.
  - Absorption chiller modules (and remote cooling towers).

Goal 5 – Market Identification and Characterization

For an IES to provide energy cost savings that justify its purchase, the purchaser should have on-site thermal energy needs that can use much of the byproduct heat available from the engine – at the time that the heat is available. This project identified commercial building applications that can most effectively make use of the heat, quantified the market potential of the most promising applications, and suggested strategies for approaching customers in those market sectors.

However, the project also showed that marketplace acceptability of IES in commercial buildings is far from universal. Lower first cost of the equipment and emissions compliance are necessary, but not sufficient. The basic economics requires that users recoup the initial cost through savings in energy costs in a reasonable time. Two aspects are vital:

- The difference between natural gas electric power rates should be large enough to generate significant energy cost savings.
- The building should have enough demand for thermal services – at the time the electric generator is operating – to enable energy cost savings through the recovery and use of the recycled thermal energy from the prime mover. In a great preponderance of commercial buildings, this means that the heat should be used to drive an absorption cycle chiller for space cooling.

Conclusions and Lessons Learned

Performance and Testing

The system met the stated goal of achieving 70% thermal overall HHV efficiency. The overall efficiency of actual installations will depend on the individual customer's thermal energy needs and the temporal patterns of those needs.

The cogeneration module performance shortfall of 7ºF was primarily due to the jacket coolant circuit heat exchangers. Possible reasons for the lower-than-expected high-temperature output are that the jacket coolant heat exchanger was too small and to high heat losses from the exhaust heat exchanger due to its environment being colder than planned for in actual installations.

The jacket coolant heat exchanger was undersized due to errors in design assumptions and calculations for parameters, such as specific heat and heat transfer coefficient. A brazed plate heat exchanger was used because heat exchangers of this type are generally less expensive and smaller than plate-and-frame heat exchangers. The advantage of plate-and-frame heat exchangers is that additional plates can be added if more heat transfer is needed, while with brazed plate heat exchangers, the entire heat exchanger would have to be replaced. When using brazed-plate heat exchangers, it would be advisable to slightly oversize them to ensure that the heat transfer is not limited.

The exhaust heat exchanger was not insulated because the design intent was for it to operate in a much warmer environment than the test environment. Because the test unit is expected to be tested in the field, we recommend that the performance of the exhaust heat exchanger be closely monitored during the field tests.

Measurement uncertainty may have been part of the reason for the shortfall in expected thermal output. Thermal output measurements are particularly sensitive to temperature measurements because the difference between the inlet and outlet temperatures is typically less than 20ºF. GTI recommends that other testing organizations use differential RTD temperature transmitters to measure these temperatures to reduce measurement errors. GTI also found that most of the measurement error in these tests was induced during signal processing to convert the analog temperature readings to the digital form used by the data recording system. The signal processors or input/output modules used for this conversion process were set to default values and covered a very large temperature range. In the future, the input/output modules should be reprogrammed to cover a much narrower temperature range to improve the accuracy of the temperature measurements. Additionally, GTI recommends that for measuring thermal output purposes, delta T transmitters should be used instead of single point transmitters. The delta-T transmitters measure the difference in temperature between two RTD measurement points instead of measuring the temperate at a particular point. The result of using a delta-T type transmitter is that it reduces the experimental uncertainty because the measurement system is based and calibrated on temperature difference and not the sum of errors from measuring two different temperatures and subtracting the result.

During testing GTI encountered problems in adjusting the jacket coolant setpoint as well as holding the jacket coolant temperature stable within GTI's specified stability parameters. The primary reasons for these issues were related to using stepped logic for controlling the radiator fans and jacket coolant temperature. GTI added PID controls for managing the thermal side of the CHP system, and these controls greatly increased the stability of the jacket coolant temperature and made it much easier to change and maintain setpoints.

Reliability

Reliability continues to be an issue for IES marketability, as indicated in the failure modes and effects analysis workshops. There are three aspects to reliability:

- First and foremost is inadequate system design, which leads to problems during startup or to failure after some period of operation. Components that are not properly specified or do not perform as expected can cause long delays in commissioning the equipment and getting it to operate as planned.
- Second is quality. Poor component quality or installation quality (such as mislabeled wiring) has led to a number of startup and operational failures.
- The third contributor to poor performance is the inability of the IES to adequately respond to or accommodate common interruptions or interferences. This will be referred to as long-term reliability.

These failure mechanisms increase the cost of installation and operation while tarnishing the IES industry's reputation and further impeding market penetration.

A basic premise of this project was that, in factory-assembled integrated energy systems, the components would interact properly and perform as expected. Factory-built modules are built to quality control standards, components can be standardized, and failure modes can be identified and corrected in the standard design and fabrication process.

The two industry workshops led by GTI provided extensive information about common failure modes and the likelihood of their occurring in the field. Several of the problems that have been encountered in the field resulted from inadequately specified designs or incorrect matching of the IES equipment to the building, and they underline the importance of having a well-designed IES. Because of the vital importance of IES reliability, GTI began to develop a predictive maintenance system and intelligent operating system for engine-driven IES installations under a separate gas-industry-funded project. These systems would reduce O&M costs by forestalling unplanned outages and improving IES reliability and availability.

In order to specify requirements for the *Intelligent Operator,*[27] GTI identified many critical parameters for monitoring IES equipment and developed an extensive list of these parameters for use in developing the *Intelligent Operator*. The next step should be to perform an economic evaluation of these parameters to help determine which monitoring points are cost-effective. The most cost-effective parameters should be selected, and specifications should be written for future software development.

Because there are no suitable commercial software offerings, software development will be required for the *Intelligent Operator*. The software should allow for features that require relatively fast response to be embedded in the IES master controller. Software for trending and

---

[27] GTI is pursuing a trademark on this name.

other slow-response control functions should be run on a separate system that would communicate with the master controller.

Modularity

The project demonstrated that modularization could greatly simplify site installation and the associated costs. Prefabrication reduced the on-site work considerably, with only four building connection points. The alpha prototype is to be installed at a middle school for less than $450/kW, a 50% reduction from typical installation costs for systems of this size.

The project also demonstrated that making an entire IES a single module for plug-and-play installation at a building was too ambitious. Designing the system revealed that a single module could be too large to lift to a building roof or to accommodate the setback requirements or space limitations at many sites. The two-module design was transportable, but maneuvering it at a site could be costly. It became clear that the range of energy needs at various sites dictates that integrated energy systems should be comprised of more modules with narrower functionality to enable matching the IES to the needs of the building.

Market Applicability

GTI and partner analysis concur that there is a significant potential in the buildings market for IES of 300-kW to just over 1,000-kW capacity. Specifically, large hotels, nursing homes, office buildings, big-box retail buildings, and large schools offer primary market targets. In terms of maximizing fuel savings through heat recovery, large hotels and nursing homes are the preferred markets. As shown in Figure 85 (based on a study of the remaining potential IES markets in New York[28]), these applications represent large potential markets.

GTI's economic analysis indicated that a smaller engine-generator (336-kW rather than 615 kW) would be adaptable to a broader range of building sizes, and it would be easier to transport and maneuver during installation. Multiples of these smaller modules could serve larger buildings.

The expected improvement in system performance and cost from ongoing R&D and the expected improvement in natural gas prices will increase the market for IES. For the present, California and New York are the states that offer the best initial possibilities for economically successful IES applications. Higher natural gas prices have eroded IES system economics in the Midwest and Southeast. Therefore, initial IES application efforts should focus on California and the Northeast, where high electricity prices offer better economics. Because a high fraction of the power plants in these two areas are fueled with natural gas, rising gas prices drive electric power prices higher, helping maintain economics favorable to gas-fueled cogeneration.

---

[28] Hedman, Bruce A. and Darrow, Ken (Energy Nexus Group Onsite Energy Corporation) and Bourgeois, Tom (Pace Energy Project), "Combined Heat and Power Market Potential for New York State," Report 02-02 of the New York State Energy Research and Development Administration, October 2002.

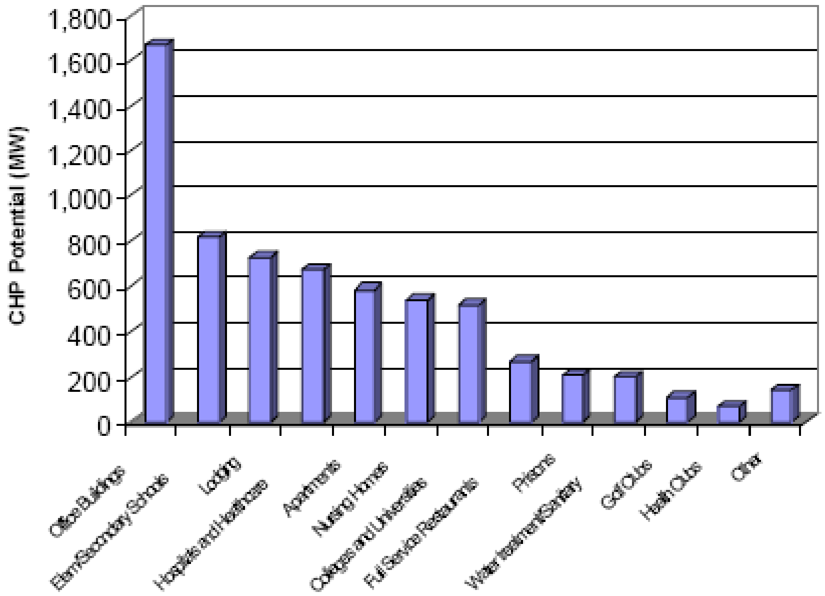


Figure 85: Remaining Commercial Sector CHP Technical Potential in New York[28]

Based on the economic evaluation of IES performance in typical building types, large hotels in both California and New York offer the most promising market targets.

Office buildings are the largest potential IES market in New York.[28] GTI's analysis of potential application economics found that IES systems sized at 25 to 50% of the office building peak load provide excellent thermal utilization. Working with Equity Office Partners, GTI determined that the office building market should be included in this program.

As expected, adding space-cooling equipment to IES in California would have a much higher marginal value than in New York.

Secondary schools are a technically attractive target market for IES, and schools are more tolerant of lengthy payback periods. However, GTI found that there are institutional barriers to exploiting this market. Each school district is autonomous, often requiring board approval of each sale.

The economic analysis performed under this project revealed that commercial building applications represent a potentially important market IES, but the systems need further R&D to improve their first cost and operating costs.

Commercialization Strategy

GTI's objective is to secure a commercialization partner that can design, manufacture, warrant, sell, and maintain a wide range of IES systems. At the outset of this project, GTI secured commitments from Waukesha and Trane to participate in the R&D effort while we explored commercialization partners. GTI initially pursued Waukesha as the manufacturer for the packaged system. Competing priorities and markets made it difficult for Waukesha to divert resources from its core business – reciprocating engines.

GTI shifted its initial commercialization strategy and sought an experienced engine-generator-set packager that is willing to expand its scope of supply to include heat recovery and chilled water. GTI identified Enercon Engineering, Inc. as such a commercialization partner and created a partnership to design, manufacture, warrant, and sell a line of IES with nominal capacities of 300 to 1,100 kW.

> Customers are interested in buying electricity, heating, and cooling – not engines, switchgear, and heat recovery equipment. Existing IES suppliers expect customers to shoulder the burden of operating and maintaining IES systems. This business model may work in industrial and institutional settings, where large maintenance staffs exist, but the model has become a barrier in commercial markets.

Enercon's involvement would provide a clear path to market for IES equipment for commercial buildings. Enercon's full field support of all components of its IES equipment would help reduce customer uncertainty and risk. Enercon has been manufacturing custom-designed engine-generator assemblies and packages since 1981 and has a solid reputation for integrity and expertise. In 2004, Enercon's Vice President and General Manager was chairman of the U.S. Combined Heat and Power Association.

Enercon has a unique "complete systems" approach that meets customers' power generation requirements by combining high-quality electrical controls and custom assembly services to ensure that the power generation system will function in a coordinated fashion. Enercon also provides follow-up support through its product support department and field-service engineers who are available whenever and wherever they are needed. Enercon's field service technicians are some of the most experienced in the industry and have an exceptional knowledge of all components in the system. The technicians are available for startup commissioning and for regular maintenance service.

Enercon power generation systems are in operation worldwide, in more than 80 countries. Enercon's services include customized training on its equipment, as needed by its customers, and Enercon can provide extended warranty and preventive maintenance programs for generator switchgear. Enercon will expand these services to include all IES components.

Enercon also provides a unique path to market by forming partnerships with the OEM distributors, leveraging their sales and maintenance capabilities. This will help the distributors see Enercon as an IES supplier, rather than a competitor.

GTI, through the National Accounts Energy Alliance, will provide Enercon and the distributors with opportunities to supply IES modules to property management, lodging, big-box retail, and health care establishments.

Recommendations

GTI, in cooperation with Waukesha, Ballard Engineering, and Trane, developed, designed, and tested a 600-kW alpha prototype IES packaged system. The team integrated the engine, controls, heat recovery, grid interconnect, and absorption system into two modular portable units that could be quickly and inexpensively installed in the field. IES performance testing verified that we achieved our overall efficiency goal of greater than 70%. This testing, combined with an independent review identified several aspects that will be addressed in Phase II, with the development of the commercial unit. They include:

- Identify design changes and system specifications that will directly improve operability and reliability. Utilize the results of a formal failure modes and effects analysis (FMEA) to develop an innovative design for system controls integration and automation, using state-of-the-art on-board diagnostics and trending techniques to predict operational patterns and failures.
- Change the IES package design to use proportional-integral-differential (PID) controllers rather than the step logic controllers used in the alpha design. This change would improve operational stability of the IES.
- Increase modularization (a larger number of smaller modules) to facilitate transport of the unit and reduce installation costs. For example, one module could include the engine, generator, switchgear, and hot water recovery, while a second module would include the radiators, exhaust treatment, and excess heat rejection radiators. A third module could house the absorption chiller and its associated auxiliaries. Improvements to the total system layout, based on lessons learned, will increase footprint flexibility and the number of sites compatible with the modular system. Integration of the switchgear and controls with the generator would reduce system size and complexity.
- Integrate means for capturing and using the radiated heat to improve the overall efficiency by capturing an additional 5% of the total energy input.
- Develop a smaller capacity IES to better match the energy needs of typical commercial buildings. The updated economic analysis demonstrated the value of using smaller systems.

The IES market will be expanded by developing IES packagers that fabricate, sell, warrant and maintain IES products; supplying electricity, heating, and cooling for a fixed price. GTI selected a commercialization partner, Enercon, that can provide this full service. Enercon also provides a unique pathway to the buildings market by working in partnership with all three U.S. OEM manufacturers. GTI and Enercon will propose further development work in Phase II to develop modules based on ARES engines.

> Under the current market conditions, now is the time to invest in R&D, positioning our partner to take advantage of the DE market as it improves. Lower natural gas prices, improved prime-mover technology performance and cost, reliable packaged systems, favorable policy changes, and incentives will provide for an improved IES market in the future. While the GTI alpha system achieved a number of the program goals, further improvements are needed prior to commercial launch.

Appendix A – Cogeneration System Testing Description

[Submitted as a separate file.]

Appendix B – Market Analysis

[Submitted as a separate file.]

Appendix C – Economic Analysis of Alpha Design

[Submitted as a separate file.]

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

For more information contact:

EERE Information Center

1-877-EERE-INF (1-877-337-3463)

www.eere.energy.gov

GTI Integrated Energy System for Buildings Final Report

Appendix A – Cogeneration System Testing Description

List of Tables

Laboratory Facilities and Measurement Specifications

This appendix describes aspects pertaining to the testing of the Waukesha cogeneration module. An earlier report[1] describes the physical arrangement of GTI's Distributed Energy Technology Center laboratory and its measurement and control arrangements.

Air Intake Subsystem

An extensive ductwork subsystem is integrated into the Distributed Energy Technology Center (DETC) to monitor and control the temperature and humidity of the test unit's intake air. The intake air subsystem consists of several components including a natural-gas-engine-driven reciprocating chiller, motorized dampers, fans, heaters, cooling coils and a desiccant to control the temperature and humidity of the intake air. Fresh air is drawn in through an air filter and is heated, cooled, dried, or humidified, depending on the temperature and humidity setpoint. For these tests, the conditioned intake air was discharged through ducts upstream of the air filters on the engine. A programmable logic controller was used to control the temperature, humidity, and flow rate setpoints based on temperature sensors mounted on the engine combustion air intake filters. The humidity and flow rate sensors are located in the outdoor air intake, the return duct, and the supply duct to the engine. Table A - 1 is a complete list of the measured parameters.

[1] Kollross, C. Todd, "Distributed Energy Test Procedures Development," Gas Research Institute report number GRI-03/0110, May 2003.

Table A - 1: Instrumentation and Parameters of Air Intake Subsystem

Parameter	Equipment	Range	Units	Accuracy
Temperature of outdoor (fresh) air for combustion air make-up	Type K thermocouple	0-150	°F	±0.75% of range
Temperature of air at intake at engine air filter				
Relative humidity of outdoor (fresh) air for combustion air make-up	Humidity transmitter	0-100	%	±2.0% of reading
Relative humidity of air entering engine air filter				
Air flow rate through air intake system ducting	Air monitoring station(s) with differential pressure transducer	0-10000	scfm	±3% of scale accuracy
Barometric pressure of outdoor (fresh) air for combustion air make-up	Barometric pressure indicator	450.0-795.1	mm Hg	±0.38 mm Hg

Exhaust Gas Subsystem

The exhaust test section consisted of a 10-inch-diameter, 10-foot-long straight pipe connected to the cogeneration module exhaust connection. Exhaust velocity and mass flow rate were measured by a Pitot tube located near the end of the straight pipe. Exhaust temperature and static pressure were measured downstream of the Pitot tube. Emissions were measured at the end of the straight pipe. Table A - 2 lists the measured parameters and instrumentation.

Table A - 2: Parameters and Instrumentation for Monitoring Exhaust Gas Subsystem

Parameter	Equipment	Range	Units	Accuracy
Temperature of exhaust exiting DE unit	Type K thermocouple	–400 to +800	°F	±0.75% of range
Pressure of exhaust exiting DE unit	Pressure transmitter	0-22	Inches of Water	±0.25% of reading
Amount of CO in DE unit exhaust	Emissions analyzer	0-1000	ppm	±1% of range
Amount of O_2 in DE unit exhaust		0-25	%	±1% of range
Amount of NO_x in DE unit exhaust		0-1000	ppm	±1% of range
Amount of CO_2 in DE unit exhaust		0-10	%	±1% of range

Fuel Supply Subsystem

The gas supply pressure to the DETC is approximately 45 psig. The gas is filtered with a 5-micron filter and regulated to the required inlet pressure. Although the allowable inlet gas pressure for the Waukesha VGF 36 GLD engine is 8 in. w.c. to 4 psig with the supplied regulator, all testing was performed at 4 psig inlet pressure, as the air/fuel ratio was set prior to testing at 4 psig inlet pressure to the gas train. Thus, varying the inlet pressure would require verification and adjustment of the gas train components. Throughout testing, the gas supply pressure, the gas flow rate, and gas composition were recorded. Table A - 3 lists the instrumentation used to monitor this subsystem.

Table A - 3: Instruments and Parameters for Fuel Supply Subsystem

Parameter	Instrument	Range	Units	Accuracy
Fuel inlet pressure	Pressure transmitter	0-200	psig	±0.25% of reading
Fuel flow	Coriolis flow meter	0-200	scfm	±0.25% of range
Fuel heating value	Gas chromatograph	20000-22000	Btu/lb	±1 Btu/lb
Fuel inlet temperature	Type K thermocouple	0-150	°F	±0.75% of range

Electrical Subsystem

During the tests, the main 480 VAC bus was connected to a load bank capable of testing resistive loads up to 2 MW. The main bus was disconnected from the grid. Parasitic loads were measured on this bus as well. It should be noted that the unit's wiring was modified for the purpose of testing and measuring the parasitic loads. Table A - 4 lists the instrumentation used to monitor this subsystem.

Table A - 4: Parameters and Instrumentation on Electrical Subsystem

Parameter	Instrument	Range	Units	Accuracy
Phase to phase voltage at output of DE unit	Power analyzer	0-600	V	±0.1% of reading
Current at output of DE unit		0-150	Amps	±0.1% of reading
Voltage frequency on output of DE Unit		0-100	Hz	±0.01% of reading
True power output from DE unit		0-100	kW_e	IEC 60687 Class .2S ±0.2% of reading
Reactive power output from DE unit		0-100	kVar	IEC 60687 Class .2S ±0.2% of reading
Apparent power output from DE unit		0-100	kVA	IEC 60687 Class .2S ±0.2% of reading
Power factor of output of DE unit		0-1		±0.5% of reading
Harmonics (to 40^{th})		0.001-100	%	IEC 61000-4-7
Harmonics (to 63rd)		0.001-100	%	±0.5% of full scale

Thermal Load System

The thermal load system used as a heat sink for the heat available from the cogeneration system consisted of three loops. A cooling tower with city water cooled the customer side of the auxiliary coolant heat recovery exchanger. A complete description of the heat recovery streams within the engine module is contained in the design section of this report. Table A - 5 lists the instrumentation used to monitor this subsystem.

Table A - 5: Parameters and Instrumentation for Monitoring Thermal Load System

Parameter	Instrument	Range	Units	Accuracy
Cooling water inlet temperature	Platinum RTD	0-500	°F	±0.025 % of range
Cooling water outlet temperature				
Chilled & hot water inlet temperature				
Chilled & hot water outlet temperature				
Chilled & hot water flow rate	Coriolis Meter	0-600	gpm	±0.1 % of rate
Cooling water flow rate	Turbine Meter	0-100		±1 % of rate
Cooling water inlet pressure	Pressure transmitter	0-60	psig	±0.25 % of range
Cooling water outlet pressure				
Chilled & hot water inlet pressure				
Chilled & hot water outlet pressure				

Testing Requirements

Data Collection Equipment

Wonderware InTouch operator interface software was used to collect and log test data. InTouch uses object-oriented graphics to create animated, touch-sensitive display windows that are connected via software drivers to the various input/output (I/O) systems comprised of the test instrumentation.

After each test run reported in the results, a historical log file was queried to extract data and write the data to a comma separated file for further data reduction. The Wonderware software allows data to be extracted at a user specified sampling rate.

Data Sampling Rate and Test Run Data Collection Duration

The data used for test reporting was extracted from the historical log file at a sampling rate interval of 2 seconds and averaged over a ten (10) minute period. For each parameter reported, the minimum, maximum, and average values were determined over each test period to validate system stability.

Instrumentation and Measurement Accuracy

To control data accuracy and repeatability, GTI established maximum uncertainty limits for the test parameters. The measurement instruments were selected to ensure that these maximum uncertainty limits would be met. The overriding requirement for accuracy of instrumentation, data acquisition hardware, data sampling rates, minimum test duration, and minimum test runs is the specified maximum uncertainty listed in Table A - 6. Unless stated otherwise, the units of uncertainty are expressed as a percentage of the reading.

Table A - 6: Maximum Allowable Measurement Uncertainty and Instrument Location

Parameter	Units	Maximum Uncertainty	Location of Instruments
Real power	*kW*	*±0.45%*	*Customer electrical connection panel*
Reactive power	*KVAR*		
Voltage	*Volts*	*±0.30%*	
Current	*Amperes*		
Frequency	*Hz*		
Total harmonic distortion – voltage	*%*	*n/a*	
Total harmonic distortion – current			
Parasitic power	*kW*	*±1.0%*	
Intake air pressure	*psia*	*±2.0%*	*Within 6 inches of intake structure*
Intake air temperature	*ºC [ºF]*	*±1.1ºC [±2ºF]*	
Barometric pressure	*Inches of Hg*	*±0.5%*	*Outdoor location at test site*
Exhaust backpressure	*Inches of* H_2O	*±3.0%*	*Customer connection flange, but within exhaust pipe*
Exhaust temperature	*ºC [ºF]*	*±2.8ºC [±5ºF]*	
Average standard volumetric exhaust flow	*scfm*	*±3.0%*	
Fuel supply pressure	*psia*	*±1.5%*	*Customer connection flange*
Fuel supply mass flow rate	*lb/hr or scfh*	*±1.0%*	
Fuel higher heating value	*Btu/lb or Btu/scf*	*±1.0%*	
Fuel lower heating value			
High-temperature coolant mass flow rate	*lb/hr*	*±1.5%*	
Low-temperature coolant mass flow rate			
High-temperature coolant inlet temperature	*ºC [ºF]*	*±0.5ºC [±1.0ºF]*	
High-temperature coolant outlet temperature			
Low-temperature coolant inlet temperature			
Low-temperature coolant outlet temperature			
Heat recovery fluid inlet temperature			
Heat recovery fluid outlet temperature			
Heat recovery fluid or coolant differential temperature	*ºC [ºF]*	*±0.5ºC [±1.0ºF]*	*Customer connection flange*
Heat recovery fluid mass flow rate	*lb/hr*	*±1.5%*	*Customer connection flange*
Specific heat	*Btu/lb °F*	*±1.0%*	
Noise level	*dB*	*±3 dB*	*Per ISO Standard 9614 2*

Steady-State Stability Criteria

With exception of the island-mode-acceptance and load-rejection tests, all tests were performed when the unit had been operated for a sufficient period and stability to achieve steady-state conditions. The following procedures were performed to ensure steady state operation.

Stabilization

Before starting a performance test, the unit was operated at the requisite conditions until stabilization was established. Stabilization was considered to be established when continuous monitoring indicated that all system parameters were within the maximum permissible deviation (variance from nominal setpoints), as specified in Table A - 7 for at least 15 minutes prior to collection of test data.

Post-Test Verification of Steady State Conditions

At completion of each test run, average, minimum, and maximum values were determined to verify that the system stability limit criteria specified in Table A - 7 were maintained throughout the run. If the stability criterion were not satisfied throughout the entire test run, the run was repeated.

Table A - 7: Maximum Deviation in Test Conditions During Testing Measurement Period

Parameter	Units	Maximum permissible deviation during test
Electrical Output	*kW*	*±2%*
Parasitic Load	*kW*	*±5%*
Intake Air Temperature	*°C [°F]*	*±2.2°C [±4°F]*
Barometric Pressure	*inches Hg*	*±1%*
Fuel Supply Flow Rate	*lb/min*	*±2%*
Fuel Heating Value	*Btu/lb*	*±1%*
High-temperature water (coolant) flow	*gpm*	*±5%*
Low-temperature water (coolant) flow	*gpm*	*±5%*
Heat recovery inlet temperature (if steam)	*°C [°F]*	*±2.8ºC [±5.0ºF]*
Heat recovery outlet temperature (if steam)	*°C [°F]*	*±2.8ºC [±5.0ºF]*
Heat recovery inlet temperature (if liquid)	*°C [°F]*	*±5°F*
Heat recovery outlet temperature (if liquid)	*°C [°F]*	*±5°F*
Heat recovery differential temperature	*°C [°F]*	*±5%*
Exhaust gas backpressure	*inches H_2O*	*±5%*
Exhaust gas flow rate	*inches H_2O*	*±5%*
Exhaust gas static pressure	*inches H_2O*	*±2%*
Exhaust gas temperature	*°F*	*±10°F*

Exhaust Back-Pressure Performance Test

Site design factors, such as ductwork, dampers, and silencers can impose back-pressure on the system's exhaust. Back-pressure usually reduces output power and efficiency. The purposes of these tests were to verify the systems capability to operate within the allowable 15 in. w.c. back-pressure as measured at the engine exhaust outlet and to determine the effect of increased back-pressure on engine performance. For this test, the generator was operated to rated electrical output and the intake air temperature was maintained at 59ºF.

The system exhaust back-pressure is the difference between the static pressure measured at the engine exhaust connection and barometric pressure.

Test Conditions

The back-pressure tests were performed under the following conditions:

- Intake air temperature: 59ºF (15ºC)
- Fuel pressure: 4 psig
- Customer exhaust back-pressure: Zero and maximum
- Power output: Rated load.
- Operating mode: Stand-alone (grid-isolated)

Measurements

Table A - 8 shows the parameters that were measured during the tests for the purposes of recording relevant data and verifying operating stability.

Table A - 8: Measured Parameters for Exhaust Back-Pressure Tests

Measurement Group	Parameter	Units
Fuel gas measurements	Fuel supply flow	lb/hr
	Fuel supply pressure	psig
	Fuel heating value	Btu/lb, LHV and HHV
Exhaust gas measurements	Exhaust temperature	˚F
	Exhaust flow	scfm
	Exhaust back-pressure	in. H_2O
Electrical performance measurements	Real power output	kW
	Parasitic power	kW
	Voltage output	VAC
	Current output	A
	Frequency	Hz
Ambient (intake) air measurements	Intake air temperature	˚F
	Relative humidity	%
	Barometric pressure	mm Hg
	Intake air flow (if possible)	scfm

Intake Air Temperature Performance Tests

Tests were performed to evaluate the sensitivity of net power output and electrical efficiency to ambient temperature.

Test Conditions

The intake air temperature tests were performed under the following conditions:

- Intake air temperatures: Tests were conducted at 59°F, 77°F, 95°F, and 104°F.
- Electrical Output: At each intake air temperature, measurements were taken at 50%, 75%, and 100% of rated electrical output.
- Fuel pressure: Set at 4.0 psig
- Exhaust back-pressure: Zero back-pressure at the customer interface flange.
- Operating mode: Stand-alone (grid-isolated)

Table A - 9 is the test matrix.

Table A - 9: Intake Air Temperature Test Matrix

Generator Output Setpoint (kW)	Intake Air Temperature (ºF)
308	59
461	59
615	59
308	77
461	77
615	77
308	95
461	95
615	95
308	104
461	104
615	104

Measurements

Table A - 10 shows the parameters that were measured during the tests for the purposes of recording relevant data and verifying operating stability.

Table A - 10: Measured Parameters for Intake Air Temperature Tests

Measurement Group	Parameter	Units
Fuel gas measurements	Fuel supply flow	lb/hr
	Fuel supply pressure	psig
	Fuel heating value	Btu/lb, LHV and HHV
Exhaust gas measurements	Exhaust temperature	˚F
	Exhaust back-pressure	in. H_2O
Electrical performance measurements	Real power output	kW
	Parasitic power	kW
	Voltage output	VAC
	Current output	A
	Frequency	Hz
Ambient (intake) air measurements	Intake air temperature	˚F
	Relative humidity	%
	Barometric pressure	mm Hg

Island-Mode-Acceptance and Load-Rejection Test

The purpose of this test was to determine the test (generator) equipment's ability to respond to load changes while the unit is operated in isochronous (island) mode from normal standby condition.

Test Conditions

Unless specified otherwise, the tests were conducted under the following conditions:

- Intake air temperatures: 59°F.
- Fuel pressure: 4.0 psig.
- Exhaust back-pressure: Zero back-pressure at the customer interface flange.
- Operating mode: Stand-alone (grid-isolated).

In this series of tests, the engine was started from the normal standby condition and allowed to idle at rated speed for two minutes after starting following a two-minute prelube cycle. After approximately two minutes of idle operation, resistive loads were added at ten-second intervals in increments of 25% of rated generator output until the unit reached full power. Once at full power, the load was removed in increments of 25% of rated power until there was no load on the engine. Table A - 11 shows the test matrix.

Table A - 11: Island-Mode-Acceptance and Load-Rejection Test Matrix

Intake Air Temperature (ºF)	Fuel Inlet Pressure (psig)	Time from Generator Start (seconds)	kW Load to Apply	Resulting Generator Output (kW)
59	4	120	+150	150
		130	+150	300
		140	+150	450
		150	+150	600
		270	-150	450
		280	-150	300
		290	-150	150
		300	-150	0

Measurements

The following parameters were measured during the tests:

Table A - 12: Measured Parameters for Intake Air Temperature Tests

Measurement Group	Parameter	Units
Fuel gas measurements	Fuel supply flow	scfm
	Fuel supply pressure	psig
	Fuel heating value	Btu/scf, LHV and HHV
Exhaust gas measurements	Exhaust temperature	˚F
	Exhaust flow	scfm
	Exhaust back-pressure	in. H_2O
Electrical performance measurements	Real power output	kW
	Parasitic power	kW
	Voltage output	VAC
	Current output	A
	Frequency	Hz
Ambient (intake) air measurements	Intake air temperature	˚F
	Relative humidity	%
	Barometric pressure	mm Hg
	Intake air flow (if possible)	scfm

Heat Recovery Tests

The purpose of the thermal energy production/heat recovery test is to determine the quantity and quality of thermal energy (both heating and cooling, as applicable) that is available for use by the end user. The systems overall energy efficiency largely depends on the amount of heat that can be recovered from the prime mover exhaust and other auxiliary subsystems.

Test Conditions

Heat recovery tests were made using different combinations of intake air temperature, generator output and jacket coolant temperature to verify off rating condition performance for design and economic evaluation purposes. Referring to **Error! Reference source not found.** or **Error! Reference source not found.**, the customer sides of the heat recovery loop and the auxiliary coolant loop were tested. The hot water heat recovery supply to the absorption chiller was tested at 95º F intake air temperature to simulate site conditions during the cooling season. The auxiliary coolant loop and the hot water circuit were tested simultaneously at 59º F intake air temperature.

Other conditions during the tests were as follows:

- Electrical Output: At each intake air temperature, measurements were taken at 50%, 75%, and 100% of rated electrical output.
- Fuel pressure: Set at 4.0 psig
- Exhaust back-pressure: Zero back-pressure at the customer interface flange.
- Operating mode: Stand-alone (grid-isolated)

Table A - 13 is the test matrix used for the heat recovery circuit.

Table A - 13: Heat Recovery Circuit Test Matrix

Intake Air Temp. (ºF)	Generator Output Setpoint (kW)	Jacket Coolant Outlet Temp. (F°)	Auxiliary Coolant Circuit Inlet Temp. (°F)	Jacket Coolant Flow Rate (gpm)	Hot Water Circuit Flow Rate (gpm)	Auxiliary Coolant Circuit Flow Rate (gpm)
95	615	200	130	218	218	62
		210	130	218	218	62
		220	130	218	218	62
		230	130	218	218	62
	461	200	130	218	218	62
		210	130	218	218	62
		220	130	218	218	62
		230	130	218	218	62
	308	200	130	218	218	62
		210	130	218	218	62
		220	130	218	218	62
		230	130	218	218	62

Table A - 14 is the test matrix used for the hot water and auxiliary coolant circuits.

Table A - 14: Test Matrix for the Hot Water and Auxiliary Coolant Circuit

Intake Air Temp. (ºF)	Generator Output Setpoint (kW)	Jacket Coolant Outlet Temp. (°F)	Auxiliary Coolant Circuit Inlet Temp. (°F)	Jacket Coolant Flow Rate (gpm)	Hot Water Circuit Flow Rate (gpm)	Auxiliary Coolant Circuit Flow Rate (gpm)
59	615	200	130	219	219	62
		210	130	219	219	62
		220	130	219	219	62
		230	130	219	219	62
	461	200	130	219	219	62
		210	130	219	219	62
		220	130	219	219	62
		230	130	219	219	62
	308	200	130	219	219	62
		210	130	219	219	62
		220	130	219	219	62
		230	130	219	219	62

Measurements

Table A - 15 shows the parameters that were measured.

Table A - 15: Measured Parameters for Intake Air Temperature Tests

Measurement Group	Parameter	Units
Fuel gas measurements	Fuel supply flow	lb/hr
	Fuel supply pressure	psig
	Fuel heating value	Btu/lb, LHV and HHV
Exhaust gas measurements	Exhaust temperature	˚F
	Exhaust back-pressure	in. H_2O
Electrical performance measurements	Real power output	kW
	Parasitic power	kW
	Voltage output	VAC
	Current output	A
	Frequency	Hz
Ambient (intake) air measurements	Intake air temperature	˚F
	Relative humidity	%
	Barometric pressure	mm Hg
Thermal recovery measurements	Thermal fluid flow rate	gpm
	Thermal fluid supply temperature	˚F
	Thermal fluid return temperature	˚F
Emissions measurements	CO	ppm
	NO_x	ppm
	CO_2	%
	O_2	%

Emissions Measurements

Emissions were measured during the intake air temperature tests. The measurements were taken with a Horiba portable emissions analyzer following GTI procedures for making the measurement. The GTI procedures were based on CARB and EPA procedures but due to the nature of the equipment, exact CARB and EPA procedures could not be used. Some intermediate stability checks and response time checks of the emissions measurement equipment were not carried out. The time required to verify stable operation of the engine, consistent with the ASERTTI stability protocol, was so long that emissions instrument response time was not an issue.

Gas Heating Value

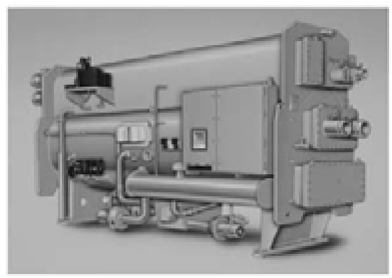
The natural gas was withdrawn with a probe inserted into the flowing gas stream of the fuel inlet pipe and analyzed by an in-line gas chromatograph. The chromatograph continuously flows gas through the sampling line and injects and analyzes a gas sample every five minutes. The chromatograph was calibrated with a certified standard gas every day of testing to ensure accuracy. This analyzer and its software can calculate the higher and lower heating values, based on the component molar compositions.

GTI Integrated Energy System for Buildings Final Report

Appendix B – Market Analysis

Contents

Chapter 1 – Preliminary Product Definition and Initial Sector Targeting



Specific Questions from Trane

- Product
  - Types of products used
  - Product features required
  - What is the expectation of the life of the equipment
- Buildings
  - Types of buildings...colleges, hospitals, etc.
  - Sizes of buildings
  - New or renovation
- Price
  - how much are people willing to pay ...
  - acceptable length of paybacks ...
  - at what size does a BCHP system make sense?
  - What is a typical "checklist" for a customer to review to see if it will make sense
- Buying Process
  - Who is the typical buyer ... building owner, contractor, ??
  - Who makes the design/buying decision
  - What factors make a job go/no go
  - How is a BCHP system specified

Starting Points

- Product Definition
- Commercial Building Sector Selection
- Regional Sector Discussion
- Who is Using Cogeneration in the Commercial/Institutional Sector Now?

Product Definition

Initial Product Definition (from 2001)

Engine Generator	Waukesha
Generator Delivery	Parallel Gear to Larger Load
Generator Capacity	~ 500 kW
Heating Delivery	Hydronic Hot Water 180 F
Heating Capacity	~2,200 MBH at Max Load
Cooling Equipment	Horizon BCHP 90
Cooling Delivery	45 F Chilled Water
Cooling Capacity	90-100 RT

Product Definition Revisions

- Range of Engines Proposed are now Specifically 310, 415, 615, 830 kW
- Cooling stands at 90-100 RT for the 615 kW
  - Other Engines Sizing Probably Developing Recovered Heat Driven Cooling at Capacities ~ Proportional to Engine Size (~ 50 -150 RT Range)
  - In Evaluation Now
  - Recent Upward Revisions in Available Fluid Temperature from Engines May Make Cooling Capacity Lower in $/RT than Initially Thought (In the Long Run)

Current Product Range Planned

	Ultimate Product Line			
Generator Size (kW)	310	415	615	830
HT Heat for Space Heating (MBH)	1264	1710	2562	3412
HT Heat for Space Cooling (MBH)	1215	1621	2428	3236
Resulting Cooling Capacity (RT)	75	101	152	203
Low Temp Heat Avail (MBH)	305-320	400-421	609-640	881-852
HT Heat Features Temperature Reset Control Delivering 235F Water During Cooling Operation and 200F Water During Heating Operation Low Temp Heat Availability Increases During Cooling Operation				

Commercial Building Sector Selection

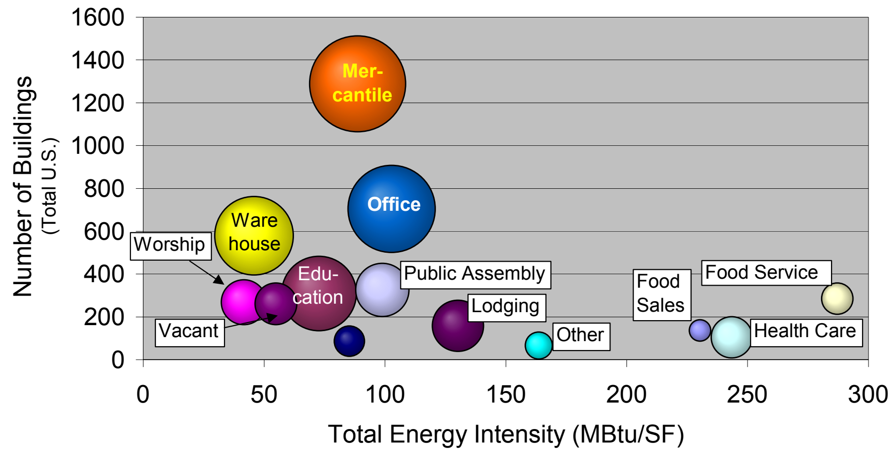
Commercial Building Sector Selection

- Sector Targeting Important to Allow Detail to Be Developed
- Basis Used in the Past
  - Size of Sector
  - Appeal within Sector for BCHP Package
  - Sector Concentration
    - Can a Large % of the Sector be Reached Though a Small Number of Owners
  - Growth within the Sector
  - Selection of Desirable Sub-Sectors

Appeal of the Product

- Energy Intensity of the Market Sector
- Potential for Operating Cost Savings Within the Sector

Segments and Overall Energy Use



Size of Bubble Indicates National Floor Space

Input from Existing Technical Analysis on Commercial Loads

- The Practicality of Cogeneration Depends on the Timing and Sizes of Typical Electric and Thermal Loads in Buildings
  – Very Dependent on Building Function
- Criteria
  – Are Thermal and Electrical Loads Frequently Coincident
  – Are Thermal Loads Large and Frequent Enough to Recover A Significant Portion of the Waste Heat on an Annual Basis
- Economics: If the Segments Selected Best Fit the Criteria, the Potential for Good Economic Return is Highest
  – Universally True Even with Differing and Changing Energy Prices

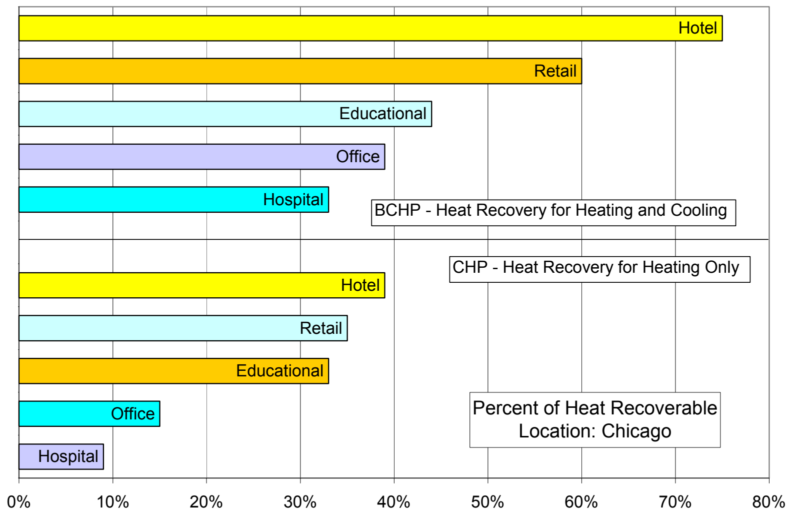
Max. Percentage of Heat Recoverable

- Need a Simple Parameter to Measure the Desirability of Building Types
- Few Technical Assumptions:
  - System Equal in Size to the Maximum Electrical Load
- What is the MAX Percentage of the Recoverable Heat That Can Be *Used*
  - Varies by Market Sector
  - Reasonable Initial Proxy for Desirability

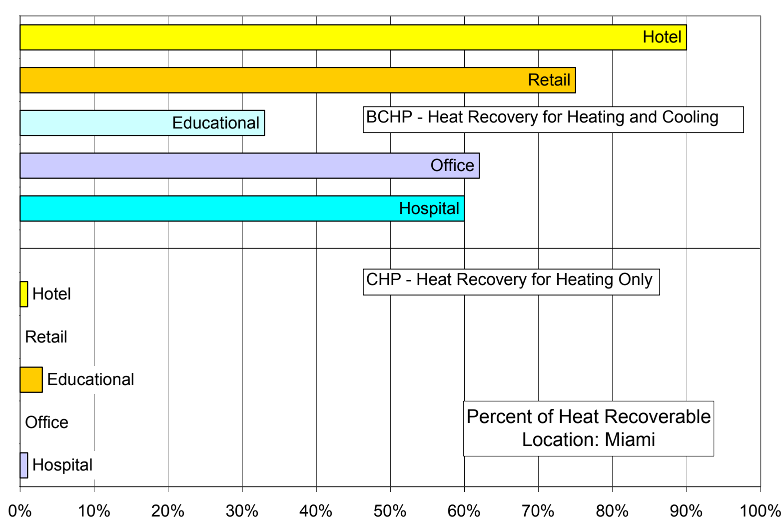
Loads

- Based on DOE-2 Analysis of Typical Building Types
  - Large Office 142,000 SF
  - Hospital 300,000 SF
  - Large Educational 71,000 SF
  - Large Hotel 220,000 SF
  - Large Retail 125,000
- Terms
  - CHP = Cogeneration with Heat Recovery for Heating Only
  - BCHP = Cogeneration with Heat Recovery for Heating and Cooling

Existing Load Analysis Data



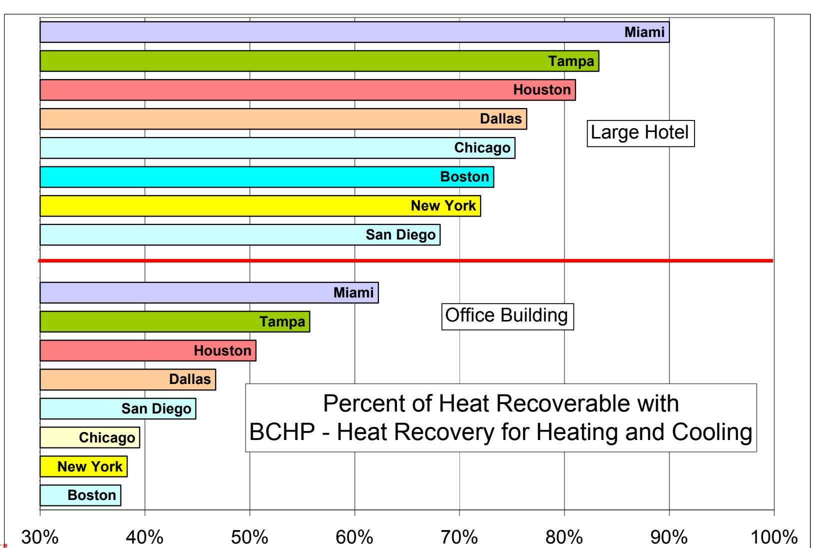
Existing Load Analysis Data



Existing Load Analysis Data

- Heat Recovery Fractions are Dramatically Improved with BCHP Vs. CHP
- Improvement is Quite Significant Even in North

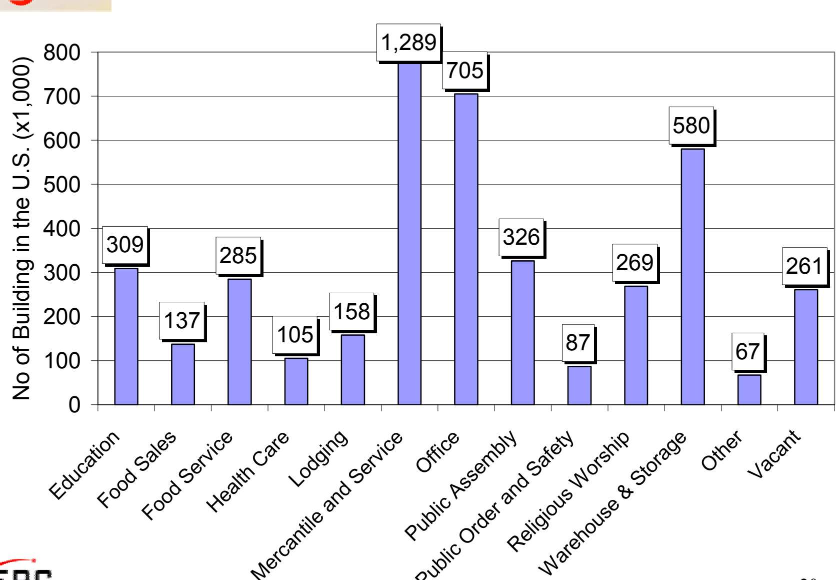
Existing Load Analysis Data



Existing Load Analysis Data

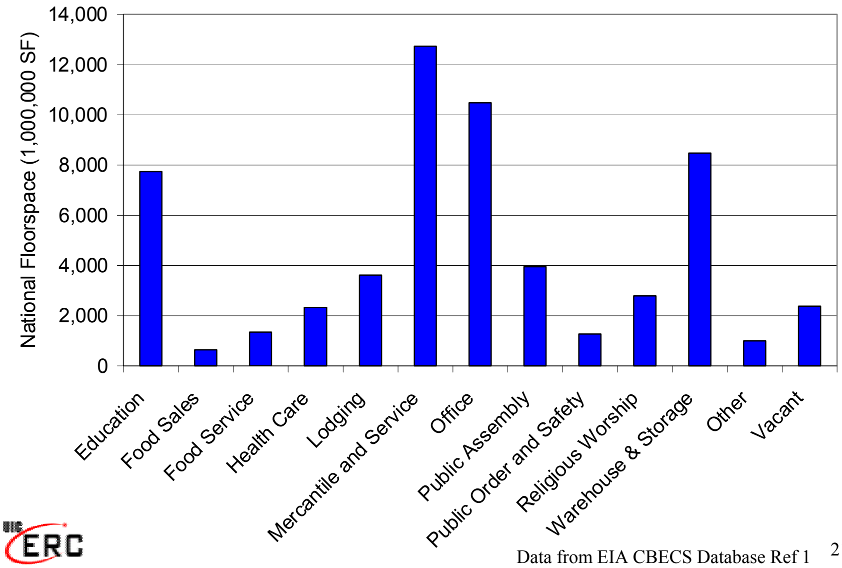
- Choice of Building Type Makes as Much or More Difference than the Local Climate

Total Number of Buildings



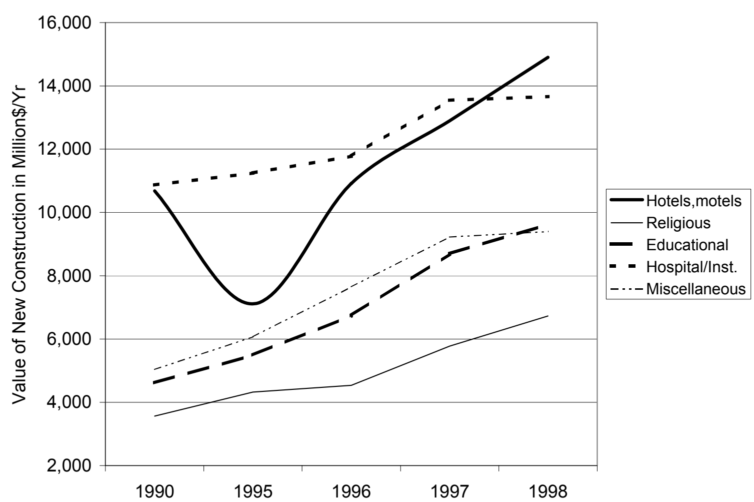
Data from EIA CBECS Database Ref 1

National Floorspace



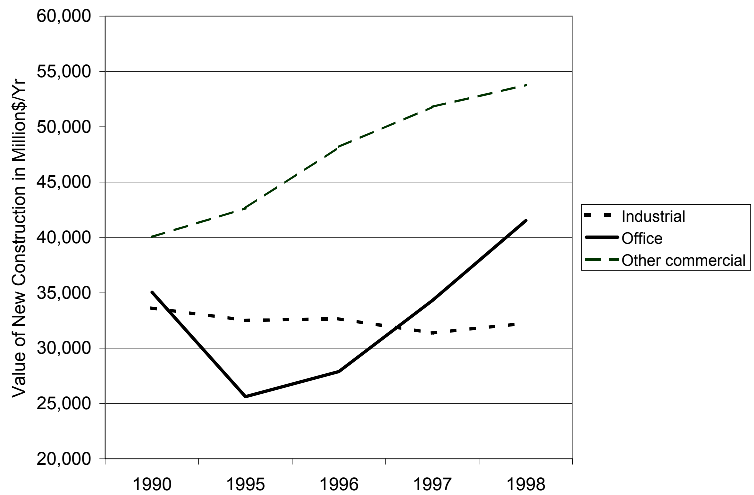
Data from EIA CBECS Database Ref 1

Census Data-New Construction by Type



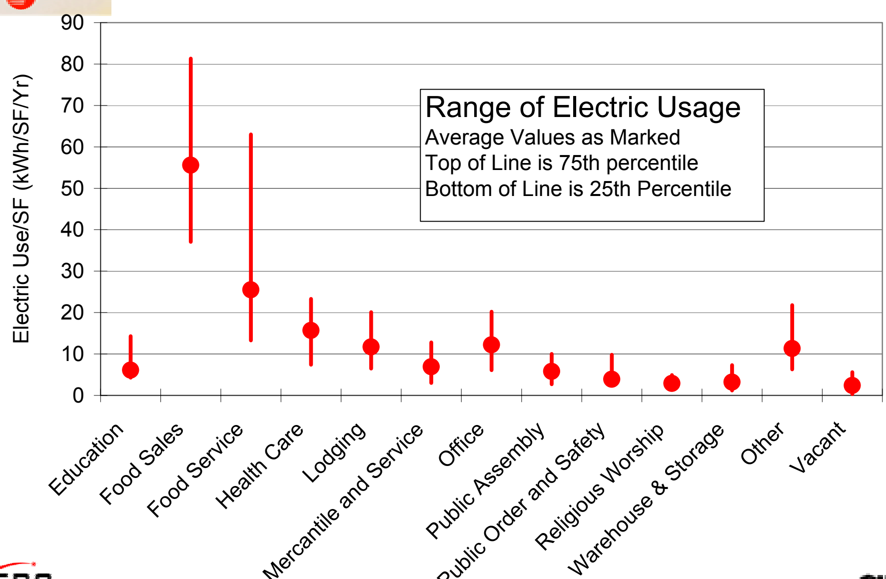
Data from the United States Census Bureau - Ref 2

Census Data-New Construction by Type



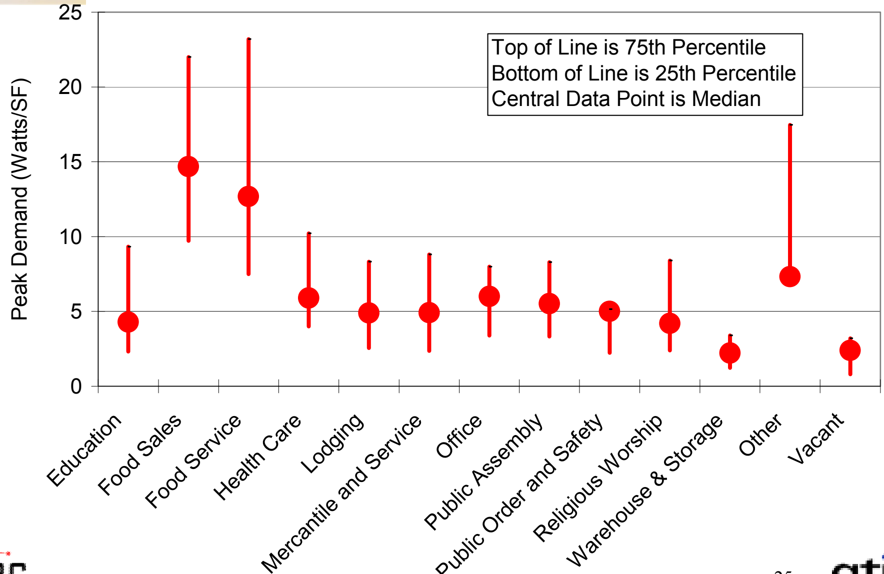
Data from the United States Census Bureau - Ref 2

Variation in Electric Usage Intensity



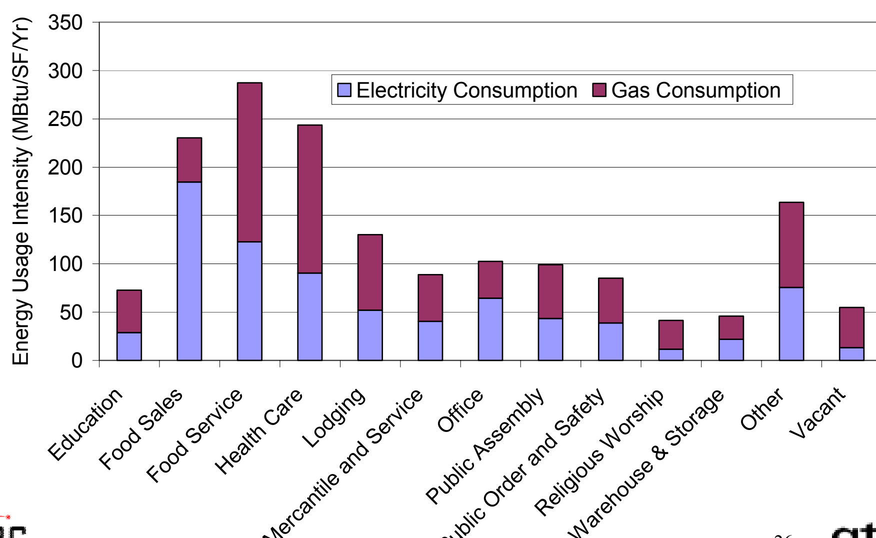
Data from EIA CBECS Database - Ref 1

Peak Electric Demand by Sector



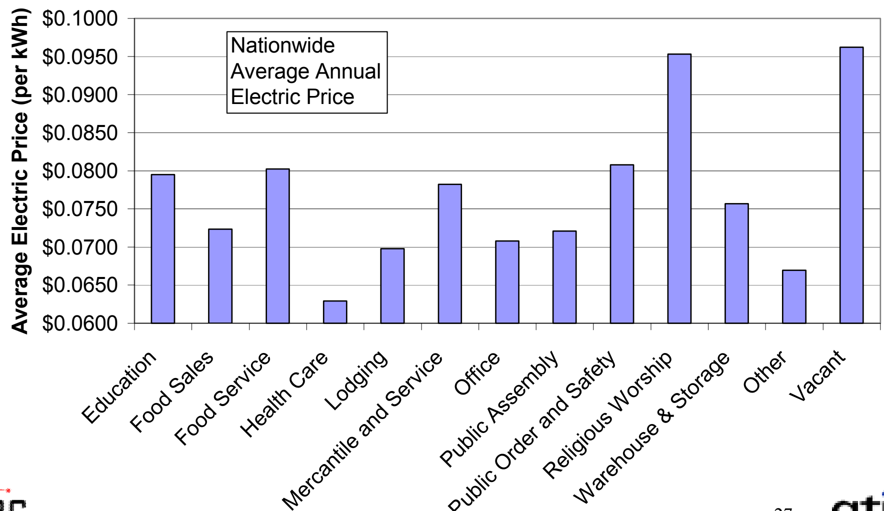
Data from EIA CBECS Database - Ref 1

Electric and Gas Usage Intensity



Data from EIA CBECS Database - Ref 1

Average Electric Price by Sector



Data from EIA CBECS Database - Ref 1

Possible Market Sectors

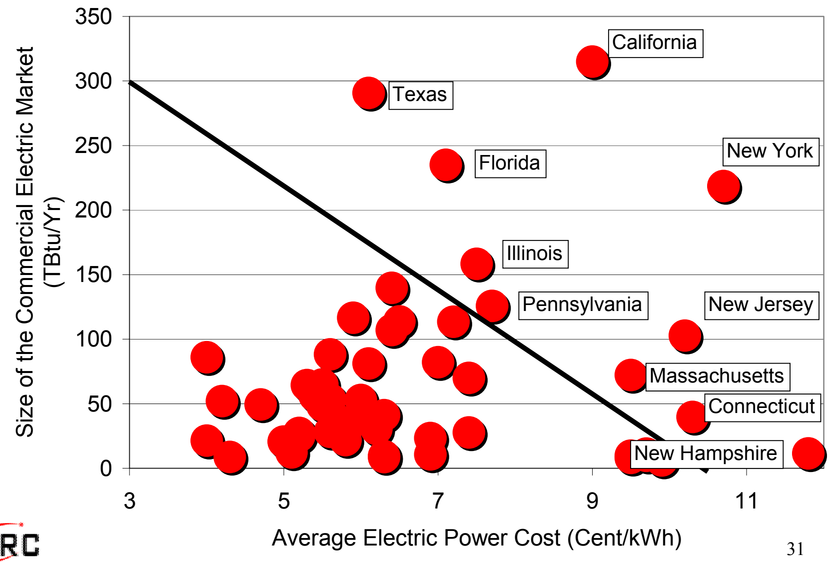
Segment	Advantages Segment May Have for BCHP	Disadvantages Segment for BCHP
Hospital	24 Hr Operation Large Maintenance Staff Back-Up Power Implications	High Electric/Thermal Ratio
Other Healthcare	24 Hr Operation Back-Up Power Implications	Limited Maintenance Staff Smaller Segment
Larger (K-12) Educational	Institutional Owner- Longer Payback Criteria More Level Thermal Load	Limited Maintenance Staff Reduced Summer Use Schedule
Office Buildings	Large Market On-Peak Operating Hours Some Market Concentration	Short Operating Hours Sizable Sub-segment in Rented Facilities
Retail	Large Well Defined Market Longer Operating Hours Good Electric/Thermal Ratio	Sizable % in Rented Facilities Large Store Sub-Segment? Shorter Payback Criteria
Large Hotel	24/7 Operating Hours Good Electric/Thermal Ratio Good National Chain Concentration	High Rise Central System Sub-Segment Only Smaller Segment

Regional Sector Discussion

Geographic Desirability

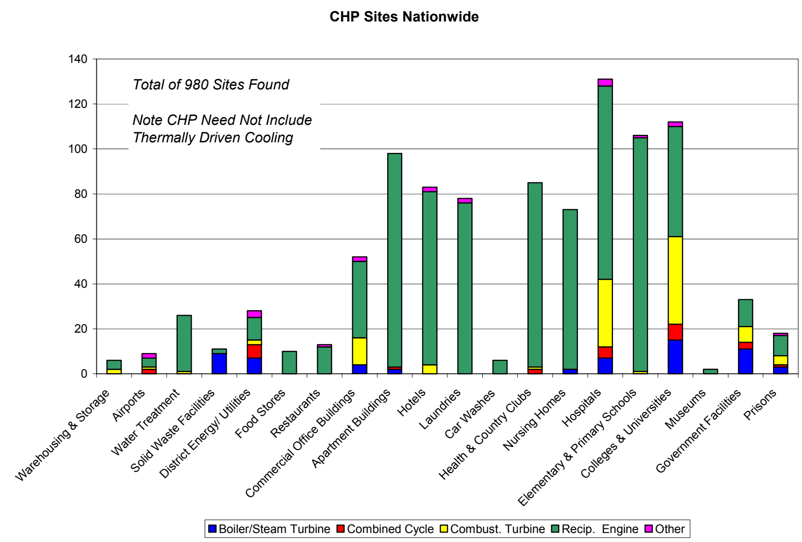
- Key Factors
  - Local Energy Costs
  - Size of the Commercial Market

10 Most Desirable States

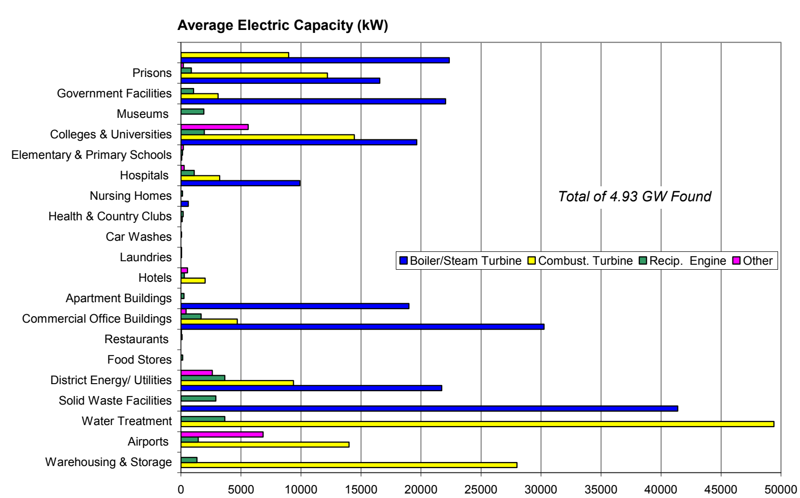


Who is Using Cogeneration in the Commercial/Institutional Sector Now?

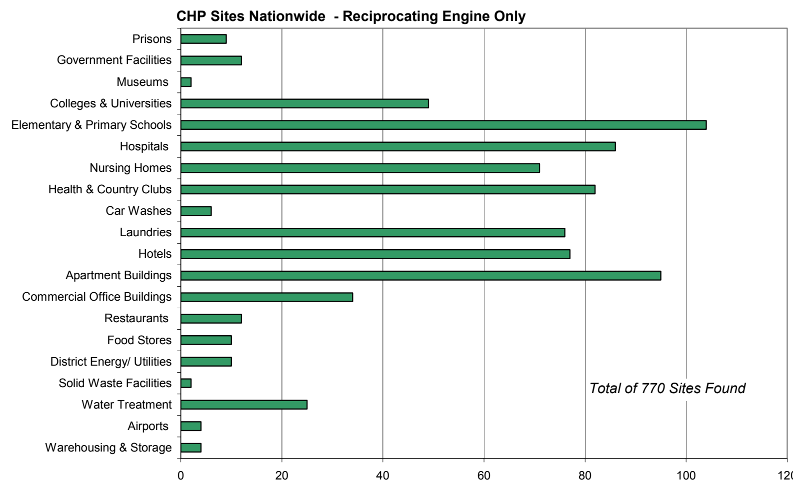
CHP by Technology by Sector



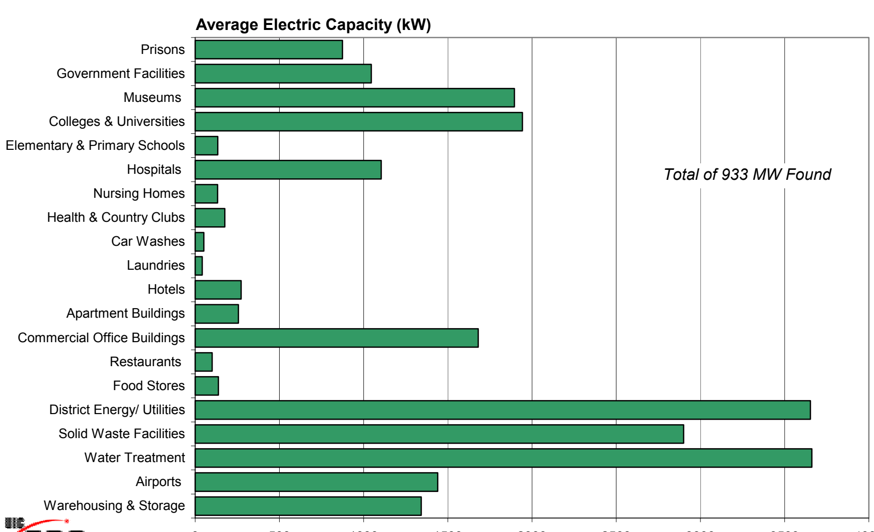
System Size Varies Widely



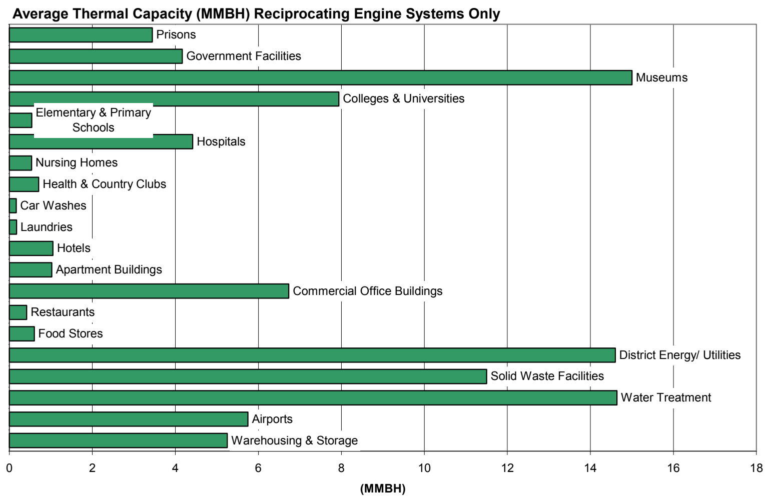
Engine Systems are the Most Numerous



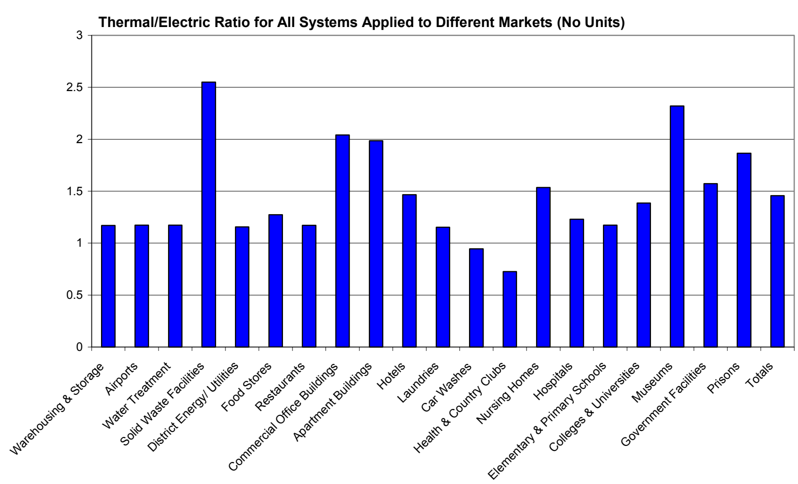
Engine Systems are the Smallest



Also in Heat Output

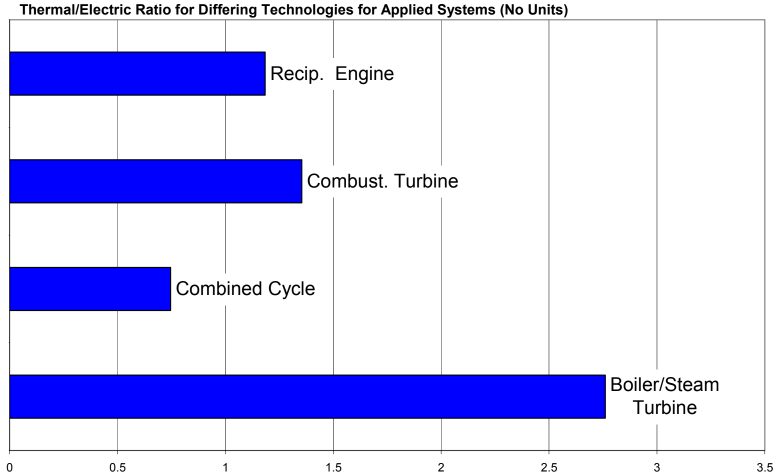


T/E Ratios of Systems Currently Applied to Differing Sectors Provides Some Indication of Sector Differences



Differing Tech. Used to Produce Varying T/E Ratios

Thermal/Electric Ratio for Differing Technologies for Applied Systems (No Units)



Starting Points

- Some Indications of Good Segments in
  - Hospital, Retail, Office, Educational, Large Hotel
  - Needs Development of Ranking Based on:
    - Attractive Sub-Segment Identification
    - Market Concentrations Identification (Large Owners)
    - User Preference Information (Where Available)

Suggested Structure

- Executive Summary
- Chapter 1 – Market Overview and Starting Points
- Chapter 2 thru ?: Chapters by Selected Sector to Include (Where Possible):
  - Overall Demographics
  - Customer Preferences
    - Info Included Decision Maker Title, Sources of Info, etc
  - Existing Equipment Used
  - Identify Leading Customers
  - Identify Number of Sites that Correspond with Output of the Product Line
- Economic Analyses to Be Done in Separate Report
  - Model Largely Complete
  - Some Generic Runs Completed

Existing Site Survey – CHP Systems – Ranked by Recip. Engine Use – Systems May Not Include Cooling

Existing Cogeneration Sites - CHP	Recip. Engine	Totals	Notes
Elementary & Primary Schools	104	106	Suggested Target Sector
Apartment Buildings	95	98	New Sector to Consider?
Hospitals	86	131	Suggested Target Sector
Health & Country Clubs	82	85	CHP for Large Heating Load - Little BCHP/Cooling Interest
Hotels	77	83	Suggested Target Sector
Laundries	76	78	CHP for Large Heating Load - Little BCHP/Cooling Interest
Nursing Homes	71	73	Suggested Target Sector
Colleges & Universities	49	112	Larger Systems than Envisioned for BCHP Package
Commercial Office Buildings	34	52	Suggested Target Sector
Water Treatment	25	26	CHP for Large Heating Load - Little BCHP/Cooling Interest
Restaurants	12	13	Smaller Systems than Envisioned for BCHP Package?
Government Facilities	12	33	Vague Category - Larger Systems than Envisioned for BCHP Package ?
District Energy/ Utilities	10	28	Larger Systems than Envisioned for BCHP Package
Food Stores	10	10	New Sector to Consider?
Prisons	9	18	Larger Systems than Envisioned for BCHP Package
Car Washes	6	6	CHP for Large Heating Load - Little BCHP/Cooling Interest
Warehousing & Storage	4	6	CHP for Large Heating Load - Little BCHP/Cooling Interest
Airports	4	9	Larger Systems than Envisioned for BCHP Package
Solid Waste Facilities	2	11	CHP for Large Heating Load - Little BCHP/Cooling Interest
Museums	2	2	Roll in as Subset of Educational
Totals	770	980	

The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector, ONSITE SYCOM Energy Corporation, Prepared for:U.S. Department of Energy

Specific Sectors/Sub-Sectors Arising from Trane Review

- Retail – Moderate Size Mall Owners & Developers
- Retail – Free Standing Large Stores
- Education – K through 12
- Hotels - Large Hotels with Central Systems
- Office Buildings – General
- Office Buildings – Data Centers
- Healthcare – Medium Size Medical Facilities (Free Standing Clinics)

Appendix 1A - CBECS Details

Description of Building Types

- Buildings were classified according to principal activity, business, commerce, or function carried on within each building.
- Buildings that were used for more than one of the activities were assigned to the activity occupying the most floorspace at the time of the interview.

Education:

- Refers to buildings used for academic or technical classroom instruction.
  - Schools:
    - Preschool
    - Elementary
    - Junior high
    - Senior high
    - College or university classroom/Laboratories
    - Vocational school.
- Other activities that occur on school campuses are reported elsewhere

Food Sales:

- Refer to buildings used for retail or wholesale sale of food.
  - Convenience store or market
  - Farmer's market, Fruit/Vegetable market
  - Grocery store/Supermarket
  - Meat/Seafood store
  - Retail bakery
  - Specialty food store.

Food Service:

- Refers to buildings used for preparation and sale of food and beverages for consumption.
    - Prepared-Meal Service - Cafeteria
    - Carry-out Service
    - Caterer
    - Fast-food establishment
    - Pizza parlor
    - Sandwich shop
    - Full-Service Restaurant:
    - Bar, Bar and grill, Coffee shop
    - Diner, Full-menu-service establishment.

Health Care:

- Refers to buildings used as diagnostic and treatment facilities for both inpatient and outpatient care.
- Medical Care Hospital:
  - Chronic disease
  - General medical and surgical
  - Mental Facility
  - Rehabilitation Facility.
- Outpatient facilities may be medical, dental, or psychiatric and involves diagnosis and treatment in which services are not required overnight.
  - Dental Clinic, Medical Clinic
  - Mental health/psychiatric clinic
  - Veterinary Facilities.

Lodging:

- Refers to buildings used to offer multiple accommodations for short-term or long-term residents, including nursing homes.
  - Short-term Residence:
    - Convention Hotel, Hotel, Inn, Motel, Shelter Home, Tourist Home
  - Long-term Residence:
    - Boarding House, Convent/monastery, Extended Stay Hotels,
    - Dormitory/sorority/fraternity, Orphanage
  - Assisted-living Elder Care Facilities (Limited Medical Facilities) With 24-hour Nursing/medical Care.

Mercantile and Service:

- Mercantile
  - Shopping malls and strip centers
  - Retail:
    - Automobile Dealers, Building Materials, Garden Supply, and Hardware Stores, Department Stores, Drugstores, Furniture, Home Equipment Stores and Home Furnishings, Liquor Stores, Wholesale Goods
- Service
    - Dry Cleaner/car Wash/laundry, Gasoline Stations, Motor Vehicle Repair/service/maintenance, Multiservice Establishments, Personal Service, Post Office.

Office:

- Refers to buildings used for general office space, professional offices, and administrative offices.
- Data Processing:
    - Computer Center, Data Entry/keypunch
- Financial Office Building:
    - Bank, Brokerage Firm, Insurance, Real Estate, Securities
- Professional Office Building:
    - Administration of an Institution, Consulting, Corporate, Engineering, Law, Management, Medical, Mixed Professional.

Other:

- Refers to buildings used for activities that do not fit into any of the specifically named categories. In the tables of this report, this category includes buildings whose largest single activity is agricultural, laboratory, industrial/manufacturing, or residential.

Public Assembly:

- Refers to buildings in which people gather.
  - Entertainment Building:
    - Archive/art gallery/exhibit hall/library/museum, Coliseum/arena (enclosed), Concert hall, Observatory/planetarium, Night Club, Radio/TV station or studio, Theater/movie house/cinema
  - Recreational Facility:
    - Amusement arcade, Bowling alley, Community Centers, Gymnasium/YMCA or YWCA/indoor racket sports, recreation center/athletic facility, Indoor pool, Poolroom, Skating rink
- Social/Public/Civic Assembly:
    - Assembly hall and Auditorium , Convention hall, Funeral home, Lecture hall, Lodge and Meeting hall, Student union, Town hall, Other Enclosed Assembly Building Passenger terminal or Stadium

Public Order and Safety:

- Refers to buildings used for the preservation of law and order or public safety.
  - Courthouse
  - Fire station
  - Jail
  - Penitentiary/Prison
  - Reformatory
  - Sheriff's office.

Religious Worship:

- Refers to buildings in which people gather for religious activities.
  - Chapel
  - Church
  - Mosque
  - Synagogue
  - Temple.

Warehouse and Storage:

- Refers to buildings used to store goods, manufacturing products, merchandise, or raw materials.
  - <u>Refrigerated Storage</u> refers to buildings specifically designed to store perishable goods or merchandise under refrigeration. Includes "cold storage" facilities, and "freezer" facilities
  - <u>Nonrefrigerated Warehouse</u> refers to buildings specifically designed to store perishable goods or merchandise without refrigeration.

Chapter 2: Educational Buildings

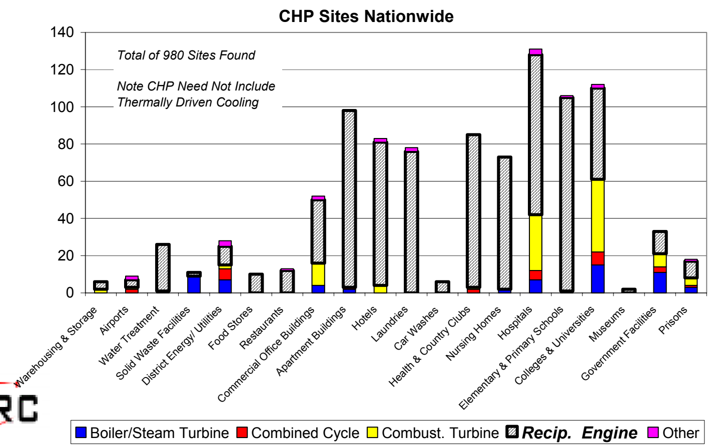
Prepared by:
Bill Ryan UIC-ERC
Cliff Haefke UIC-ERC
630-561-4448
Marek Czachorski GTI
847-768-0526

Overall Objective

- Determine the Potential Market Size in Schools K-12 for Cogeneration

Why K-12 Schools?

- Primary and Secondary Educational Buildings
- Largest Current Users of Engine Driven Generating Systems



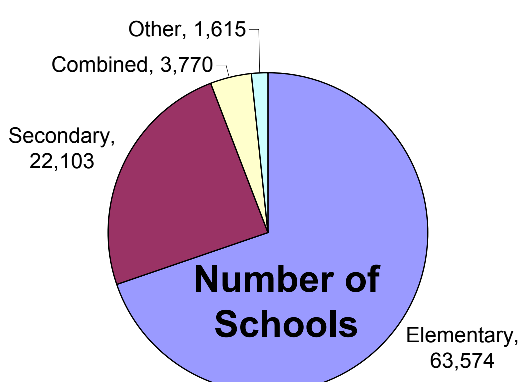
Ref. 2

Market Evaluation Process

- Existing Facilities
  - How Many Schools are There Now?
  - What Size are the Schools?
  - What are the Power Requirements?
  - Where is the Market "Concentrated"?
  - What Condition are American Schools In?
  - What Kind of Mechanical Systems Do They Currently Have?
- New Construction
  - How Much New Construction is Projected?
  - Where is the New Construction Projected?
- The Buying Process in Schools
  - Who is the Chief Decision Maker?
  - Where Do They Get Information?
- Summary

Existing Schools

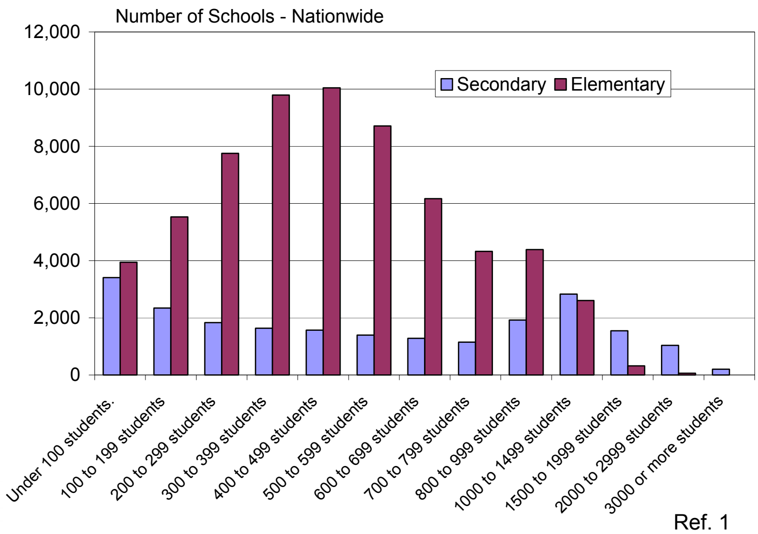
How Many K-12 Schools are in the US



Total Number of K-12 Schools in US = 91,062

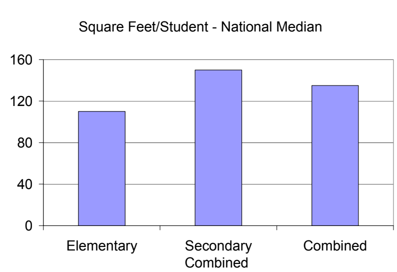
Ref. 1

How Large are These Schools?



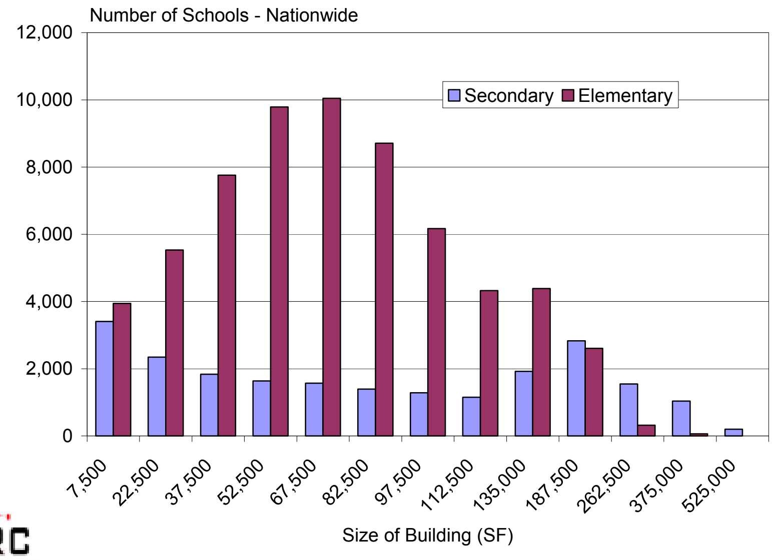
Ref. 1

Size and Power Calculation

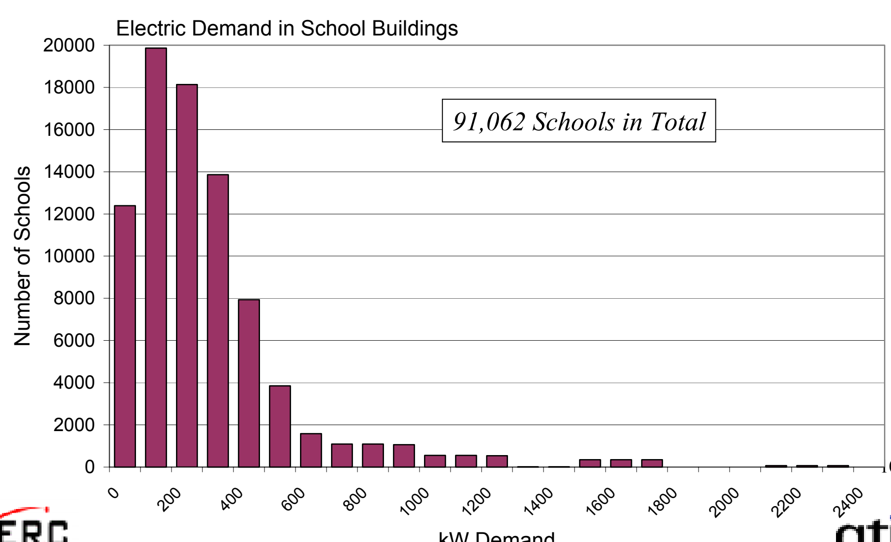


- Median Square Footage per Student
  - Use to Size Schools from School Population Statistics
  - (Ref 3)
- Average Power Demand 4.3 w/SF
  - Use to Calculate Power Requirements from School Sizes
  - (Ref 4)

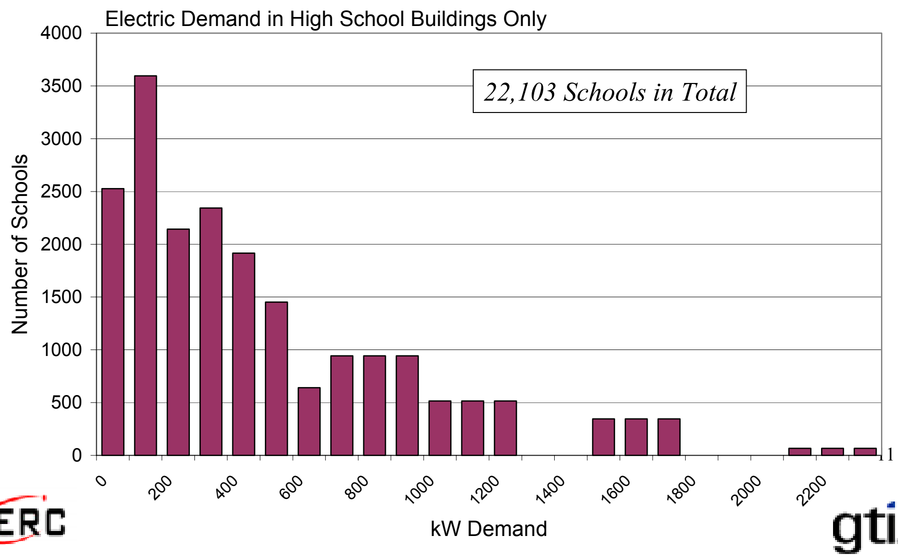
Size of School



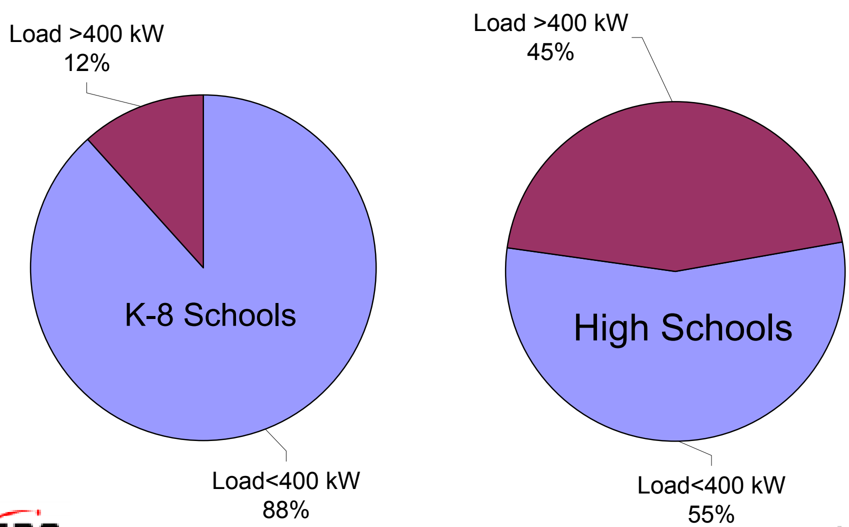
Peak Power Demand



Focusing on High Schools



High Schools are a Stronger Focus Market



Size of the Market

- Focusing on Facilities Over 400 kW
  - 7,400 Grade Schools
  - 10,000 High Schools
- Retrofit Market
  - 11.9 GW
  - Includes Schools over 400 kW Peak Demand Only
  - Smallest Planned Product Size at 310 kW as Outlined in Chapter 1

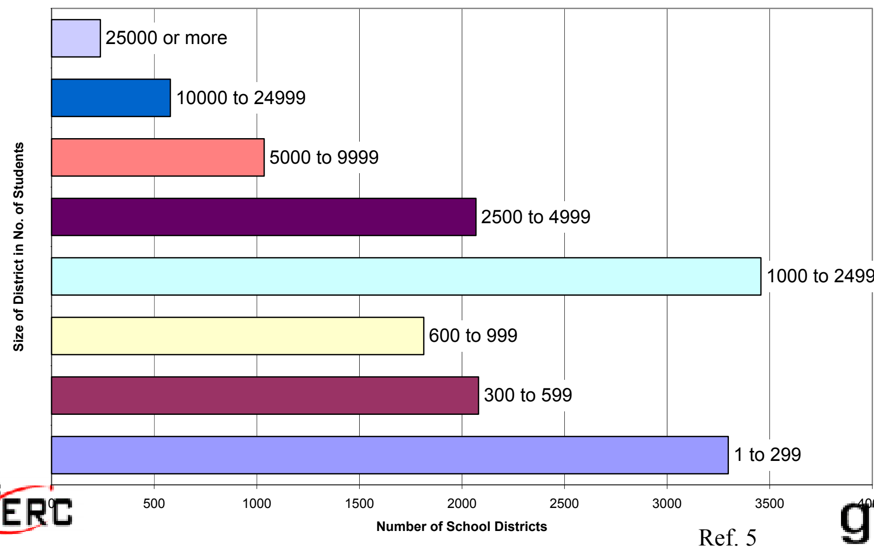
Market Concentration

- Market Concentration
  - Finding the Smallest Market Sub-Segment with the Greatest Concentration of Potential Customers
  - Minimize Marketing Costs and Maximum Sales Results
- High Schools Form a More Concentrated Market
  - 7400 Grade Schools (K-8) Out of 63,000 have Loads Over 400 kW
  - 10,000 High Schools (9-12) Out of 22,000 Have Loads Over 400 kW
- BUT There are 14,981 School Districts in the United States !

Ref. 5

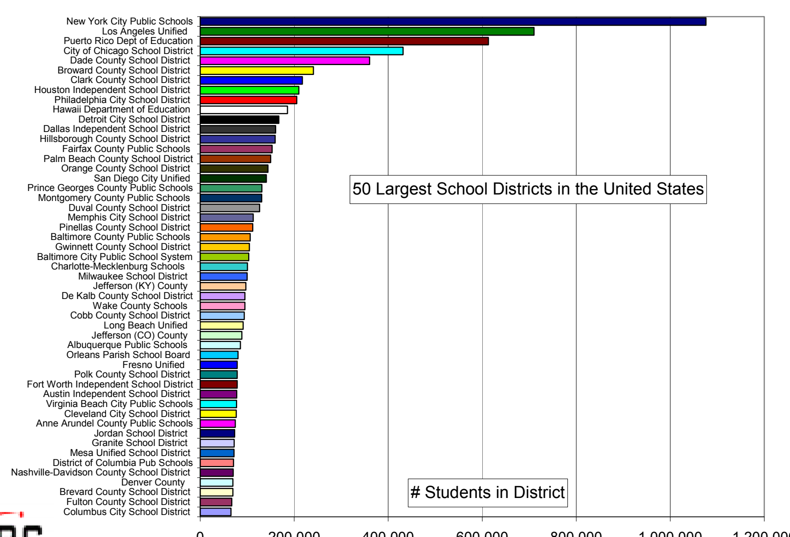
However – The Largest 1.6% of School Districts Nationwide Have 32.1% of the Students

Size Distribution of School Districts



Ref. 5

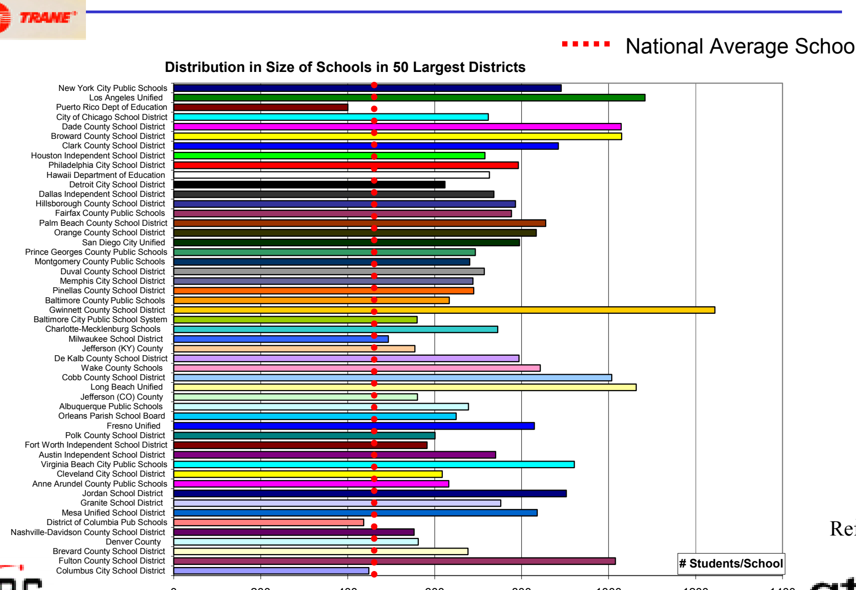
Where are the 50 Largest Districts



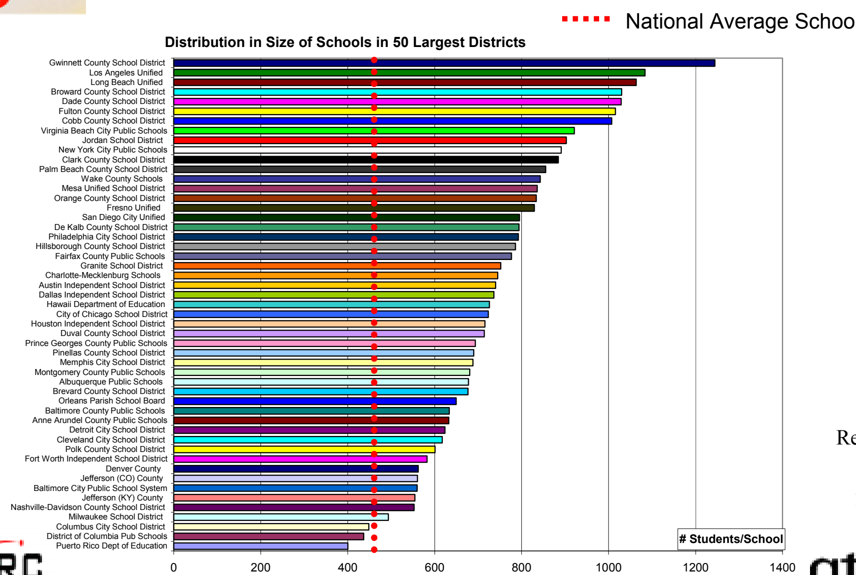
Ref. 8

Location of the 100 Largest Districts

Do They All Feature Larger Schools? – Not All



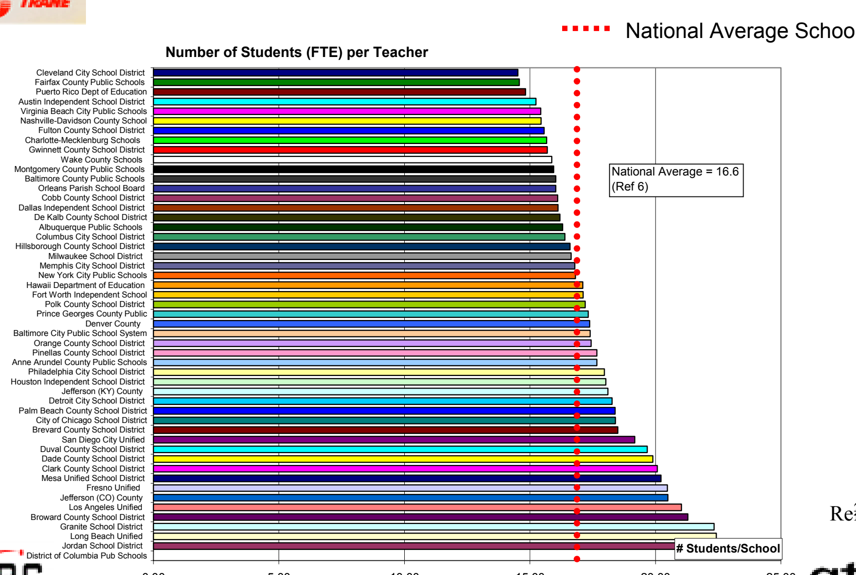
But They Do Average Larger Schools? - Yes



Ref. 8

19

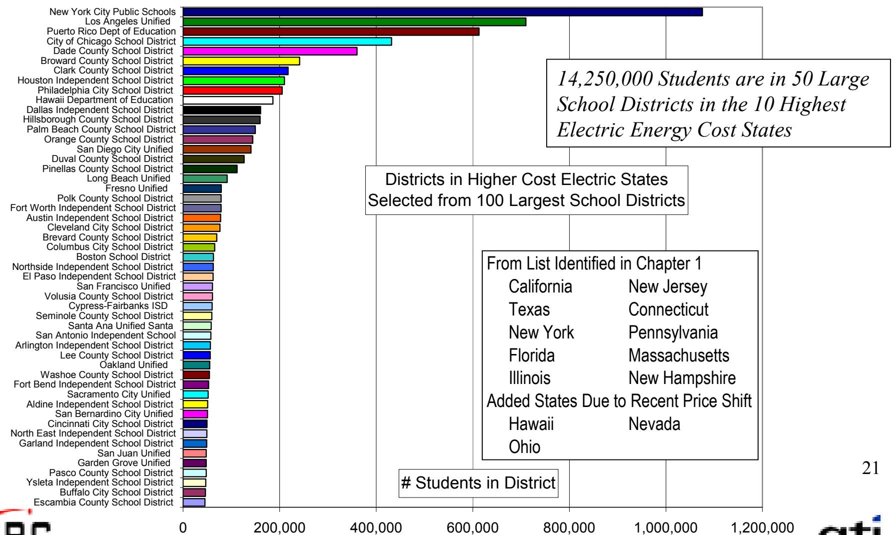
Do These School Districts Spend More Than Average on Education ?



Ref. 8

20

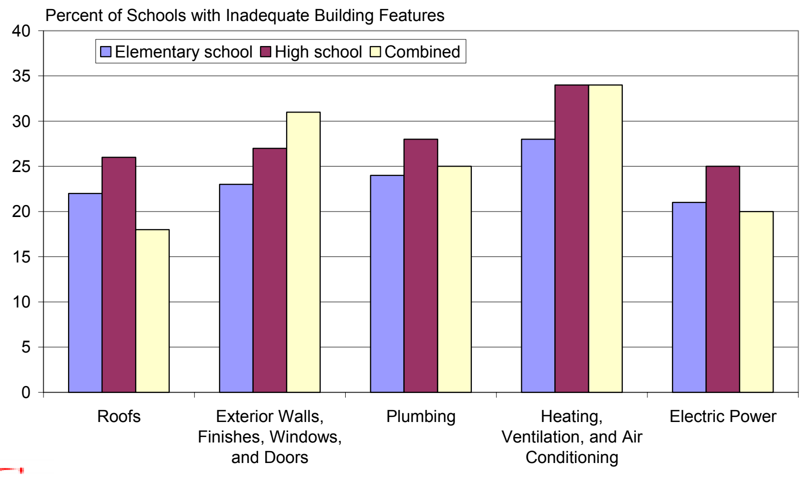
Overlaying Location on Higher Electric Cost States



What Condition are U.S. Schools In ?

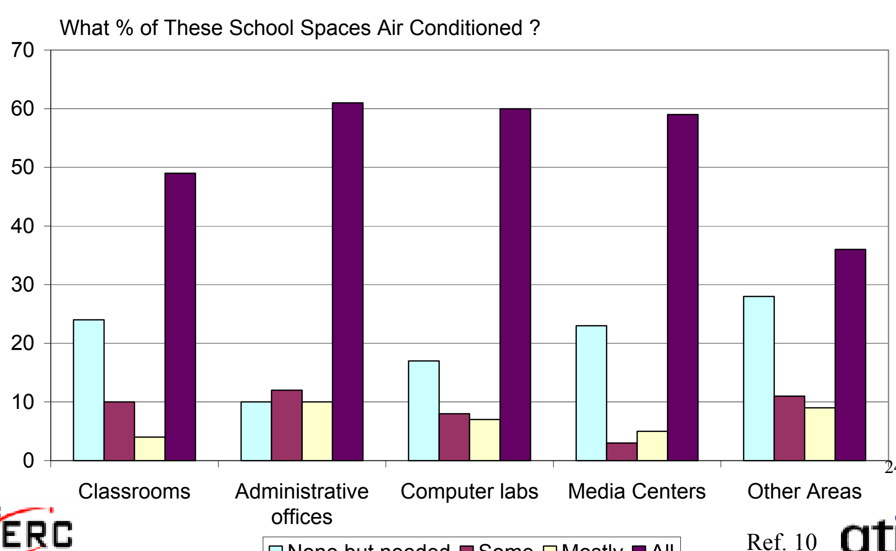
- What Do They Need?
- Do They Have BCHP Related Needs?
  - Are They Air Conditioned?
  - Are They in Need of Electrical Upgrades?
- What is the Most Common Renovation Underway Today?

What Do These Schools Need?



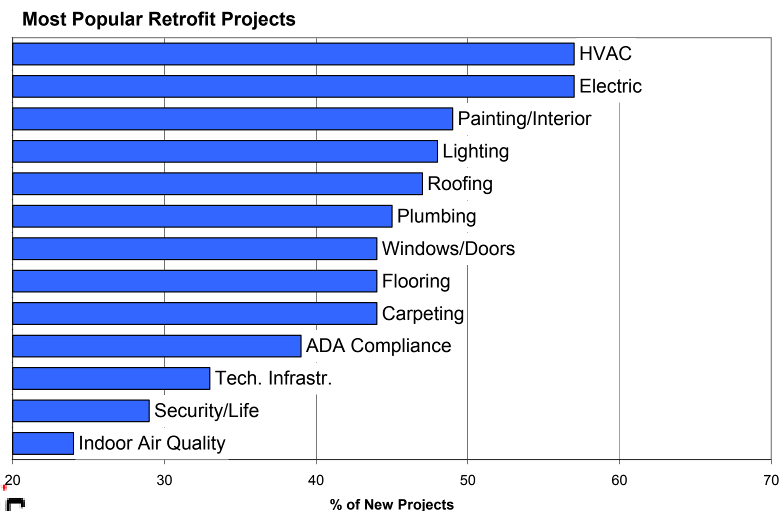
Ref. 7

Indicators of the Retrofit Market



Ref. 10

What is Most of the Refurbishment Money Going Into ?



Ref. 10

Totals Exceed 100% as Some Projects have Dual Objectives

Summary – Existing Buildings

- Power Needs in the Most Amenable Loads
  - Demand Above 400 kW
  - Range of 11,900 MW
- Market Concentration
  - Top 100 School Districts (Out of 14,981 Nationwide) Handle 11 Million Students Out of 53 Million Nationwide
  - More than Half are in High Electric Energy Cost States
- Refurbishment Needs
  - Electric and HVAC Equipment are the Most Popular Refurbishment Projects in Schools

Survey Information on Existing Building Equipment

Equipment in Existing Educational Buildings

- Information from 1997 AGA/GRI Market Survey
  - 625 In Depth Interviews of Educational Facility Decision Makers
  - In Control of 6,358 Educational Facilities
  - Representative of 113,000 Facilities Overall

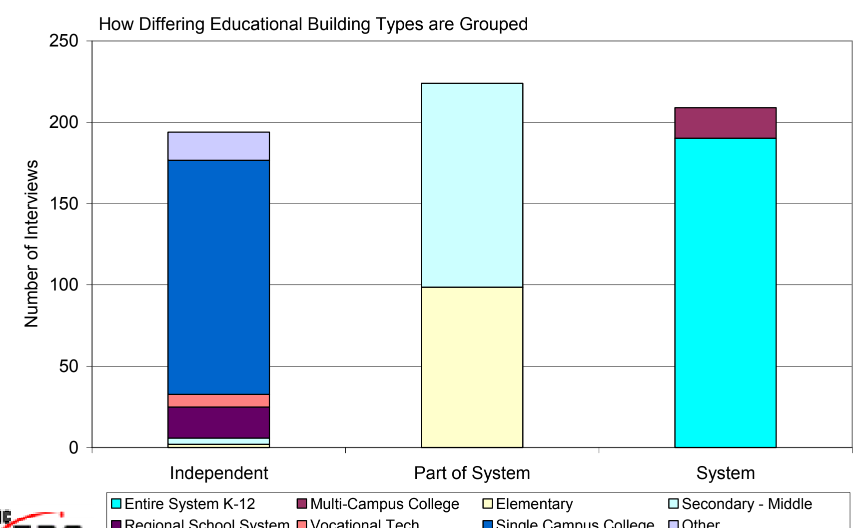
Ref. 11

Survey Results Originally Sorted into 3 Categories by Decision Making Process

1. Independent Operations
2. Education Facility Locally Controlled but Coordinated within a Larger System
3. Central Multi-Facility Management for an Entire System

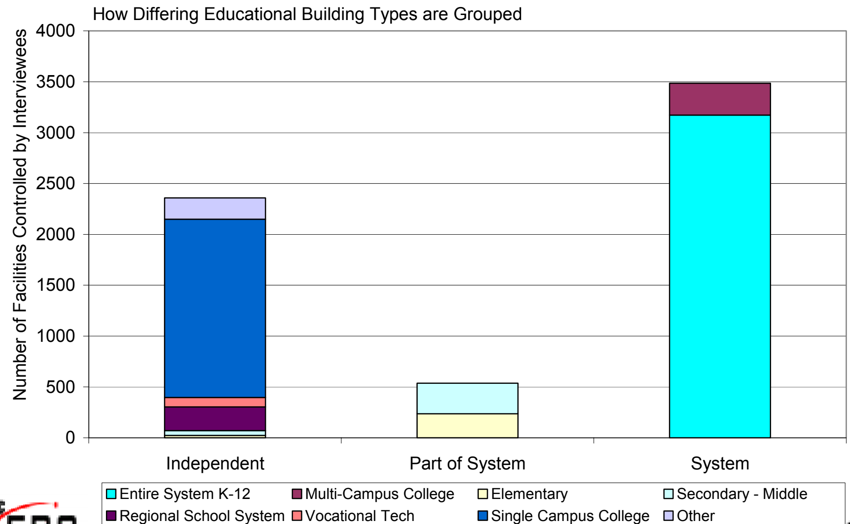
Need to Sort into K-12 and College Categories

How the Interview Data was Sorted



Ref 11

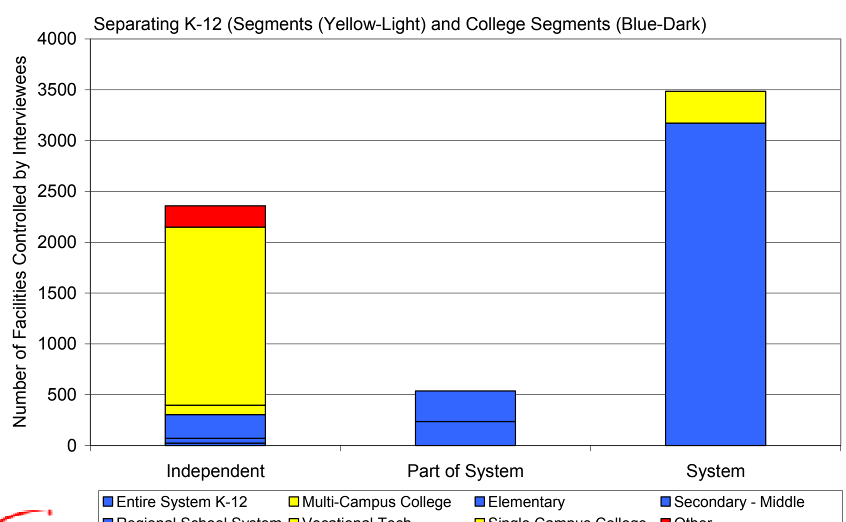
No of Facilities Controlled by the Interviewees



31

Ref 11

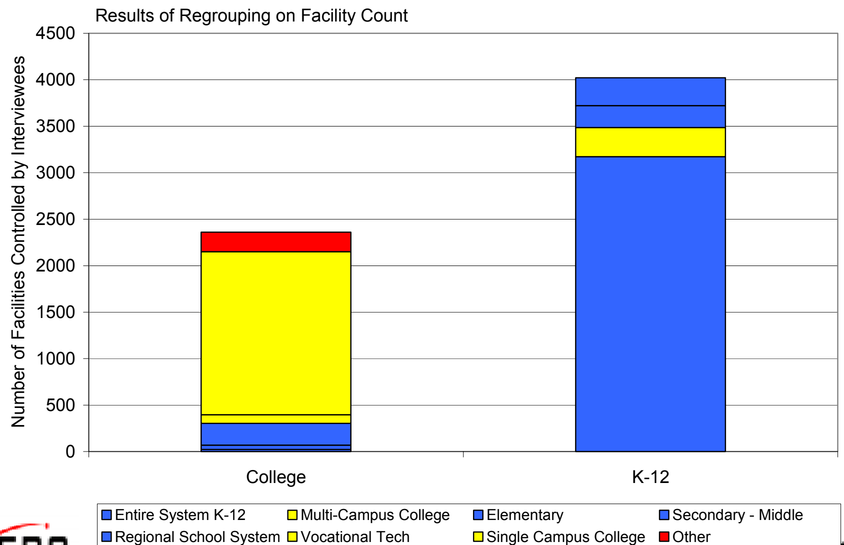
Identify K-12 (Blue-Dark) and College (Yellow-Light) Sectors by Color



32

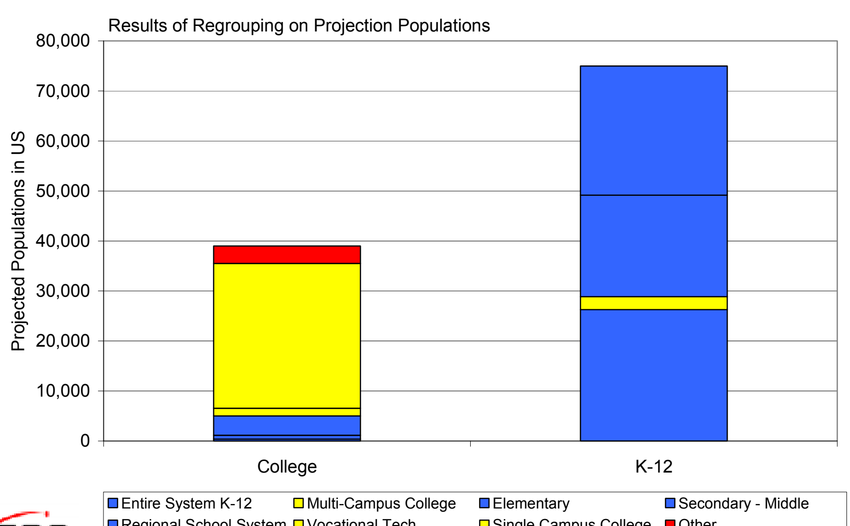
Ref 11

Adding "Part of System" Data to "System" Comes Close to Separating College and K-12 Data



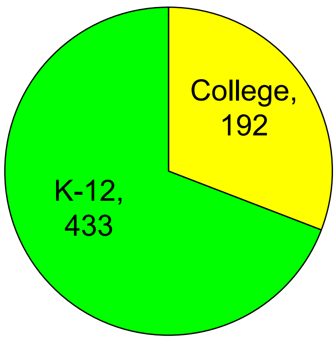
Ref 11

Looking at Projected National Building Population Based on New Segmentation Shows Good Results

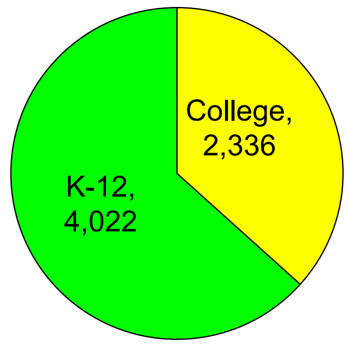


Ref 11

Sampling: No. of Interviews and Types of Facilities



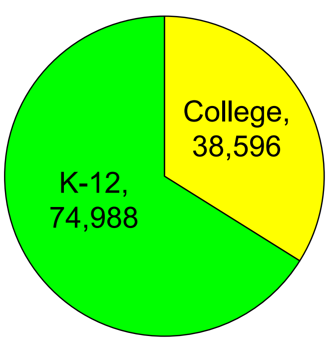
Actual Interviews



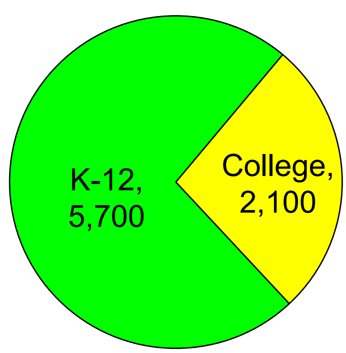
Number of Facilities
Represented by Interviewees

Ref 11

Sample Representative of a Larger "Projected" Number of Facilities



Projected Number of
Facilities Nationwide

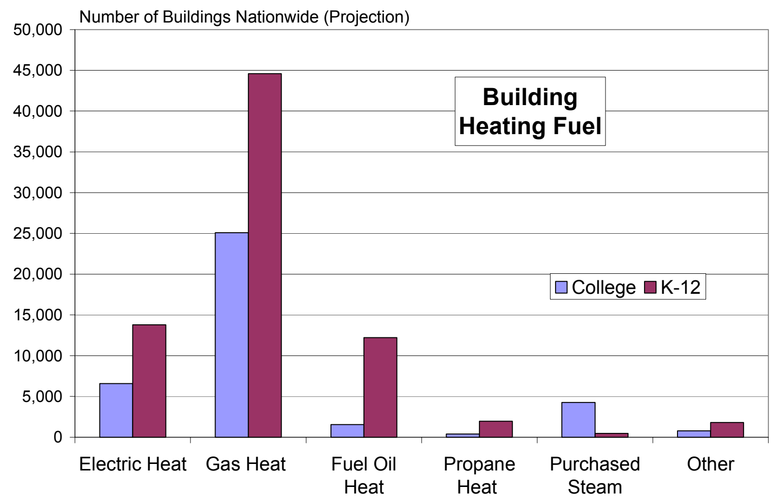


Projected Floorspace (MMSF)

Note 74,988 K-12 Represented by Interviews, 91,062 K-12 is the U.S. Total

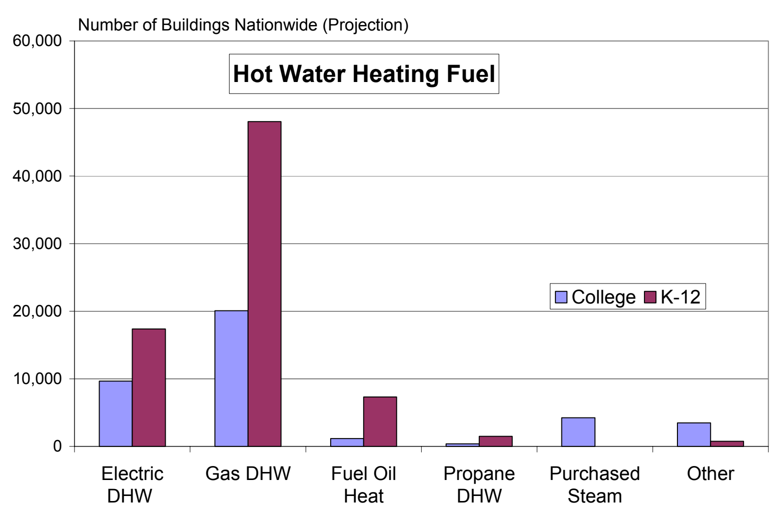
Ref 11

Fuel Used for Heating?



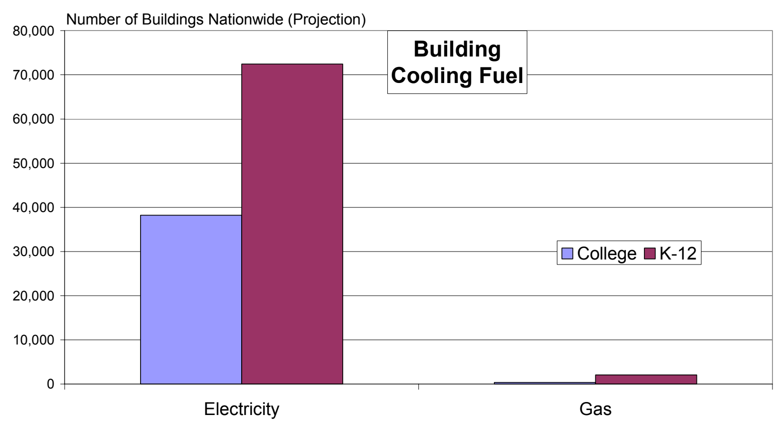
Ref 11

Fuel Used for Water Heating?



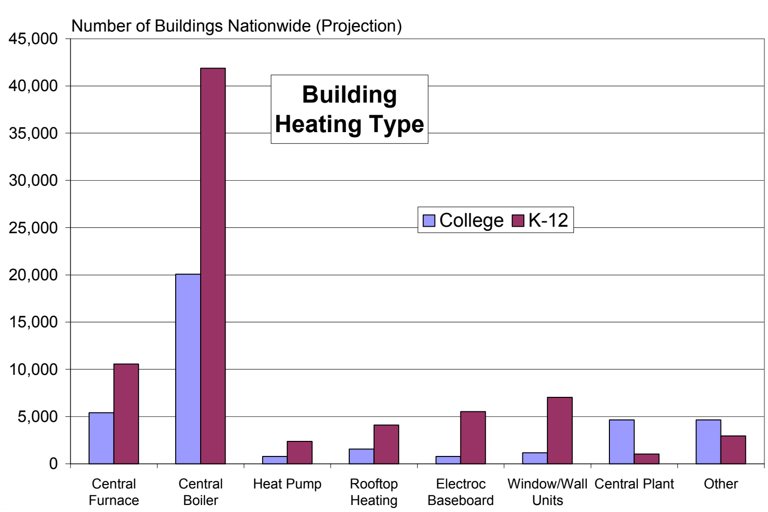
Ref 11

Fuel Used for Cooling?



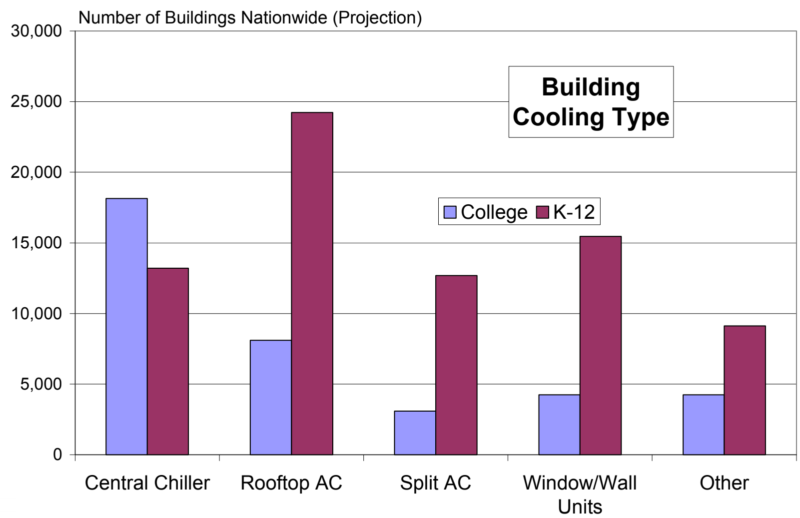
Ref 11

Equipment Used for Heating?



Ref 11

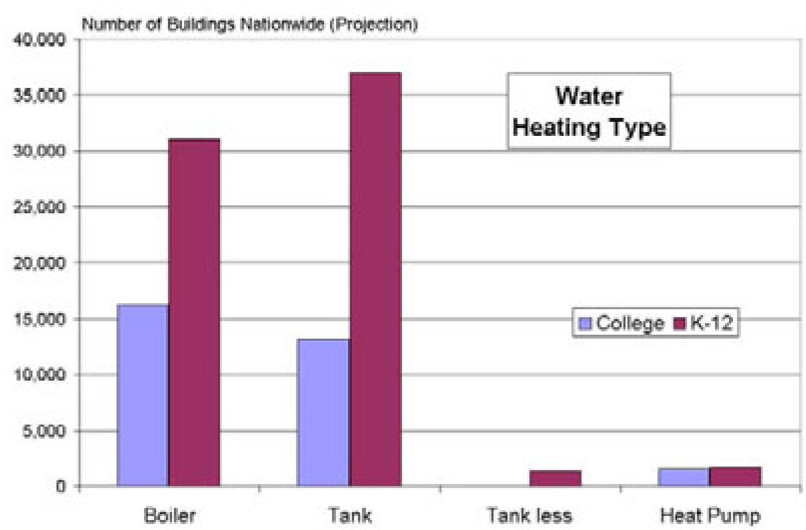
Equipment Used for Cooling?



41

Ref 11

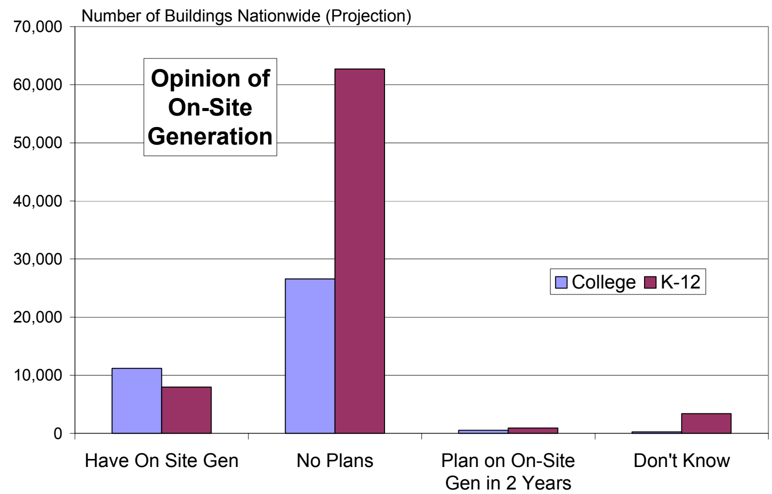
Equipment Used for Water Heating?



42

Ref 11

Interest in On-Site Generation?



Ref 11

Summary - Existing Equipment

- Most Amenable Buildings for BCHP are Buildings with:
  - Gas Available
  - Central Boilers (Hot Water or Steam Heating)
  - Central Chillers (Chilled Water Cooling)
- We Find
  - Nearly 50,000 K-12 Buildings Have Gas Available - Used for Heat or Water Heating
  - 42,000 K-12 Have Central Boilers
  - 14,000 K-12 Have Central Chillers
    - 12,000 Have Split Systems
    - 15,000 Have Window/Wall Units

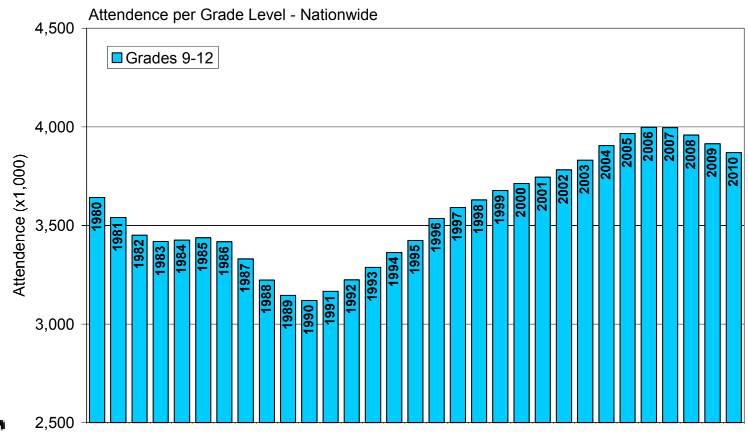
Familiarity Factors

- If School Facility Engineers were Familiar with Power Generation and Absorption Chillers, This Would Assist in Selling BCHP
  - Only 2,000 Use Some Type of Gas Cooling
    - Probably Steam Fired Absorbers – May be Quite Old
  - 8,000 Claim to Have Some Type of On-Site Generation – Probably Back-Up Power

New Construction

The History of the Secondary School Population with Projections

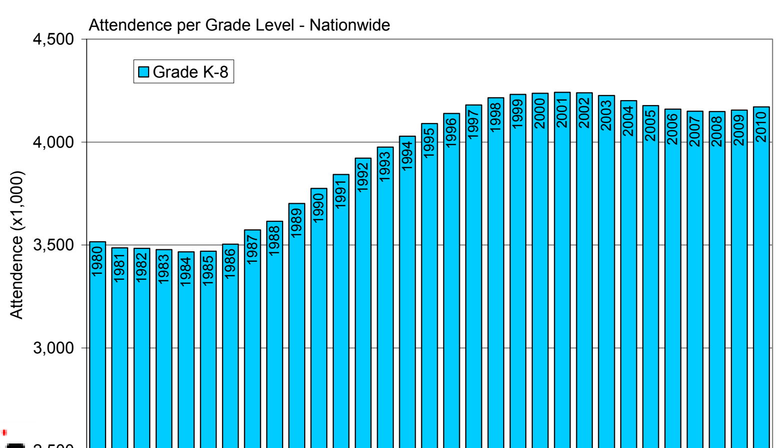
- Secondary Populations to Rise and Plateau in this Decade



47

The History of the Primary School Population with Projections

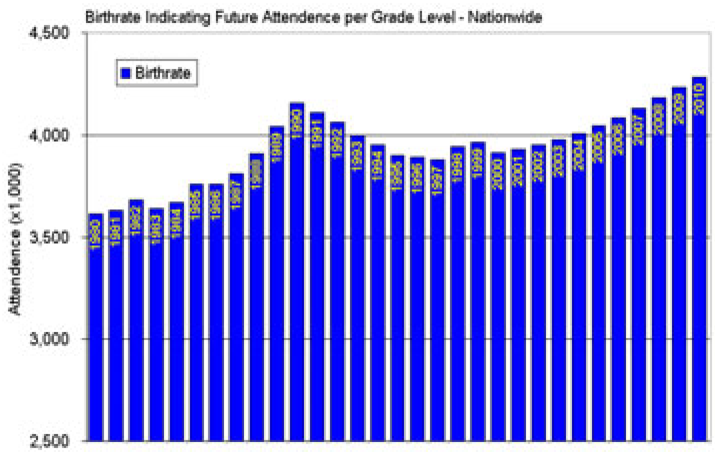
- Caused by a Nearer Term Plateau in Primary School Population



48

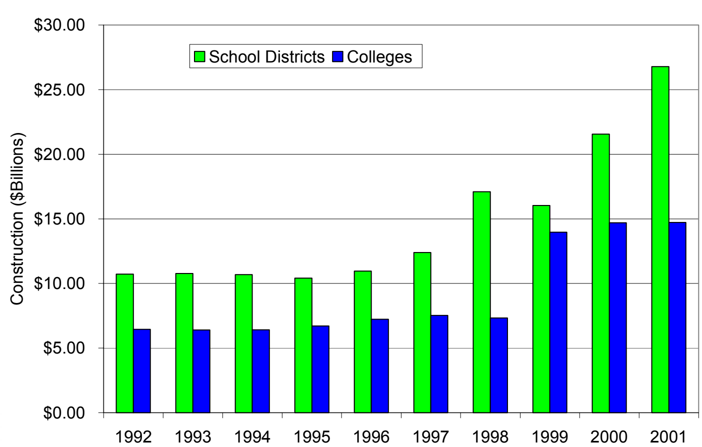
History of the American Birthrate with Projections

- However, the Rising Birthrate Indicates an Increase in School Population in the Next Decade



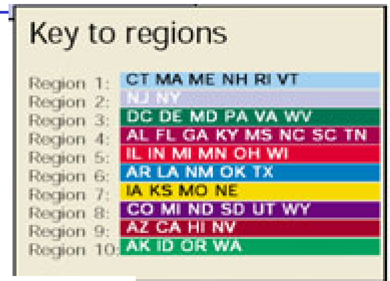
Construction History

- History of Construction Growth Throughout the Last Decade



Where is New Construction Projected to Be Strongest?

- Examine Regional Data

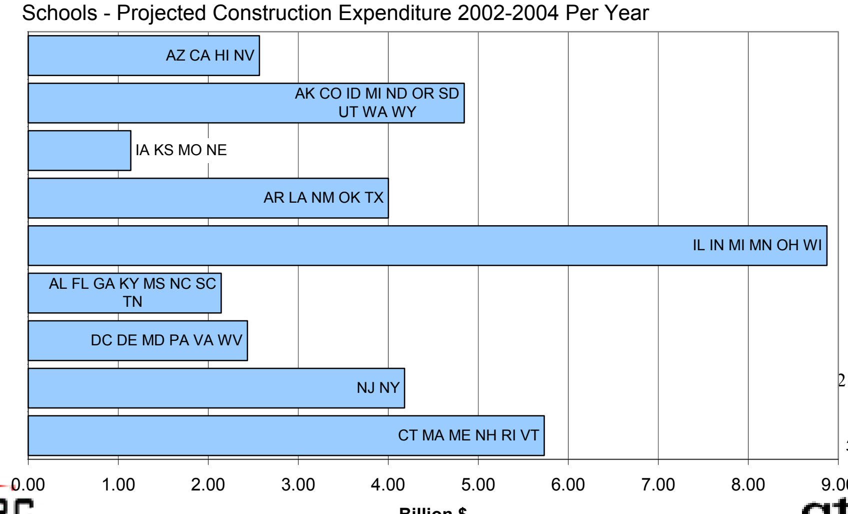


Key to regions

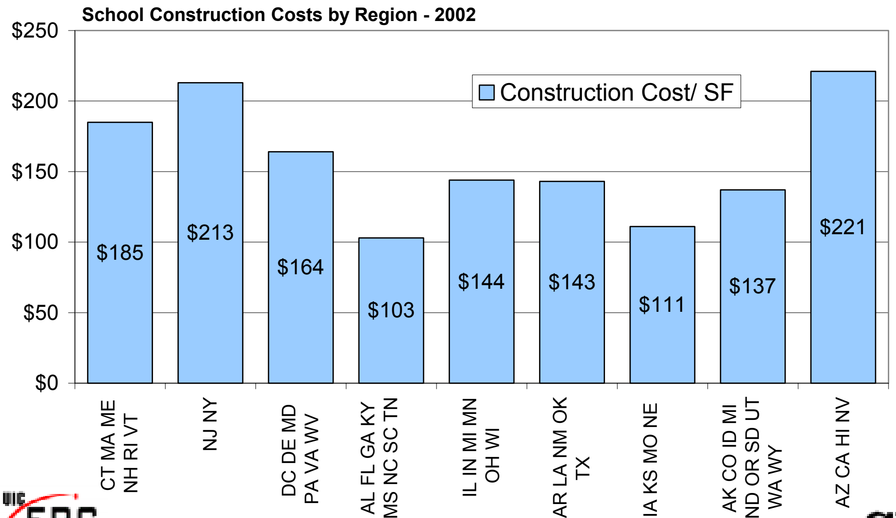
Region 1:	CT MA ME NH RI VT
Region 2:	NJ NY
Region 3:	DC DE MD PA VA WV
Region 4:	AL FL GA KY MS NC SC TN
Region 5:	IL IN MI MN OH WI
Region 6:	AR LA NM OK TX
Region 7:	IA KS MO NE
Region 8:	CO MI ND SD UT WY
Region 9:	AZ CA HI NV
Region 10:	AK ID OR WA

Where is New Construction Projected to Be Strongest?

Schools - Projected Construction Expenditure 2002-2004 Per Year

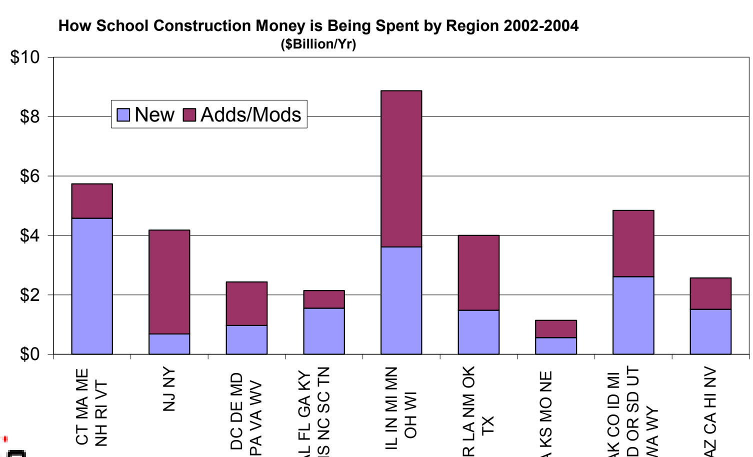


Construction Cost Varies Significantly by Region



Near Term Regional Projections

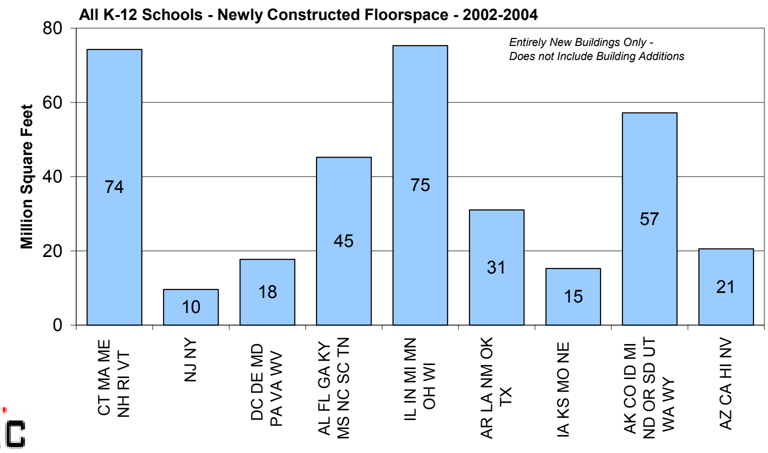
- Need to Separate New Construction from Refurbishment Projects



Ref 12

How Much is in New Floor Space is in Construction ?

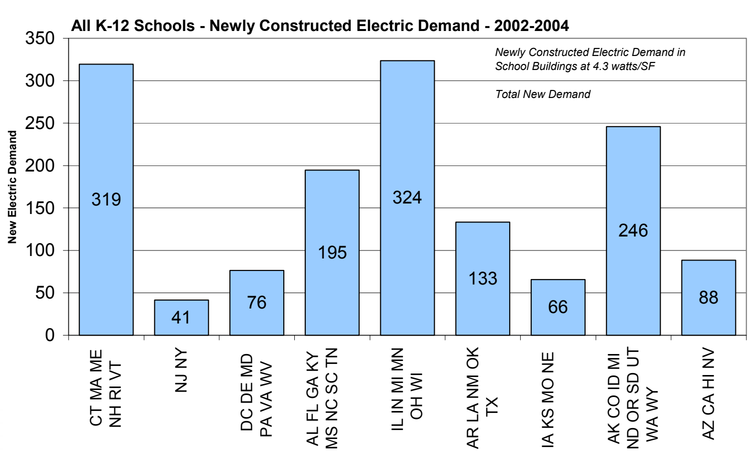
- Using Average New Construction Costs by Region Reveals How Much Floor Space in New Building is Being Added



55

Electric Demand from New Schools

- Using the Median Electric Load (4.3 w/SF) gives the Projected Consumption of This New Construction



56

Summary - New Construction Market

- Currently Adding an Average of 115 Million Square Feet per Year
  - Represents a New Electric Load of 500 MW/ Yr. Should Remain Reasonably Stable through 2006 at least.
  - New Construction Data Does Not Sort Out Large Versus Small Buildings
- However as 23% of All Schools Have a Demand Over 400 kW – A Practical New Construction Market Size for Would be 115 MW/Yr.
- Hot Areas Seem to be the Midwest and Northeast at Present
  - Northeast has a History of Very High Power Rates

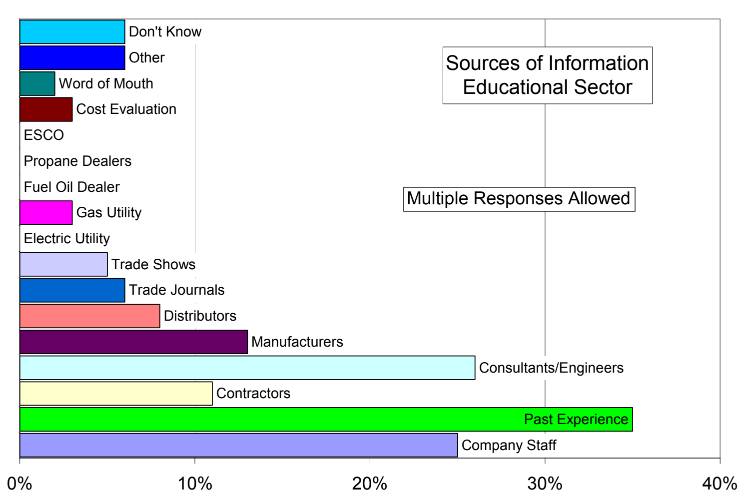
The Buying Process

Buying Process Data

- Taken from the AGA/GRI Market Segmentation Study
- Result of Customer Interviews
  - Data Resorted into K-12 and College Data as Previously Described
- Focus on Three Questions
  - Where Must Production Information be Placed to Reach Decision Makers in Educational Markets?
  - Who Are the Decision Makers in Educational Markets?
  - What Do the Decision Makers in Educational Markets Want to See in Product Attributes

Where Do Facility Mangers Get Information on New Equipment?

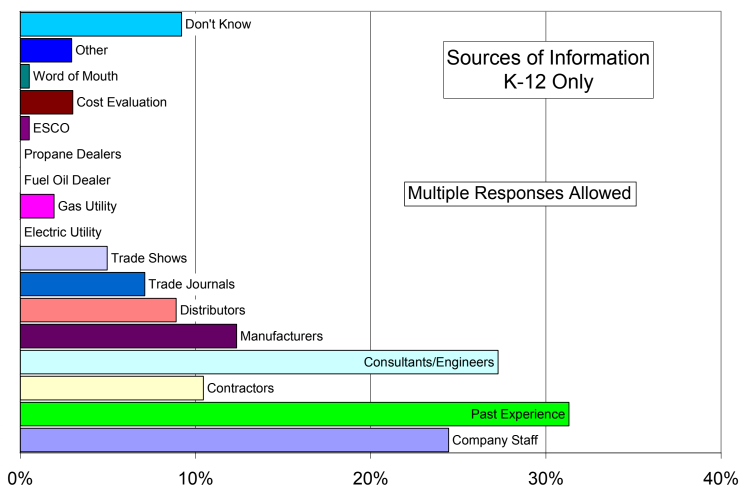
- Overall Educational Facility Responses



Ref 11

Where Do K-12 Facility Mangers Get Information on New Equipment

- K-12 Market Seems to Place High Importance on Input from Engineering Consultants – May Be to Due to Small Size of In-House Staff

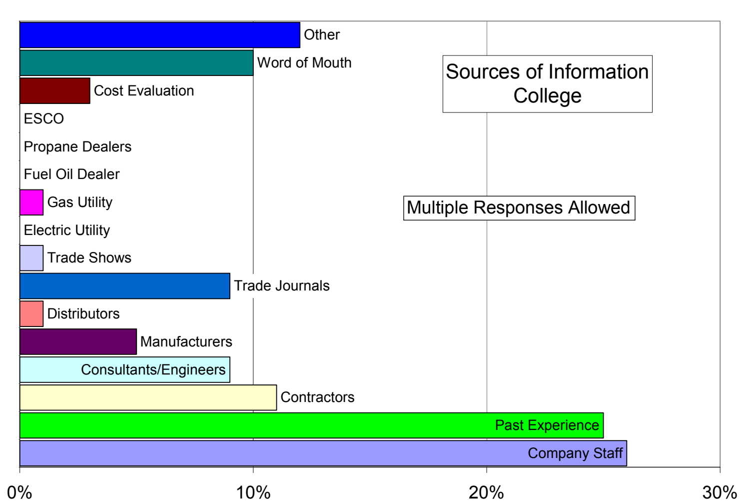


Ref 11

61

Where Do College Facility Mangers Get Information on New Equipment

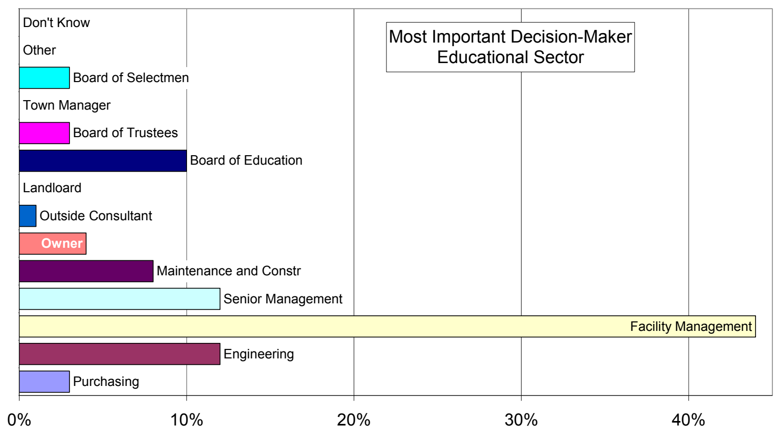
- College Market More Inclined to Follow Recommendations from Inside Staff



Ref 11

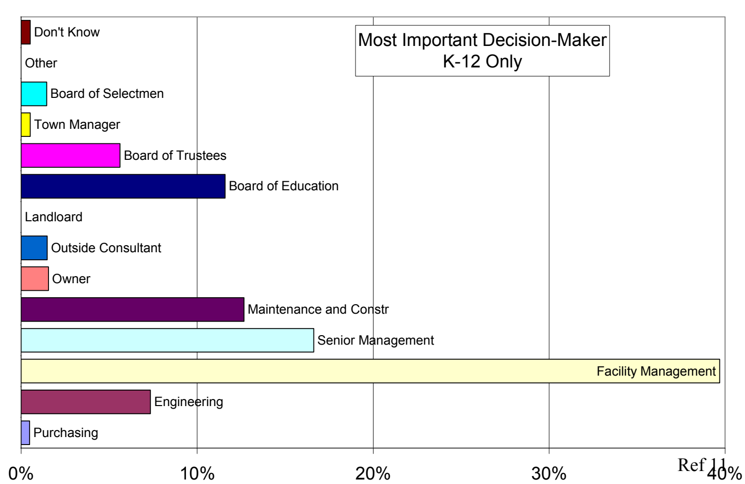
62

Who is the Most Important Decision Maker?



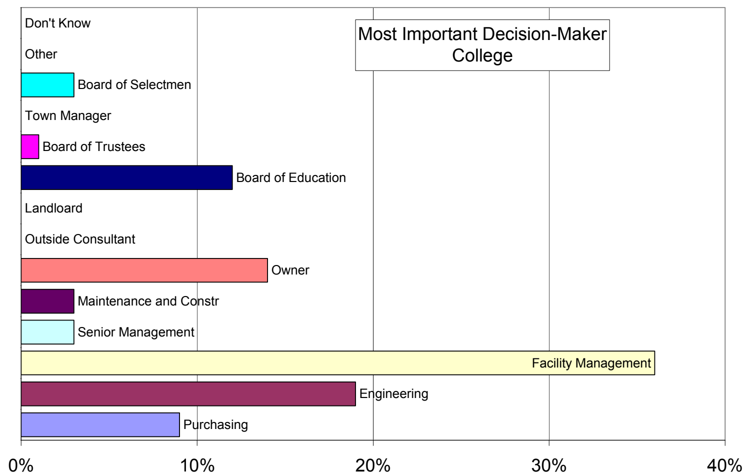
Who is the Most Important Decision Maker in K-12 ?

- Facility Management Seen as Being Key Decision-Makers

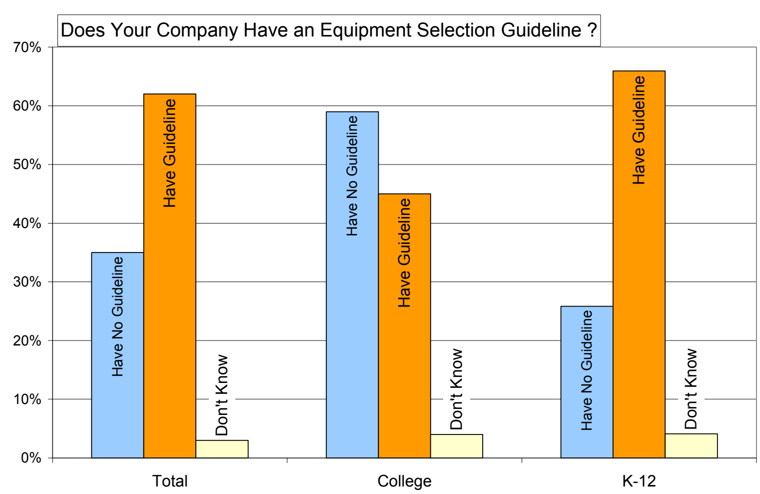


Who is the Most Important Decision Maker in Colleges?

- College Market More Balanced Between Facility Management and "Engineering" Staff

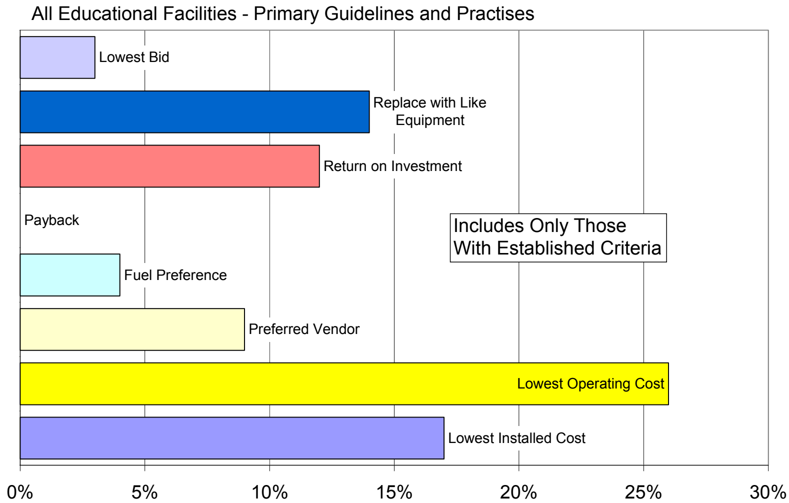


Ref 11



Ref 11

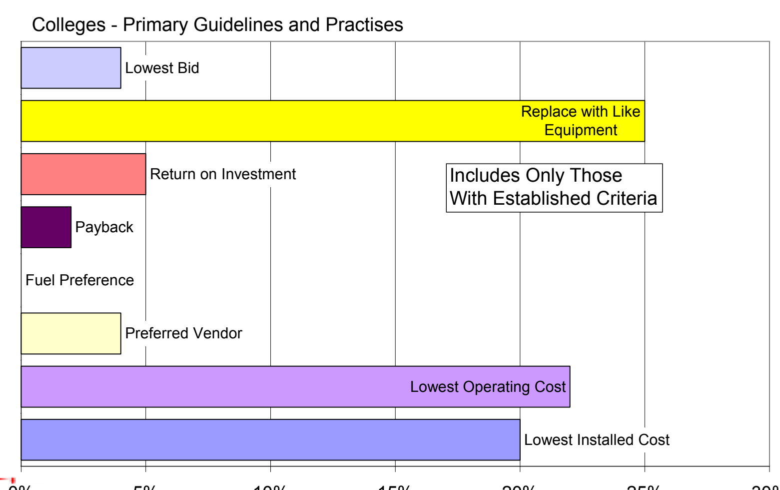
Guideline Criteria



67

Ref 11

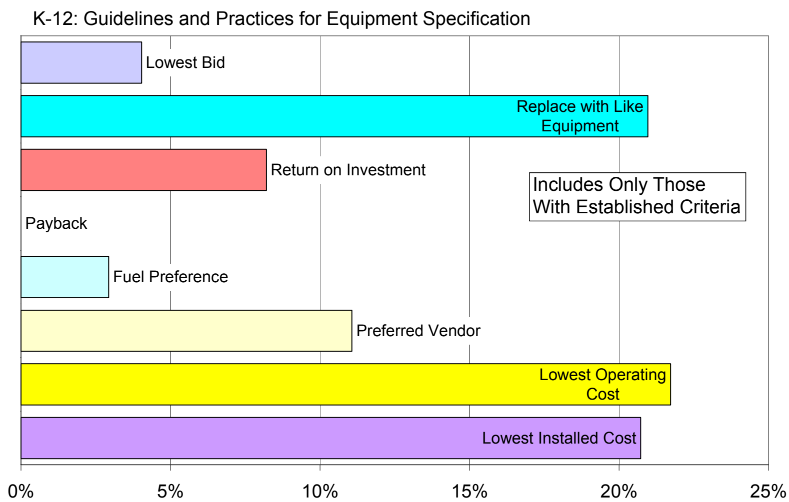
Guideline Criteria



68

Ref 11

Guideline Criteria



Ref 11

Summary - Decision Making Process

- K-12
  - Facility Management Rated as Most Important Decision Makers
    - Scale of the Financial Decision for Building a BCHP May Affect This
  - Outside Consulting Engineers are an Important Part of the Information Sourcing Process
    - Unusually Significant Role
    - May be Using Long Term Consulting Relationships to Replace Keeping Expertise On-Staff in Smaller Districts
  - Past Experience is Ranked High as an Information Source – A potential Problem with the Integration of New Technology into Existing School Systems
  - 2/3rds of School Districts Claim to Have a Decision Guideline
    - "Claim" Lowest Operating Cost Outranks Lowest Initial Cost

Putting It All Together – Sector Summary

- Market Size
  - Overall Retrofit Market – 11,600 MW
  - Market Expansion Due To New Construction – 115 MW
- Market Concentration
  - The Largest 1.6% of School Districts Nationwide Have 32.1% of the Students
  - 14,250,000 Students are in 50 Large School Districts in the 10 Highest Electric Energy Cost States
    - List of Districts Included
- Technical Practicality
  - Chapter 1 Characterizes Product as 310-810 kW
  - System will be Most Practical in Buildings Above 400 kW
  - 23% of K-8 Schools Have a Peak Demand Above 400 kW
  - 45% of High (9-12) Schools Have a Peak Demand Above 400 kW

Suggested Market Strategy

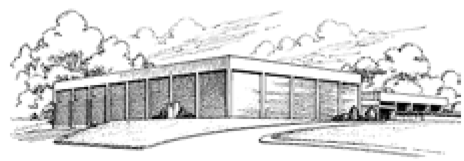
1. Steer Product Information Toward High School Applications
2. Target Districts on the 50 Large Districts in High Cost States First
3. Target District Engineering or Facility Management Staff at the District Headquarters Level - No Need to Market to Individual Schools. In Many Cases, Key Influencer May Be Engineering Consultant for the District Rather than Employee
4. Back-Up Power Capability of the BCHP Unit May be a Benefit Given that ~10% Existing Schools Have Back-Up Generation
5. Greater Penetration of Pools and Shower Facilities in High School Loads Will Allow More Effective Heat Recovery

References

1. U.S. Census Bureau, Statistical Abstract of the United States: 2001, Section 4 Education, No. 229. Public Elementary and Secondary Schools by Type and Size of School:1998-99
2. The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector, ONSITE SYCOM Energy Corporation, Prepared for U.S. Department of Energy Energy Information Administration, 2000
3. School Planning & Management, 2002 Construction Report by Paul Abramson, Education Industry Analyst, TABLE 5 Profile of New Schools Currently Underway (School Construction Ending in 2002)
4. Peak Power Demand: Table 19. Distribution of Peak Watts per Square Foot and Load Factors, "U.S. Department of Energy, Energy Information Administration, "A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures."
5. Table 89 and 90.—Public school districts and public and private elementary and secondary schools: 1869–70 to 1999–2000, Digest of Education Statistics, NATIONAL CENTER FOR EDUCATION STATISTICS, 2001
6. Table 64.—Public elementary and secondary pupil/teacher ratios, by level, type, and enrollment size of school: Fall 1987 to fall 1999, Digest of Education Statistics, NATIONAL CENTER FOR EDUCATION STATISTICS, 2001
7. U.S. National Center for Education Statistics, Fast Response Survey System, Facilities, 1999, NCES 2000-032, Facilities, 1999, NCES 2000-032, June 2000 U.S. Census Bureau, Statistical Abstract of the United States: 2001, Section 4 Education
8. Table 1.—Selected statistics for the 100 largest school districts in the United States 1:School year 1999–2000, Characteristics of the 100 Largest Public Elementary and Secondary School Districts in the United States: 1999–2000, NATIONAL CENTER FOR EDUCATION STATISTICS Statistical Analysis Report October 2001
9. TABLE 10 28TH ANNUAL OFFICIAL EDUCATION CONSTRUCTION REPORT, WWW.ASUMAG.COM
10. Table 9.—Percentage distribution of public schools according to the status of air conditioning in various areas of their school buildings: 1999, Condition of America's Public School Facilities: 1999, NATIONAL CENTER FOR EDUCATION STATISTICS Statistical Analysis Report June 2000
11. Commercial Market Segmentation Study, National Educational Sector, AGA/GRI, January 1998 GRI 97/0385
12. BUCKING THE TREND, 28TH ANNUAL OFFICIAL EDUCATION CONSTRUCTION REPORT, AMERICAN SCHOOL & UNIVERSITY MAY 2002 WWW.ASUMAG.COM

Chapter 3 – Data Processing Centers and Internet Server Farms

Prepared by:
Bill Ryan UIC-ERC
Cliff Haefke UIC-ERC
630-561-4448
Marek Czachorski GTI
847-768-0526



Overall Objective

- Develop Better Estimates of the Key Market Segments
- Identify the Most Promising Market Sub-Segments to Allow Technical Development to be Targeted as Well as Future Marketing Efforts

Overview

- Internet Server Farms
  - New Volatile Commercial Segment
  - Challenge to Characterize and to Collect Data
  - Recent History of Intense Growth and Decline
- Free-Standing Data Processing Centers
  - Available Statistics will Not Include Data Processing from Corporate “Mainframes” or Central Servers Housed within Commercial Operations
  - Will Include Older More Stable “Data Processing” Business
    - Processing Data for Multiple Clients or Supplying Computer Power on a Time-Sharing Basis

The Industry Classified as Census Bureau NAICS 51 – The “Information” Sector

- 511 Publishing Industries
- 512 Motion Picture and Sound Recording Industries
- 513 Broadcasting & Telecommunications
- 514 Information and Data Processing Services

514 Information and Data Processing Services

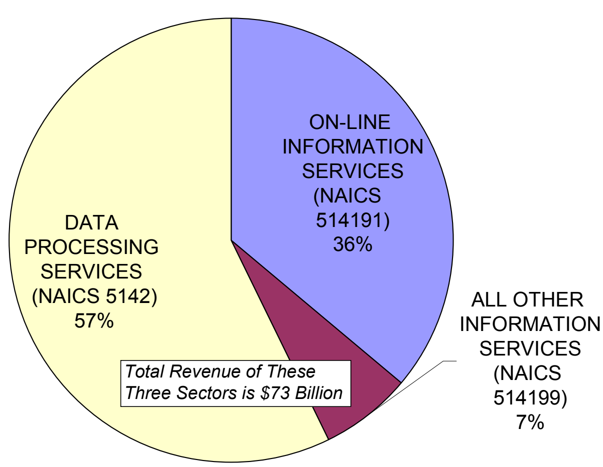
- **5141 Information Services**
  - **51411 News Syndicates**
  - **51412 Libraries and Archives**
  - **51419 Other Information Services**
    - **514191 Online Information Services**
    - **514199 All Other Information Services**
- **5142 Data Processing Services**
  - **51421 Data Processing Services**

Data Server Farms (ISP's)

Data Processing Centers

Total Revenue in 2000

Overall Computer Service Sector Revenue



Ref 3

Limitations of the Census Data

- Complete Economic Census Not performed Since 1997
  - Results Published from 1999 through 2001
- New Economic Census Underway in 2002
  - Results Begin to be Available at End of 2003
- Some Limited Data Taken Yearly

Given the Volatility of This Market Segment – This Delay is Unfortunate

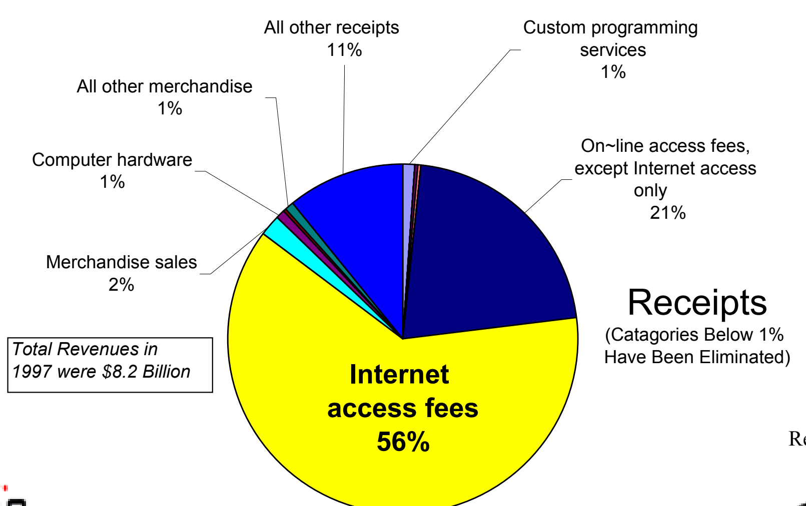
General Area Description: 51419 – "Other Information Services"

- This industry comprises establishments primarily engaged in providing information services (except news syndicates, libraries, and archives).
- Included in this industry are Internet service providers, on-line information access services, and telephone-based (i.e., toll call) information services.
- On-line information services establishments are engaged in the provision of direct access to computer-held information published by others via telecommunications networks. These establishments often provide electronic mail services, bulletin boards, browsers, and search routines.

More Specific Area Description : 514191 Online Information Services

- This U.S. industry comprises Internet access providers, Internet service providers, and similar establishments primarily engaged in providing direct access through telecommunications networks to computer-held information compiled or published
- Server Farms Fall In This Area

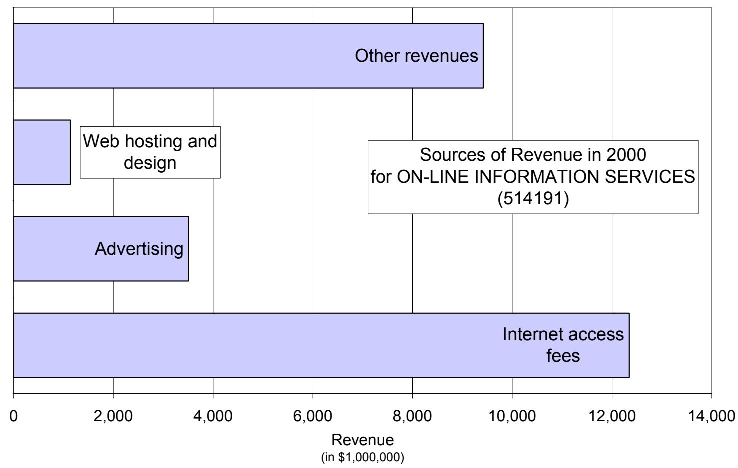
Even Though a Company is in 514191 – It May Have Multiple Sources of Revenue



Ref 2

Sources of Income for 514191 in 2000

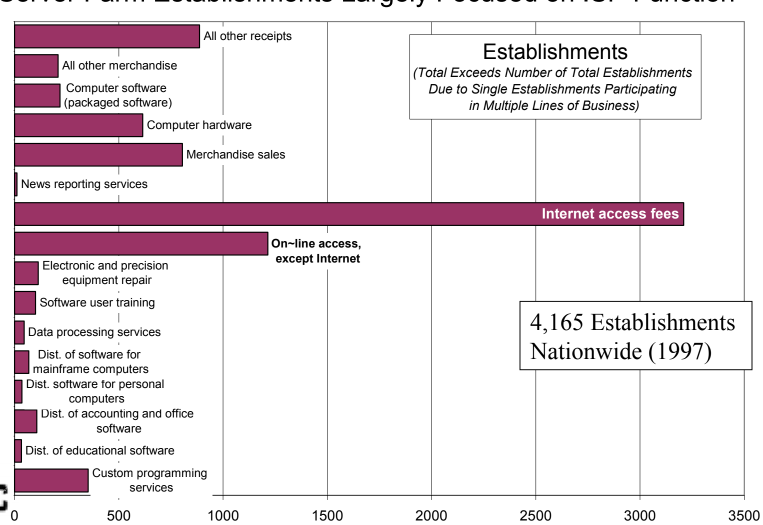
- Server Farm Operation - Dominated by Internet Service Fees



Ref 3

NAIC 514191 – Lines of Business By Establishment

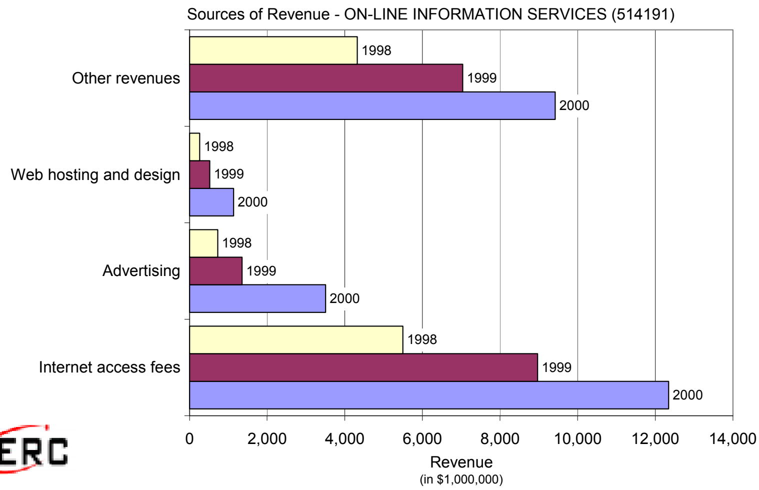
- Server Farm Establishments Largely Focused on ISP Function



Ref 2

The Internet Boom

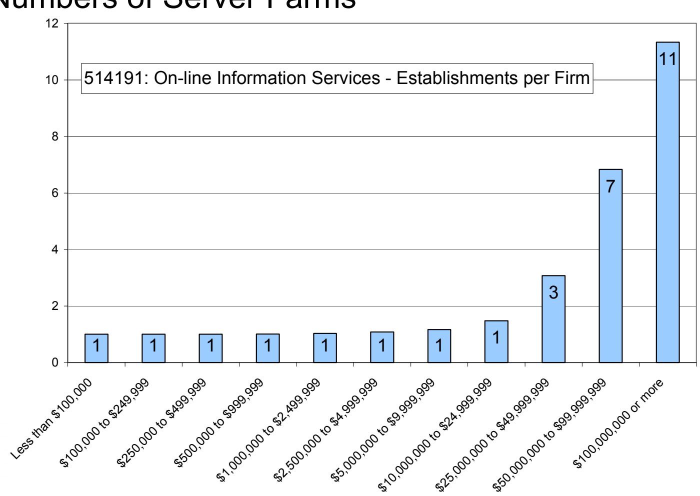
- Growth During the Boom was Brisk, ~50% per Year



Ref 3

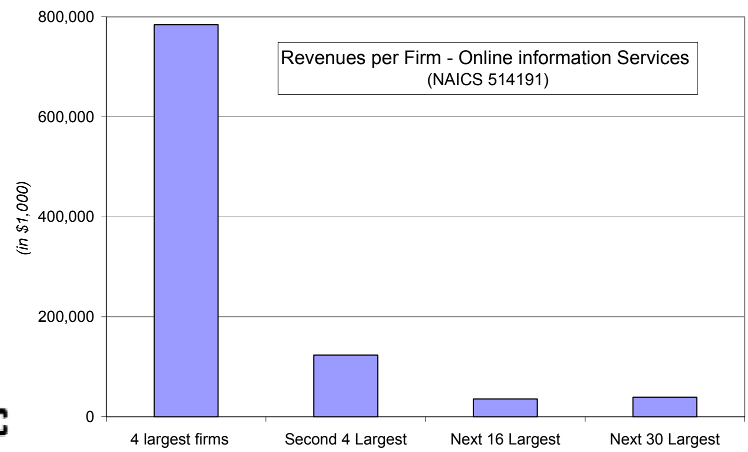
Structure of the Industry

- Even the Largest ISP Firms Do Not Have Large Numbers of Server Farms



Market Concentration

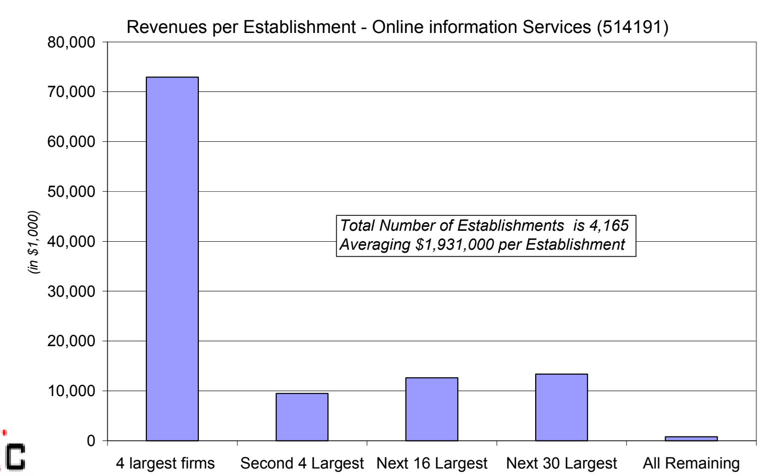
- Unusually Highly Concentrated Industry



Ref 5

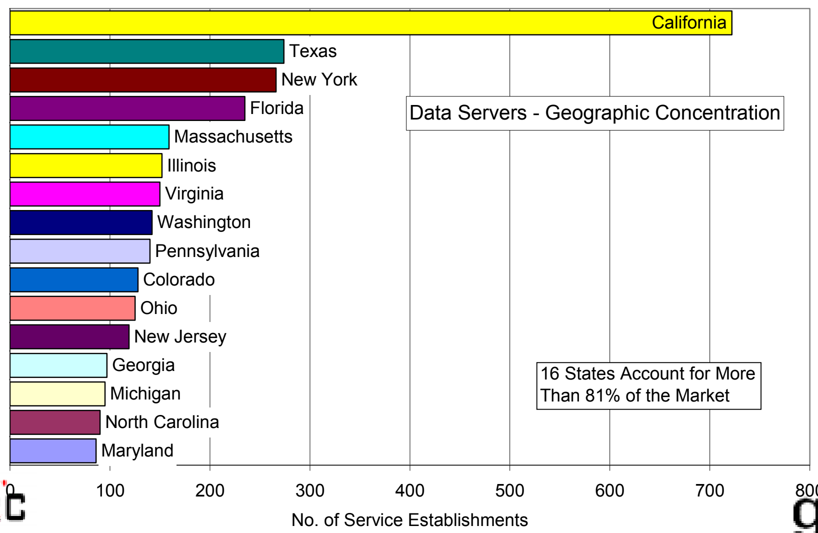
Establishment Productivity

- Market Leaders Focus on High Volume Sites



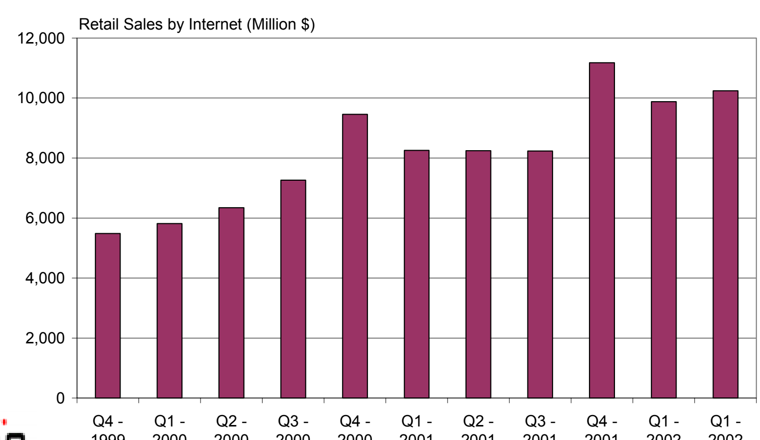
Ref 5

Geographic Concentration



How Has the "Internet Boom" Fared ?

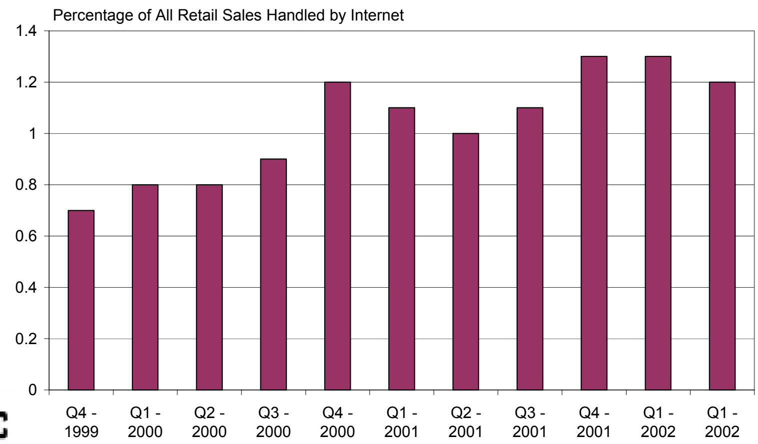
- Internet Sales are Still Moderately Expanding – Even in this Economic Climate



Ref 4

How Has the "Internet Boom" Fared ?

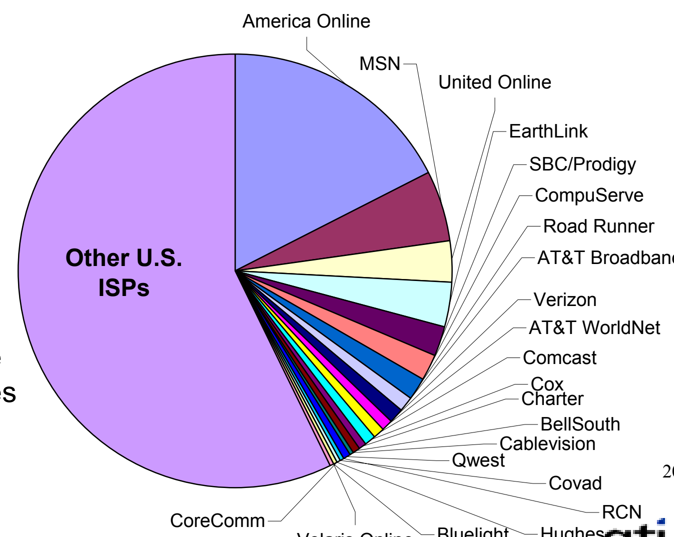
- Internet Sales are Masking Good Progress as a Percent of Overall Retail Sales
- Note that the Actual Percentage is Still Very Small



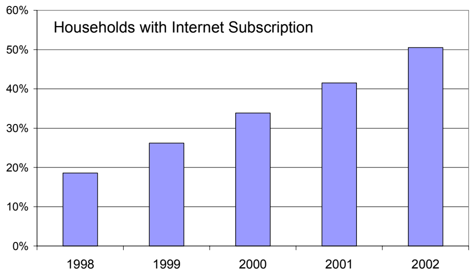
Ref 4

Market Share

- Except for AOL – This Market is a Mass of Smaller Suppliers
  - Note AOL Owns Some Other Names



Growth and Penetration



- Subscriptions are the Main Source of ISP Income
  - Actual Usage is Largely a Cost
- Internet Subscription Penetration in Households has Grown Quickly
  - Penetrations will be in the 60%+ Range in 2003

The Future

- Market is Saturating - Future Slower Growth is Inevitable
- This Will Drive ISP's from Collecting New Users to Raiding Competitors for Market Share
  - Need for Greater Expenditure of Income on Marketing
  - Buy-Up Smaller Competitors
- Slowing Income Growth and Higher Costs will Force Consolidation of the Large Number of Players

ISP Market Leaders

	Company	Subscribers
		(Millions)
1	America Online	26.5
2	MSN	7.7
3	United Online [NetZero + Juno Online]	4.8
4	EarthLink	4.7
5	SBC/Prodigy	3.5
6	CompuServe [AOL Owned]	3
7	Road Runner [AOL Owned]	2.5
8	AT&T Broadband	1.8
9	Verizon	1.5
10	AT&T WorldNet	1.4
11	Comcast	1.2
12	Cox	1.1
13	Charter	0.9
14	BellSouth	0.8
15	Cablevision	0.61
16	Qwest	0.51
17	RCN	0.46
18	Covad	0.36
19	CoreComm [Formerly Voyager.Net]	0.29
20	Hughes	0.22
21	Volaris Online	0.24
22	Bluelight	0.17
23	Other U.S. ISPs	86.2
	Total Market	103.26

As of the Second Quarter of 2002

Summary - 514191 Server Farms

- Market Structure(1997)
  - By Number – Industry Dominated by Small (<$20M/Yr) Single Establishment Firms with only 4,165 Establishments Nationwide
  - 4 Market Leaders Average $800 Million but Still Average Only 11 Establishments
  - Establishments (Individual Server Farm Buildings) Counts are Low Given the Market Revenue
- Market Concentration(1997)
- Top 4 Firms are Dominant
  - Top 4 Average Nearly $800 Million in Revenue
  - Second Four Average Only $60 Million

Summary - 514191 Server Farms

- Establishment Productivity (1997)
  - Top 4 Average $70 Million per Establishment
  - Remainder in Top 50 Average in the 10 Million Range
  - Industry Average is only $1.6 Million
- Explosive Growth in 1998-2000 Period
  - From $10.6 Billion to $26.6 Billion
  - Much of that Gain May Have Been Lost in 2001-2002

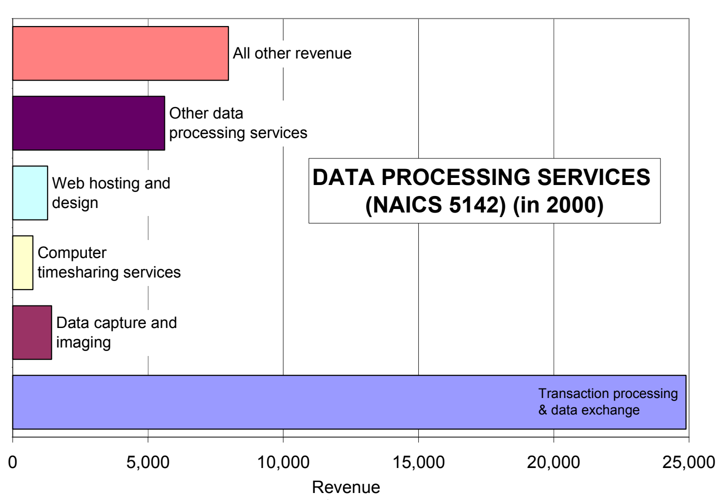
5142 Data Processing Services

5142 Data Processing Services

- This industry comprises establishments primarily engaged in providing electronic data processing services. These establishments may provide complete processing and preparation of reports from data supplied by customers; specialized services, such as automated data entry services; or may make data processing resources available to clients on an hourly or timesharing basis.

Sources of Income for 5142

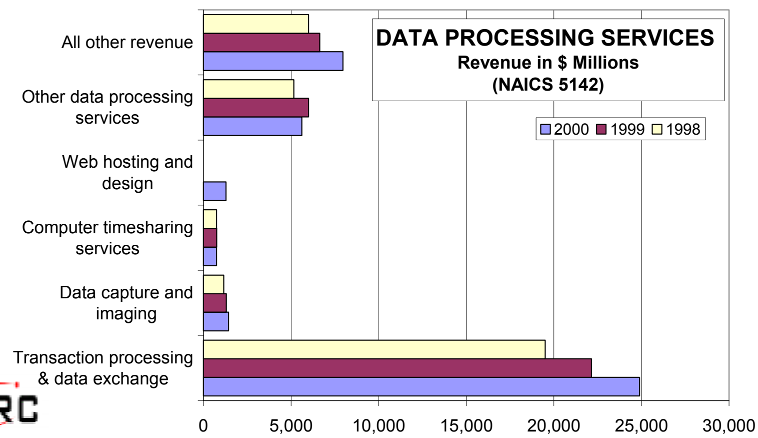
- Dominated by Transaction Processing



Ref 3

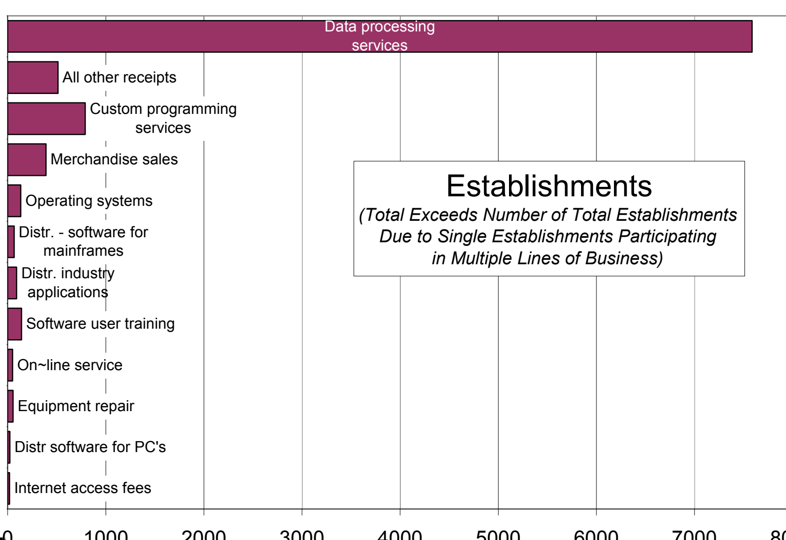
Data Processing

- Larger More Established Sector
  - Less Dominated by Explosive Growth in Late 1990's - Less "Dot. COM" Exposure



Ref 3

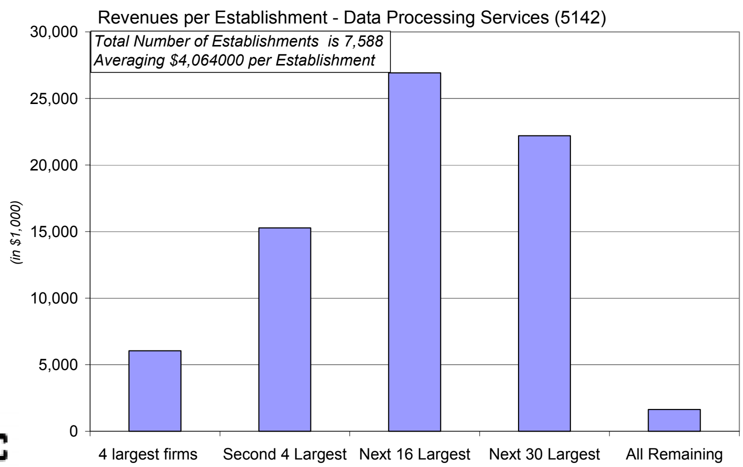
NAIC 5142 – Lines of Business in Detail



Ref 2

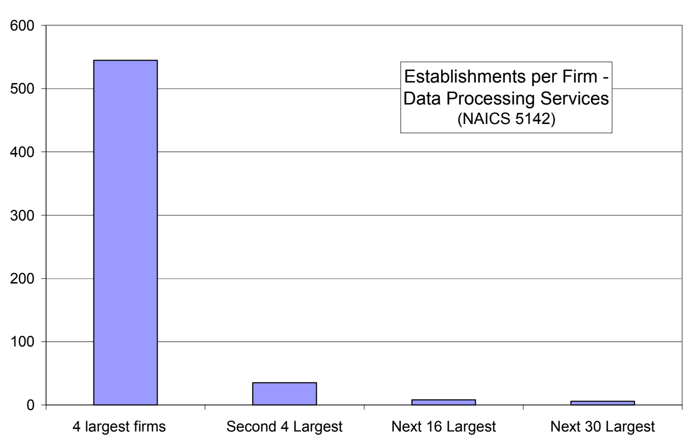
NAIC 5142 – Revenue Per Establishment

- No Clear Pattern to Establishment Productivity by Largest Firm



NAIC 5142 – Number of Establishments Per Firm

- Very Different Structure from ISP's
- Far More Establishment Intensive Market Leaders



5142 Summary

- More Stable Slower Focus on Transaction Processing
  - Business to Business Service Market
  - More Establishment and Employee Intensive than ISP's
  - Mass Marketing is Less of an Issue

Power Usage

Cogeneration Market Projection for ISP and Data Centers (NAIC 514191&5142)

- Need to Find the Power Usage for Computer Equipment and the Usage for Critical Equipment Support
- Cogeneration on These Loads Would Have the Advantage of Also Serving to Deliver Back-Up Power Needs

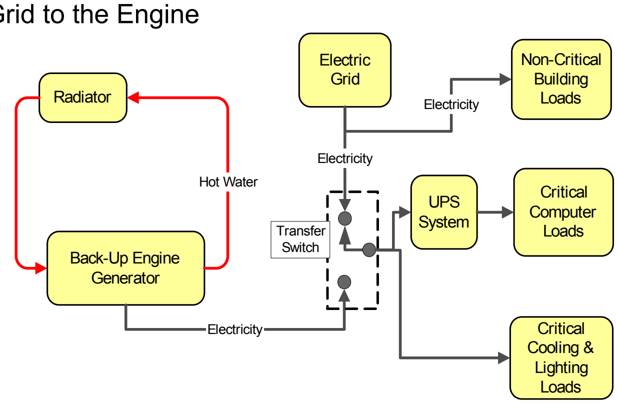
What Goes into a Freestanding Data Center Back-Up Power Systems?

- In the Event of Grid Power Failure
- Computers Must be Kept on Without Any Flutter
  - UPS System Maintains Uniform Voltage to Computers as System Shuts Down
  - Generally Battery Power for 3-10 minutes of Operation
- Critical Non-Computer Loads Can be Brought Back on After Back-Up Engine Start-Up
  - No Need for Expensive UPS System on These Loads
  - Includes Cooling and Lights in Critical Areas
- Some “Non-Critical” Loads Can be Left Off Entirely

What Goes into a Freestanding Data Center Back-Up Power Systems?

In the Event of Grid Power Failure

1. Computer Operation is Maintained by UPS
2. Back-Up Engine Starts
3. Transfer Switch Moves Critical Loads and UPS Power Supply from the Grid to the Engine



How Can Cogeneration be Incorporated?

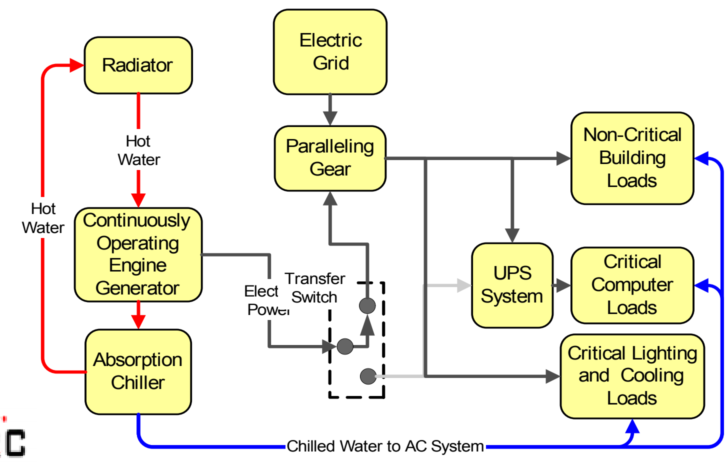
- In Normal Cogeneration Operation
  - Engine Generator is Sized to the Critical Load
  - Engine Generator Runs and Power is Supplied to the Paralleling Gear
  - The Paralleling Gear Pulls Power from Both Generator and the Grid and Supplies All Loads
- In a Black-Out
  - UPS Keeps Computers on Continuously
  - Transfer Switch Takes Engine Generator Off of the Paralleling Gear and Onto the Critical Load Circuits Only
- In Either Situation
  - Recoverable Heat from the Engine Produces SOME of the Facilities Heating and Cooling

Why Should Cogeneration be Incorporated?

- Allows Engine Generator System to Become a Productive Economic Asset
- However
  - Engine Will be More Expense (probably Gas Engine)
  - Paralleling Gear Will Now be Required
  - UPS will Still be Needed
    - Without UPS - Transfer Switch Delay Would Take Down Computers
    - Also Engine May Need to be Started to Cover a Power Outage – Not All Cogeneration Makes Sense on a 24/7 Basis

How Can Cogeneration Serve Freestanding Data Center Back-Up Power Systems?

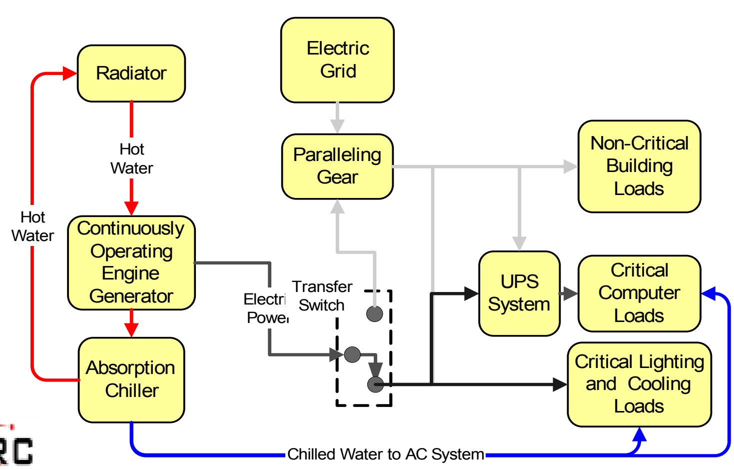
Normal Operation



41

How Can Cogeneration Serve Freestanding Data Center Back-Up Power Systems?

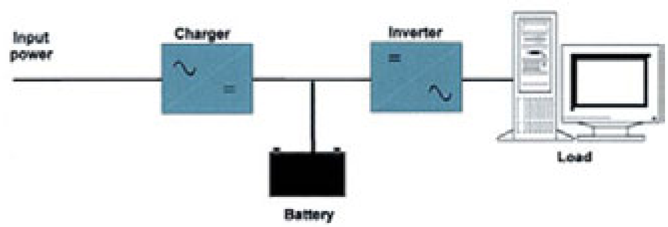
During Power Outage



42

Power Usage of IPS & Data Centers
Naics 514191 and 5142

- Tracking the Size of the IPS and Data Server Market by a Common Equipment Item
  - Uninterruptible Power Supply (UPS) Systems are a Common Thread in These Markets
  - Larger UPS systems Almost Exclusively Used in IPS and Data Center Facilities



Range of UPS Systems

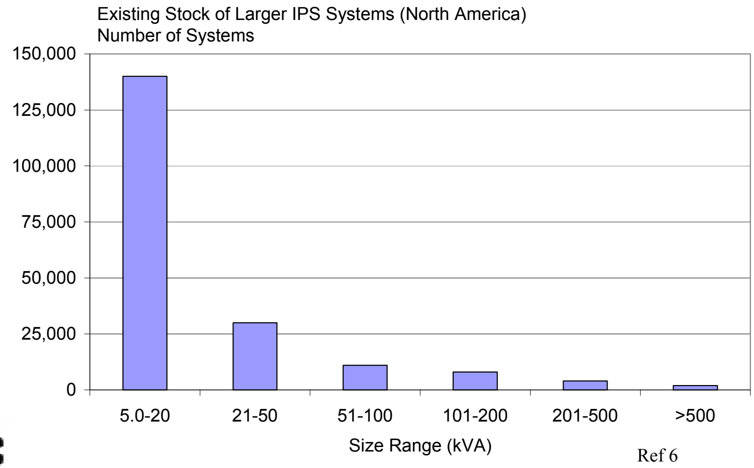
- Our Interest is in Sizes Used for Larger Centers (>100 kVA)

UPS Power Range	kVA Typical Applications
<1 kVA	PCs, Workstations
1 - 5kVA	Multiple Computers Servers
5 – 100kVA	Telecom Switching Centers, ISP, Data Networks
>100kVA	Larger Telecom Centers, Data Centers

Ref 6

Existing UPS Stock in the Telecom, ISP, and Data Center Size Range

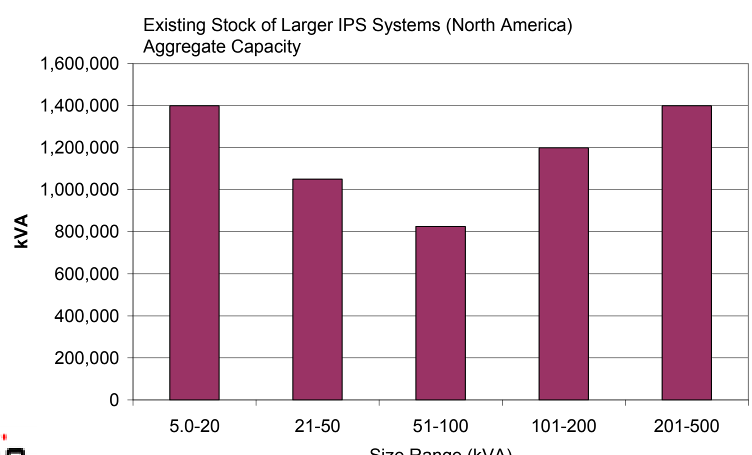
- Number of Sites Declines in the Larger Sizes



Ref 6

Existing UPS Stock in the Telecom, ISP, and Data Center Size Range

- Amount of Power Required is Significant

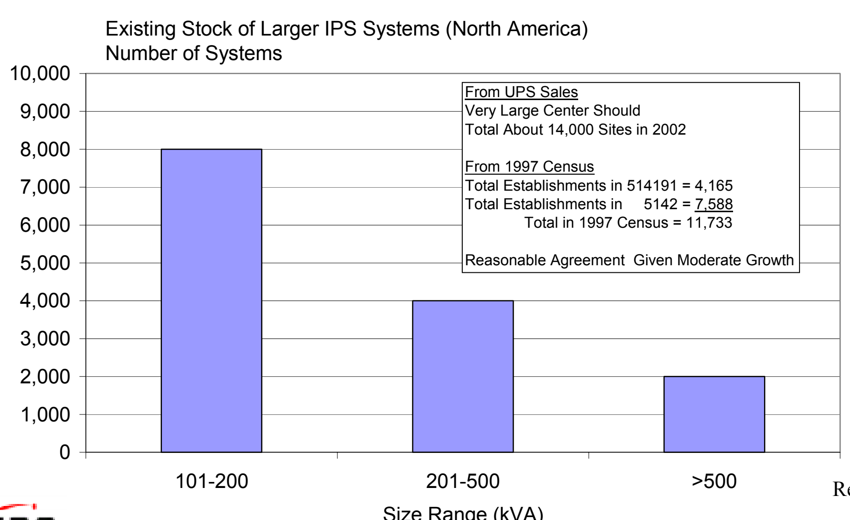


Ref 6

Translating to Cogeneration Market

- kVA Capacity is Close to kW
  - Difference is the Loads Power Factor
  - Most Generators Actually Nameplated in kVA
- Therefore – Above 100 kW is ~ 2.6 Million kW or 2.6 GW Demand for the Computer Power Needs – This Does Not Include the Other Critical Power Needs

Comparing with Census Values



Ref 6

How Large are the “Other Critical Power” Needs?

- Cooling
  - Sufficient Capacity to Remove 2.6 GW of Raw Heat
  - Is = 443,000 tons of Cooling
- Assumptions in Cooling Calculation
  - 0.6 kW./ton Chiller, 0.15 kW/ton Tower Pumps and Fan, 0.1 kW/ton for Chilled Water Pumping
- Assumption in Floor Space, Lighting and Fan Power Calculation
  - Computer Heat Output = 50 w/sq.ft (Ref 7) resulting in 52,000,000 sq.ft. of computer space..
    - On a per Square Foot Basis – 50 w/sf is VERY High
    - On a per Ton Basis – Similar Numbers Occur from Any Other Cooling System
  - Fan Power – 6 w/sq.ft. – Very High versus most Commercial Loads
  - Lighting 3 watts per sq. ft. - Typical of Commercial Load

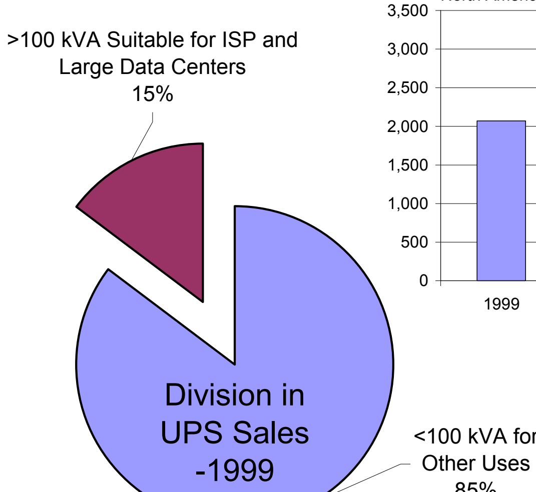
Existing Equipment Results

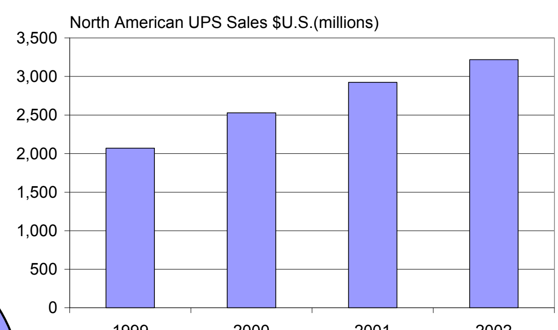
- Total Cooling Demand of 0.629 GW
- Fans and Lights are 0.525 GW
- The Total Overall Critical Load Market is 3.7 GW
- Market which can Capitalize on BCHP

Where are the “Huge” Numbers ?

- Substantial Publicity has been Generated on the “Hugh” Power Draw Caused by the “Internet” (Term Used Non-Specifically)
- Much of this Based on the “Mills” Study in 1999 (Ref 9)
  - Mills Included All the Office Equipment Locally Involved with Internet Access
  - Used Power Draw Factors Roughly an Order of Magnitude Larger than Other Authors
- Such Results Overstated the Power “Problem” Posed by the Internet and Have Been Avoided Here to Prevent Overstating the Distributed Generation Opportunity

Market Growth Rate

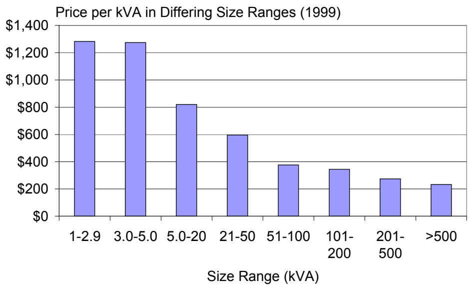




15% of The 1999-2002 Revenues are Assumed to be Above the 100 kVA Size Range Based on the 1999 Data Shown

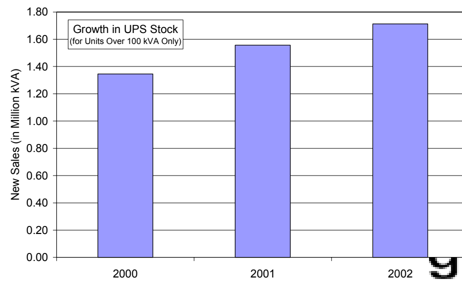
Ref 6

Increasing Sales in Large UPS Stock



For an Industry in a Serious Slump, the Growth is Impressive

Sales Data Available in Revenues – Translated to kVA by Average Price for Each Size Range



Ref 6

"New Construction" Market

- UPS Sales at the 0.14 GW Level
- Should Bring in Cooling and Critical Power needs on the .13 GW Level
- Total New Market ~0.3 GW/Yr.
- Market which can Use BCHP in New ISP or Data Center Construction

Putting It All Together – Sector Summary

- Market Size
  - Overall Retrofit Market – 6,300 MW
  - Market Expansion Due To New Construction – 300 MW/Year
- Market Concentration
  - The Largest 4 ISP's Nationwide Have 35.5% of the Market
    - Remainder of the Market is Highly Fragmented
- Technical Practicality
  - Chapter 1 Characterizes Product as 310-810 kW
  - System will be Most Practical in Buildings Above 400 kW
  - Larger ISP/Telecom/Data Centers Characterized as Having UPS of 100 kVA or Higher – Indicating Overall Facility at 400 kW +
    - Only the Computers Themselves Need UPS Capability
    - Lighting and Cooling Will Expand on this at Least Fourfold
    - Heat Recovery for Cooling is Essential Element
    - Due to High Internal Loads – Heat Recovery for Space Heating May be Unnecessary

Suggested Market Strategy

1. Steer Product Information Toward Larger Freestanding Telecom/ISP/Data Processing Centers
2. Target 4-8 Large Firms First
3. Back-Up Power Capability of the BCHP Unit is the Key Selling Point
   - "Making Back-Up Power Productive"
   - First Cost of BCHP System Can Be Credited for Back-Up Engine Costs Avoided in New Facilities
4. Tailoring the Package for This Application
   - Heat Recovery for Cooling
   - Multiple Engine Approach for High Reliability where Possible
     - Continuous Computer Operation Even with One Engine Out
   - Paralleling System and Controls Set-Up to Work with UPS
5. Take Direction from Current Marketing of Large UPS Systems
6. Strategic Collaboration with a UPS Supplier Suggested
   - Already Being Done by Caterpillar

References

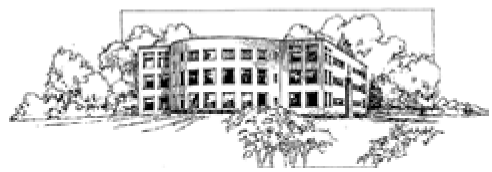
1. Information Services and Data Processing Services (NAICS 514)—Estimated Revenue for Employer Firms: 1998 Through 2000, 2000 Service Annual Survey, US Census Bureau
2. Table 2. Major Sources of Receipts for the United States: 1997 INFORMATION SUBJECT SERIES SUMMARY 31 U.S. Census Bureau, 1997 Economic Census Apr. 30, 2001
3. Information Services and Data Processing Services (NAICS 514)—Estimated Revenue for Employer Firms: 1998 Through 2000, 2000 Service Annual Survey, US Census Bureau
4. Table 1.Estimated Quarterly U.S. Retail Sales1: Total and E-commerce http://www.census.gov/mrts/www/current.html
5. Table 3. Concentration by Largest Firms Subject to Federal Income Tax: 1997INFORMATION SUBJECT SERIES SUMMARY 39 U.S. Census Bureau, 1997 Economic Census Apr. 30, 2001

References

6. Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings - Volume I: Energy Consumption Baseline Arthur D. Little Reference No. 72895-00 Prepared For Office of Building Equipment, Office of Building Technology State and Community Programs January, 2002
7. Data Center Power Usage Exaggerated By Greg Mazurkiewicz / News and Legislation Editor. E-mail him at gregmazurkiewicz@achrnews.com
8. Mills, M.P., 1999, “The Internet Begins with Coal: A Preliminary Exploration of the Impact of the Internet on Electricity Consumption”, A Green Policy Paper for the Greening Earth Society, May.
9. A NATION ONLINE: How Americans Are Expanding Their Use Of The Internet, Published in HTML Format at http://www.ntia.doc.gov/ntiahome/dn/html/toc.htm
10. Top U.S. ISPs by Subscriber: Q2 2002 Copyright 2002 Jupitermedia Corporation http://www.isp-planet.com/research/rankings/usa.html

Chapter 4: Medium Size Medical and Healthcare Facilities

Prepared by:
Bill Ryan UIC-ERC
Cliff Haefke UIC-ERC
630-561-4448
Marek Czachorski GTI
847-768-0526



Executive Summary

Overall Objective

- Develop Better Estimates of the Key Market Segments
- Identify the Most Promising Market Sub-Segments to Allow Technical Development to be Targeted as Well as Marketing Efforts

Medical Care Sector

- Complex Area Covering:
  - Hospitals
    - From Full Scale Urban Medical Centers to Small Emergency Care
  - Doctors Offices
  - Outpatient Care Centers
    - Growing Markets as More Procedures are Performed on an Outpatient Basis
  - Residential Care
    - In-Patient but with a Lesser Level of Professional Treatment
    - Covering Everything from Nursing Homes to Drug Treatment Centers

Look for Opportunities by Sub-Sector

62 HEALTH CARE AND SOCIAL ASSISTANCE: Census Bureau Summary

- The Health Care and Social Assistance sector comprises establishments providing health care and social assistance for individuals.
- The sector includes both health care and social assistance as it is difficult to distinguish between these two activities.
- Segments are arranged on a continuum starting with those providing medical care exclusively to those providing only social assistance.
- Services are delivered by health practitioners or social workers.
- Many sectors are defined based on the educational degree held by the practitioners.

62 HEALTH CARE AND SOCIAL ASSISTANCE: Sector Segments by Census Bureau NAICS Codes

- 621 Ambulatory Health Care Services
- 622 Hospitals
- 623 Nursing and Residential Care Facilities
- 624 Social Assistance

Where are Facilities that May Favor Smaller BCHP ?

- 621 Ambulatory Health Care Services
  - Includes Outpatient Medical Centers
    - May Have Emergency Power Requirements and High Cooling Loads (Particularly in Ambulatory Outpatient Surgery Centers)
    - Will NOT have 24/7 Schedules
- 622 Hospitals
  - Including Smaller Specialized Hospital Care
    - Have Emergency Power Requirements
    - 24/7 Schedules
    - Smaller Hospitals are a Natural Market for Smaller BCHP
- 623 Nursing and Residential Care Facilities
  - Smaller Facilities
    - May Have Emergency Power Requirements
    - 24/7 Schedules
- 624 Social Assistance
  - Few Potential Applications

62 HEALTH CARE AND SOCIAL ASSISTANCE: Census Bureau Sector Definitions

- **621 Ambulatory Health Care Services**
  - Provide health care to ambulatory patients and do not usually provide inpatient services. Health practitioners provide outpatient services, with facilities and equipment not being the most significant part of the production process.
- **622 Hospitals**
  - Provide medical, diagnostic, treatment services, and specialized accommodation services required by inpatients. Hospitals may also provide some outpatient services. Provide many health services which can only be provided using the specialized facilities and equipment.
- **623 Nursing and Residential Care Facilities**
  - Provide residential care combined with either nursing, supervisory, or other care. The facilities are a significant part of the production process and the care provided is a mix of health and social services with the health services being largely nursing.
- **624 Social Assistance**
  - Provides a wide variety of services directly. These services do not include residential accommodations, except on a short stay basis.

Major Segment

621 Ambulatory Health Care Services

621 Ambulatory Health Care Services: Sub-Sector Definitions

Low BCHP Opportunity:
- 6211 Offices of Physicians
- 6212 Offices of Dentists
- 6213 Offices of Other Health Practitioners

Better BCHP Opportunity:
- 6214 Outpatient Care Centers
- 6215 Medical and Diagnostic Laboratories

Non-Facility Operations:
- 6216 Home Health Care Services
- 6219 Other Ambulatory Health Care Services

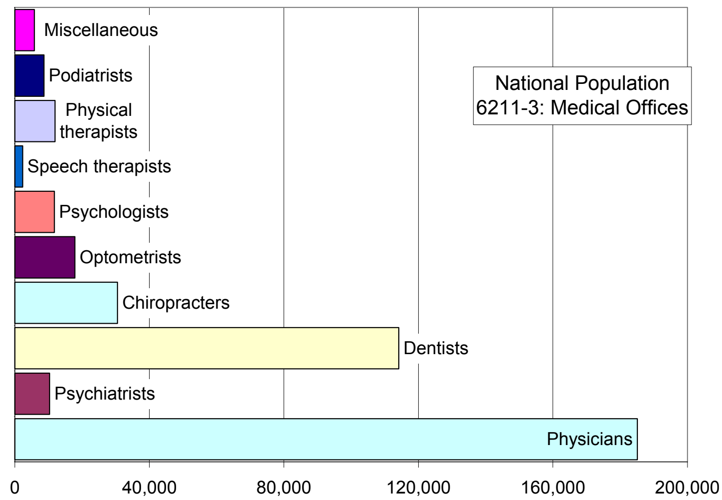
621 Ambulatory Health Care Services: Sub-Sector Definitions

- 6211 Offices of Physicians
  - 62111 Offices of Physicians (Except Mental Heath)
    - 6211111 Offices of Doctors of Medicine
    - 6211112 Offices of Doctors of Osteopathy
  - 621112 Offices of Physicians, Mental Health Specialists
    - 6211121 Offices of Doctors of Medicine, Mental Health Specialists
    - 6211122 Offices of Doctors of Osteopathy, Mental Health Specialists
- 6212 Offices of Dentists

621 Ambulatory Health Care Services: Sub-Sector Definitions

- 6213 Offices of Other Health Practitioners
  - 62131 Offices of Chiropractors
  - 62132 Offices of Optometrists
  - 62133 Offices of Mental Health Practitioners (Except Physicians)
  - 62134 Offices of Physical, Occupational and Speech Therapists, and Audiologists
    - 6213401 Speech Therapists and Audiologists
    - 6213402 Physical and Occupational Therapists
  - 62139 Offices of All Other Health Practitioners
    - 621391 Offices of Podiatrists
    - 621399 Offices of All Other Misc. Health Practitioners

621 Ambulatory Health Care Services: National Demographics



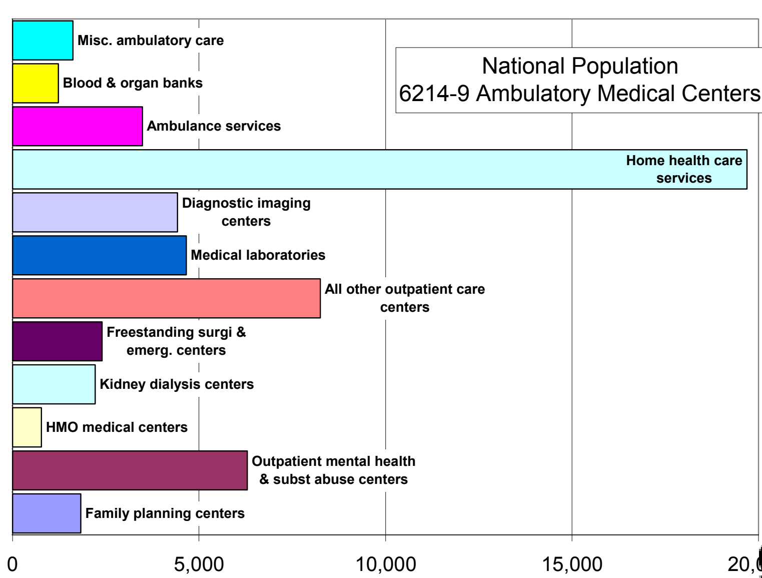
621 Ambulatory Health Care Services: Sub-Sector Definitions

- 6214 Outpatient Care Centers
  - 62141 Family Planning Centers
    - 6214101 Childbirth Preparation Classes
    - 6214102 Family Planning Centers (Except Childbirth Preparation)
  - 62142 Outpatient Mental Health and Substance Abuse Centers
  - 62149 Other Outpatient Care Centers
    - 621491 HMO Medical Centers
    - 621492 Kidney Dialysis Centers
    - 621493 Freestanding Ambulatory Surgical and Emergency Centers
    - 621498 All Other Outpatient Care Centers

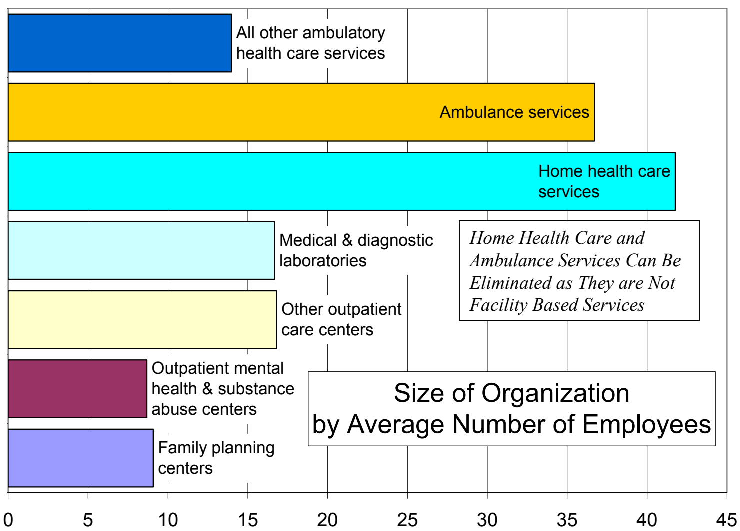
621 Ambulatory Health Care Services: Sub-Sector Definitions

- 6215 Medical and Diagnostic Laboratories
  - 621511 Medical Laboratories
  - 621512 Diagnostic Imaging Centers
- 6216 Home Health Care Services
  - 621610 Home Health Care Services
- 6219 Other Ambulatory Health Care Services
  - 62191 Ambulance Services
    - 6219101 Air Ambulance Services
    - 6219109 Ambulance or Rescue Service (Except by Air)
  - 62199 All Other Ambulatory Health Care Services
    - 621991 Blood and Organ Banks
    - 621999 All Other Miscellaneous Ambulatory Health Care Services

6214-9 Ambulatory Health Care Services: National Demographics



6214-9 Ambulatory Health Care Services: Indicators of Facility Size



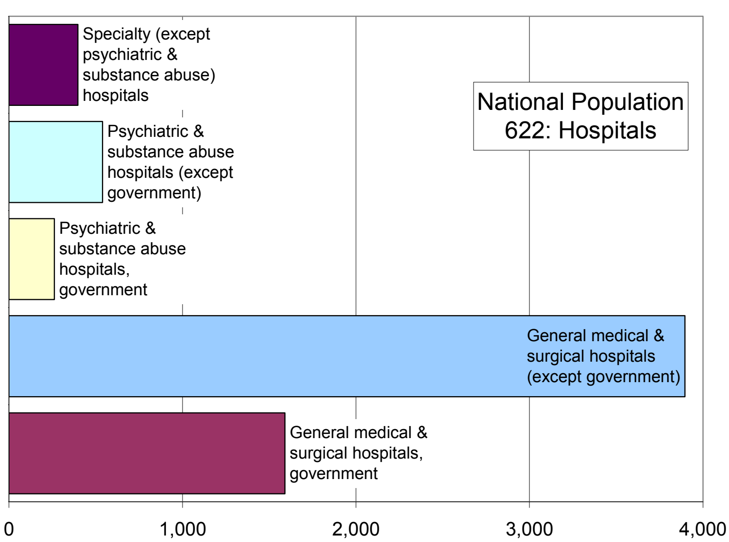
Major Segment

622 Hospitals

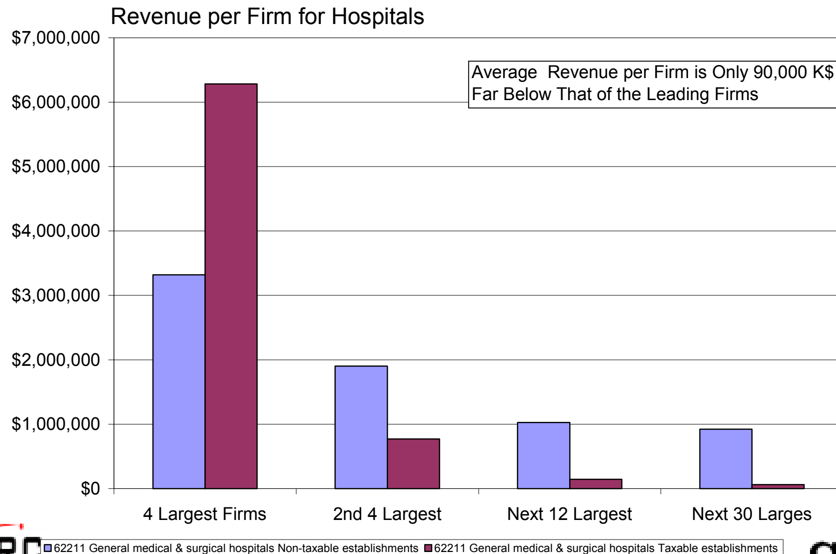
622 Hospitals: Sub-Sector Definitions

- 6221 General Medical and Surgical Hospitals
  - 62211011 Children's Hospitals, Government
  - 62211012 General Medical and Surgical Hospitals (Except Children's Hospitals), Government
  - 62211021 Children's Hospitals (Except Government)
  - 62211022 General Medical and Surgical Hospitals (Except Children's Hospitals or Government)
- 6222 Psychiatric and Substance Abuse Hospitals
  - 62221011 Substance Abuse Hospitals, Government
  - 62221012 Psychiatric Hospitals, Government
  - 62221021 Substance Abuse Hospitals (Except Government)
  - 62221022 Psychiatric Hospitals (Except Government)
- 6223 Specialty (Except Psychiatric and Substance Abuse) Hospitals
  - 6223101 Specialty Hospitals, Government.
  - 6223102 Specialty Hospitals

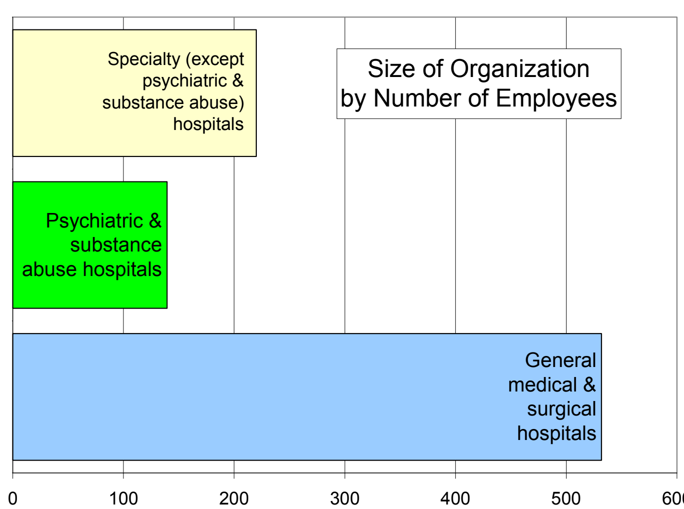
622 Hospitals: National Demographics



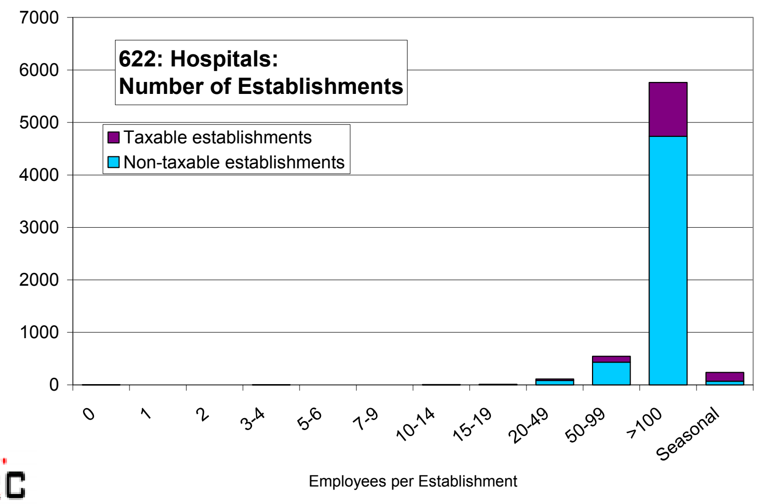
622 Hospitals: Market Concentration



622 Hospitals: Indicators of Facility Size



622 Hospitals: Diversity of Facility Size



Major Segment

623 Nursing and Residential Care Facilities

623 Nursing and Residential Care Facilities: Sub-Sector Definitions

- 6231 Nursing Care Facilities
- 6232 Residential Mental Retardation, Mental Health and Substance Abuse Facilities
  - 62321 Residential Mental Retardation Facilities
  - 62322 Residential Mental Health and Substance Abuse Facilities
- 6233 Community Care Facilities for the Elderly
  - 623311 Continuing Care Retirement Communities
  - 623312 Homes for the Elderly
- 6239 Other Residential Care Facilities

623 Nursing and Residential Care Facilities: Sub-Sector Definitions

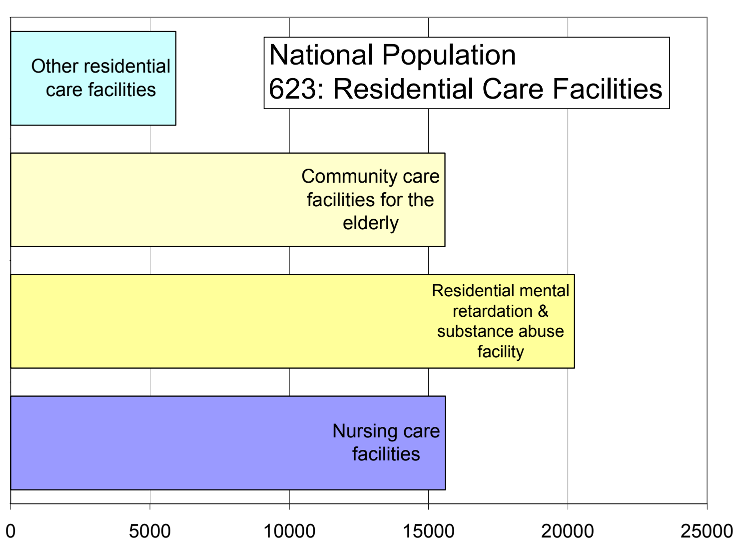
- **6231 Nursing Care Facilities**
  - Provide inpatient nursing and rehabilitative services. The care is generally provided for an extended period of time. Establishments provide nursing and continuous personal care services.
- **6232 Retardation, Mental Health & Drug Abuse**
  - 62321 Residential Mental Retardation Facilities
    - This industry comprises establishments providing residential care for persons diagnosed with mental retardation. Focus is room, board, protective supervision, and counseling.
  - 62322 Residential Mental Health and Substance Abuse Facilities
    - Establishments primarily providing residential care and treatment for patients with mental health and substance abuse illnesses. Establishments provide room, board, supervision, and counseling services. Medical services are incidental. Establishments provide a wide range of social services in addition to counseling.

623 Nursing and Residential Care Facilities: Sub-Sector Definitions

- **6233 Community Care Facilities for the Elderly**
  - 623311 Continuing Care Retirement Communities
    - Provide residential and personal care services with on-site nursing care for the elderly and others who are unable to care for themselves and/or who do not desire to live independently. Individuals live in a variety of residential settings with meals, housekeeping, social, and leisure, available
  - 623312 Homes for the Elderly
    - Provide residential and personal care services without on-site nursing care for the elderly or other persons who are unable to fully care for themselves and/or who do not desire to live independently. The care typically includes room, board, supervision, and assistance, such as housekeeping services.
- **6239 Other Residential Care Facilities**
  - Establishments providing residential care (except residential mental retardation, residential health and substance abuse facilities, continuing care retirement communities, and homes for the elderly). These establishments also provide supervision and personal care services.

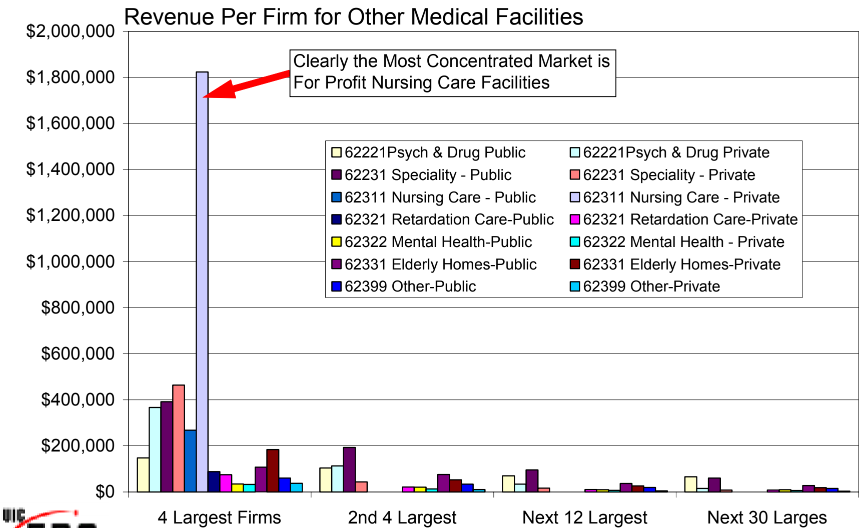
623 Nursing and Residential Care Facilities: National Demographics

Ref. 1



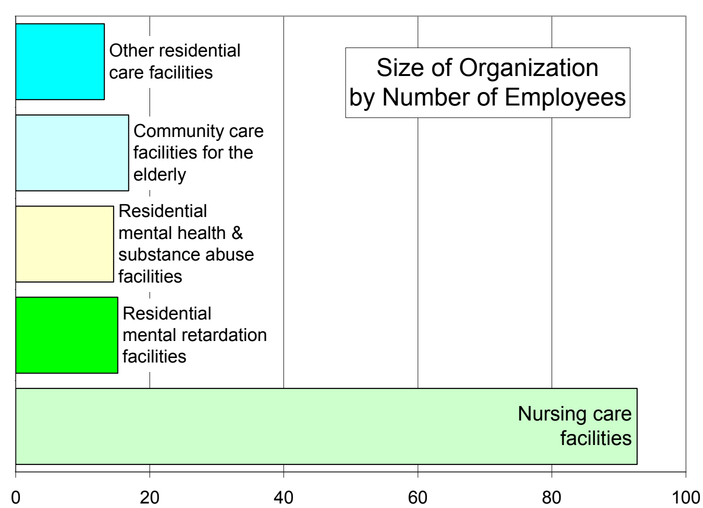
623 Nursing and Residential Care Facilities: Market Concentration

Ref. 1

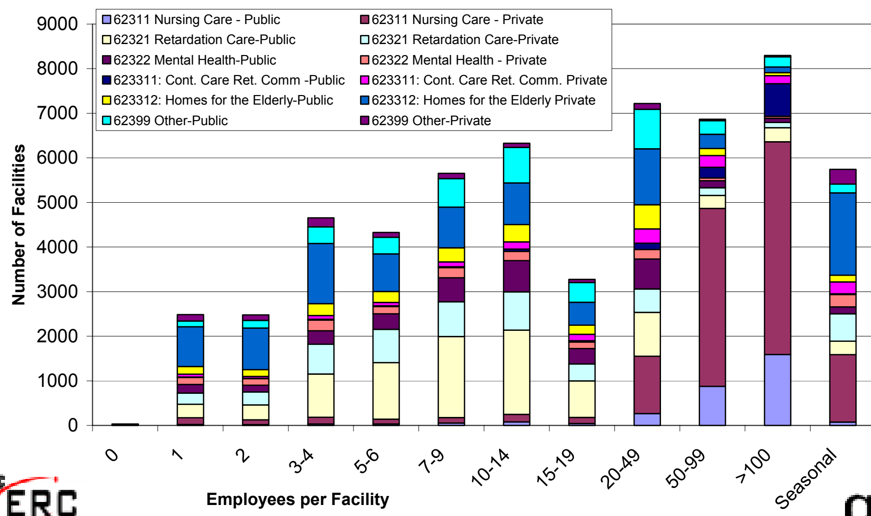


623 Nursing and Residential Care Facilities: Indicators of Facility Size

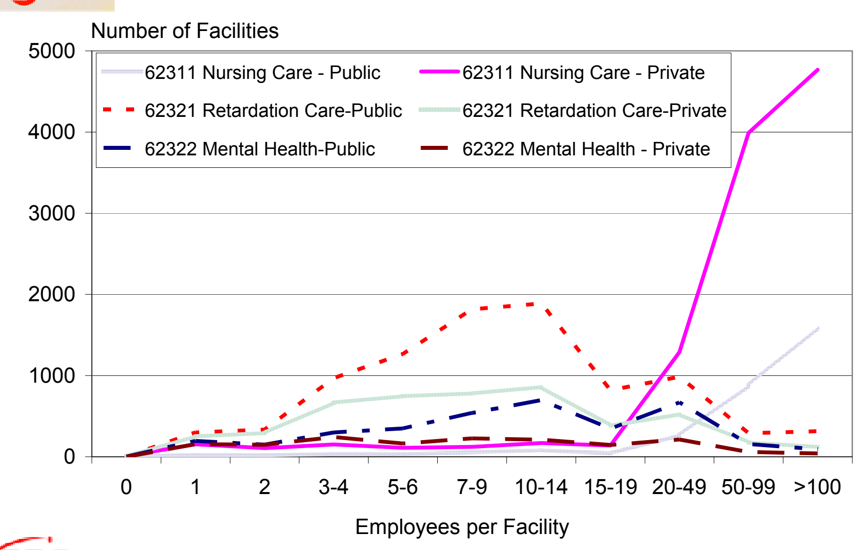
Ref. 1



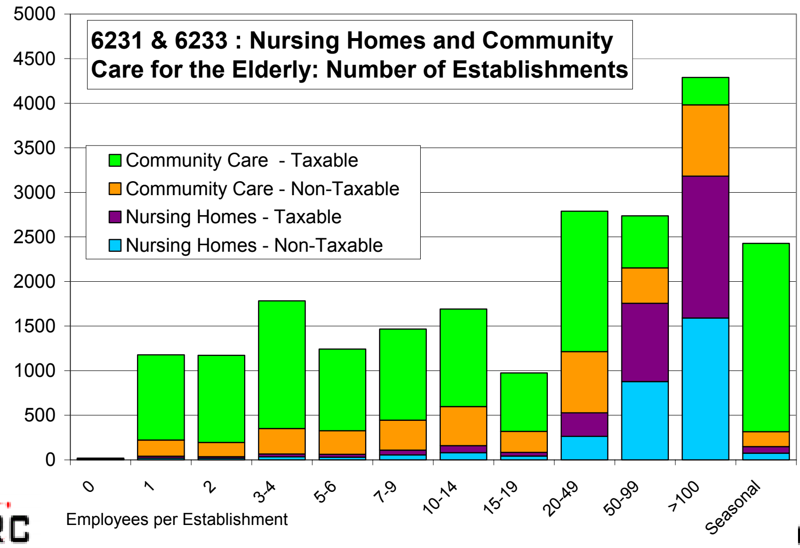
623 Nursing and Residential Care Facilities: Indicators of Facility Size by Sub-Sector



Viewing only the Major Facilities



623 Nursing and Residential Care Facilities: Specifically for Elderly - Indicators of Facility Size



Major Segment

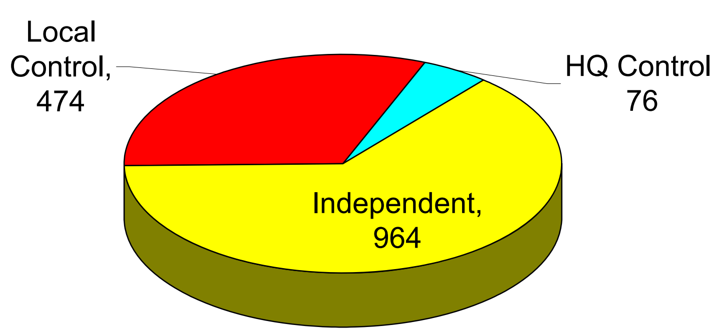
<u>AGA/GRI Market Study</u>

AGA/GRI Market Study

- Survey of Facility Decision Makers
- Across Both Hospital and Nursing Care Segments
- Classification Used
  - Independent – An independently operated facility of chain of 3 establishments or less
  - Local Control – A facility within a chain of more that 3 establishments which makes major buying decisions at the LOCAL level.
  - HQ Control - A facility within a chain of more that 3 establishments which makes major buying decisions at Headquarters. For these chains, only headquarters staff were interviewed

The Size of the Survey

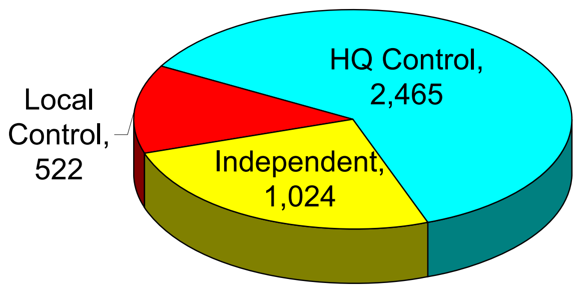
- Total of 1514 Interviews
- Number Dominated by Independents



Actual Number of Interviews
by Survey Segment

The Number of Facilities Controlled by Those Surveyed

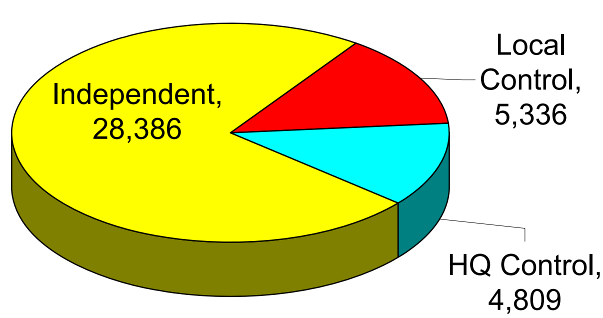
- The Interviewees in Systems Controlled by Headquarters Controlled an Average of 32 Facilities
- “Independents” and “Local Control” Averaged a Little over 1
- Expanded “HQ Control” Segment Representation



Actual Number of Facilities Controlled by the Interviewed

Projecting the Survey Sample to the National Market by Number of Buildings

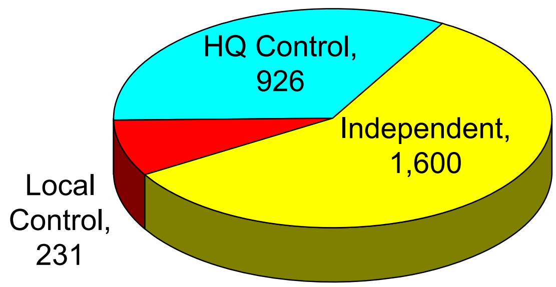
- On a National Basis, “Independents” Far Outnumber Other Segments by Number



Projected Number of Facilities Nationwide by Survey Segment

Projecting the Survey Sample to the National Market by Total Floorspace

- Finally, “HQ Control” Segments Expand Again in Floorspace Count as “HQ Controlled” Chains Average 192,000 SF Facilities Versus Independent 56,000 SF

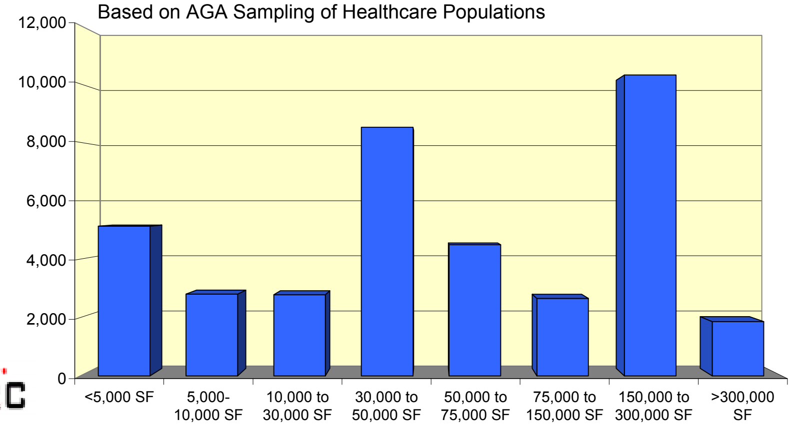


Projected Floorspace (MMSF) by Survey Segment

Facility Size Data

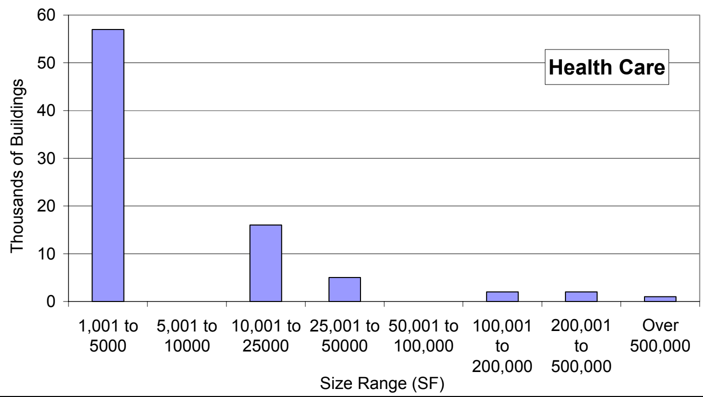
- Survey is the Only Data Source (Other than CBECS) that Delivers Facility Size Breakdown
- Based on Respondents from Actual Surveys

Projecting to the Entire Population By Size
Based on AGA Sampling of Healthcare Populations



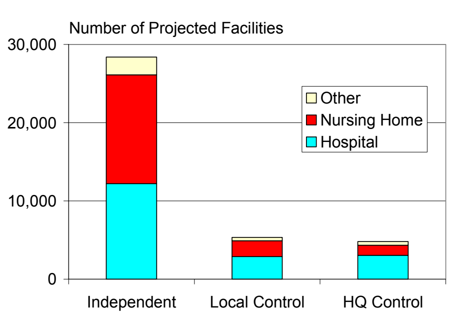
Comparable CBEC Data is Less Desirable

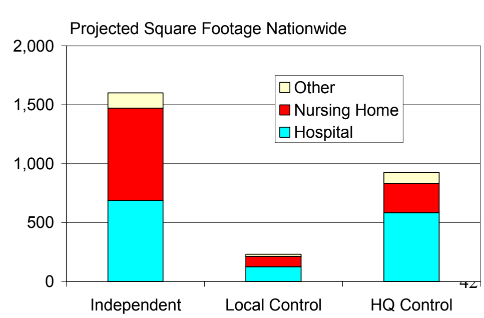
- CBECS Shows 83,000 Buildings vs. 38,000 in AGA Survey, BUT
  - 57,000 are Below 5,000 SF,
  - Above 5000 SF: 36,000 (CBECS) Vs. 33,400 (AGA/GRI)
  - CBEC Data Has Two Classes with Insufficient Statistic Response to Make Projections at 5-10K SF and 50-100K SF,
  - These are Areas of Interest for This Product



Examining the Grouping

- Unfortunately, the Survey Groupings Do Not Lend Themselves to Breakdown by Building Function
- Groupings are Too Evenly Split Between Hospitals and Nursing Homes





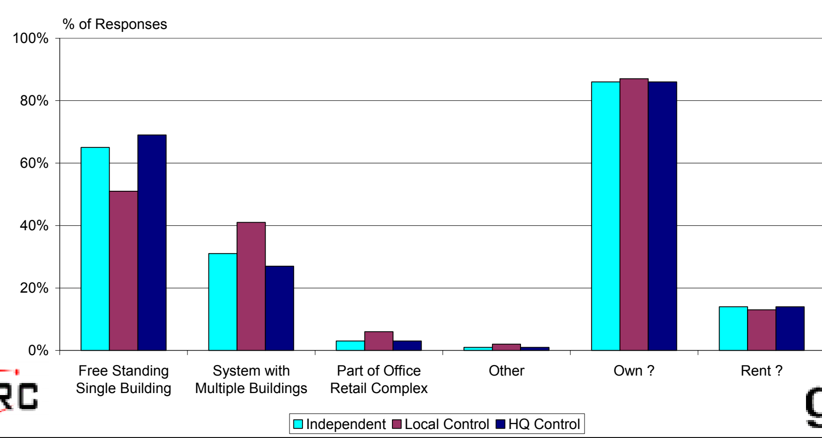
Comparing to Census Statistics

- AGA Data Covers All Classes of Hospitals and Nursing Homes
- Totals Agree Well – AGA Projections Over-Predict Number of Hospitals (Sampling % in Hospitals Exceeded Actual %)

NAIC 622	Hospitals - All	6,685
NAICS 6231	Nursing Homes	15,605
NAICS 6233	Community Care for the Elderly	15,588
	Total	37,878
	AGA Total	38,531

AGA/GRI Survey Results

- The Survey Asked a Number of Questions About the Nature of the Facility and the Current Equipment in the Facility
- This Was Then Projected to the Overall Population of Facilities

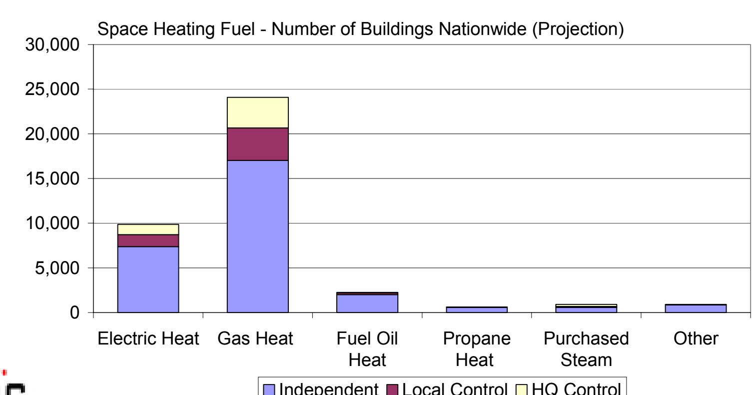


National Projections

- National Projections
  - Projecting Survey Results to the Overall Population is Key in Estimating Market Size
- Segment Preferences:
  - Using Actual Percent of Response Data to See Distinctions by Segment in Preference for Fuel Type and Equipment Usage
- Market Penetration of Existing Equipment:
  - Cogeneration Technologies May Fit in Better with Certain Existing Equipment Types, Such as Chiller and Boilers, than Others, Such as Rooftop Heating and Cooling. The Number of Existing Facilities by Existing Equipment Type is Shown

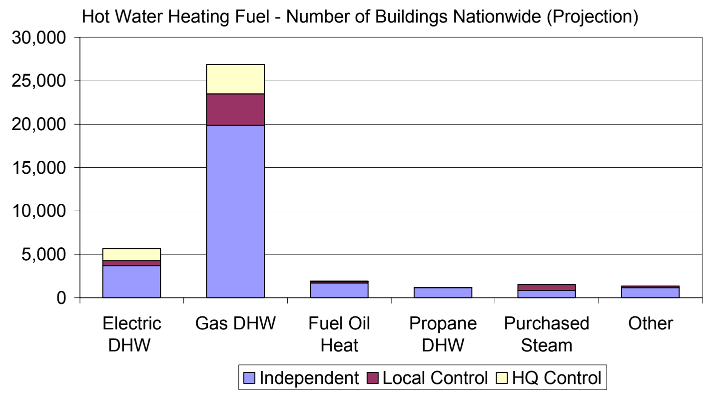
Fuel Currently Used for Heating

- Widespread Popularity for Gas Heating



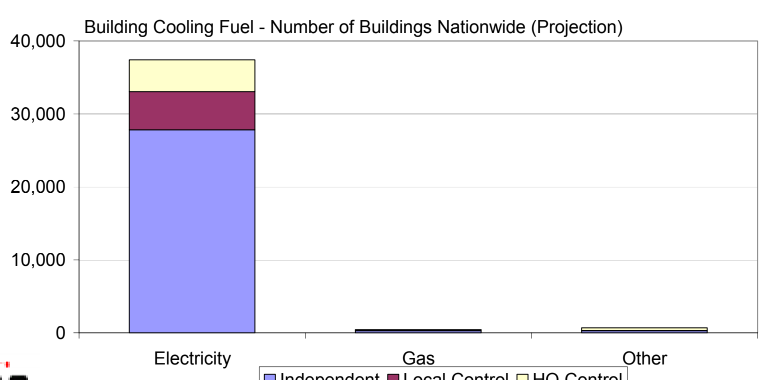
Fuel Currently Used for Heating Water

- >25,000 Facilities have Gas Available – Essential for the Application of the BCHP Package



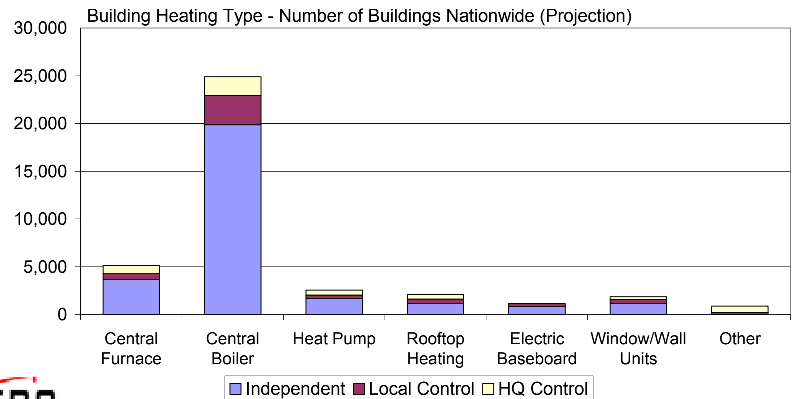
Fuel Currently Used for Cooling

- Use of Gas for Cooling is Relatively Rare
- Indicates that Nationwide – Familiarity with Absorption Systems will be Limited



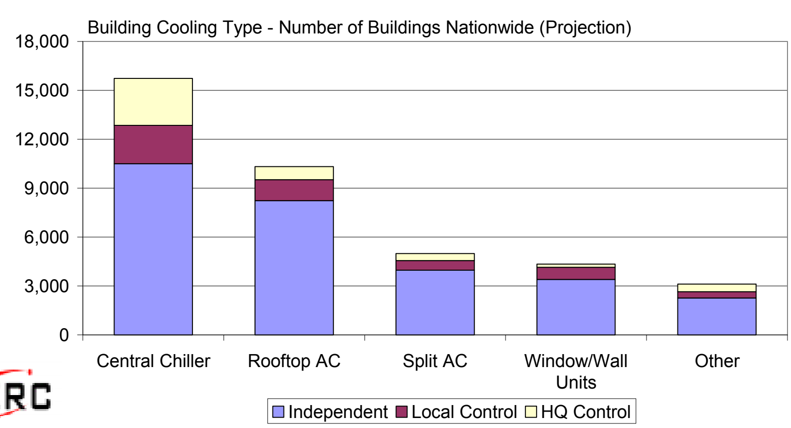
Type of Equipment Currently Used for Heating

- Central Hot Water or Steam Distribution in at Least 25,000 Facilities
- Great Asset in Applying Heat Rejection from BCHP Package to General Heating Loads



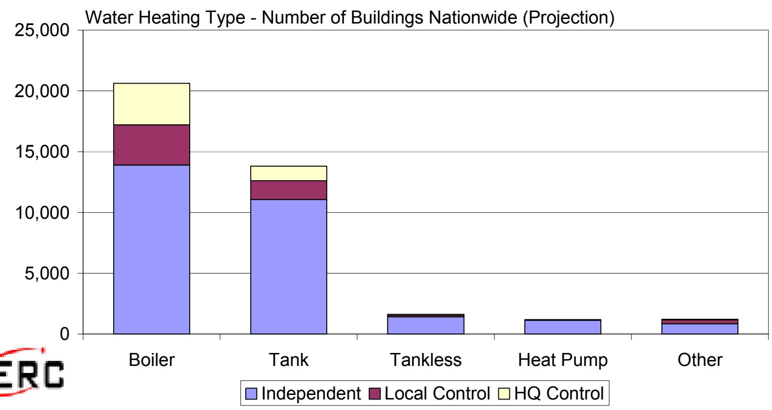
Type of Equipment Currently Used for Cooling

- ~16,000 Facilities Have Central Chilled Water Systems
- Only Market Segment Examined where Chilled Water Systems Predominate
- Will Help in Application of BCHP Package that Supplies Chilled Water



Type of Equipment Currently Used for Water Heating

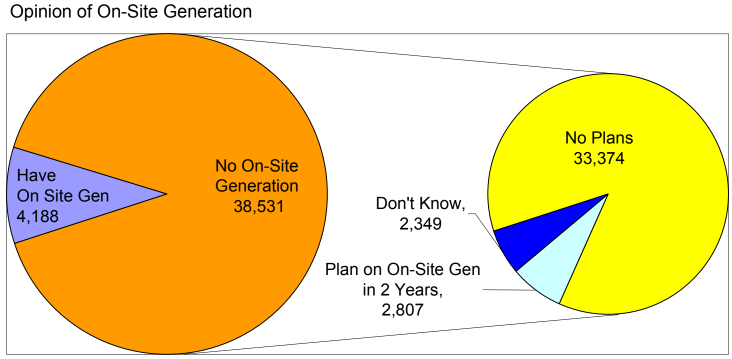
- 20,000+ Facilities use Central Boiler to Make Domestic Hot Water
- Allows DHW Load to be Applied to BCHP Package with a Minimum of Facility Changes



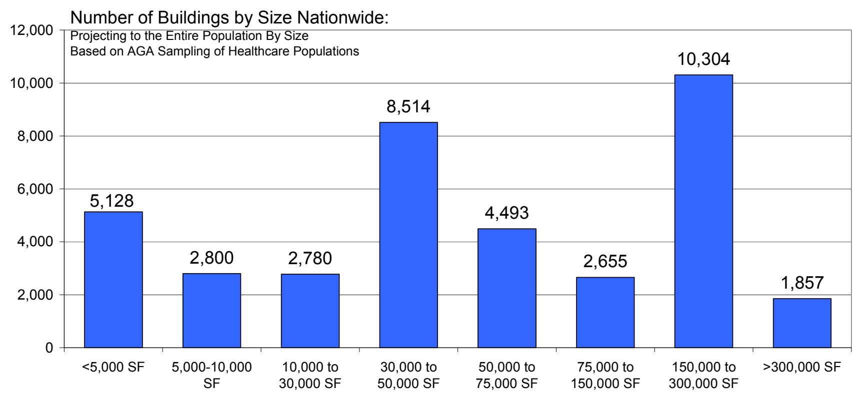
On Site Generation

- High Percentage Has “On-Site Generation
  - Possible Some Facilities Confused Back-Up Generation with On-Site Generation
- Given the Medical Functions of the Facilities - Surprisingly Small Number of Facilities Have On-Site Generation or Plans for New On-Site Generation
  - Number of On-Site Generators Corresponds Well with Number of Hospitals
  - May Indicate How Seldom On Site Generators are Applied to Nursing Facilities

Opinion of On-Site Generation



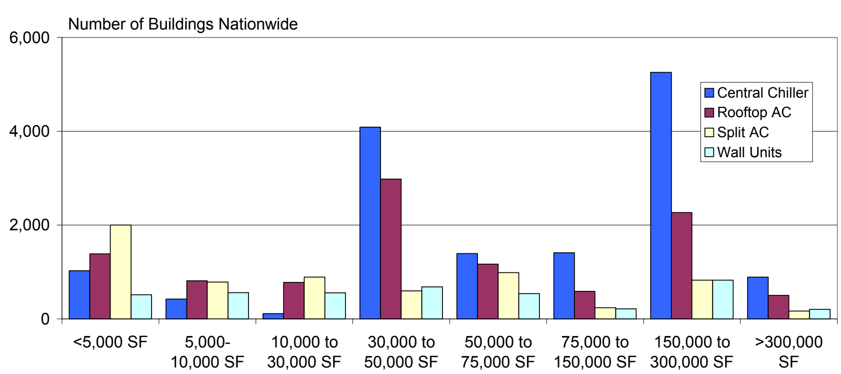
Examining Building Sizes



- Census Data Indicates Most Nursing Homes < 100,000 SF
  - ~15,000 Facilities
- Hospitals are the Largest Facilities (~6,600 Facilities)
- Community Care Homes are the Smallest

53

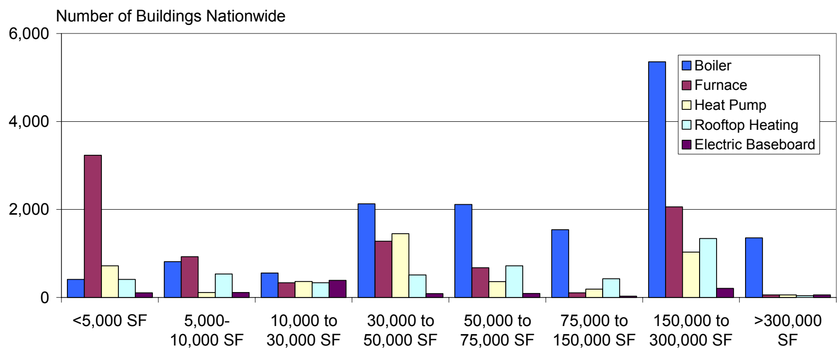
Building Cooling Equipment by Size



- Split AC Dominates Small Facilities
- Rooftops and Chillers Compete in Medium Faculties
- Central Chillers Dominate Larges Facilities

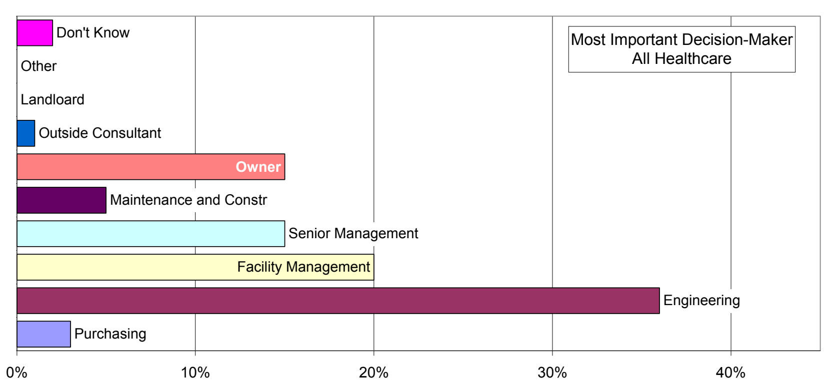
54

Building Heating Equipment by Size



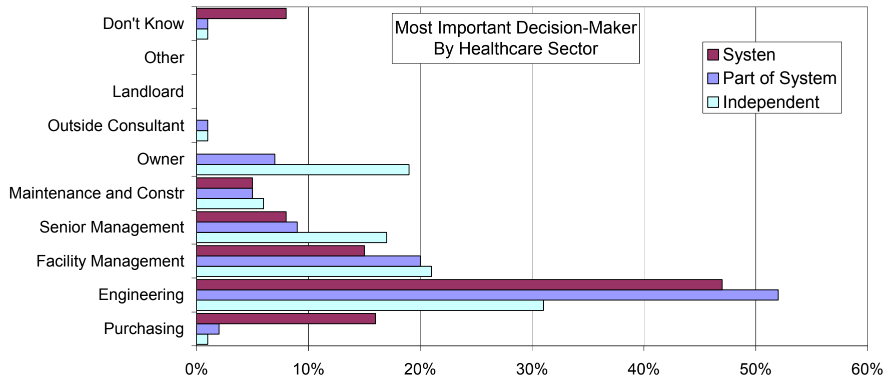
- Boilers Dominate as Soon as Facility Exceeds 10,000 SF
- Make Medium-Sized Faculties Boiler Dominated

Decision Makers



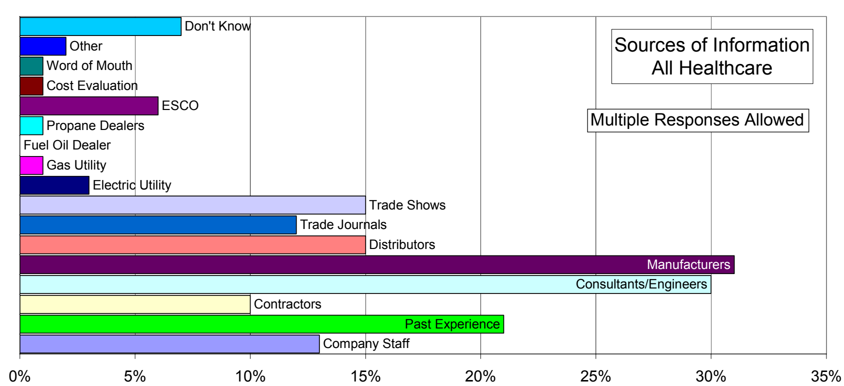
- Decision Maker for the Entire Sector is Dominated by Internal Engineering Staff
- No Other Segment is Dominated by "Internal" Engineering
- Makes Internal Engineers the Key to Penetrating Market

Decision Makers by Segment



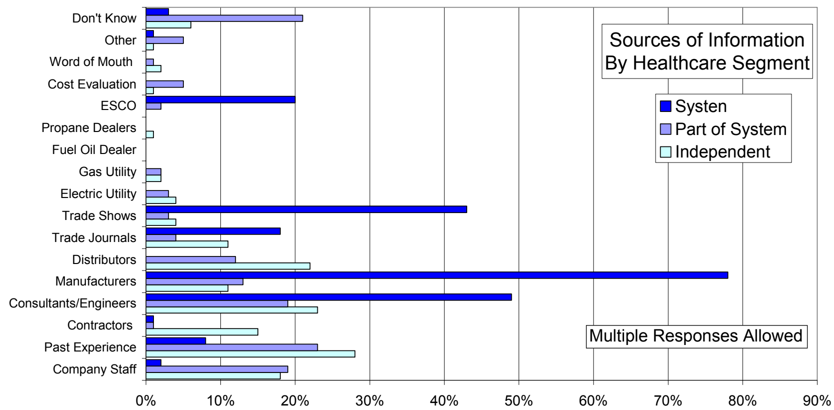
- Decision Maker for the Each Segment is Also Dominated by Internal Engineering Staff
- Owner is More Significant – But Not Dominating – in Independent
  - Size of Operation May Make Owner More Remote from Daily Operations and Decisions than Independents in Other Sectors

Sources of Information



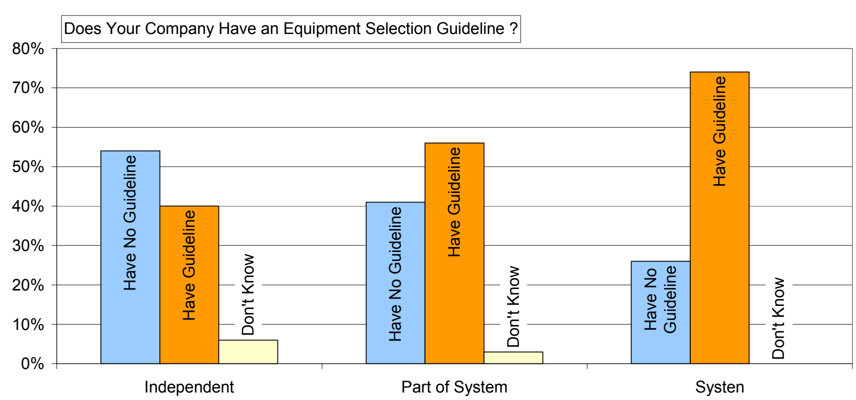
- Manufacturers and Engineers Depended on to Provide Information
- Indicative of a More Technically Oriented Sector than Other Markets
  - Customers Want Information Directly from Manufacturers

Sources of Information by Segment



- Systems Segments is Significantly Different from Other Segments
  - System Owners Look More Directly to Manufacturers, Trade Shows, Outside Engineers, and ESCO's than Any Other Group
  - Far Less Focus on Staff and Experience

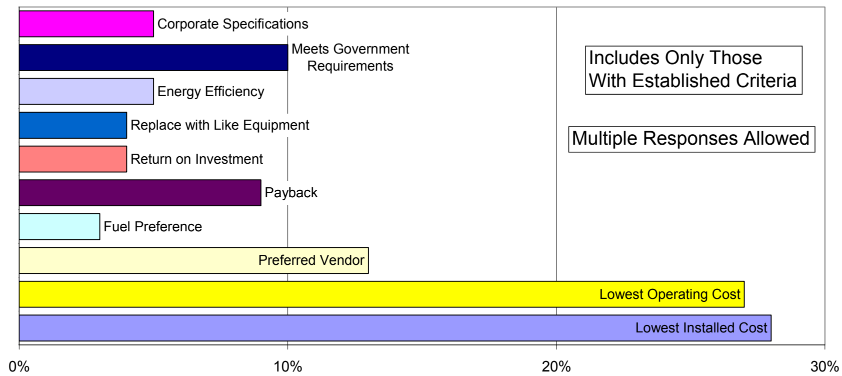
Equipment Selection Guidelines



- As Expected – Larger Operations Such as Systems are More Inclined to Have Written Selection Guidelines

Equipment Selection

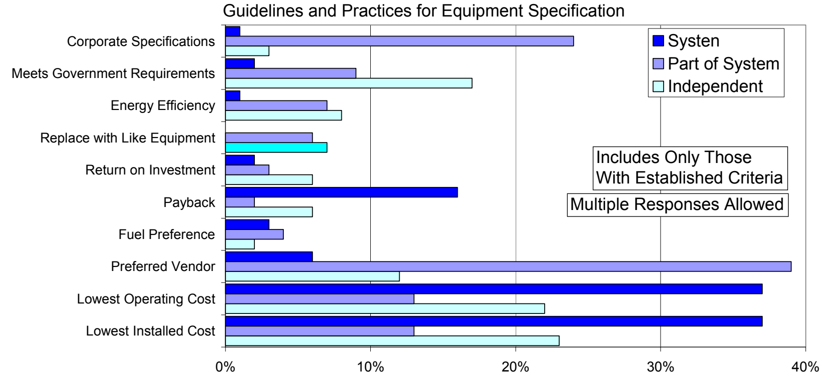
Most Important Issues in Selection Guidelines - All Healthcare Facilities



- No Surprises – Lowest Operating and First Cost Vying with Each Other for Greatest Influence

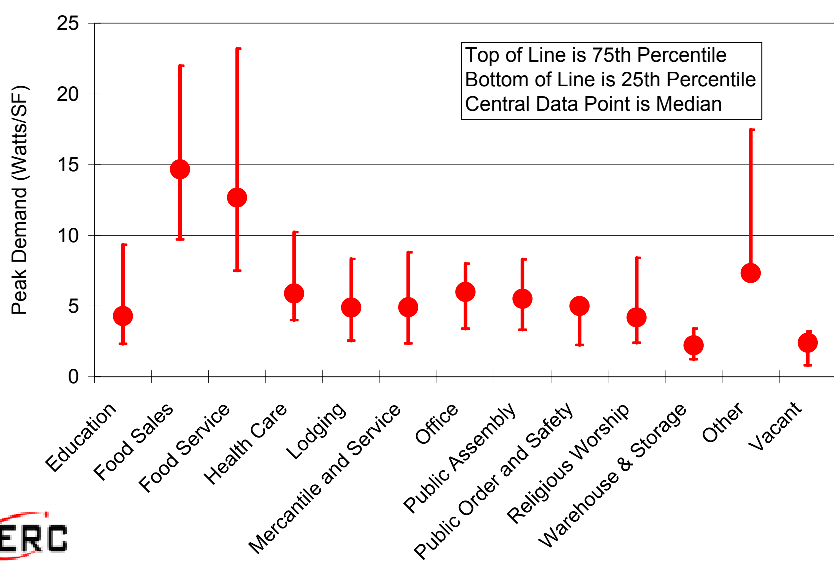
Equipment Selection by Segment

Guidelines and Practices for Equipment Specification

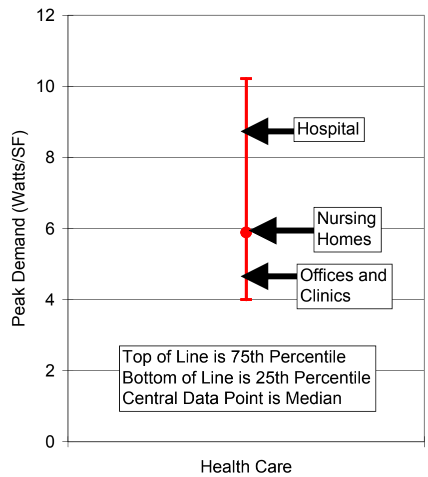


- Differences Appear by Sector
  - Once Again “Systems” are the Least Traditional,
    - Least Influenced by Vendor Preferences, or Replacing with Like Equipment
    - Most Influenced by Straight Economic Factors
  - “Part of System” Facilities with Independent Buying Power are Controlled Heavily by Corporate Specifications

Summary of Best Sector and Electric Load



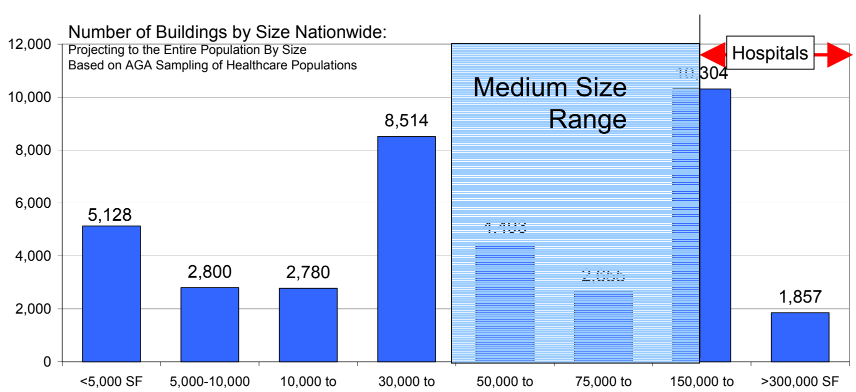
Determine Appropriate Medium Size Range from Product Specification



CBECS Data for the Entire Health Care Segment

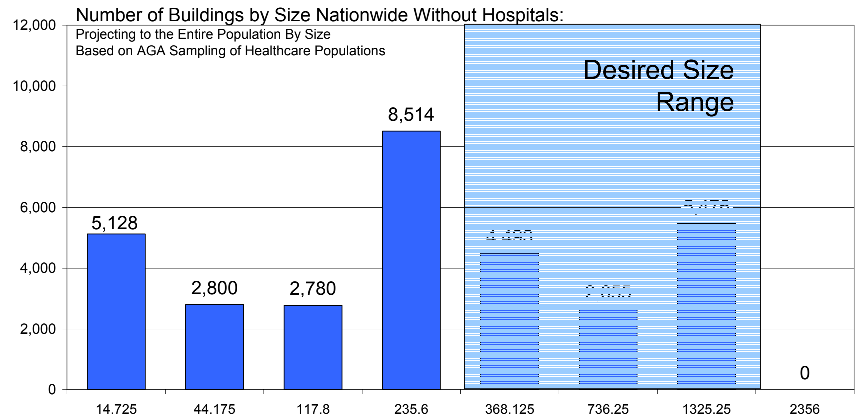
- Product Range from 300 to 800 kW
- Best Economics when On-Site Generation is in 40-60% of Total Building Demand
- Suggests Buildings in the 500 kW to 2 MW Range
- CBECS Data (for Health Care) Suggest
  - Hospitals ~9W/SF (Only 6,000 Facilities)
  - Nursing Care ~ 5-6 W/SF
  - Offices ~4-5 W/SF

Examining Building Sizes



- Census Data Indicates Most Nursing Homes < 100,000 SF
  - ~15,000 Facilities
- Hospitals are the Largest Facilities (~6,600 Facilities)
- Community Care Homes are the Smallest

Subtracting Out Hospitals



- Focusing on Appropriate Size Ranges Leaves 12,600 Facilities
- Covering 1844 Million Square Feet and 10.86 GW of Demand

Conclusions

Conclusions

- Medium Size Health Care
  - Largely Nursing Facilities
  - Covering 10-11 MW Capacity
  - Most Concentrated Market – Large Privately Owner Nursing Home Systems
  - Most Common Current Equipment for Facilities in This Size Range
    - Heating: Central Boilers with Boiler Drive Water Heat
    - Cooling: Central Chillers Predominate with Some Percentage of Rooftop Applications
  - Owner Predisposition
    - System Owners are Non-Traditional and Balance First Cost and Operating Cost Concerns

Conclusions – Reaching the Market

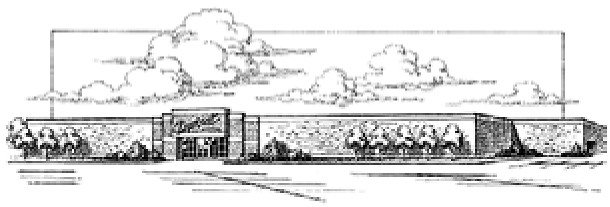
- Healthcare "Systems"
  - More Depend on Outside Engineers, Trade Shows, Journals, and Manufacturers for New Product Information than Other Health Care Segments
  - Less Devoted to Past Experience or Replacing Like-with-Like than Other Health Care Segments
- Overall Non-Hospital Health Care Have Little Back-Up Power Capability
  - Yet Nursing Homes May Have Populations that are Difficult or Impossible to Evacuate
  - Medical Clinics are Hosting More Outpatient Surgery that Cannot be Interrupted
  - Smaller Health Care Buildings Include Medical Testing Labs that May Have Cooling and Refrigeration Loads that Must Be Carried at All Times
  - Cogen. May Also Provide Back-Up Capability for These Applications

References

1. U.S. Census Bureau, American Fact Finder, Sector 62: Health Care and Social Assistance: Establishment and Firms Size: Single Unit and Multiunit Firms: 1997 http//factfinder.census.gov/servlet/EconSectorServlet?_SectorId=62&survey=Economic%20Census&_ts=49646024290
2. U.S. Census Bureau, American Fact Finder Sector 62: Health Care and Social Assistance: Establishment and Firms Size: Employment Size of Firms: 1997
3. "U.S. Department of Energy, Energy Information Administration, "A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures."

Chapter 5:
The Large Retail Sector

Prepared by:
Bill Ryan
UIC-ERC
630-561-4448



Objective

- Initial Target Sector Visualization
  - Large Retail – Ideally 100,000 SF Range
  - Wal-Mart/ K Mart “Big Box” Stores
  - Principally Non - Grocery
  - Single Operator Free Standing
  - Not Shopping Centers
- Objective
  - Find the Market Size
  - Target the Retail Segment Opportunity

The Retail Building Segment

- Hugh and Highly Varied Market
- Need to Break Down into Sub-Segments

Procedure

- Find General Market Background
  - Identify Sub-Segments
- Focus In on Promising Sub-Segment (s)
  - Find the Size of the Sub-Segment in Sites/Floorspace/kW's
  - Identify Major Marketing Avenues Where Possible
- Determine Details for Modeling

Retail Building Overview

Major NAICS Classes by Store Number

NAICS Code	Kind of Business	Establishments
		(Number)
44		1,118,447
448	Clothing & clothing accessories stores	156,601
445	Food & beverage stores	148,528
453	Miscellaneous store retailers	129,838
447	Gasoline stations	126,889
441	Motor vehicle & parts dealers	122,633
444	Building material & garden equipment & supplies	93,117
446	Health & personal care stores	82,941
451	Sporting goods, hobby, book, & music stores	69,149
442	Furniture & home furnishings stores	64,725
454	Nonstore retailers	44,482
443	Electronics & appliance stores	43,373
452	General merchandise stores	36,171

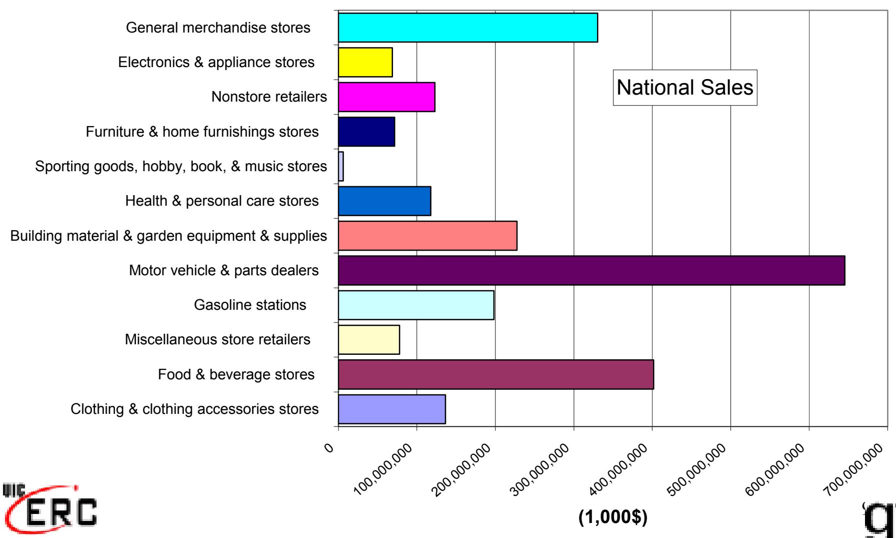
US Census Data

Sorting Process

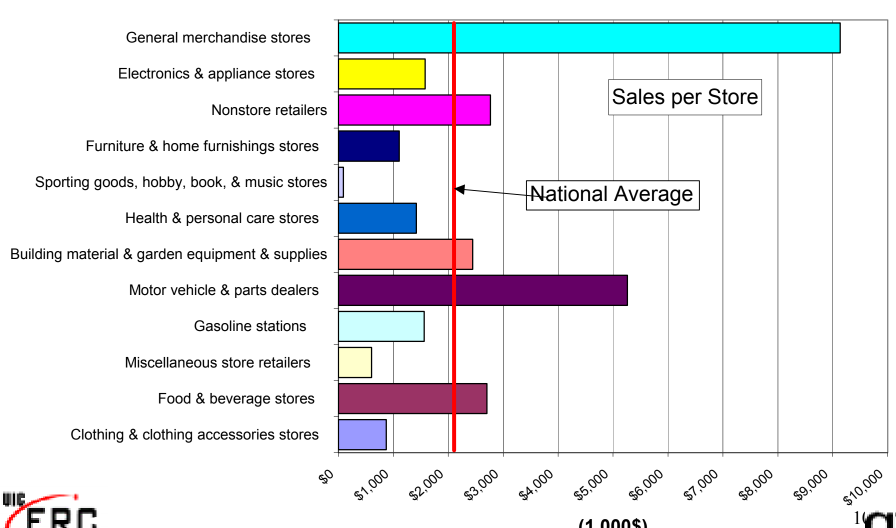
- Objective is to Find Most Promising Sub-Segment
- Looking for Larger Stores
  - Should Stand Out as Higher Sales per Store
  - Rather than Most Common Stores in Market Count

Major Store Types in the US

National Sales by Type of Retail

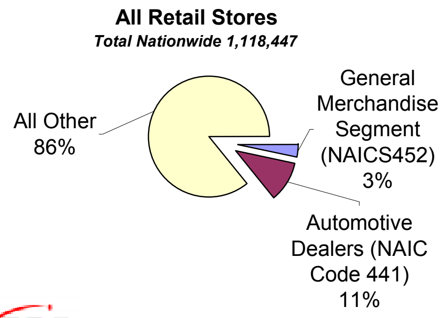


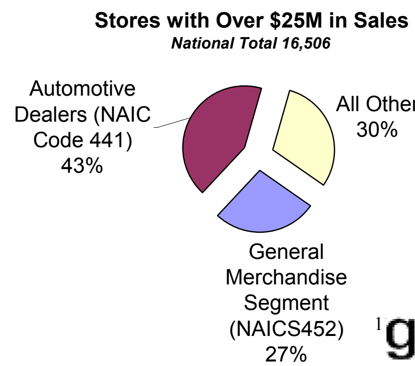
Retail by Sales per Establishment



Which Specific Retail Types Dominate the Largest Establishments ?

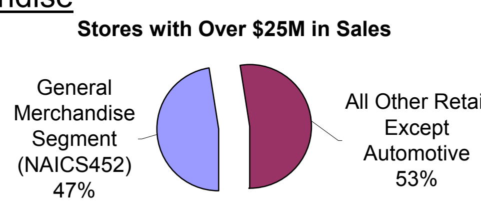
- Two Segments Dominate Large Retail
  - General Mechandise (Department) Stores
  - Automotive Dealers





General Merchandise

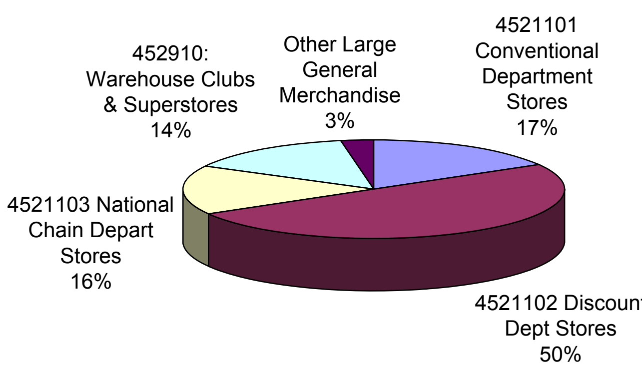
- Automotive Dealers Can Be Eliminated
  - Very Limited Indoor Floor Space/Dollar Sales
- Net Result
  - General Merchandise is 3% of the 1,118,447 Retail Establishments in the US
  - BUT only 9,499 Stores Do More the $25M in Sales
  - <u>AND 47% of All $25M+ Stores are General Merchandise</u>



Sub-Segment NAICS 452

- General Merchandise (NAICS 452) Seems to be of the Greatest Interest
- Sub-Segment Breakdown
  - NAICS 452-1101: Conventional Department Stores (excluding leased departments)
  - NAICS 452-1102: Discount or Mass Merchandise Department stores (excluding leased departments)
  - NAICS 452-1103: National Chain Department Stores (excluding leased departments)
  - NAICS 452-910: Warehouse Clubs and Superstores
  - Various Smaller Sub - Segments

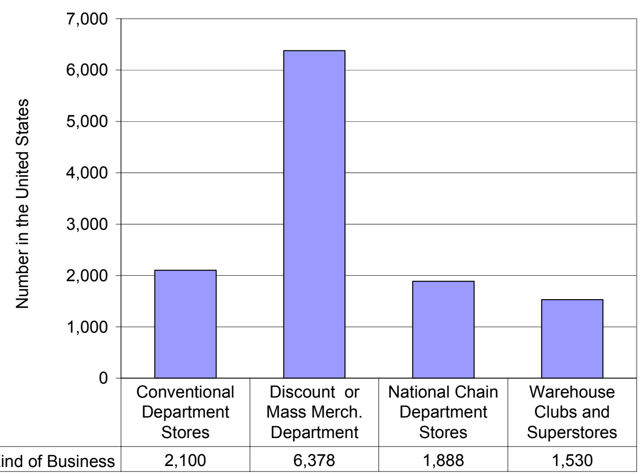
Concentration within General Merchandise



Of the Seven Sub-Classes in NAICS 452
A Full 97% of All Retail Stores
with More than $10M in Sales is in
These 4 NAIC Subclasses

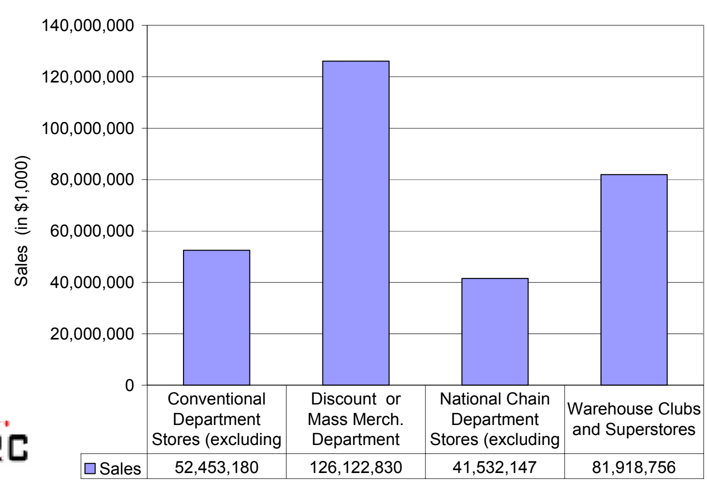
Sub-Segment NAICS 452

- Of the 36,000 Stores in General Merchandise – These 12,000 Stores Dominate the $10+ Million Revenue Stores.



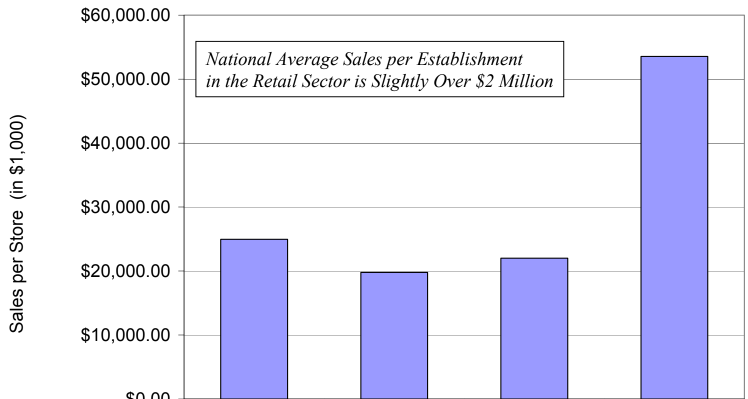
Class 452: General Merchandise

- Total Sales by Class are Very Large.



Class 452: General Merchandise

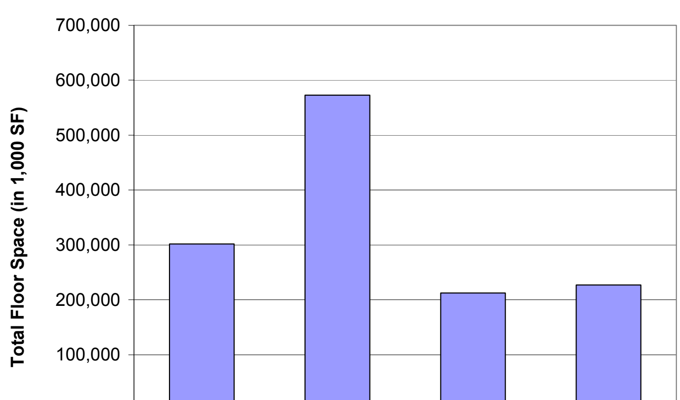
- Sales per Store is Also Huge in Comparison to Other Retail



	Conventional Department Stores	Discount or Mass Merch. Department	National Chain Department Stores	Warehouse Clubs and Superstores
Sales per Store	$24,977.70	$19,774.67	$21,997.96	$53,541.67

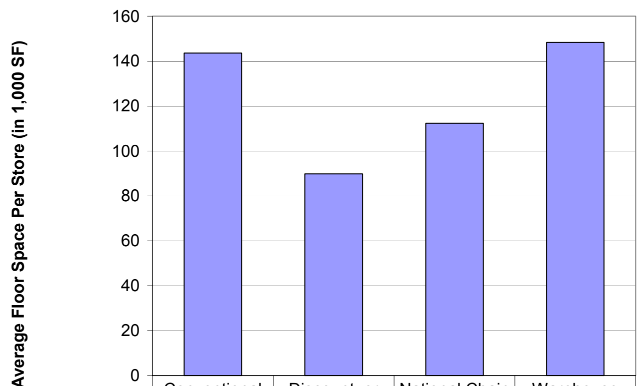
Class 452: General Merchandise

- Census Data on Total Floorspace



	Conventional Department Stores	Discount or Mass Merch. Department	National Chain Department Stores	Warehouse Clubs and Superstores
Total Floor Space	301,602	572,742	212,208	227,029

Class 452: General Merchandise



	Conventional Department Stores	Discount or Mass Merch. Department	National Chain Department Stores	Warehouse Clubs and Superstores
Average Floor Space	144	90	112	148

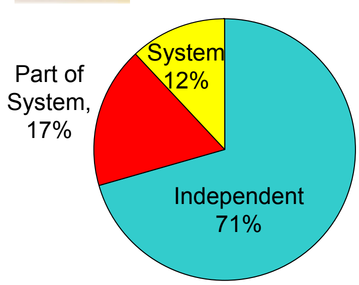
AGA Customer Segmentation Study for the Retail Segment

Data Collected

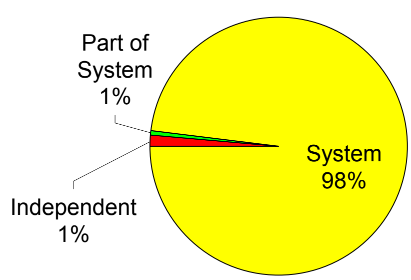
Classifications

- Independent – Equipment Decision Maker for a Single Independently Owned Retail Operation
- Part of System – Equipment Decision Maker for a Single Site of a Multi-Site Retail Operation
- System – Equipment Decision Maker for All Sites of a Multi-Site Retail Operation

Data Statistics



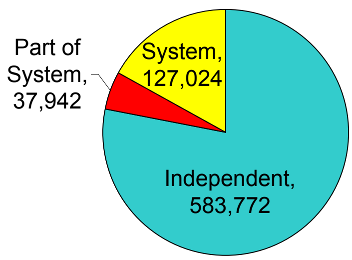
Number of Actual Interviews was 567



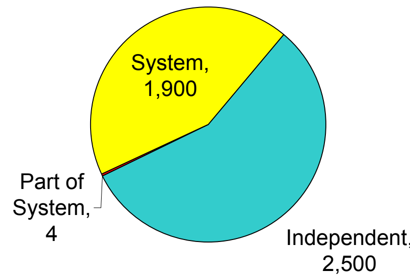
Number of Facilities Directly Represented by Interviewees (Total = 32,237)

- The Largest Number of Interviews were With Independent
- However, the Smaller Number of "System" Managers Interviewed Represented a MUCH Larger Number of Buildings than in Other Catagories

Data Statistics



Projected Number of Facilities Nationwide

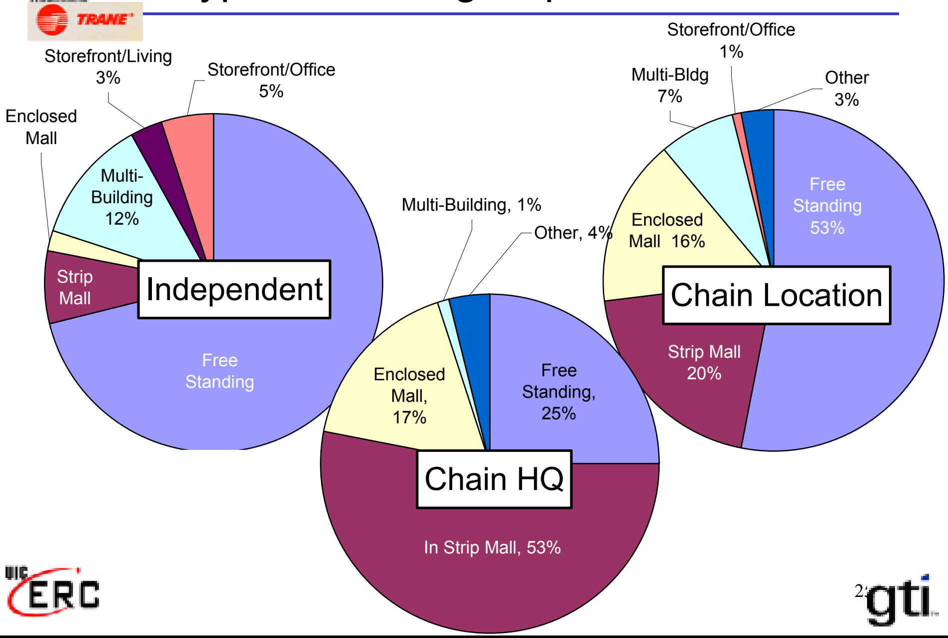


Projected Floorspace (MMSF)

- Nationwide – Independents are the Largest in Store Number by Far
- But on Average, the Systems Managers Represented Larger Stores
- Independents Dominate in the Large Footprint Retail Operations

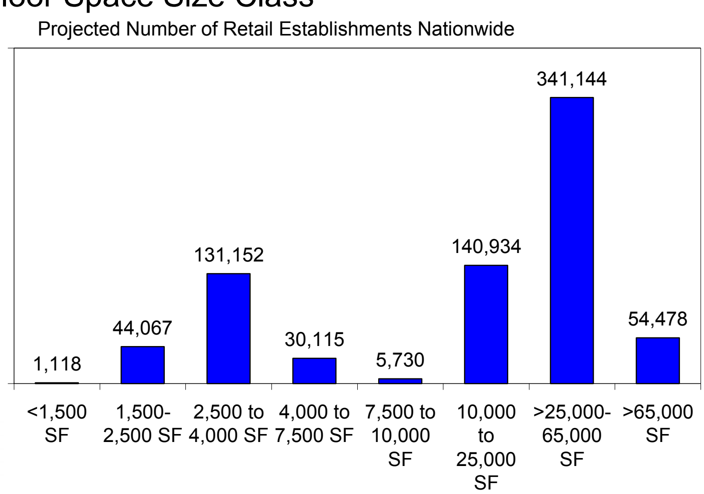
- Needs Distribution by Interview Class by Size

Type of Building Reported in Interviews



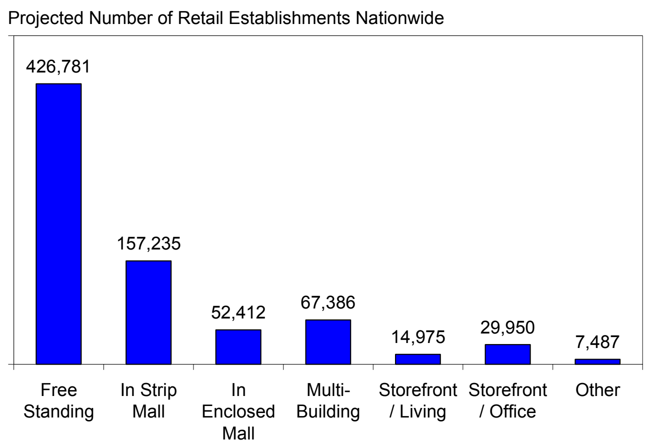
AGA's Projection of Retail Space Sizes

- Only Source Found that Lays Out National Market by Floor Space Size Class



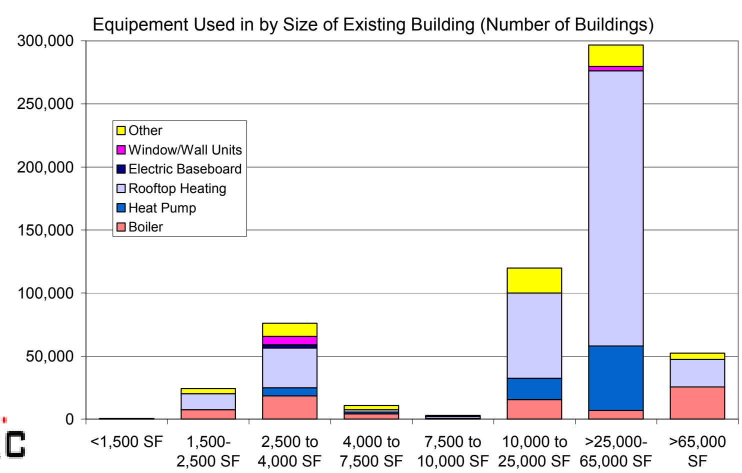
High Percentage of Free Standing Buildings

- Surprising Percentage of Retail is Free Standing
- Enclosed Malls are Less than 8 % of the Retail Space



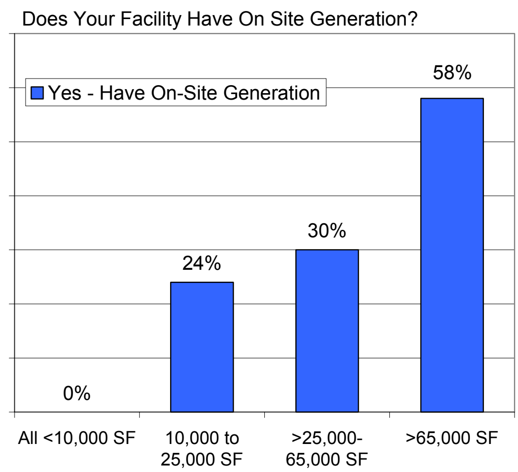
Heating Equipment Used

- Boiler Systems Largely in Facilities Above 65,000
- Below This Size Range Rooftop Heating Predominates



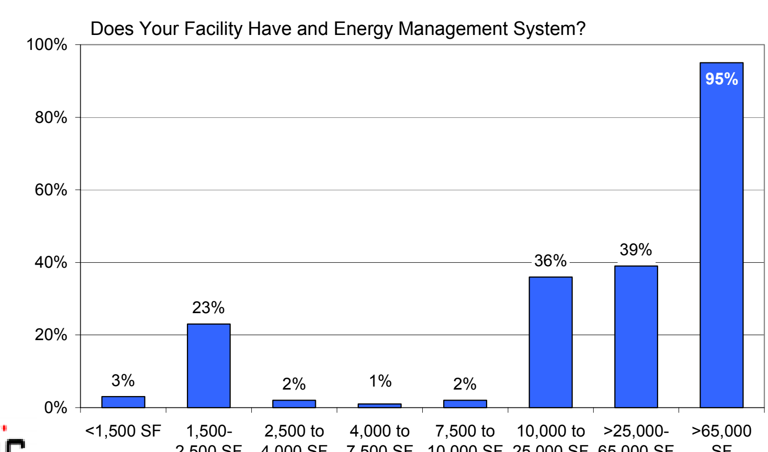
On-Site Generation

- A Large Number of Respondents Claimed to Have On Site Generation – Probably Back-Up Generation
- Quite a High Percentage in Larger Facilities Above 65,000 SF
- Size–Range Most Compatible with BCHP



HVAC Control Systems

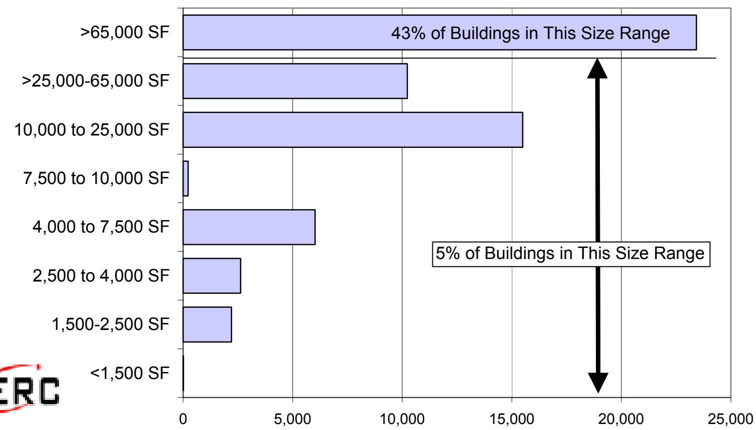
- Large Retail is Far More Likely to Have Energy Management Systems than the Average Retail Site



Chiller Systems

- Buildings with Centralized Cooling Make BCHP Easier to Install
- Use of Central Systems (Chillers) is Only Significant in Stores above 65,000 SF

Use of Central Chiller in Existing Retail Buildings
(Number of Establishments)



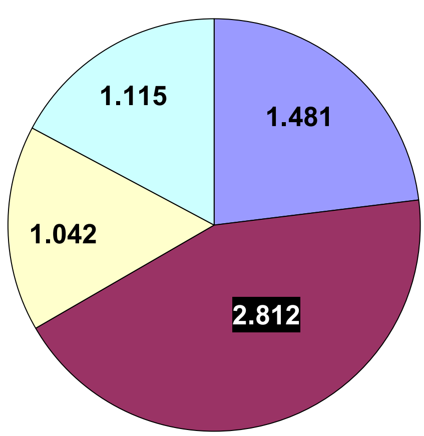
Electric Usage Calculations

- Comparing Data Selections
  - AGA Data Suggested Best Sub-Market is Retail Establishments of 65,000+ SF
  - Total of 54,478 Sites
- Census Data Allowed Further Concentration to 4 Specific Retail Types
- Average Size is Much Larger than 65,000 SF

Electric Usage Calculations

- Focus Entirely on 4 Sub-Classes Identified
- Bring in CBECS Data on Median Energy Consumption per Floor Space
- Calculate the Peak and Annual Total Electric Consumptions for All Stores Nationwide (Size of Market) and for the Average Store.

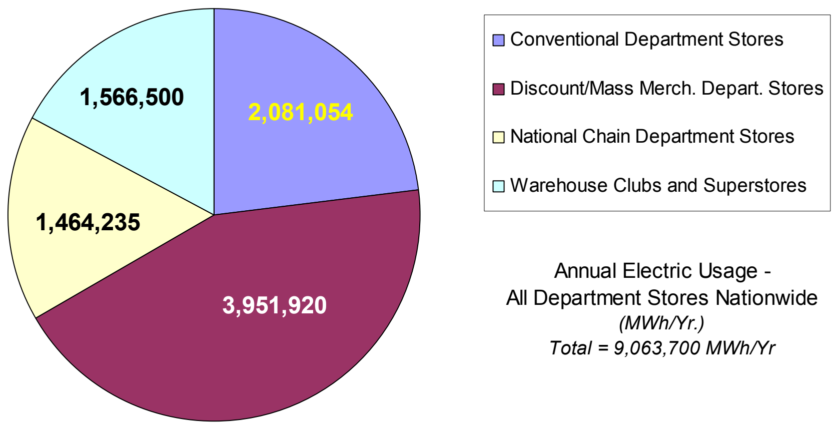
Market Size by Electric Demand



- Conventional Department Stores
- Discount/Mass Merch. Depart. Stores
- National Chain Department Stores
- Warehouse Clubs and Superstores

Peak Electric Use -
All Department Stores Nationwide
(GW)
Total = 6.45 GW

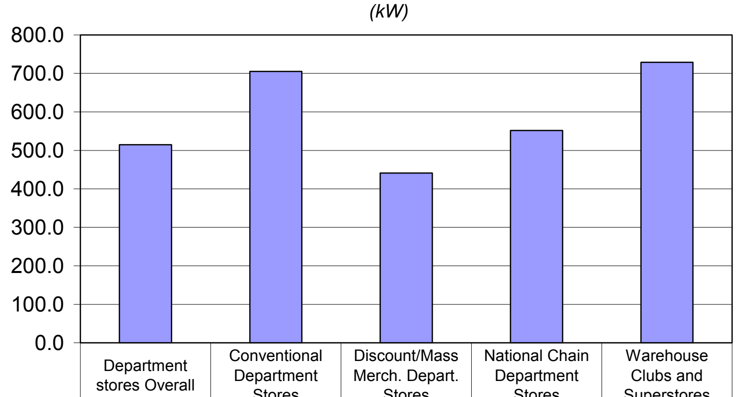
Market Size by Electric Usage



Annual Electric Usage -
All Department Stores Nationwide
(MWh/Yr.)
Total = 9,063,700 MWh/Yr

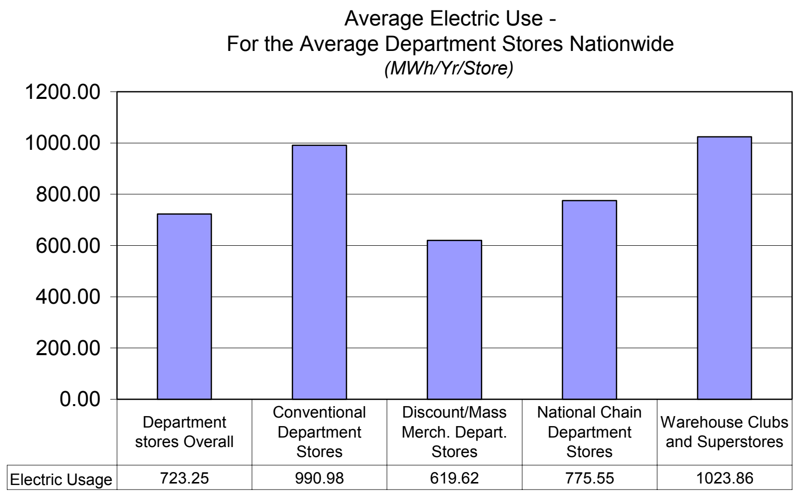
Electric Demand – Average Store

Peak Electric Use -
For the Average Department Stores Nationwide
(kW)



	Department stores Overall	Conventional Department Stores	Discount/Mass Merch. Depart. Stores	National Chain Department Stores	Warehouse Clubs and Superstores
Peak Electric Use	514.7	705.2	440.9	551.9	728.6

Electric Usage – Average Store



Summary

Segment	NAICS Code	Number of Establish-ments	Sales	Floor Space	Overall Market Electric Demand	Overall Market Electric Consump-tion
Overall Retail (US Census)	44 (All) 45 (All)	1,118,447	$2,460 Billion			
General Merchandise	452	36,171 (3% of Total)	$330 Billion (13%)			
Selected General Merchandise	452100 1-3 & 452910	11,896 (1% of Total)	$302 Billion (12%)	1,313 MSF	6.45 GW	9,064 GWHr/Yr

Summary

- Selected Large General Merchandise
  - Dominate Retail Sales with Small Percentage of All Stores
    - Focus Market Effort to <12,000 Sites
    - These are Less than 1% of Establishments but Over 47% of All Retail Establishments Over $25M/Yr in Sales
  - Market Challenges
    - Peak Demand Will Be in the 400-700 kW Range
      - Potential Competition from Engine Generators in this Range
    - Retail Has Limited Need for Back-Up Power

References

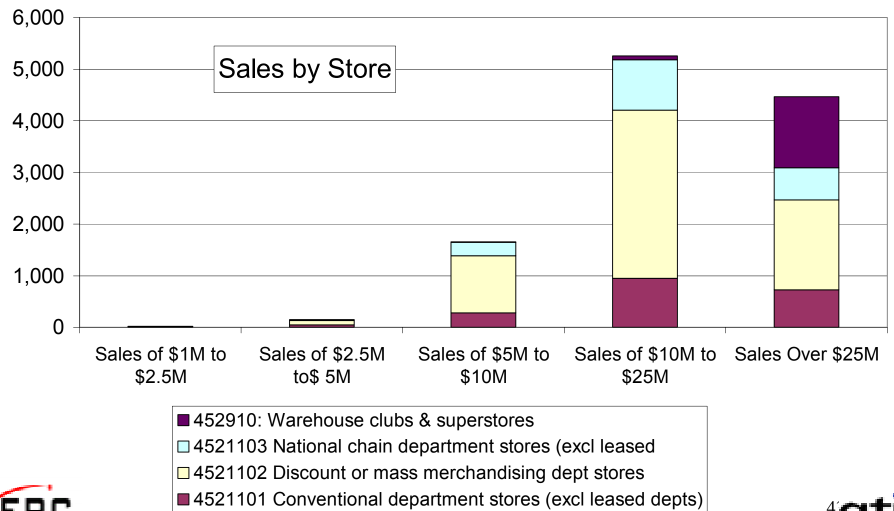
- Retail Trade - Subject Series Miscellaneous Subjects, U.S. Census Bureau, 1997 Economic Census Oct. 31, 2000
- Retail Trade - Subject Series Summary, U.S. Census Bureau, 1997 Economic Census Jan. 29, 2001
- Retail Trade - Subject Series Establishment & Firm Size, U.S. Census Bureau, 1997 Economic Census Oct. 13, 2000

Appendix 1:
Sub- Segment Details and NAIC Code Definitions

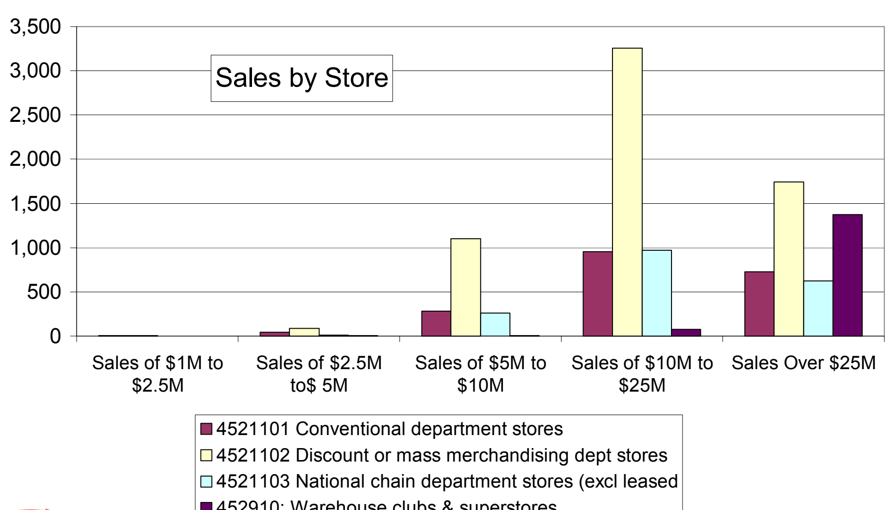
Sub-Segment Details

- Sub-Segments Covered
  - NAICS 452-1101: Conventional Department Stores (excluding leased departments)
  - NAICS 452-1102: Discount or Mass Merchandise Department stores (excluding leased departments)
  - NAICS 452-1103: National Chain Department Stores (excluding leased departments)
  - NAICS 452-910: Warehouse Clubs and Superstores

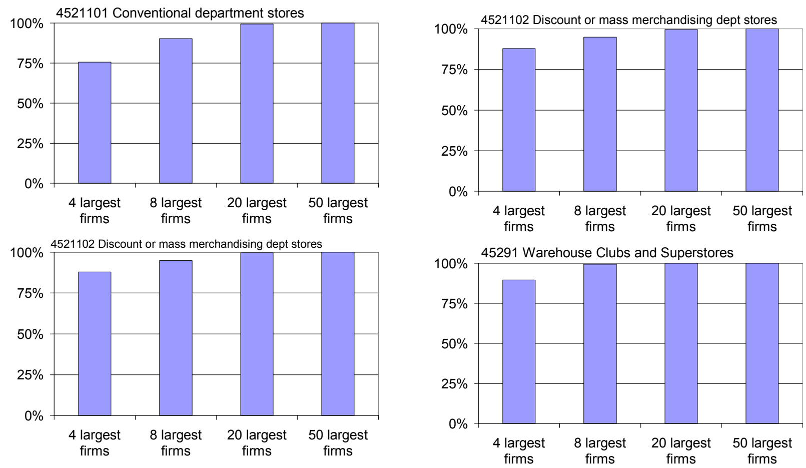
What is the Distribution in Sizes



What is the Distribution in Sizes



High Market Concentration



Market is Extremely Concentrated in These Sub-Sectors Compare to the Overall "Other General Merchandise – 45299" Where Only 38% of the Market is With the 4 Largest Players

452110 Department Stores

- This industry comprises establishments known as department stores primarily engaged in retailing a wide range of the following new products with no one merchandise line predominating:
  – apparel, furniture, appliances and home furnishings; and selected additional items,such as paint, hardware, toiletries, cosmetics, photographic equipment, jewelry, toys, and sporting goods.
- Merchandise lines are normally arranged in separate departments.

4521101 Conventional Department Stores

- Establishments that satisfy the criteria of a department store and:
  - usually provide check-out service and customer assistance (sales persons) within each department;
  - frequently have a catalog order desk
  - are NOT affiliated with a company that operates similar establishments on a national basis.

4521102 Discount or Mass Merchandising Department Stores

- Establishments that satisfy the criteria of a department store and usually:
  1. convey the image of a high-volume, fast-turnover outlet selling a variety of merchandise for less than conventional prices;
  2. provide centralized check-out service
  3. provide minimal customer assistance within each department.

4521103 National Chain Department Stores

- Establishments that satisfy the criteria of a department store and:
  - usually provide check-out service and customer assistance (sales persons)within each department;
  - frequently have a catalog order desk
  - ARE affiliated with a company that operates similar establishments on a national basis.

452910 Warehouse Clubs and Superstores

- This industry comprises establishments known as warehouse clubs, superstores or supercenters primarily engaged in retailing a general line of groceries in combination with general lines of new merchandise, such as apparel, furniture, and appliances.
- The data published with NAICS code 452910 are comprised of these parts of the following SIC industries:
  - 5311 (pt) Supercenters
  - 5399 (pt) Warehouse clubs
  - 5411 (pt) Supermarket/general merchandise combination store

4529101 Warehouse Clubs

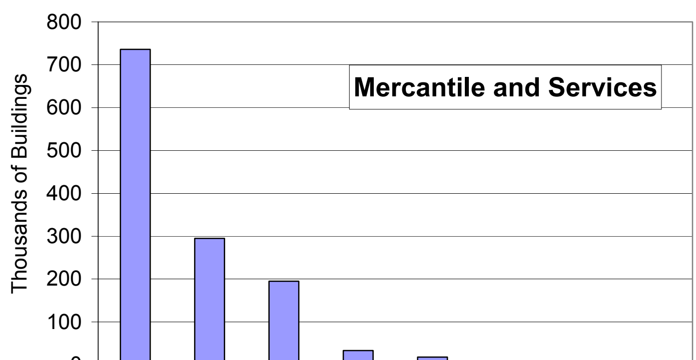
- Establishments that sell general lines of merchandise, such as automotive tires, parts, and accessories; audio and video equipment; household appliances; office equipment and supplies; apparel; books; and groceries, through warehouse-based operations. These establishments are sometimes known as membership warehouse clubs.

4529102 Supermarket/ General Merchandise Combination Stores

- Establishments primarily engaged in selling a full line of perishable and nonperishable grocery items in combination with hardware, clothing, and other general merchandise.
- 45291021 Supercenters
  - Sales of hardware, clothing, and other general merchandise are greater than sales of grocery items.
- 45291022 Supermarket/General Merchandise Combination Stores
  - Sales of grocery items are greater than sales of hardware, clothing, and other general merchandise.

Appendix 2:
CBECS Data of Retail

Overall Sector CBECS Data



	1,001 to 5000	5,001 to 10000	10,001 to 25000	25,001 to 50000	50,001 to 100,00	100,001 to 200,00	200,001 to 500,00	Over 500,000
Mercantile and Service	736	295	195	33	18	8	2	2

Size Range (SF)

CBECS Sector Definition

Mercantile and Service:

- refers to buildings used for sales and displays of goods or services (excluding food). This category includes shopping malls and strip centers, as well as retail and service as outlined below.

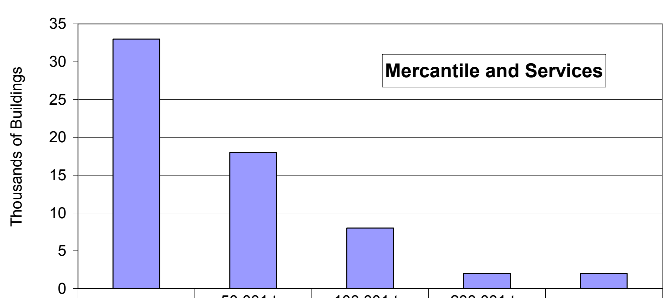
CBECS Sector Definition

- Service (other than food service):
  - Dry cleaner/car wash/laundry
  - Gasoline stations
  - Motor vehicle repair/service/maintenance
  - Multiservice establishments
  - Personal service
  - Post office.

CBECS Sector Definition

- Retail (other than shopping mall or strip center)
  - Automobile dealers
  - Building materials, G
  - Garden supply stores,
  - Hardware
  - Department stores
  - Drugstores
  - Furniture, home equipment stores and home furnishings
  - Liquor stores
  - Wholesale goods (except food)

Zooming in on the Larger End



	25,001 to 50000	50,001 to 100,000	100,001 to 200,000	200,001 to 500,000	Over 500,000
Mercantile and Service	33	18	8	2	2

Size Range (SF)

Over 200,000 SF ?

- Mercantile Buildings Over 200,000 SF are Likely to be Shopping Centers
  - Most Typical Leasing is Net Leasing where Tenant Pays Utility Bills but Makes No Permanent Investment in Infrastructure
  - Owner Has No Stake in Operating Costs Nor Any Investment Recovery Potential Through Efficiency
  - Poor Market Opportunity for Cogeneration

Appendix 3: Size of Chain Stores

Chains with Stores Over 150,000 SF

Chain	Headquarters	Location
Belk Inc.	CHARLOTTE	NC
bigg's	MILFORD	OH
Bloomingdale's	NEW YORK	NY
The Bon Marche	SEATTLE	WA
Boscov's Dept. Store LLC	READING	PA
Burdines	MIAMI	FL
Dillard's Inc.	LITTLE ROCK	AR
Famous-Barr	SAINT LOUIS	MO
Filene's	BOSTON	MA
Foley's	HOUSTON	TX
Gottschalks Inc.	FRESNO	CA
Hecht's	ARLINGTON	VA
Hudson's Bay Company	TORONTO	ON
IKEA	PLYMOUTH MEETING	PA
Kaufmann's Department Stores	PITTSBURGH	PA
Kmart Corp.	TROY	MI
The Kroger Co.	CINCINNATI	OH
Lord & Taylor	NEW YORK	NY
Macy's East	NEW YORK	NY
Macy's West	SAN FRANCISCO	CA
Marshall Field's	MINNEAPOLIS	MN
Meier & Frank	PORTLAND	OR
Meijer Inc.	GRAND RAPIDS	MI
Menard Inc.	EAU CLAIRE	WI
Nordstrom Inc.	SEATTLE	WA
Rich's/Lazarus/Goldsmith's	ATLANTA	GA
Robinsons-May	NORTH HOLLYWOOD	CA
Saks Incorporated	BIRMINGHAM	AL
SuperTarget	MINNEAPOLIS	MN
SUPERVALU Inc.	EDEN PRAIRIE	MN
Target	MINNEAPOLIS	MN
Wal-Mart Stores Inc.	BENTONVILLE	AR

Chains with Stores 100,000-150,000 SF

American TV & Appliance of Madison Ir	MADISON	WI	Macy's East	NEW YORK	NY
Bass Pro Shops L.P.	SPRINGFIELD	MO	Marshall Field's	MINNEAPOLIS	MN
BJ's Wholesale Club Inc.	NATICK	MA	Meier & Frank	PORTLAND	OR
Building #19 Inc.	HINGHAM	MA	Neiman Marcus	DALLAS	TX
Burdines	MIAMI	FL	R.C. Willey Home Furnishings	SALT LAKE CITY	UT
Burdines Furniture Galleries	MIAMI	FL	Revy Home Centre Inc.	SURREY	BC
Burlington Coat Factory Warehouse Co	BURLINGTON	NJ	Rich's/Lazarus/Goldsmith's	ATLANTA	GA
Costco Wholesale Group	ISSAQUAH	WA	Robinsons-May	NORTH HOLLYWOOD	CA
Dillard's Inc.	LITTLE ROCK	AR	Saks Incorporated	BIRMINGHAM	AL
Edwards Theatres	NEWPORT BEACH	CA	Sam's Club	BENTONVILLE	AR
Famous-Barr	SAINT LOUIS	MO	Sears Canada Inc.	TORONTO	ON
Filene's	BOSTON	MA	ShopKo Stores Inc.	GREEN BAY	WI
Finger Furniture Co. Inc.	HOUSTON	TX	Target	MINNEAPOLIS	MN
Foley's	HOUSTON	TX	The Andersons Inc.	MAUMEE	OH
Fred Meyer Inc.	PORTLAND	OR	The Bon Marche	SEATTLE	WA
Fry's Electronics Inc.	SAN JOSE	CA	The Home Depot Canada	SCARBOROUGH	ON
Gander Mountain	MINNEAPOLIS	MN	The Home Depot Inc.	ATLANTA	GA
Garden Ridge Inc.	HOUSTON	TX	The Kroger Co.	CINCINNATI	OH
Grossman's	STOUGHTON	MA	Von Maur Inc.	DAVENPORT	IA
Hecht's	ARLINGTON	VA	Wal-Mart Canada Inc.	MISSISSAUGA	ON
HomeBase Inc.	IRVINE	CA	Wal-Mart Stores Inc.	BENTONVILLE	AR
Hudson's Bay Company	TORONTO	ON	Zellers Inc.	BRAMPTON	ON
IKEA Canada	BURLINGTON	ON			
J.C. Penney Company Inc.	PLANO	TX			
Kaufmann's Department Stores	PITTSBURGH	PA			
Kmart Corp.	TROY	MI			
Liberty House	HONOLULU	HI			
Lord & Taylor	NEW YORK	NY			
Lowe's Companies Inc.	WILKESBORO	NC			

CHAIN STORE Database

- List of 566 Chains with Stores from 20,000 to 50,000 SF is Available
- List of 165 Chains with Stores from 50,000 to 100,000 SF is Available
- Each Includes Name and City and State of Headquarters

References

- CHAIN STORE GUIDE
  http://www.csgis.com/products_services/search.asp

Chapter 6: Lodging

Prepared by:
Bill Ryan
UIC-ERC
630-561-4448

1

Objective

- Objective
  - Find the Overall Lodging Market Size
  - Target the Hotel Segment Opportunity
  - How Large is the Market for BCHP Sales?
  - Is the Hotel Market Amenable to BCHP Equipment ?
  - What Does the Market Use Now?
  - How Does the Market Make Decisions?
  - Who are the Major Players

2

Find the Overall Lodging Market Size

Census Bureau NAICS 721 Accommodation Classes Eliminating Redundant Levels

- **7211 Traveler Accommodation**
  - **72111 Hotels (Except Casinos) and Motels**
    - 7211101 Hotels (except Casino Hotels) With 25 Guestrooms or More
    - 7211102 Hotels With Less Than 25 Guestrooms
    - 7211103 Motels
    - 7211104 Motor Hotels
    - 7211105 Organization Hotels
  - **72112 Casino Hotels**
  - **72119 Other Traveler Accommodation**
    - 721191 Bed-and-Breakfast Inns
      - 7211911 Bed-and-Breakfast Inns With 25 Guestrooms or More
      - 7211912 Bed-and-Breakfast Inns With Less Than 25 Guestrooms
    - 721199 All Other Traveler Accommodation
- **7212 RV (Recreational Vehicle) Parks and Campgrounds**
  - **72121 RV (Recreational Vehicle) Parks and Recreational Camps**
    - 721211 RV (Recreational Vehicle) Parks and Campgrounds
    - 721214 Recreational and Vacation Camps (Except Campgrounds)
- **72131 Rooming and Boarding Houses**
  - **721310 Rooming and Boarding Houses**
    - 7213101 Rooming and Boarding Houses
    - 7213102 Organization Rooming and Boarding Houses

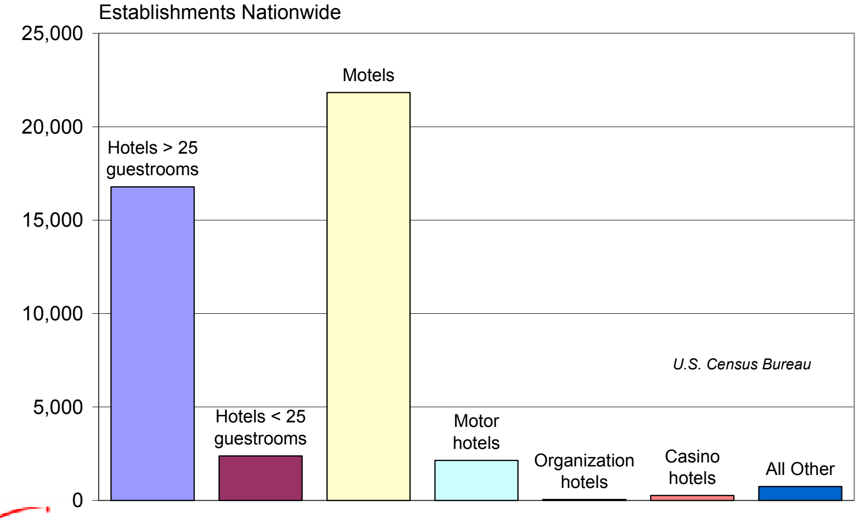
Product Size Suggests:

- Hotels with More than 25 Rooms – Larger Hotels
  - Small Hotels and Motels – Generally Use PTAC Systems
  - Organizational Hotels Can be Left In (only 52 Nationwide)
- RV (Recreational Vehicle) Parks and Campgrounds – Out
  - Little Building Structure Involved
- Bed and Breakfasts - Out
  - Even Larger Operations Are Generally Older Building Conversions

Census Bureau Segments to Be Studied

- 7211 Traveler Accommodation
  - 72111 Hotels (Except Casinos) and Motels
    - 7211101 Hotels (except Casino Hotels) With 25 Guestrooms or More
    - 7211105 Organization Hotels
  - 72112 Casino Hotels
  - 721199 All Other Traveler Accommodation

How Many are There



Ref 2

How Many are There

- Clearly Hotels and Motels are the Dominant Market
- MOST of this Market is Not Amenable to the Size of Equipment Planned Here

NAICS		
7211101	Hotels > 25 guestrooms	16,782
7211102	Hotels < 25 guestrooms	2,386
7211103	Motels	21,829
7211104	Motor hotels	2,139
7211105	Organization hotels	52
72112	Casino hotels	257
721199	All Other	736
		44,181

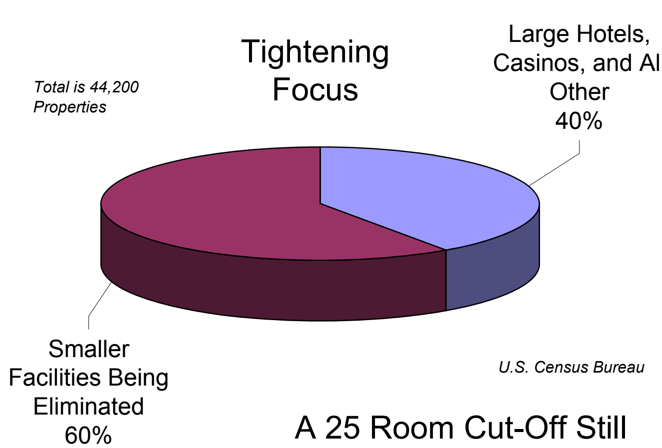
Ref 2

Target the Hotel Segment Opportunity

We are Eliminating 60% of the Hotel Motel Market with a 25 Room Cut-Off

Total is 44,200 Properties

Tightening Focus

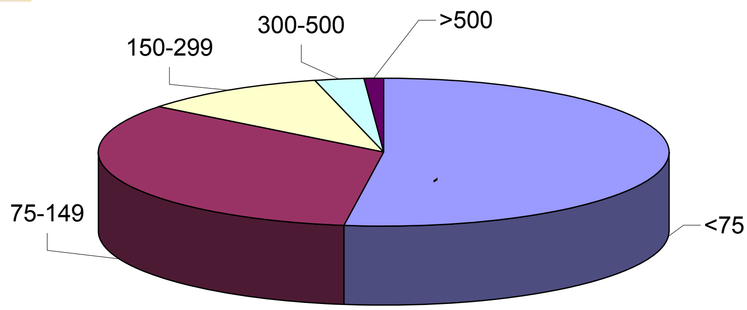


Ref 2

U.S. Census Bureau

A 25 Room Cut-Off Still Seems Rather Small

Other Data Can Give More Detail



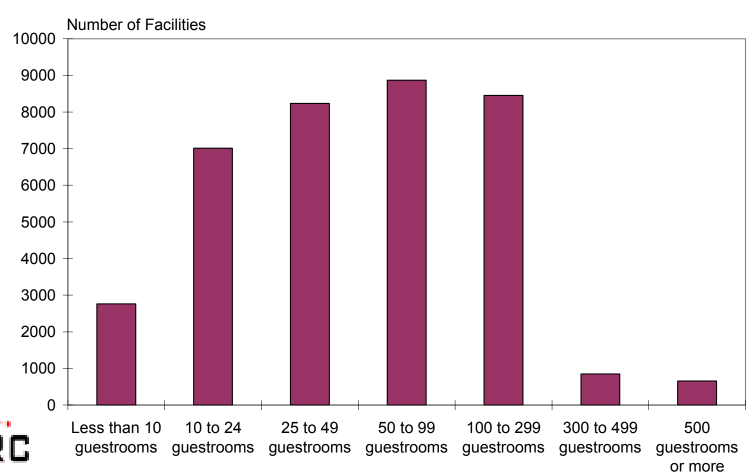
American Hotel and Lodging Association
Statistics on Number of Rooms per Property

- Look Only to Large Hotels Over 150 Rooms
- Focus Now Down to 5,993 Domestic Sites
- Data Agreement
  - AHLA Hotel Total = 41,400 Agrees Well with Census Total of 44,200

Ref 3

More Detailed Data on Facility Size Obtained from the Census Bureau

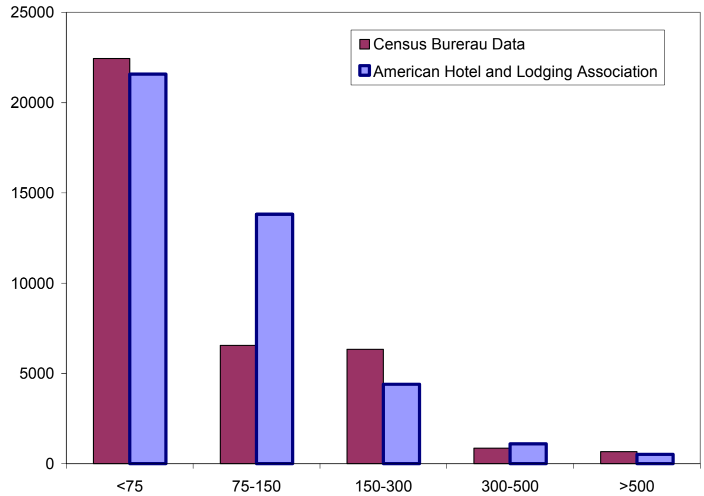
- Divisions are Slightly Different than AHLA Data



Ref 5

Comparing the Data Sets

- AHLA Picks Up More Facilities in the 75-150 Room Set
- Above 150 Rooms – Good Agreement

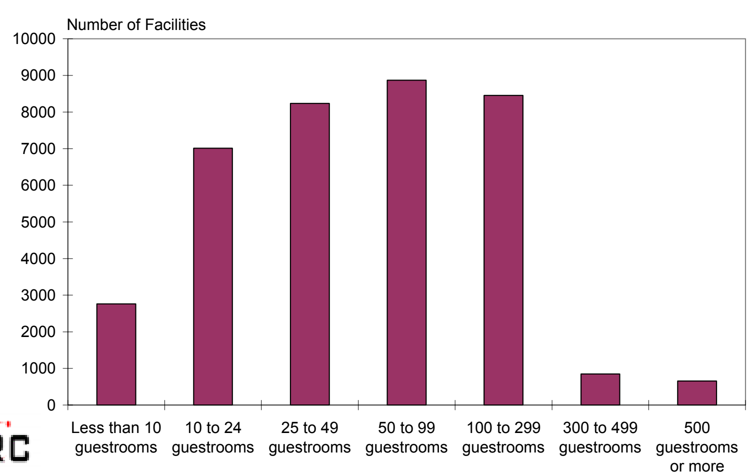


Hotels Over 150 Rooms

Facility Size	Number of Facilities in the US — Census Bureau	AHLA
Less Than 75 Guestrooms	22,445	21,580
From 75 to 150 Guestrooms	6,547	13,820
From 150 to 300 Guestrooms	6,341	4,397
From 300 to 500 Guestrooms	852	1,091
Over 500 Guestrooms	656	505
Number over 150 Guestrooms	7,849	5,993

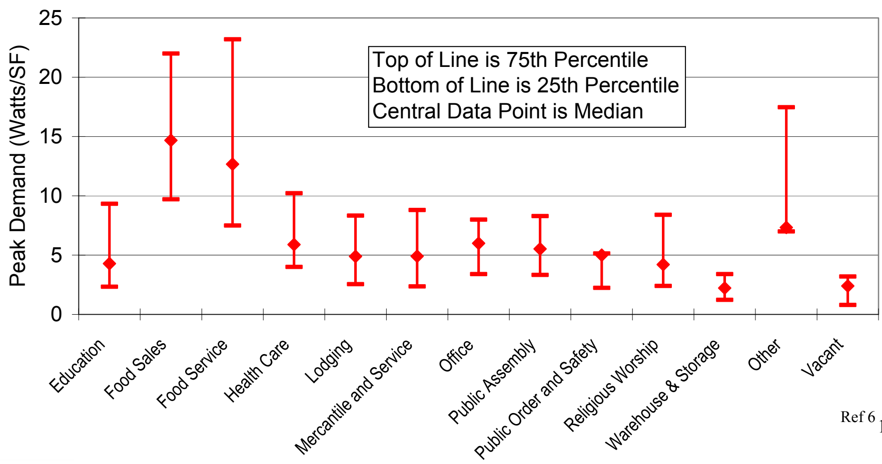
How Large is the Market for BCHP Sales?

More Detailed Data on Facility Size



Ref 5

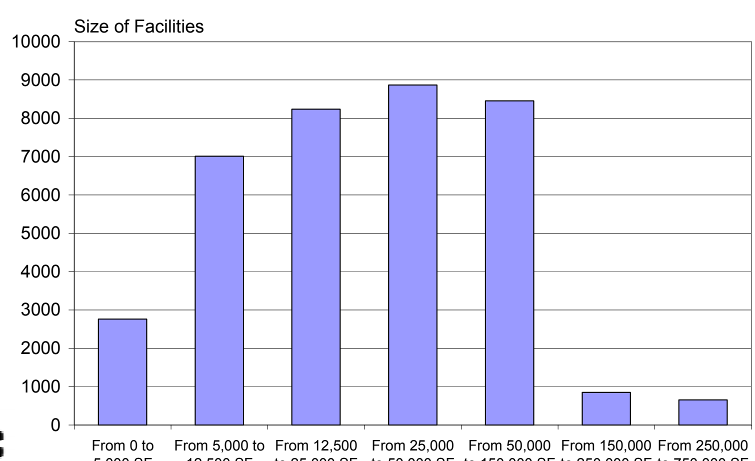
Peak Power Usage



Ref 6

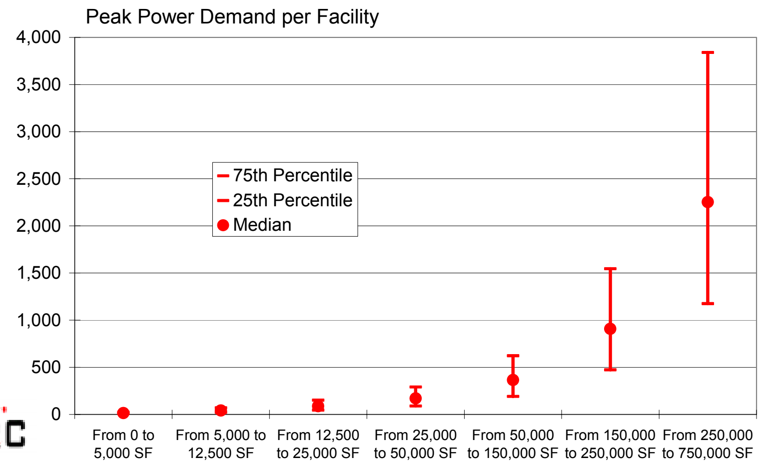
Find Square Footage from Guest Room Numbers

- Assumes 500 SF per Guestroom for Entire Facility
- Must Cover Portion of Hallways, Lobby, and So On per Room



Peak Power Required

- Peak Power Requirements for Lodging:
  - 25th Percentile: 2.55 Watts/SF, Median (50th Percentile) - 4.89 Watts/SF, 75th Percentile - 8.33 Watts/SF (CBECS Statistics)



Practical Markets

- Once Again, Only the Top Three Segments are Practical for Equipment of the Size Planned
- Low End of 50-150,000 SF Looks Doubtful (100-300 Guestroom Sector)
- Earlier Conclusion Not to Go Below ~150 Rooms Confirmed

Total Market

Facility Size	Number of Facilities in the US		Floor Space	Peak Power Needs	Market Size
	Census Bureau	*AHLA*	SF	kW/Site	MW
Less Than 75 Guestrooms	22,445	21,580			
From 75 to 150 Guestrooms	6,547	13,820			
From 150 to 300 Guestrooms	6,341	4,397	112,500	550	2,419
From 300 to 500 Guestrooms	852	1,091	200,000	978	1,067
Over 500 Guestrooms	656	505	475,000	2323	1,173
Number over 150 Guestrooms	7,849	5,993			4,659

- Calculation Uses More Conservative ALHA Data
- Total Market 4.65 GW

Is the Hotel Market Amenable to BCHP Equipment ?

Does the Large Hotel Market Need Full BCHP?

- Hotels Use a Large Amount of Hot Water for Morning Shower Loads
  - General System Features a Moderate Sized Boiler and a Large Hot Water Storage to Meet This Morning Load
  - Much Cheaper than a Boiler Capable of Picking Up the Entire Load
- Concern
  - Given this Large 12 Month Heating Load – Is Full BCHP Required or Can All Heat Rejection Go to the Water Load?

Does the Large Hotel Market Need Full BCHP?

Calculable Shower Load	
Std Shower Head	3 gpm
Delivery Temperature	110 F
Supply Temperature	50 F
Occupancy	6
Period	10 min
Daily Shower Load	91,044 Btu/Day/Room
Annual Shower Load	33,231,060 Btu/Year/Room
Based on 500 SF/RM	66,462 Btu/SF/Yr
Shower Heat Load Est.	13.2 MBtu/SF

- Order of Magnitude Calculation of Shower Load
- Average Hotel Gas Consumption (CBECS) is 61 MBtu/Yr/SF
- Scale 10-15 MBtu/Yr/SF seems in Scale with CBECS Total

Will Year-Round Water Load Make Heat Recovery for Heating and Cooling Unnecessary? - NO

Hotel	400 Rooms
Square Footage	200000 SF
Median Power Demand	4.89 Watts/SF
Demand Required	978 kW
Cogenerator at 50% of Peak	489 kW
Approx. Heat Available from Cogenerator	150.00% of Power Output
Approx. Heat Available from Cogenerator	2503.4355 MBH
If Run 10 Hours	25,034.36 Mbtu/Day
Daily Shower Load	7,283.52 Mbtu/Day
Shower %	29.09% of Heat Available

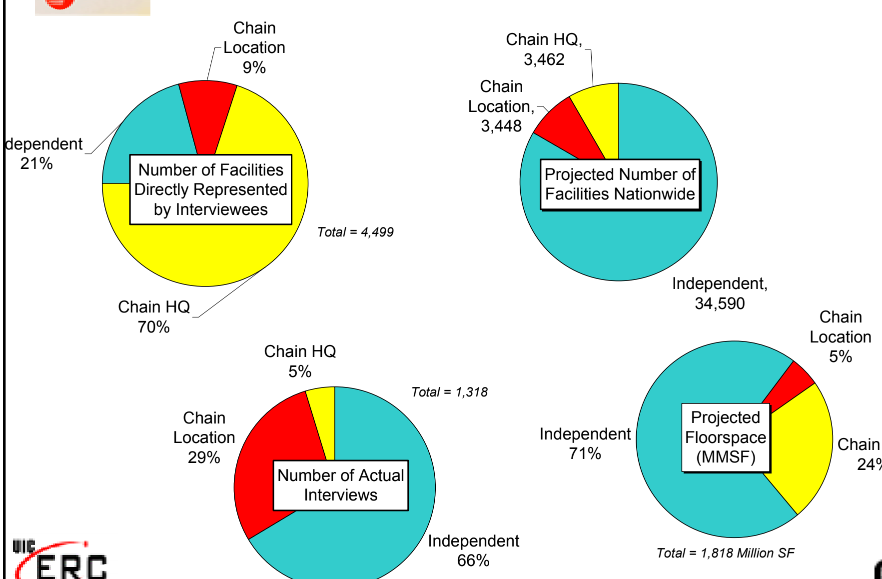
- The Shower Load is Substantial. However, even if
  - Extensive Hot Water Storage were used,
  - Generator Sized at 50% of the Electric Load
  - Generator Ran Only 10 Hours/Day
- the Shower Load Would Consume only 30% of the Available Rejected Heat
- Result: Water Heating is a Good Load But More Rejected Heat is Still Available

What Does the Market Use Now?

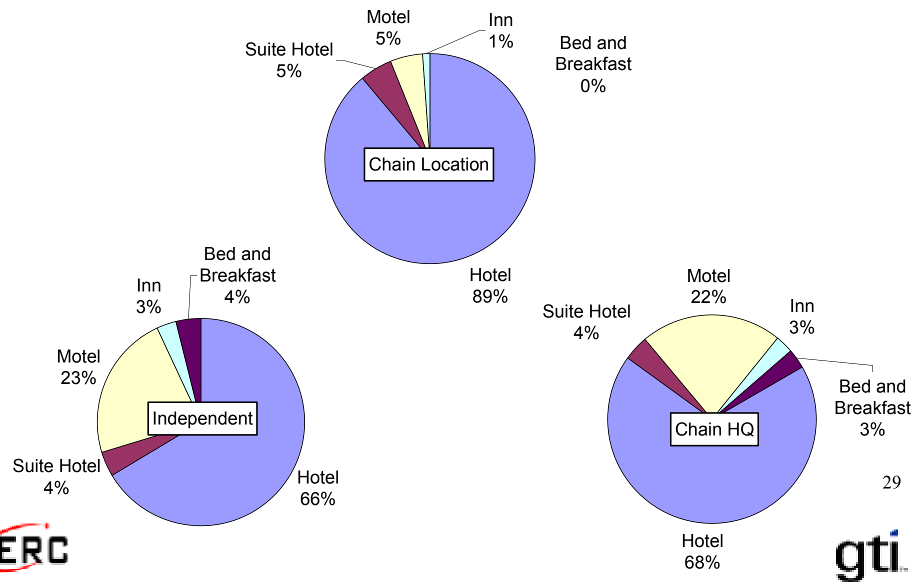
AGA/GRI Survey of the Lodging Sector

- Extensive Sector Survey Done in 1997-98
- Direct Interviews with Facility Managers in the Lodging Industry
- Data Split into 3 Groups by Business Structure
  1. Independent: An Independently Owner Hotel (Interview was Done with Owner or Local Staffer)
  2. Chain Location: A Franchised or Other Structure Chain Hotel Where Equipment Decisions are Made by On-Site Staff (Interview was Done with Local Staffer)
  3. Chain HQ: A Chain Hotel Where Equipment Decisions are Made by Headquarters Staff (Interview was Done with HQ Staffer)

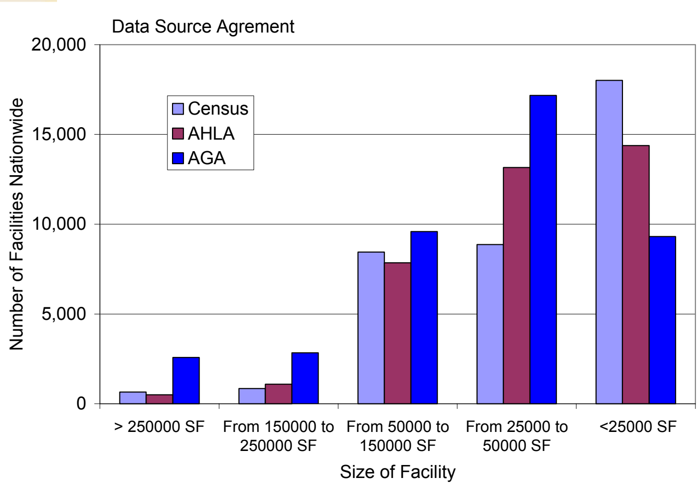
Size of the Survey in the Lodging Sector



Types of Lodging in Interview Groups

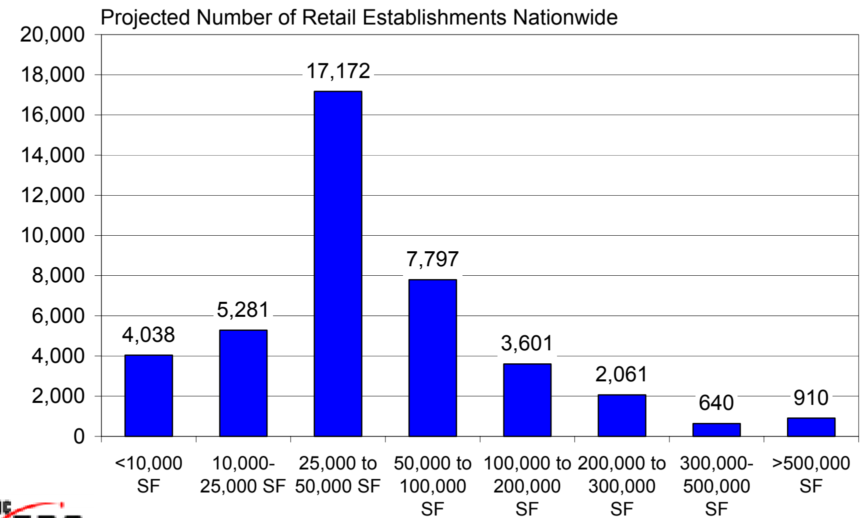


Data Sources

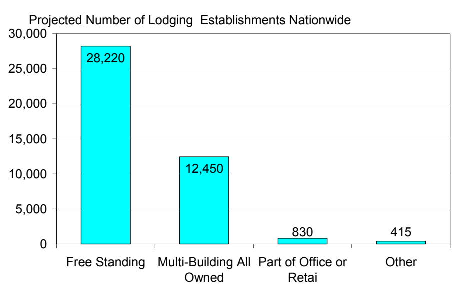


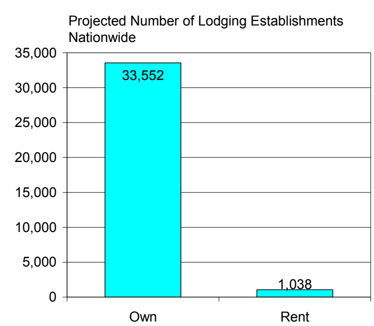
- AGA Survey Data Is More Heavily Weighted To Larger Lodging Facilities

Size Distribution of Facilities Nationwide - Projected from Survey Responses



Buildings and Ownership



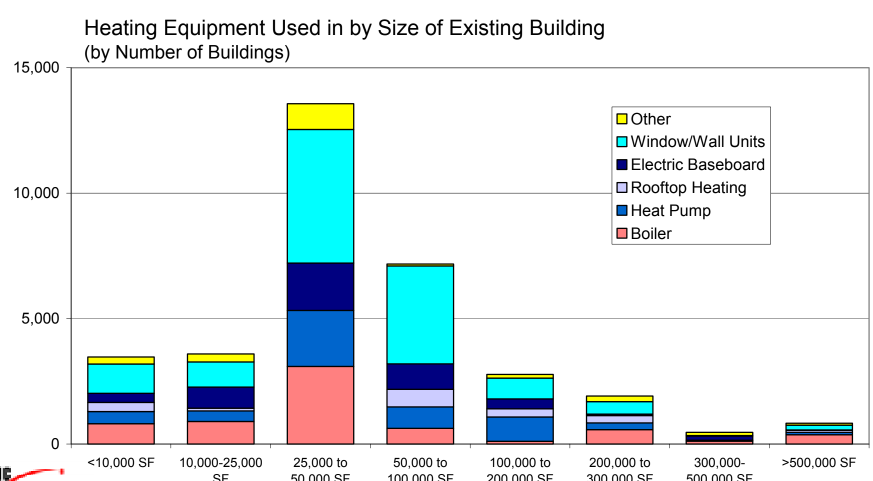


- The Lodging Industry tends to own their facilities and they are rarely part of another operation

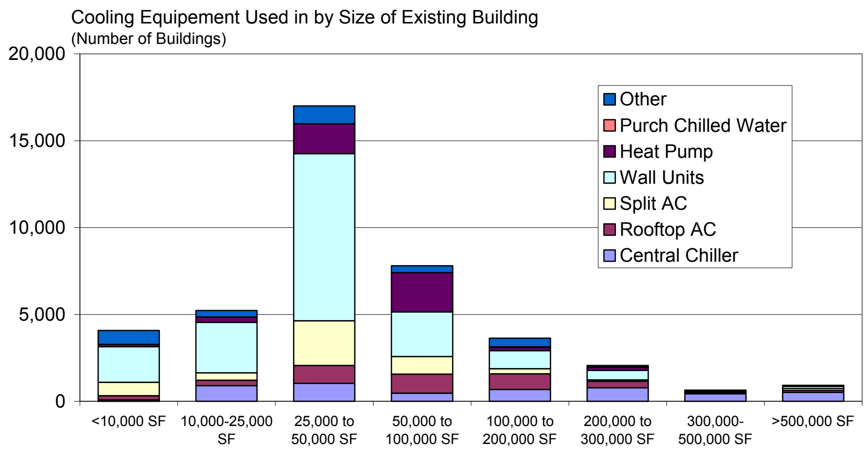
Equipment Usage

- The Type of Heating, Water Heating and Cooling Equipment Currently Used by the Industry will Affect the Retrofit Market
- For the Waukesha/Trane Package - Generally Interested in Large High Rise Lodging:
  - With a Larger Electric Load
  - With Some Degree of Centralized Heating and Cooling Equipment to Take Recovered Heat and Recovered Heat Driven Cooling

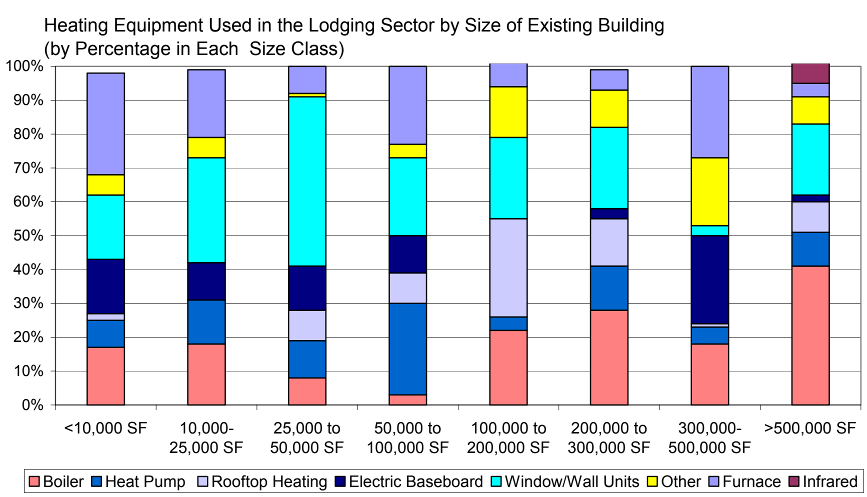
Even Smaller Facilities Are Not as Dominated by Window/Wall Units as Commonly Believed



Smaller Facilities Very Dominated by Window/Wall Units in Cooling

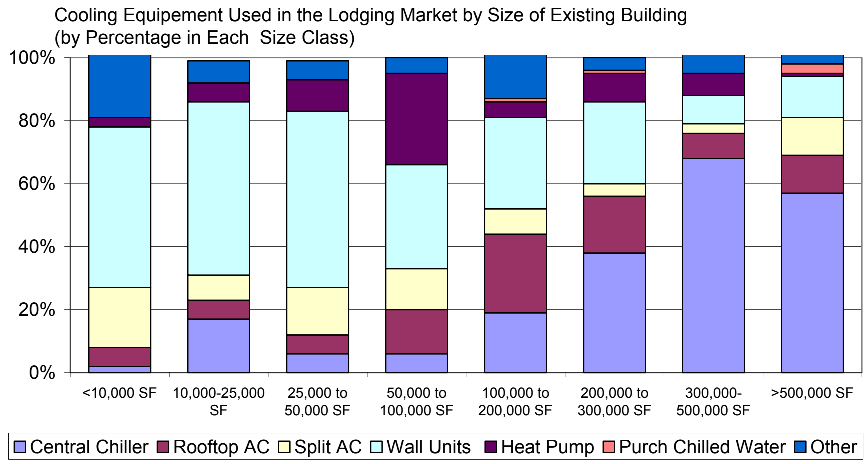


To Get a Little Better View of the Larger Facility Data in Heating



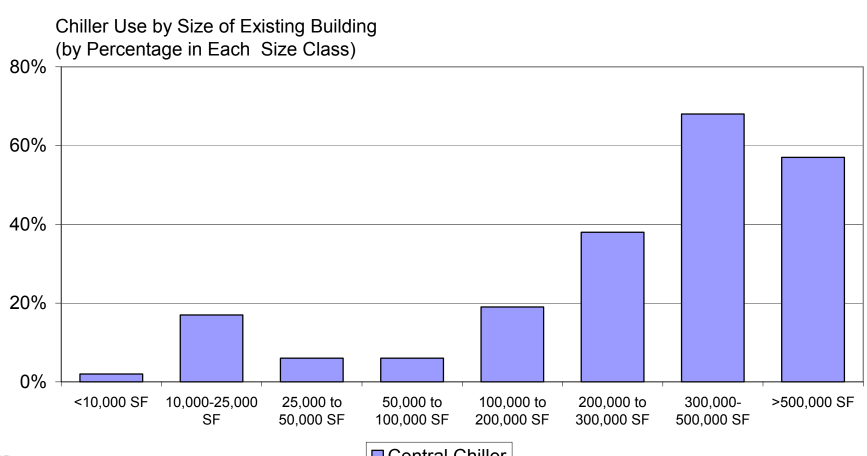
- Significant Increase in the Penetration of Hot Water Heating Systems for Larger Facilities, as Expected

To Get a Little Better View of the Larger Facility Data in Cooling

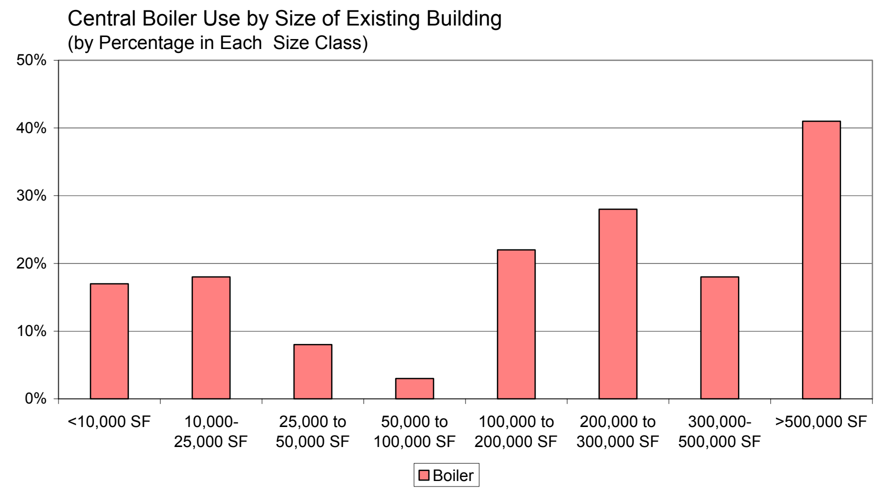


- Significant Increase in the Penetration of Chilled Water Systems for Larger Facilities, as Expected

Isolating Out the Use of Centralized Chillers and Chilled Water



Isolating Out the Use of Centralized Boilers and Hot Water



Core Focus Market

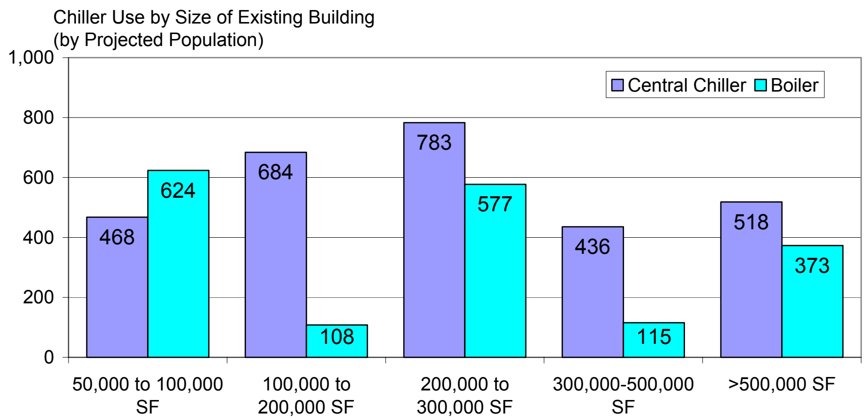
Previous Focus

- Hotels over 150 Rooms – 6000

Tighter Focus

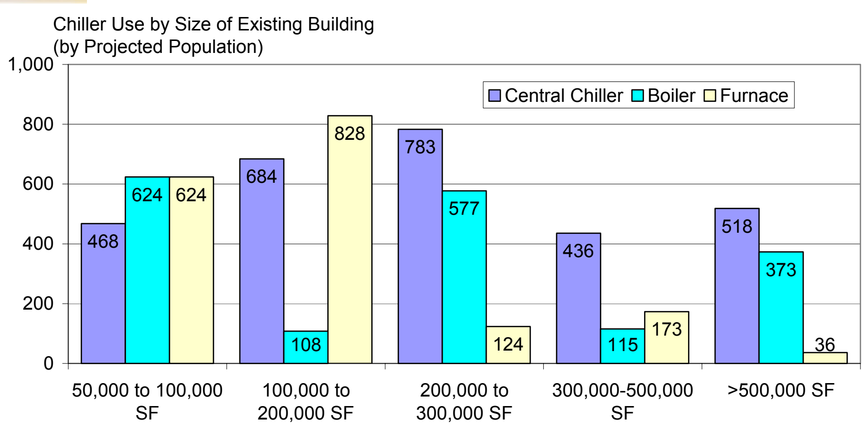
- Hotels Over 50,000 SF (100 Rooms) That Use Central Boilers and Chiller

Results Seem Inconsistent



- Use of a Central System Generally Means Using Both a Chiller and a Boiler

Possible Explanation

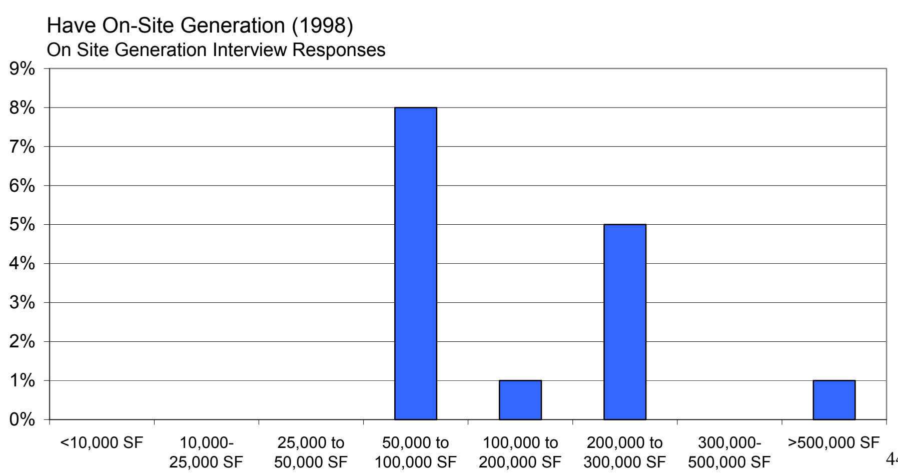


- The Response “Furnace” Was Allowed Under Heating
- Less Technical Respondents May Have Confused a Central Boiler with a Central “Furnace”
  - Some Areas of the US Use the Term “Furnace Room” to Mean Boiler Room
- Will Use Chiller Responses to Avoid This Possibility

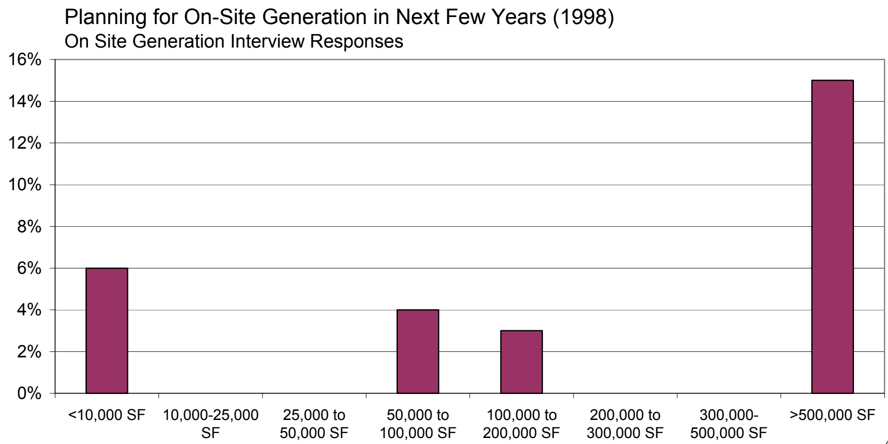
This Brings the Focus Down to ~3,000 Facilities in the US

Number of Facilities in the Strongest Potential Market	
50,000 to 100,000 SF	468
100,000 to 200,000 SF	684
200,000 to 300,000 SF	783
300,000-500,000 SF	436
>500,000 SF	518
Total	2,889

How Much of the Market Has Any Experience in On-Site Generation

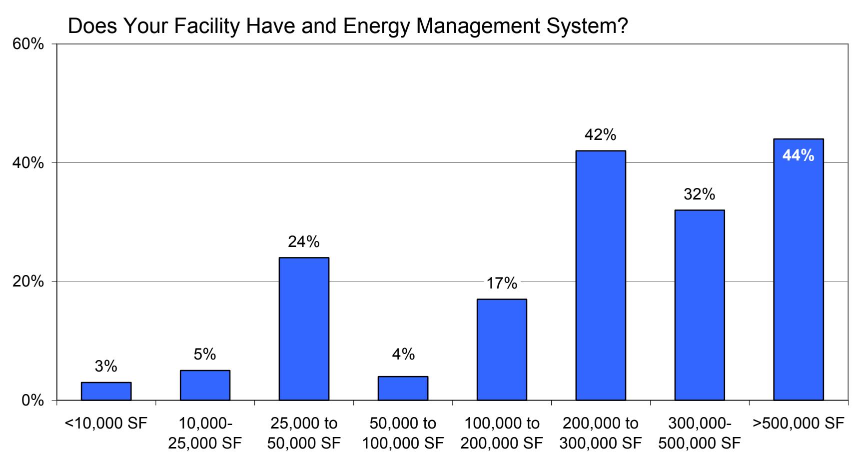


How Much of the Market Has an Interest in On-Site Generation in the Future

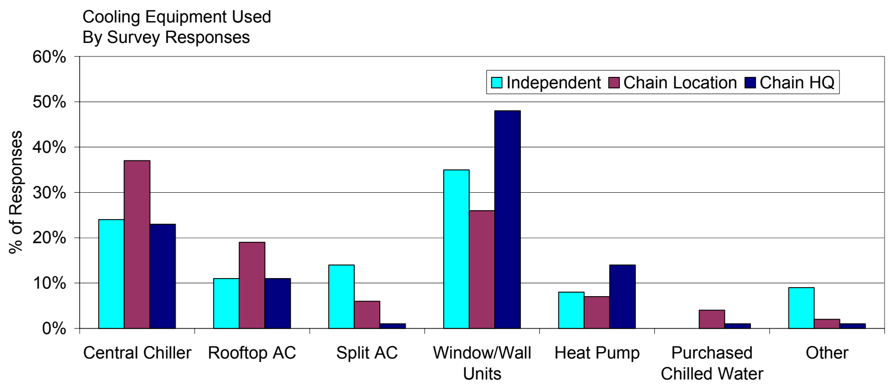


- Significant Increase in the Penetration of Chilled Water Systems for Larger Facilities, as Expected

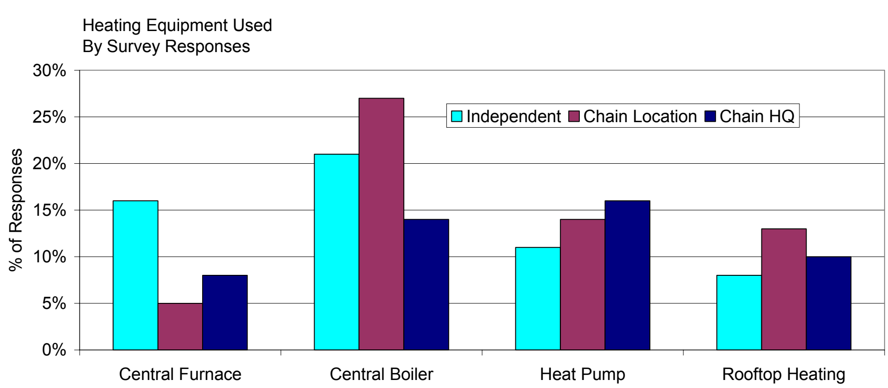
What Percentage of the Market is Sophisticated Enough on Energy Issues to Have an Energy Management System



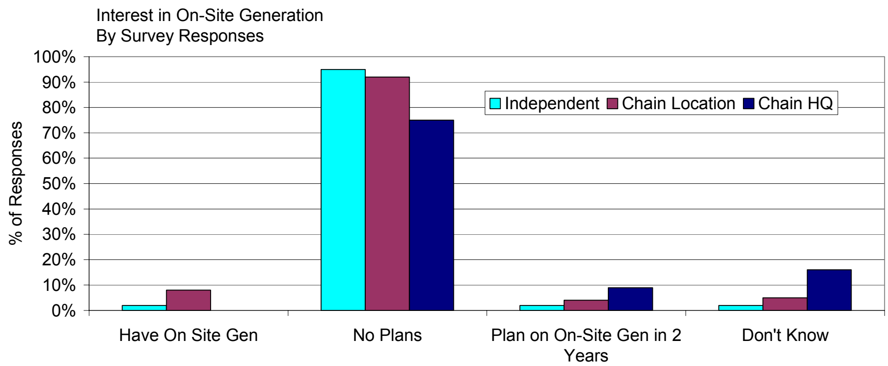
How Does the Use of Differing Cooling Systems Vary by Ownership



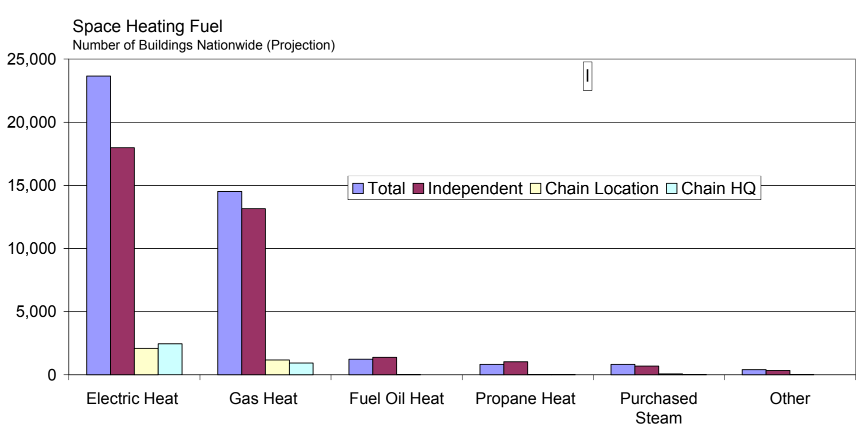
How Does the Use of Differing Heating Systems Vary by Ownership



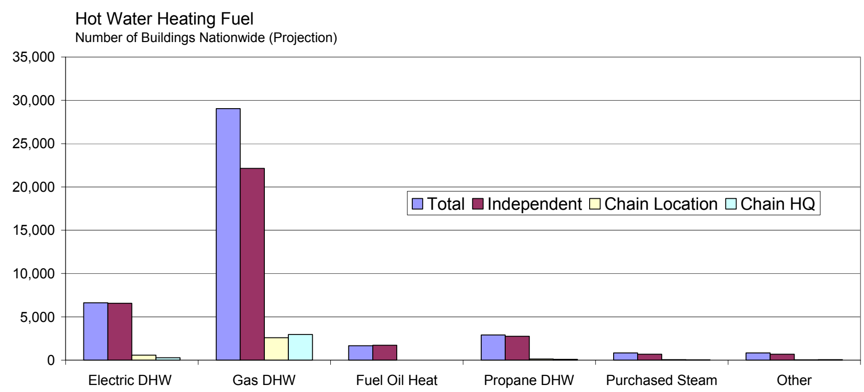
How Does the Interest in On-Site Power Vary with Ownership



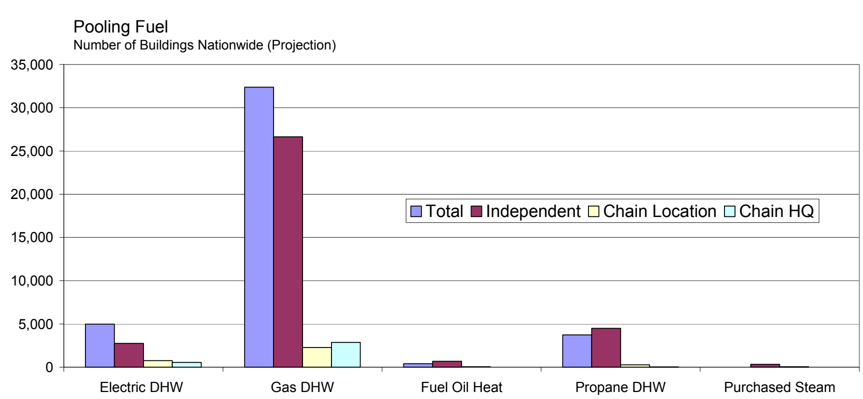
How Does the Use of Differing Fuel Types for Space Heating Vary by Ownership



How Does the Use of Differing Fuel Types for Water Heating Vary by Ownership



How Does the Use of Differing Fuel Types for Pool Heating Vary by Ownership



- Demonstrates that Over 32,000 Sites Have as Available
- Pool Heating is the Highest Gas Penetration -78% of the AGA 41,500 Total

Section Summary

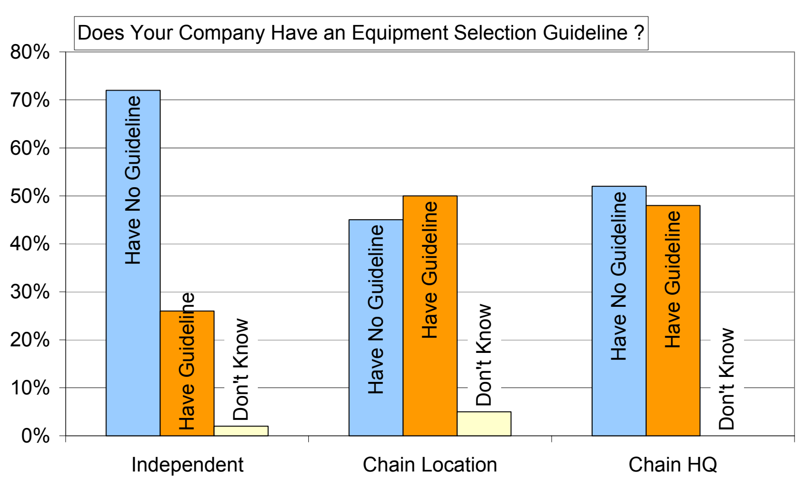
- Gas is Available in 78% or More of Lodging Facilities
- Previously Found 6,000 Facilities of Appropriate Floor Space for This 300-800 kW BCHP System
- Have Now Determined Roughly 3,000 of These Large Facilities are Set Up with Central Systems
- Takes the Focus Down to Under 10% of the Overall Lodging Market
  - Need to Target the Marketing Effort to Those Facilities to Avoid Wasted Effort
  - HOW Does the Market Decide ?? Next Section
  - WHO is the Market ?? Last Section

How are Purchase Decisions Made?

Overview

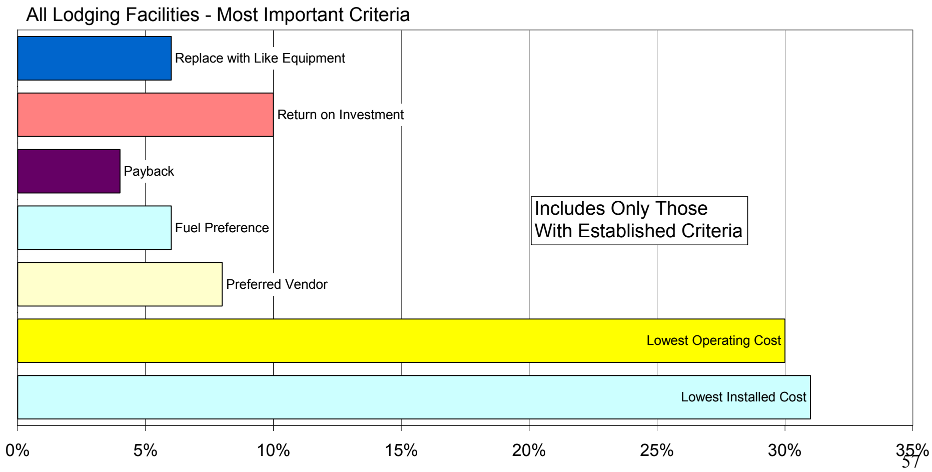
- Do These Companies Have Formal Decision Guidelines
  - What are the Criteria in Those Decision Guidelines
  - Who is the Chief Decision Maker
  - What is the Most Important Source of Information Used for Making Decisions
  - What Other Factors Influence Equipment Decisions

Formal Equipment Selection Guides are Far from Universal



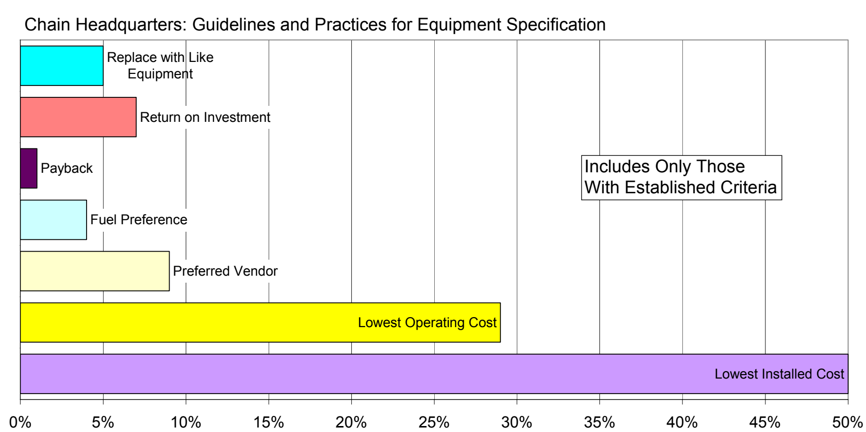
- Chains Have About a 50% of Having a Guideline

What is Important in the Established Guidelines?



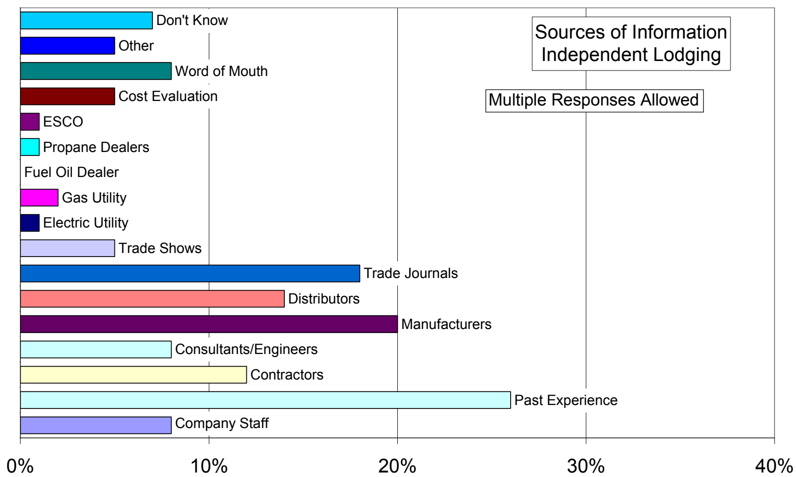
Overall Guidelines Indicate a Balance Between First Cost and Operating Cost Concerns

What is Important in the Established Guidelines?



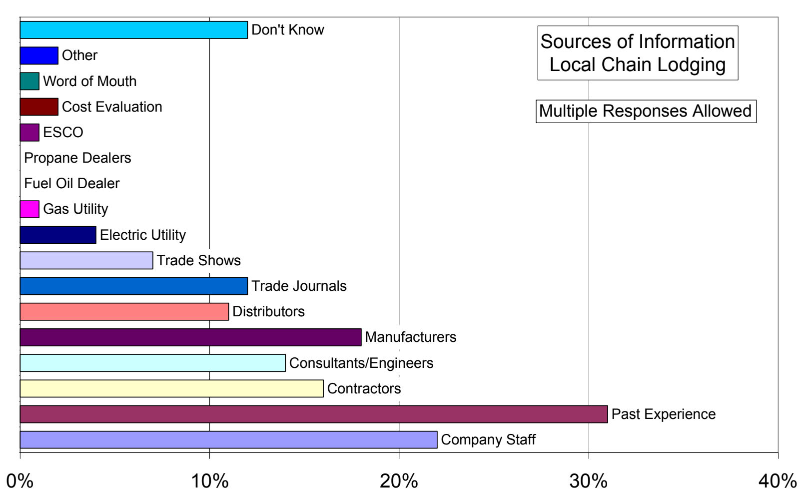
- "Chain HQ" Guidelines Seem More Devoted to Lowest First Cost than Other Segments

Where Do You Go to Get Information on New Equipment?



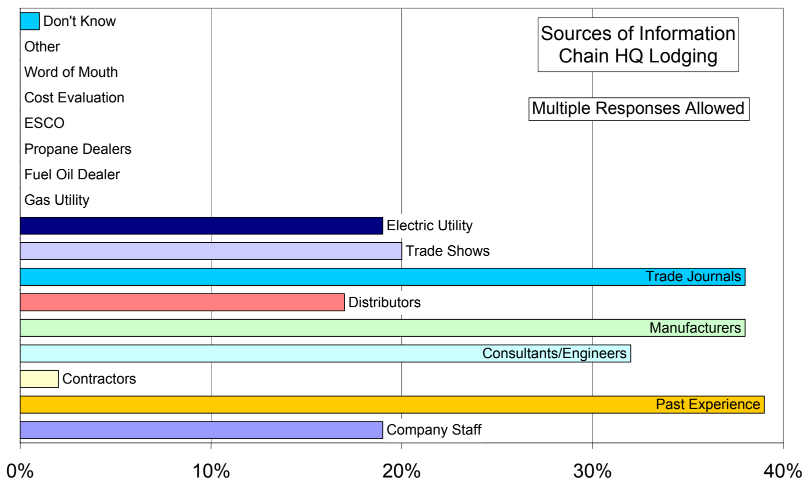
- Information is Key – Indicates How to Disseminate Information on New Products (or Through Whom)

Where Do You Go to Get Information on New Equipment?



- Information is Key – Indicates How to Disseminate Information on New Products (or Through Whom)

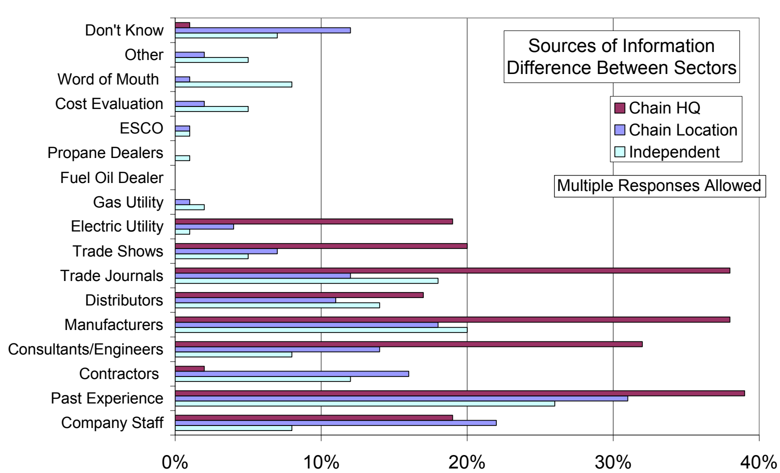
Where Do You Go to Get Information on New Equipment?



61

- Hugh Difference Between Chain HQ and Other Market Segments

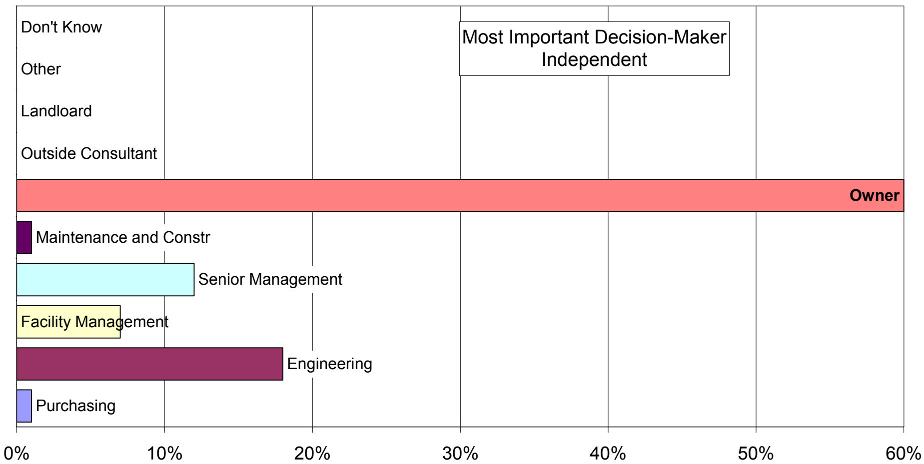
This Shows These Differences Between the Segments More Clearly



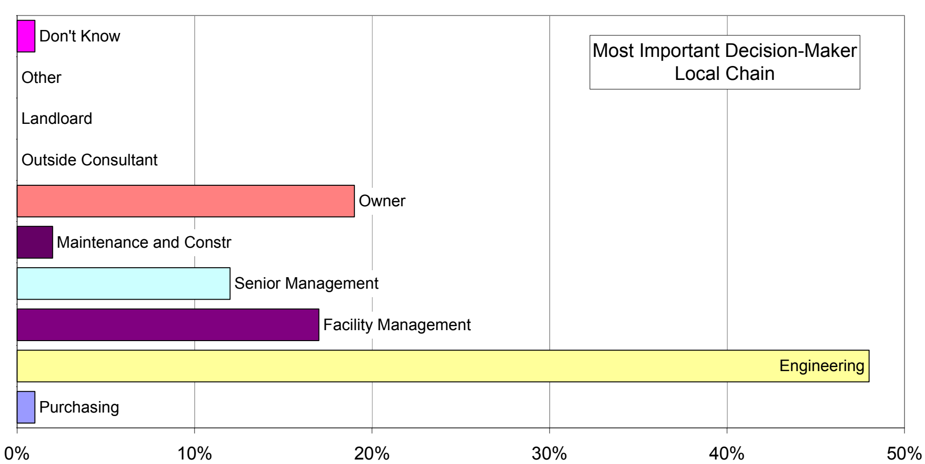
62

- Chain HQ's are Much More Reachable Thru National Avenues
  - Trade Journals, Shows, and Thru the Manufacturers Directly

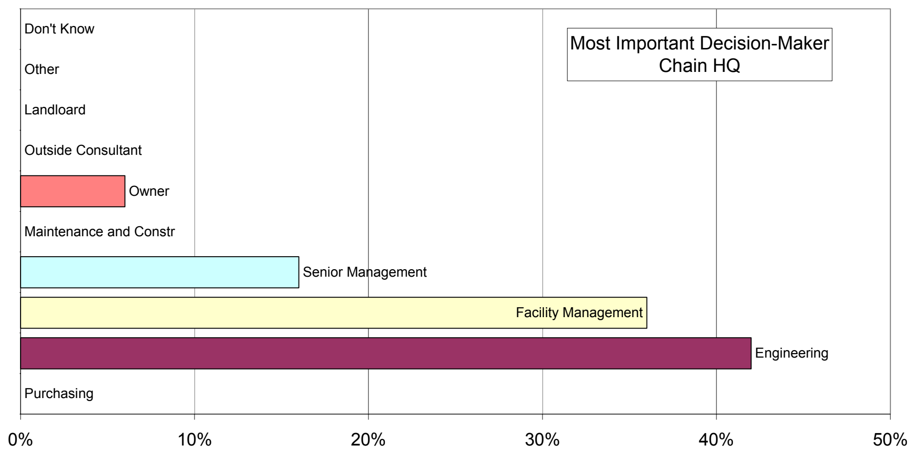
Who is the Most Important Decision Maker?



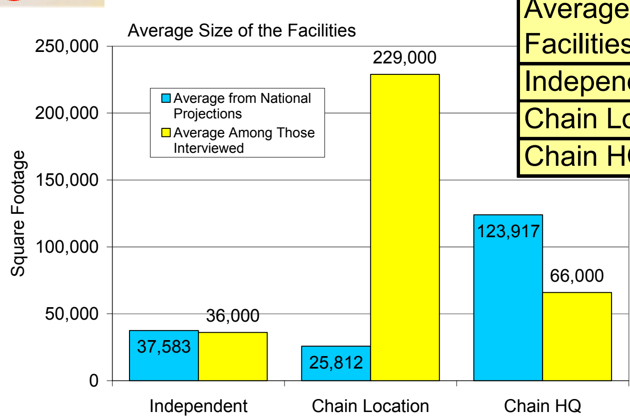
Who is the Most Important Decision Maker?



Who is the Most Important Decision Maker?



Some Information on The Interviewees

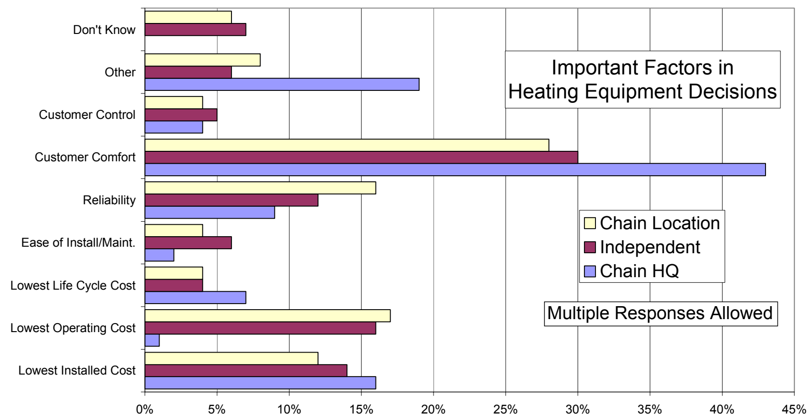


Average Number of Facilities Answered For	
Independent	1.07
Chain Location	1.09
Chain HQ	50.03

- Skew in the Sampling - The Sampling Under "Local Chain" are Single Site Operators for Much Larger Locations than the Average. May be More Sophisticated than the Average Chain Location Manager
- On Decisions Making - The Average "Chain HQ" Manager Interviewed Handles 50 Sites, Allowing Little Time for In Depth Decision Making

Important "Factors" in Heating Equipment

Factors are the Beliefs of the Manager that Go Beyond a Corporate Guideline



- This is an Unusually "Comfort" Sensitive Market
- Even the Remotely Directly Chain HQ Operations are Very Concerned on Comfort Issues

Summary

- Most Important Decision Maker for All Chains was Corporate Engineering Staff
  - In House Engineering Ranked Very Highly for Larger Hotels
  - Indicates Large Hotels Keep Trained Staff
- Best Information Source was Trade Journals, Shows, and Manufacturers.
  - Outside Consultants Ranked Lower Which Also Indicates In-House Engineering
  - This Market Can Be reached on a National Basis
- Lowest Installed Cost was a Major Criterion, but Operating Cost and Comfort are Major Factor in Decision Making
- Roughly Half of the Chains Have a Formal Purchasing Guideline

Find the Major Players

50 Top Hotel Owners Worldwide and Their Chain Brand Names

[1] Cendant Corporation
- AmeriHost Franchise Systems, Inc.
- Days Inn Worldwide
- Howard Johnson International
- Knights Franchise Systems
- Ramada Franchise Systems
- Super 8 Motels
- Travelodge Hotels
- Villager Franchise Systems
- Wingate Inns

[2] Six Continents Hotels
- Crowne Plaza
- Forum Hotels & Resorts
- Holiday Inn
- Holiday Inn Express
- Holiday Inn Garden Court
- Holiday Inn Select
- Holiday Inn Sunspree Resort
- Inter-Continental Hotels & Resorts
- Staybridge Suites by Holiday Inn

[3] Marriott International
- Courtyard by Marriott
- Fairfield Inns by Marriott
- Marriott Conference Centers
- Marriott Hotels, Resorts, & Suites and Ritz Carlton
- Renaissance Hotels and Resorts/Ramada International
- Residence Inn by Marriott
- Spring Hill Suites by Marriott
- TownePlace Suites by Marriott

[4] Choice Hotels International
- Comfort Inns, Suites
- EconoLodge
- Flag Hotels, Suites & Inns
- Friendship Inns
- MainStay Suites
- Quality Inns, Suites & Hotels
- Rodeway Inns
- Sleep Inns, Clarion Inns

[5] Hilton Hotels Corporation
- Conrad International Hotels
- Doubletree Guest Suites & Hotels
- Embassy Suites
- Hampton Inns
- Harrison Conference Centers & Independents
- Hilton Garden Inns
- Hilton Hotels
- Homewood Suites by Hilton
- Red Lion Hotels & Inns

[6] Best Western International, Inc.

[7] Accor
- Accor Leisure Division
- Accor North America
- Mercure Hotels
- Motel 6 *
- Novotel
- Red Roof Inns *
- Sofitel
- Studio 6 *

[8] Starwood Hotels & Resorts Worldwide, Inc.
- Four Points Hotels
- Sheraton Hotels, Inns & Resorts
- St. Regis/Luxury Collection
- W Hotels
- Westin Hotels & Resorts

[9] Carlson Companies, Inc.
- Country Inns & Suites by Carlson
- Radisson Hotels Worldwide

[10] Bass Hotels & Resorts Europe, Middle East & Africa (EMEA)
[11] Sol Melia
[12] Hyatt Hotels Corporation
[13] The Universal Group
[14] FelCor Lodging Trust
[15] MeriStar Hotels & Resorts, Inc.
[16] Hilton International Company
[17] U.S. Franchise Systems, Inc.
- Best Inns & Suites
- Hawthorn Suites
- Microtel Inns & Suites

[18] Wyndham International, Inc.
[19] LaQuinta Inns, Inc.
[20] Hyatt International Corporation
[21] Oakwood Worldwide
[22] Golden Tulip Worldwide
[23] Prime Hospitality Corporation
[24] Hospitality Properties Trust
[25] Interstate Hotels
[26] Radisson SAS Hotels Worldwide
[27] Le Meridien Hotels & Resorts
[28] Mandalay Resort Group
[29] MeriStar Hospitality Corporation
[30] Prince Hotels
[31] Olympus Real Estate Corporation
[32] Tharaldson Lodging
[33] Millennium & Copthorne Hotels PLC
[34] Marcus Corp.
- Baymont Inn & Suites
- Marcus Hotels & Resorts

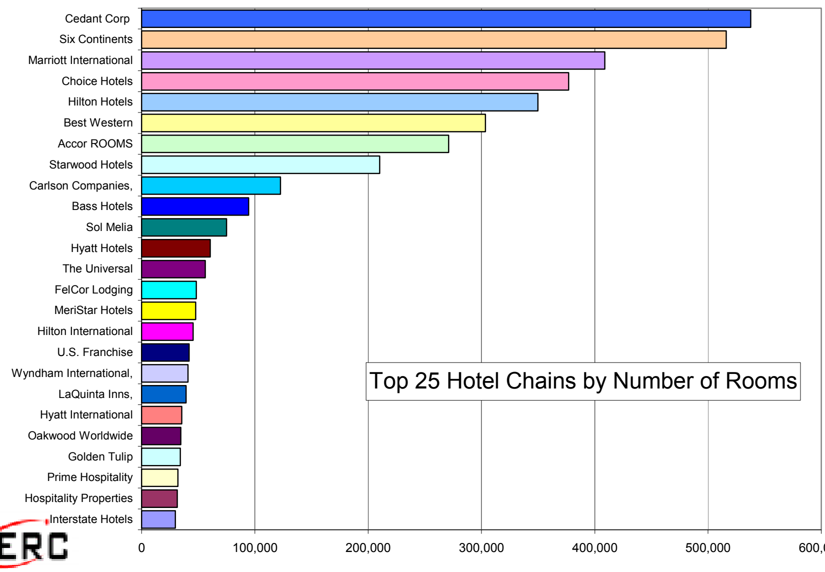
[35] Preferred Hotels & Resorts Worldwide, Inc.
[36] Walt Disney World Resorts
[37] Flag International Hotels
[38] Shangri-La Hotels & Resorts
[39] Lodgian, Inc.
[40] Choice Hotels Canada, Inc.
- Clarion Inns, Hotels, & Resorts
- Comfort Inns, Hotels & Suites
- EconoLodge
- Quality Inns, Hotels & Suites
- Sleep Inns

[41] A.H.M.I.
[42] Westmont Hospitality Group Canada
[43] JAL Hotels Company, LTD
[44] Fairmont Hotels & Resorts
[45] Homestead Village, Inc.
[46] Royal Host
[47] Suburban Lodges of America, Inc.
[48] Four Seasons Hotels & Resorts, Inc.
[49] AFM Hospitality Corporation
- Aston Hotels
- Best Inns
- Hawthorne Suites
- Howard Johnson
- Knights Inn
- Park Plaza
- Ramada Inn
- Villager Lodge

[50] Omni Hotels

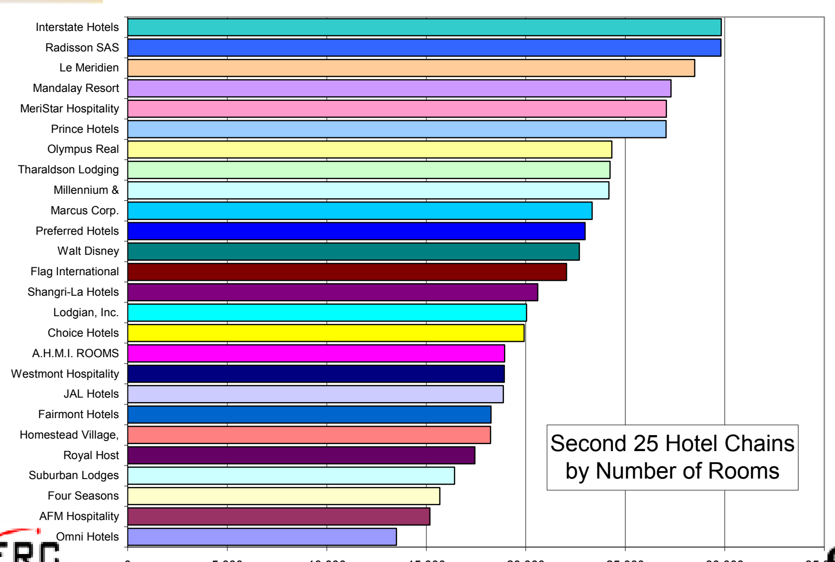
Ref 4

Market Concentration



Ref 4
71

Market Concentration

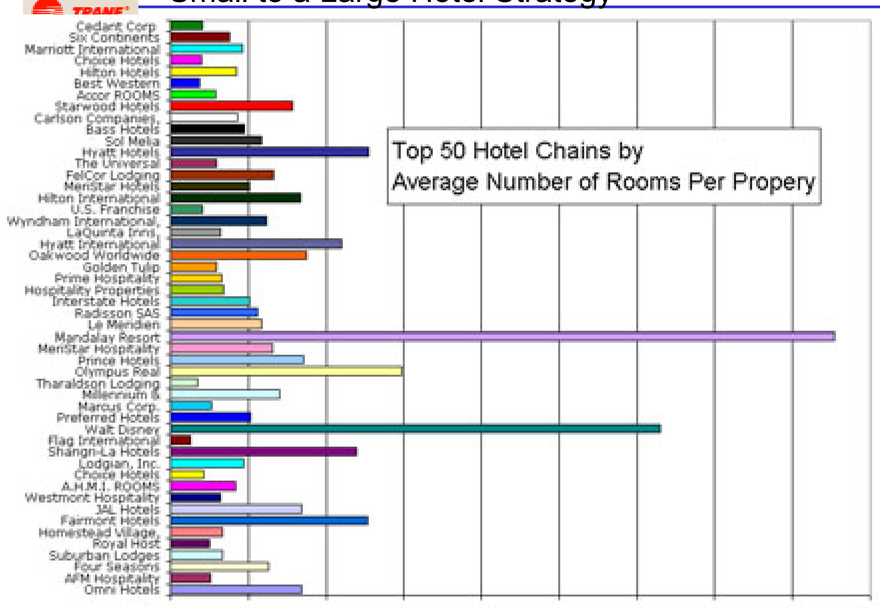


Ref 4
72

Top Drivers for Good Potential Cogeneration Customers

- Want Financial Power of the Top 50 Corporations
- Want Only Those Who Run a “Large Hotel” Strategy
- Rank Remaining by Number of Properties as Cogeneration Systems Would be Generally One per Property

The Business Model of the Top 50 Range from a Small to a Large Hotel Strategy



Focus on the Large Hotel Players

- Top 50 Corporations Sorted by Average Hotel Size
- Cut-Off at 200 Rooms per Property
  - Lowest Value of Any Corp. Listed is 313
- Reorder Short List by Number of Properties
- List Shown
  - These 24 Companies Run 948,000 Rooms
- List Covers All Rooms Domestic and Overseas

Rank	Owner	# Properties
8	Starwood Hotels	671
11	Sol Melia	321
15	MeriStar Hotels	235
14	FelCor Lodging	183
18	Wyndham International,	166
25	Interstate Hotels	146
16	Hilton International	136
26	Radisson SAS	133
27	Le Meridien	122
12	Hyatt Hotels	119
35	Preferred Hotels	112
29	MeriStar Hospitality	103
21	Oakwood Worldwide	99
33	Millennium &	86
20	Hyatt International	81
30	Prince Hotels	79
48	Four Seasons	62
43	JAL Hotels	56
38	Shangri-La Hotels	43
31	Olympus Real	41
50	Omni Hotels	40
44	Fairmont Hotels	36
36	Walt Disney	18
28	Mandalay Resort	16

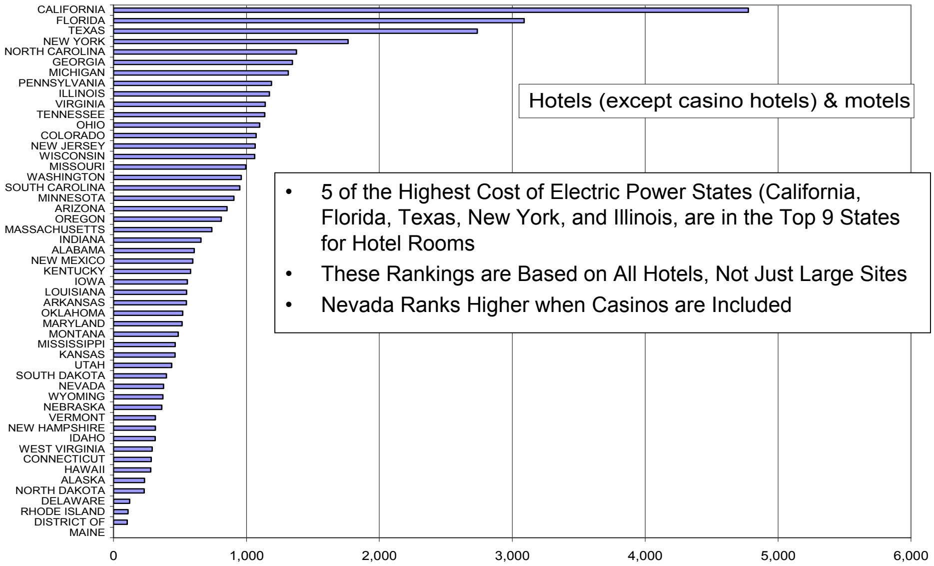
Ref 4

More Detail on Large Hotel Operators

Rank	Owner	# Properties	Average Size	% Rooms Overseas
8	Starwood Hotels	671	313	39%
11	Sol Melia	321	233	100%
15	MeriStar Hotels	235	203	2%
14	FelCor Lodging	183	264	3%
18	Wyndham International,	166	247	13%
25	Interstate Hotels	146	204	0%
16	Hilton International	136	335	98%
26	Radisson SAS	133	224	100%
27	Le Meridien	122	233	92%
12	Hyatt Hotels	119	508	8%
35	Preferred Hotels	112	205	24%
29	MeriStar Hospitality	103	263	2%
21	Oakwood Worldwide	99	349	5%
33	Millennium &	86	281	65%
20	Hyatt International	81	439	100%
30	Prince Hotels	79	342	93%
48	Four Seasons	62	253	52%
43	JAL Hotels	56	337	92%
38	Shangri-La Hotels	43	479	100%
31	Olympus Real	41	593	77%
50	Omni Hotels	40	337	5%
44	Fairmont Hotels	36	507	69%
36	Walt Disney	18	1261	0%
28	Mandalay Resort	16	1706	0%
	Total	3104		46%

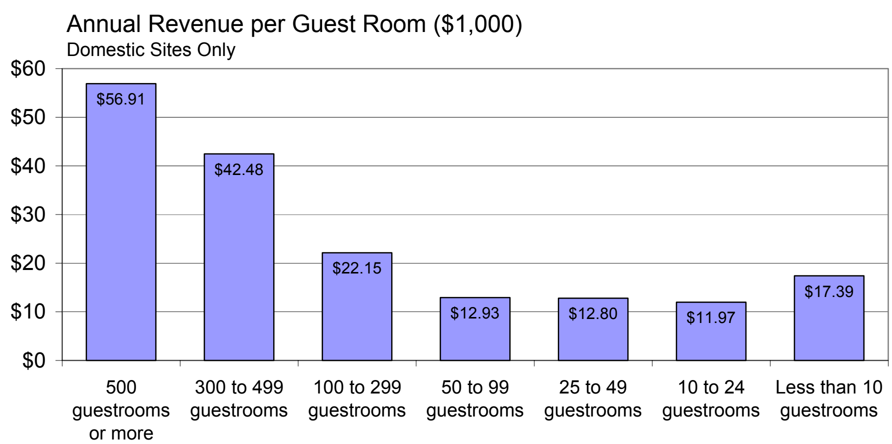
This List Cover 1,670 Domestic Large Hotel Sites Which is Over 50% of the Market

Where are Hotels Located?



- 5 of the Highest Cost of Electric Power States (California, Florida, Texas, New York, and Illinois, are in the Top 9 States for Hotel Rooms
- These Rankings are Based on All Hotels, Not Just Large Sites
- Nevada Ranks Higher when Casinos are Included

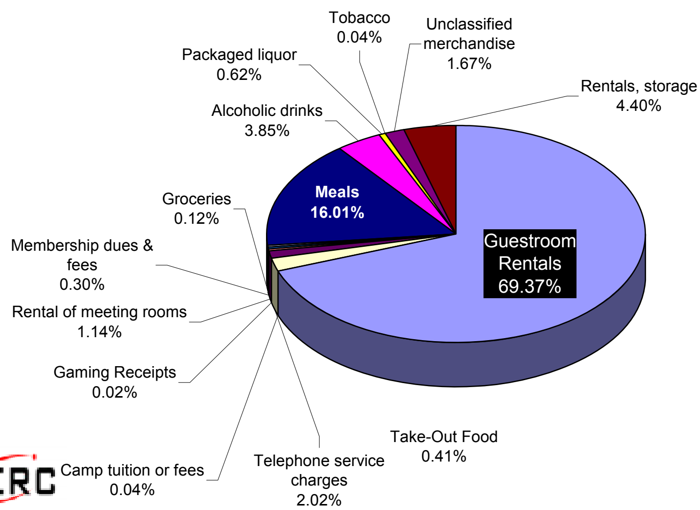
Rational for a Large Hotel Strategy – Average Revenue per Guestroom is Higher



- Revenue per Room Disparity is Extremely High
- Tend to Provide Larger Hotels with More Money to Spend on Capital Improvements like BCHP

Sources of Revenues for Larger Hotels

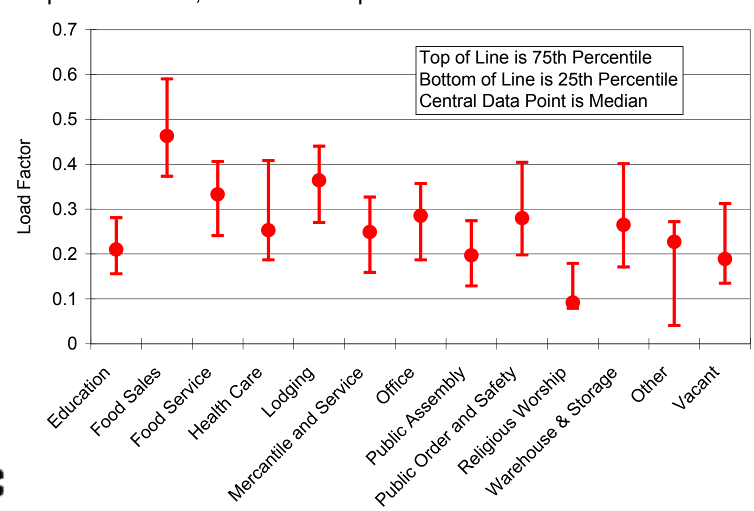
Hotels (except casino hotels) with 25 guestrooms or more



Ref 1

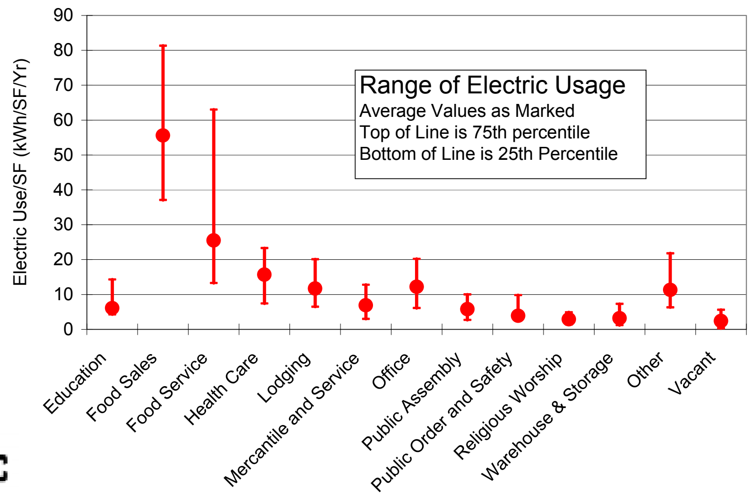
Electric Load Factor by Sector

- Lodging Has a Higher Load Factor than All Commercial Segments, Except Food Sales, Due to 24/7 Operation



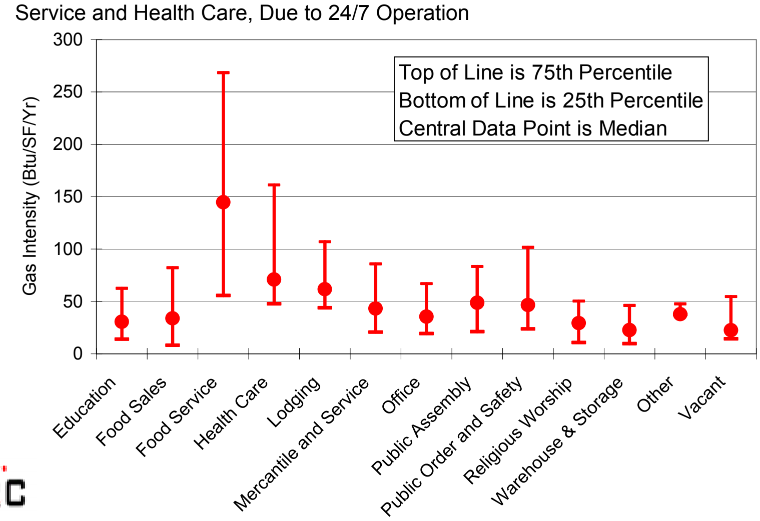
Load Factor is Reflected into Actual Usage

- Lodging Ranges Lower on Overall Electric Use Because of the Lower Usage Intensity



Usage Intensity for Gas

- Lodging Has a Higher Gas Usage than All Commercial Segments, Except Food Service and Health Care, Due to 24/7 Operation



Notes on the Foreign Large Hotel Market

- The 24 Operators Shown in this Segment Control 1,500 Large Overseas Hotels
- The Waukesha/Trane BCHP Package May Be an Even Better Fit Overseas for:
  - Urban Business Hotels in Countries with Power Supply Problems
  - Vacation Hotels in Remote Locations Where
    - Grid Power May Not Even Be Available or May Be Insufficient
    - Cooling Loads are Dominant
  - All Water Systems are More Common in Other Areas of the World than North American, Particularly in Europe and the Far East

Section Summary

- Highly Concentrated Market
  - The 24 Operators Identified Control Over 1,600 of the 6,000 Domestic Large Hotels
  - As Well as Running 1,500 Large Hotels Overseas
  - Overseas Market May Be Very Important as Well

References

1. 1997 Economic Census, Accommodation and Foodservices, Subject Series, Merchandise Line Sales
2. 1997 Economic Census, Accommodation and Foodservices, Subject Series, Summary, Issued February 2001
3. American Hotel & Lodging Association (AH&LA), The 2001 Lodging Industry Profile, http://www.ahla.com/infocenter/lip.asp
4. American Hotel & Lodging Association (AH&LA), Top 50 Hotel Companies: http://www.ahla.com/infocenter/top50.asp
5. 1997 Economic Census, Accommodation and Foodservices, Subject Series, Miscellaneous Subjects, Table 10. Guestroom Size of Establishments for the United States: 1997
6. "A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures." 1995 Commercial Buildings Energy Consumption Survey (CBECS), a national probability sample survey of commercial buildings sponsored by the Energy Information Administration

Appendix 1: Census Bureau Segmentation and Definitions

72 ACCOMMODATION AND FOODSERVICES

- The Accommodation and Food Services sector comprises establishments providing customers with lodging and/or preparing meals, snacks, and beverages for immediate consumption. The sector includes both accommodation and food services establishments because the two activities are often combined at the same establishment. Excluded from this sector are civic and social organizations; amusement and recreation parks; theaters; and other recreation or entertainment facilities providing food and beverage services.

721 Accommodation

- Industries in the Accommodation subsector provide lodging for travelers, vacationers, and others. Some provide lodging only; while others provide meals, laundry, and recreational facilities, as well. Lodging establishments are classified in this subsector even if complementary services generate more revenue.
- The subsector is organized into three industry groups:
- (1) traveler accommodation,
- (2) recreational accommodation,
- (3) rooming and boarding houses.
- The Traveler Accommodation industry group includes establishments that primarily provide traditional types of lodging services. This group includes hotels, motels, and bed and breakfast inns.
- The RV (Recreational Vehicle) Parks and Recreational Camps industry group includes establishments primarily designed to accommodate outdoor enthusiasts. Included are travel trailer campsites, recreational vehicle parks, and outdoor adventure retreats.
- The Rooming and Boarding Houses group includes establishments providing accommodations that may serve as a principal residence.

7211 Traveler Accommodation

- This NAICS Industry Group includes establishments classified in the following Industries:
  - 72111, Hotels (except Casinos) and Motels
  - 72112, Casino Hotels;
  - 72119, Other Traveler Accommodation.

72111 Hotels (Except Casinos) and Motels

- This industry comprises establishments primarily engaged in providing short-term lodging in facilities known as hotels, motor hotels, resort hotels, and motels.
- The establishments in this industry may offer services, such as food and beverage services, recreational services, conference rooms and convention services, laundry services, parking, and other services.
- **721110 Hotels (Except Casinos) and Motels**
- Defined Same as 721 and Include

Subclass Definitions

- 7211101 Hotels (except Casino Hotels) With 25 Guestrooms or More
  - Establishments, known as hotels, with a total of 25 guestrooms or more primarily engaged in providing short term lodging.
- 7211102 Hotels With Less Than 25 Guestrooms
  - Establishments, known as hotels, with less than 25 guestrooms primarily engaged in providing short-term lodging.
- 7211103 Motels
  - Establishments, known as motels, primarily engaged in providing short-term lodging.
- 7211104 Motor Hotels
  - Establishments, known as motor hotels, motor lodges, or motor inns, primarily engaged in providing short-term lodging.
- 7211105 Organization Hotels
  - Hotels operated by membership organizations for the benefit of their constituents and not open to the general public.

72112 Casino Hotels

- This industry comprises establishments primarily engaged in providing short-term lodging in hotel facilities with a casino on the premises.
- The casino on premises includes table wagering games and may include other gambling activities, such as slot machines and sports betting.
- These establishments generally offer a range of services and amenities, such as food and beverage services, entertainment, valet parking, swimming pools, and conference and convention facilities.
- 721120 Casino Hotels
  - Same as 72112

72119 Other Traveler Accommodation

- This industry comprises establishments primarily engaged in providing short-term lodging (except hotels, motels, and casino hotels). Sub-Classes Include
- 721191 Bed-and-Breakfast Inns
  - This U.S. industry comprises establishments primarily engaged in providing short-term lodging in facilities known as bed-and-breakfast inns.
  - These establishments provide short-term lodging in private homes or small buildings converted for this purpose.
  - Bed-and-breakfast inns are characterized by a highly personalized service and inclusion of a full breakfast in a room rate.
  - Subclasses Include:
    - 7211911 Bed-and-Breakfast Inns With 25 Guestrooms or More
      - Establishments, known as bed-and-breakfast inns, providing lodging of more than 25 guestrooms in private houses or buildings converted for this purpose.
    - 7211912 Bed-and-Breakfast Inns With Less Than 25 Guestrooms
      - Establishments, known as bed-and-breakfast inns, providing lodging of less than 25 guestrooms in private houses or buildings converted for this purpose.

721199 All Other Traveler Accommodation

- This U.S. industry comprises establishments primarily engaged in providing short-term lodging (except hotels, motels, casino hotels, and bed-and-breakfast inns).

7212 RV (Recreational Vehicle) Parks and Recreational Camps

- 72121 RV (Recreational Vehicle) Parks and Recreational Camps
  - Establishments engaged in operating recreational vehicle parks and campgrounds and recreational and vacation camps. These establishments cater to outdoor enthusiasts and are characterized by the type of accommodation and by the nature and the range of recreational facilities and activities provided to their clients. These Include the following sub-classes:
  - 721211 RV (Recreational Vehicle) Parks and Campgrounds
    - This U.S. industry comprises establishments primarily engaged in operating sites to accommodate campers and their equipment, including tents, tent trailers, travel trailers, and RVs (recreational vehicles). These establishments may provide access to facilities, such as washrooms, laundry rooms, recreation halls and playgrounds, stores, and snack bars.
  - 721214 Recreational and Vacation Camps (Except Campgrounds)
    - Establishments primarily engaged in operating overnight recreational camps, such as children's camps, family vacation camps, hunting and fishing camps, and outdoor adventure retreats that offer trail riding, white-water rafting, hiking, and similar activities. These establishments provide accommodation facilities, such as cabins and fixed camp sites, and other amenities, such as food services, recreational facilities and equipment, and organized recreational activities.

72131 Rooming and Boarding Houses

- Establishments primarily engaged in operating rooming and boarding houses and similar facilities, such as fraternity houses, sorority houses, off-campus dormitories, residential clubs, and workers' camps. These provide accommodations which may serve as a principal residence and may provide services, such as housekeeping, meals, and laundry services.
- 721310 Rooming and Boarding Houses
  - Same as 72131
  - 7213101 Rooming and Boarding Houses
    - Establishments primarily engaged in operating rooming and boarding houses and similar facilities, such as dormitories and residential clubs. These establishments are open to the general public and may serve as a principal residence.
  - 7213102 Organization Rooming and Boarding Houses
    - Lodging houses operated by membership organizations for the benefit of their constituents and not open to the general public.

GTI Integrated Energy System for Buildings Final Report

Appendix C – Economic Analysis of Alpha Design

Introduction

The purpose of the economic analysis was to examine an optimum application of Waukesha 615-kWe internal-combustion-engine-based on-site power generation systems for four selected typical commercial buildings (schools, hospitals, retail stores, and hotels) and five geographical locations (Chicago, Miami, New York, San Diego, and Boston). (Although office buildings were also a selected building type, the initial calculations of payback times showed it to be a less attractive market. This was felt to be because the 500-kW IES is too large for the typical building. This issue will be reevaluated in the beta phase of the economic analysis.) We examined the effectiveness and economic benefit of using natural-gas-driven internal-combustion (IC) engines for power generation with heat recovery in commercial buildings. The recovered heat would be used to meet space heating and domestic hot water loads and to satisfy a portion of the building cooling loads. A BCHP-90 Trane prototype absorption chiller, designed to be powered by recoverable heat was used to generate the required cooling capacity, up to the chiller's maximum capacity of 112 refrigeration tons (RT). The target buildings were selected, based on the Commercial Buildings Energy Consumption Study (CBECS) database using criteria of high energy density, total number of buildings, and electric demand that can be satisfied, or supported with 615 KWe generators. Building Energy Analyzer (BEA), a commercial software/ engineering tool utilizing the DOE2.1E hour-by-hour computational engine, was used to generate 8760-hour-per-year load profiles (cooling, heating, and electric and gas consumption by end use) for the analyzed buildings. A separate, GTI-developed program was later used to simulate integration of the engine, generator, heat recovery system, and absorption chiller with the building HVAC and utility systems using load profiles developed in the first stage of the modeling process.

Nomenclature

The following nomenclature is used throughout this appendix:

- 24/7 – Available 8760 hours per year
- AC – Air conditioning
- ABS – Absorption cooling
- BEA – Building Energy Analyzer
- CFM – Cubic feet per minute
- CHP – Cooling, heating, and power generation
- COP – Coefficient of performance
- DHW – Domestic hot water
- Eff. – Efficiency [%]
- Overall Eff. = ((generated kWh * 3412) + recovered heat)) / generator fuel heating value input [%]

- Effect. – Effectiveness [%]
- Heat Rec. Effect. = recovered heat / recoverable heat [%]
- HT – Space heating
- HVAC – Heating, cooling, and air conditioning
- IC – Internal combustion
- kW – Thousand watts
- kWe – Thousand watts electric
- MMBtu – Million Btus
- O&M – Operation and maintenance
- Rec. – Recovery
- RT – Refrigerating ton [12,000 Btu/hour]
- SCFM – Standard cubic feet per minute
- SDG&E – San Diego Gas & Electric Company
- sf – Square feet

Modeling Assumptions

The benefits of installing Waukesha 615 kWe on-site power generation systems in commercial building application were studied. The study concentrated on optimizing economic benefits of IC-engine-based on-site power generation with heat recovery for space heating/domestic hot water, and absorption gas cooling. Four commercial building types at four different geographical locations (representing four different climates) were examined. For each geographical location, Spring 2004 local electric utility rate structures were used. The following is a detailed description of specific modeling assumptions.

Applications and HVAC Equipment Configuration

Four different building types were selected for evaluation: Hospital, large school, large hotel, and large retail store. Table C-1 shows assumed attributes of the selected building applications.

Table C-1: Basic Parameters of Analyzed Buildings

	Application			
Attribute	**Hospital**	**Large School**	**Large Hotel**	**Large Retail**
Typical floor space [sf]	300,000	110,000	220,000	125,000
Number of buildings	5,000	48,000	6,000	30,000
Operating schedule [hours]	24 / 7	0700 to 1800 hours Mon.-Fri. and 1000 to 1300 hours Sat.**	24 / 7	0600 to 2400 hours Mon. - Sat. and 0700 to 2200 hours Sun.
Typical* annual electric consumption [kWh]	7,222,082	1,412,817	3,605,393	2,573,888
Typical* peak demand [kW]	~1380	~700	~900	~700
Typical* annual gas consumption [MMBtu]	43,432	10,414	17,518	7,240

* Based on Chicago, IL location

** Limited-operation summer schedule 0600 to 0900 hours

Table C-2 provides details of typical HVAC equipment parameters in each type of building.

Table C2 - Basic HVAC Parameters of Analyzed Buildings

	Application			
Attribute	**Hospital**	**Large School**	**Large Hotel**	**Large Retail**
Cooling equipment type	Electric centrifugal, cooling tower	Electric screw, cooling tower	Electric centrifugal, cooling tower	Electric screw, cooling tower
Chiller design capacity* [RT]	584	516	489	384
Chiller energy rating [kW/RT]	0.68	0.78	0.68	0.78
Heating equipment type	Natural gas boiler	Natural gas boiler	Natural gas boiler	Natural gas boiler
Heating design capacity* [MMBtu/h]	11.8	11.8	6.9	6.9
Boiler energy eff. [%]	82	82	82	82
Outside air [SCFM]	64,760	78,000	58,030	37,510
Active humidity control	Surgical suites only	No	No	No

* Based on Chicago, IL location

Modeled Locations and Electric and Gas Utility Rates

To limit scope of this study to a practical size for evaluation, we selected one city in California with the objective of analyzing southwest locations that potentially could most benefit economically from BCHP equipment. The first criterion used during the selection was a favorable (high-priced) electric rate structure. The location selected was San Diego, CA and San Diego Gas and Electric (SDG&E) service territory. Another criterion was that the selected locations have a relatively hot climate, so the modeled buildings have a high electric and cooling load factor. A third criterion was that the selected locations represent a relatively high population with high system sales potential. Based on these criteria the following locations were added: Southeast, Miami FL, serviced by Florida Power and Light; New York, NY serviced by Consolidated Edison (ConEd); Boston, MA, serviced by Boston Electric (BE); and Midwest, Chicago, IL, serviced by Commonwealth Edison (ComEd).

Table C- 3 identifies the electric rate structures used in the analysis. Due to recent volatility in natural gas prices, we used a uniform flat delivered gas rate of $6.00 per MMBtu for all locations**.**

Table C-3. Electric Utility Rates Applicable to Buildings at Various Locations, With and Without On-Site Power Generation Systems

Location	DG Status	Application			
Target City		Hospital	Large School	Large Hotel	Large Retail
Boston, MA*	Without DG	Boston Edison T-2	Boston Edison T-2	Boston Edison T-2	Boston Edison T-2
	DG installed	Boston Edison T-2	Boston Edison T-2	Boston Edison T-2	Boston Edison T-2
Chicago, IL*	Without DG	ComEd Rate 6L TOU	ComEd Rate 6 TOU	ComEd Rate 6 TOU	ComEd Rate 6 TOU
	DG installed	ComEd Rate 18 Standby	ComEd Rate 18 Standby	ComEd Rate 18 Standby	ComEd Rate 18 Standby
Miami, FL*	Without DG	FPL GSLDT-1	FPL GSLDT-1	FPL GSLDT-1	FPL GSLDT-1
	DG installed	FPL SST-1	FPL SST-1	FPL SST-1	FPL SST-1
New York, NY*	Without DG	ConEd PSC No. 9	ConEd PSC No. 9	ConEd PSC No. 9	ConEd PSC No. 9
	DG installed	ConEd 14-RA	ConEd 14-RA	ConEd 14-RA	ConEd 14-RA
San Diego, CA*	Without DG	SDG&E AL-TOU_DER + EECC	SDG&E AL-TOU_DER + EECC	SDG&E AL-TOU_DER + EECC	SDG&E AL-TOU_DER + EECC
	DG installed	SDG&E AL-TOU_DER + EECC + Gen. Charge	SDG&E AL-TOU_DER + EECC + Gen. Charge	SDG&E AL-TOU_DER + EECC + Gen. Charge	SDG&E AL-TOU_DER + EECC + Gen. Charge

* Note: Uniform flat delivered gas rate of $6.00 per MMBtu was used for all locations

Power Generation and Heat Recovery Equipment Configuration and Performance

The benefits of installing 615 kWe IC engine-based on-site power generation systems with specific configurations of heat recovery were examined. Heat was recovered for space heating and domestic hot water heating and for driving a single-stage BCHP-90 prototype absorption chiller developed by Trane Co. During simulation, heat recovered from the IC engine was passed to an absorption chiller if a cooling load was present, then to the space heating/reheating load and the domestic hot water load. Unutilized heat was rejected to the atmosphere. The absorption chiller had a fixed rated cooling capacity. Only that portion of the recoverable heat that was available at temperatures higher than the minimum required for driving single-stage absorption was used to drive the chiller. The actual cooling capacity of the absorption chiller depends on the availability of recoverable heat. If needed, the remaining building cooling load was satisfied by a standard electric AC system, comprised of either 0.78 kW/RT screw chiller or a 0.68 kW/RT centrifugal compressor chiller (depending on the application, see Table C-2).

BCHP-90 absorption chiller performance was modeled using the laboratory test results shown in the main body of this report.

The system was modeled assuming availability of hot water from the IC engine at 230ºF (125-RT mode). The BCHP-90 chiller rating point cooling capacity and cooling COP as functions of cooling tower water temperature were modeled using the test data. Chiller part-load performance (cooling capacity and COP) was also modeled using the test data. Although the part load performance data were only available for chiller runs at 207ºF (90-RT mode), for modeling purposes, we assumed that, at 230ºF (125-RT mode), the relative degradation in cooling capacity and COP at part load would be similar.

BCHP-90 chiller parasitic losses of chilled water, tower water, and hot water circuit pumps were modeled using flow rates from the 125-RT operating mode, however, pressure drops were assumed to be that of the original design 90-RT unit. This assumption was based on the understanding that the BCHP-90 prototype design was optimized for 90-RT operation, and the production unit will have pressure drops more in line with those usually exhibited by typical TRANE products.

Evapco cooling tower model LRT 5-68 performance and parasitic electric losses were modeled, based on the data from the manufacturer. Two LRT 5-68 units with design approach temperature of 7ºF at a wet bulb temperature of 78ºF will be used. Each unit is equipped with a 7.5-HP electric fan motor and 2.8-gpm fresh-water pump with a head pressure of 2.2 psi. The cooling tower will maintain 85ºF as lowest acceptable water temperature. At chiller part-load condition or lower ambient temperatures, only one unit will operate.

Waukesha VGF series 615 kWe engine driven generator performance when operated at a jacket water outlet temperature of 230ºF was modeled using actual test data. For modeling purposes, the following was assumed:

Engine-Generator Electrical Efficiency

Load [%]	Electric Efficiency HHV [%]	Fuel Heat Input Btu/kWe
100	30.70	11,107
75	29.40	11,662
50	26.79	12,729

Engine-Generator Heat Recovery Effectiveness

- 36.4% of total engine fuel heat input at 230ºF
- 9.3% of total engine fuel heat input at 146ºF

Engine-Generator Electric Parasitic Power

- Three wall cooling fans at 2 HP each for a total of 6 HP, operating continuously.
- Eight radiator fans at 3 HP each for a total of 24 HP, operating as needed.
- One 3-HP water jacket pump, operating continuously.
- One 10-HP heat recovery system pump, operating continuously.

Equipment Installed Cost and Generator Operating and Maintenance Costs

To realistically evaluate the economic benefits of the examined systems, a set of estimated first/installed costs of the equipment was developed, based on updated information from the equipment manufacturers. The following equipment installed costs were assumed: $1,700/kW - $1,400/kW.

O&M cost was $ 0.011 per kWh.

Generator Control Strategies

The modeled generator deployment control strategy was to follow the application's electric load profile. A generator could follow the electric load down to a minimum part-load of 200 kWe.

The generator operating hours were optimized to achieve the highest annual energy cost savings for the building. Consequently, the generator operating hours varied, depending on the location, local utility rates, and the type of application being modeled. Several different combinations of generator control strategies were examined for each modeled case:

- Generating electricity during the electric utility energy on-peak hours.
- Generating electricity during the electric utility demand on-peak hours.

- Generating electricity during the electric utility energy on-peak and mid-peak hours.
- Generating electricity during the electric utility demand on-peak mid-peak hours.
- Generating electricity during all hours that the building operated and the electric demand exceeded generator minimum part load capacity of 200 kWe.

Modeling Output Data Types

The following five modeling output data tables and five charts were created for each modeled case to present the calculated results in a consistent format.

- Table of annual and monthly electric and gas utility consumption, demands, and associated costs for a baseline-case building without on-site power generation.
- Table of annual and monthly electric and gas utility consumption, demands, and associated costs for the building with on-site power generation.
- Table of annual and monthly details of generator performance, including electric, thermal, and overall efficiency.
- Table of annual and monthly details of absorption chiller performance, including overall efficiency and details of displaced electric chiller load.
- Table of annual and monthly details of baseline and alternative building configuration utility costs, value of recovered heat, and total expected annual energy cost savings.
- Chart of monthly electric consumption for the building with and without the IES.
- Chart of monthly electric demand for the building with and without the IES.
- Chart of monthly natural gas consumption for building with and without the IES.
- Chart of monthly natural gas demand for building with and without the IES.
- Chart of monthly availability of recoverable heat from the IES that was actually recovered and utilized.

Some of the above- listed output data types are used directly during the interpretation of the results for each of the 16 analyzed cases, and some are provided only as background information for readers who are interested in a more detailed analysis and interpretation of specific cases.

Electric Rates for San Diego, California

Two different electric rates, SDG&E AL-TOU_DER + EECC SDG&E AL-TOU_DER + EECC + Standby were used during analysis of the San Diego location. (See Tables C-5 and C-6.)

The optimal IES control strategy was to run it 24/7 whenever the application's requirements exceeded the minimum generator capacity of 200 kW.

Table C-5. Electric Rate SDG&E AL-TOU-DER + EECC 01/22/2004

	Summer Months	Winter Months
	05 to 09 (inclusive)	10 to 04 (inclusive)
	Time (on-peak, mid-peak, off-peak)	
On-peak	11 to 18	17 to 20
Mid-peak	6 to 11 and 18 to 22	6 to 17 and 20 to 22
Off-peak	22 to 6	22 to 6
	Energy Cost $/kWh	
On-peak	0.11487	0.11363
Mid-peak	0.0881	0.087796
Off-peak	0.08693	0.08696
	Demand Charges $/kW	
On-peak	5.73	3.82
Mid-peak	0	0
Off-peak	0	0
Standby	0	0
Non-coincident	10.59	
	Customer Charge $/meter/month	
	48.95 (<500kW) and 195.8 (>500kW)	

Table C-6. Electric Rate SDG&E AL-TOU-DER (>500 kW) 01/01/2004

	Summer Months	Winter Months
	05 to 09 (inclusive)	10 to 04 (inclusive)
	Time (on-peak, mid-peak, off-peak)	
On-peak	11 to 18	17 to 20
Mid-peak	6 to 11 and 18 to 22	6 to 17 and 20 to 22
Off-Peak	22 to 6	22 to 6
	Energy Cost $/kWh	
On-peak	0.11487	0.11363
Mid-peak	0.08810	0.08796
Off-peak	0.08693	0.08696
	Demand Charges $/kW	
On-peak	5.73	3.82
Mid-peak	0	0
Off-peak	0	0
Non-Coincident	10.59	
	Generator Output Billing $/kWh*	
On-peak	0.01348	0.0124
Mid-peak	0.01073	0.01075
Off-peak	0.00991	0.00994
	Customer Charge $/meter/month	
	195.8	

* Applied to the customer's loads served by the customer's generator, as measured by the generator net output meter.

Electric Rates for New York, New York

Two different electric rates ConEd PSC No. 9 ConEd 14-RA Standby, were used. (See Tables C-7 and C-8.)

The optimal IES control strategy was to run it 24/7 whenever the application's requirements exceeded the minimum generator capacity of 200 kW.

Table C-7. Electric Rate ConEd PSC No. 9 (<1500 kW) 5/1/2004

	Summer Months				Winter Months
	6	7	8	9	10 to 5 (inclusive)
	Energy Cost $/kWh				
First 15,000 kWh	9.12	10.71	10.56	9.11	8.37
Over 15,000 kWh	9.12	10.71	10.56	9.11	8.37
	Demand Charges $/kW				
First 5 kW	117.00	110.80	113.00	113.85	100.00
Next 895 kW	23.40	22.16	22.60	22.77	20.00
Over 900 kW	22.18	20.94	21.38	21.55	18.78
	Customer Charge $/meter/month				
	$67/month/meter				

Table C-8. Electric Rate ConEd 14-RA Standby (<1500 kW) 5/1/2004

	Summer Months				Winter Months
	6	7	8	9	10 to 5 (inclusive)
	Time (on-peak, mid-peak, off-peak)				
On-peak for transmission	9 to 18				9 to 22
Off-peak for transmission	All other hours				All other hours
On-peak for distribution	9 to 22				
Off-peak for distribution	All other hours				
	Energy Cost $/kWh				
First 15,000 kWh	9.12	10.71	10.56	9.11	8.37
Over 15,000 kWh	9.12	10.71	10.56	9.11	8.37
	Demand Charges $/kW				
As-used daily transmission*	0.3353	0.2737	0.2948	0.3030	0.1408
Distribution contract (non-coincidental)	4.6200	3.7800	4.0700	4.1900	4.1900
As-used daily distribution*	0.6812	0.5561	0.5991	0.6158	0.2276
	Customer Charge $/meter/month				
	74.67	60.95	65.66	67.48	67.65

Electric Rates for Miami, Florida

Two electric rates, FPL GSLDT-1 and FPL GSLDT-1 Standby were used during simulation of the Miami location, (See Table C-9.)

The optimal IES control strategy was to run it on-peak whenever the application's requirements exceeded the minimum generator capacity of 200 kW.

Table C-9. Electric Rate FPL GSLDT-1 (>500 kW) 11/15/2002

	Summer Months	Winter Months
	4 to 10 (inclusive)	11 to 3 (inclusive)
	Time (on-peak, mid-peak, off-peak)	
On-peak	12 to 21	6 to 10 and 18 to 22
Mid-peak		
Off-peak	All other hours	All other hours
	Energy Cost $/kWh	
On-peak	0.06364	
Mid-peak		
Off-peak	0.04383	
	Demand Charges $/kW	
On-peak	5.81	
Mid-peak		
Off-peak		
Standby		
Non-coincident	2.39	
	Customer Charge $/meter/month	
	38.12	

Table C-10. Electric Rate FPL GSLDT-1 (>500 kW) 11/15/2002

	Summer Months	Winter Months
	4 to 10 (inclusive)	11 to 3 (inclusive)
	Time (on-peak, mid-peak, off-peak)	
On-peak	12 to 21	6 to 10 and 18 to 22
Mid-peak		
Off-peak	All other hours	All other hours
	Energy Cost $/kWh	
On-peak	0.04923	
Mid-peak		
Off-peak	0.04433	
	Demand Charges $/kW	
Standby contract	2.34	
Reservation	1.01	
Daily standby on-peak	0.47	
	Customer Charge $/meter/month	
	125.51	

Electric Rates for Chicago, Illinois

Three different electric rates were used to model Chicago buildings. Commonwealth Edison Rate 6 TOU (<1000 kW) and Edison Rate 6L TOU (>1000 kW) were used for baseline buildings, and Commonwealth Edison Standby Rate 18 TOU was used during analysis of the Chicago location. (See Tables C-11, C-12, and C-13.)

The optimal IES control strategy was to run it on-peak whenever the application's requirements exceeded the minimum generator capacity of 200 kW.

Table C-11. Electric Rate Commonwealth Edison Rate 6 TOU (<1000 kW) 01/01/1999

	Summer Months	Winter Months
	06 to 09 (inclusive)	10 to 05 (inclusive)
	Time (energy on-peak, off-peak)	
On-peak	9 to 22	9 to 22
Off-peak	22 to 9	22 to 9
	Energy Cost $/kWh	
On-peak	0.05022	0.05022
Off-peak	0.02123	0.02123
	Time (demand on-peak, off-peak)	
On-peak	9 to 18	10 to 18
Off-peak	18 to 9	18 to 9
	Demand Charges $/kW	
On-peak	14.24	11.13
Standby	0	0
Non-coincident	N/A	
	Customer Charge $/meter/month	
	39.93	

Table C-12. Electric Rate Commonwealth Edison Rate 6L TOU (>1000 kW) 01/01/1999

	Summer Months	Winter Months
	06 to 09 (inclusive)	10 to 05 (inclusive)
	Time (energy on-peak, off-peak)	
On-peak	9 to 22	9 to 22
Off-peak	22 to 9	22 to 9
	Energy Cost $/kWh	
On-peak	0.05599	0.05599
Off-peak	0.02341	0.02341
	Time (demand on-peak, off-peak)	
On-peak	9 to 18	10 to 18
Off-peak	18 to 9	18 to 9
	Demand Charges $/kW	
On-peak	16.41	12.85
Standby	0	0
Non-coincident	N/A	
	Customer Charge $/meter/month	
	246.39	

Table C-13. Electric Rate Commonwealth Edison Rate 18 TOU 06/01/2002

	Summer Months	Winter Months
	06 to 09 (inclusive)	10 to 05 (inclusive)
	Time (energy on-peak, off-peak)	
On-peak	9 to 22	9 to 22
Off-peak	22 to 9	22 to 9
	Energy Cost $/kWh	
On-peak	0.05022	0.05022
Off-peak	0.02123	0.02123
	Time (demand on-peak, off-peak)	
On-peak	9 to 18	10 to 18
Off-peak	18 to 9	18 to 9
	Demand Charges $/kW	
On-peak	15.16	13.41
Standby	2.99	
Non-coincident	N/A	
	Customer Charge $/meter/month	
	137.93 (<1000kW) & 344.39 (>1000kW)	

Electric Rates for Boston, Massachusetts

A single electric rate, Boston Electric T-2 (>10 kW), was used for the simulation. (See Table C-13.)

The optimal IES control strategy was to run it on-peak whenever the application's requirements exceeded the minimum generator capacity of 200 kW.

Table C-13. Electric Rate Boston Electric T-2 (>10 kW) 01/01/2004

	Summer Months	Winter Months
	06 to 09 (inclusive)	10 to 05 (inclusive)
	Time (on-peak, off-peak)	
On-peak	9 to 18	8 to 21
Off-Peak	11 to 8	11 to 8
	Energy Cost $/kWh	
On-peak	0.03051	0.01825
Off-Peak	0.00844	0.00502
	Demand Charges $/kW	
On-peak	24.72	11.54
Standby	0	0
Non-Coincident	N/A	
	Customer Charge $/meter/month	
	28 (<150kW), 115 (<300kW), 166 (<1000kW)	

Modeling Results

The following charts show payback periods for the 615-kW Waukesha alpha prototype design for the four applications in the five cities studied. The charts show the effect of equipment installed cost and gas costs on the payback times. In general, they show that New York and San Diego have the shortest payback periods, which is consistent with the relatively high electric power rates in those cities.

Schools

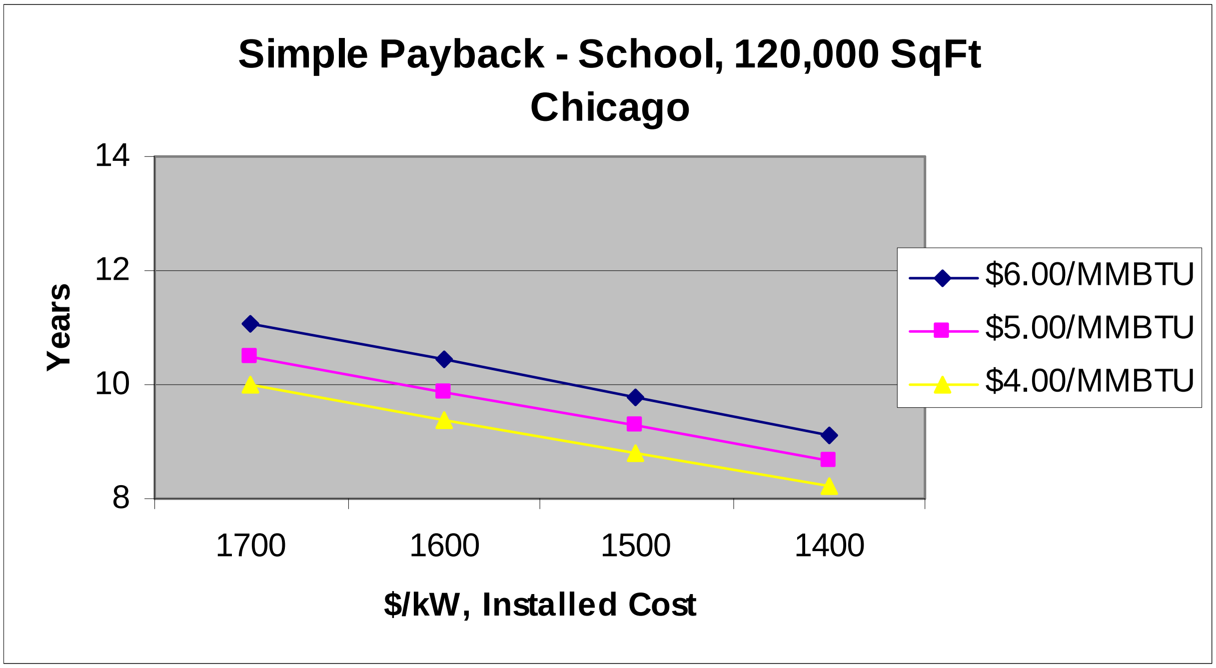


Figure 1: Payback Chart for Chicago School

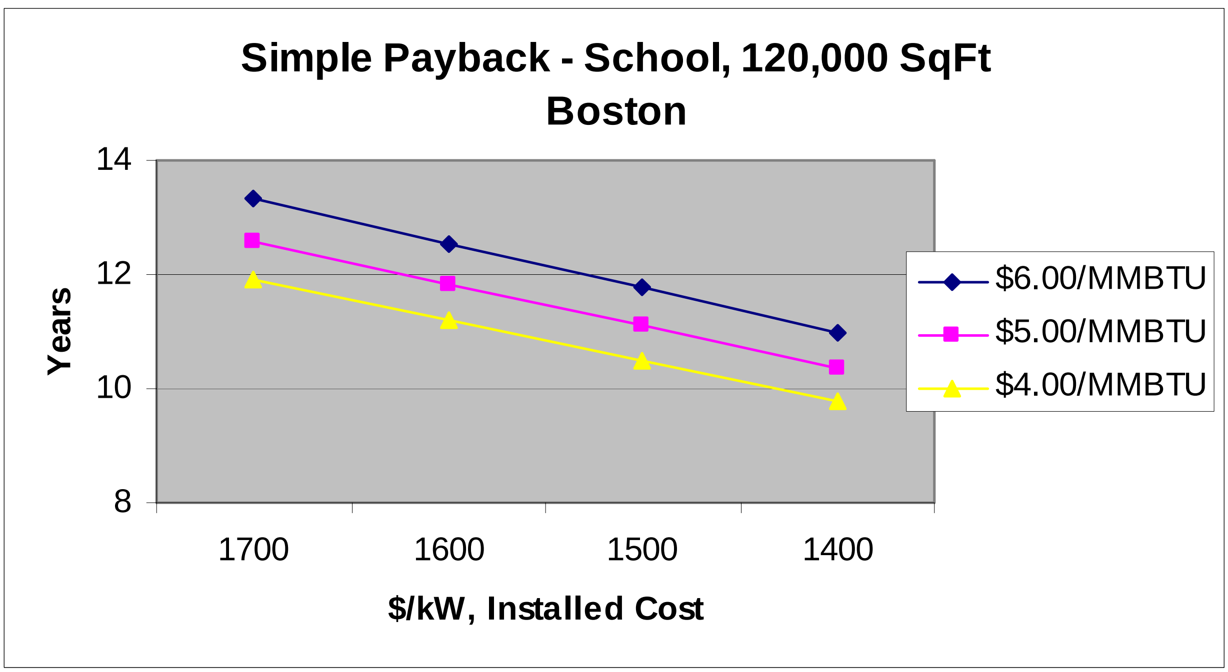


Figure 2: Payback Chart for Boston School

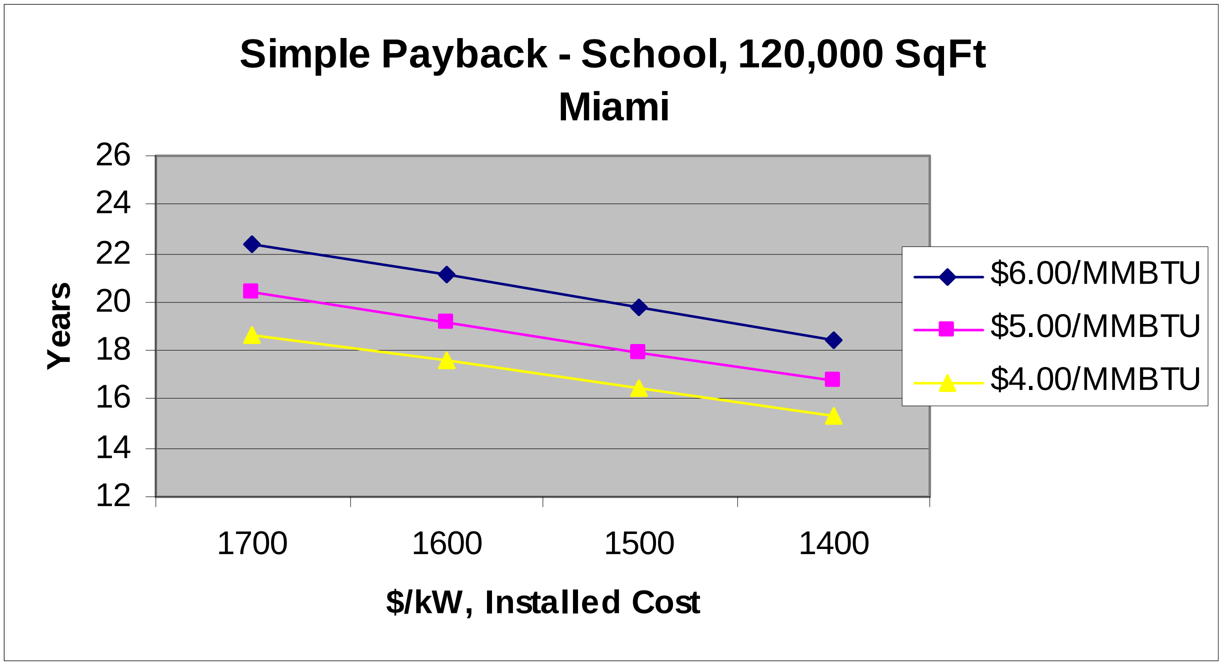


Figure 3: Payback Chart for Miami School

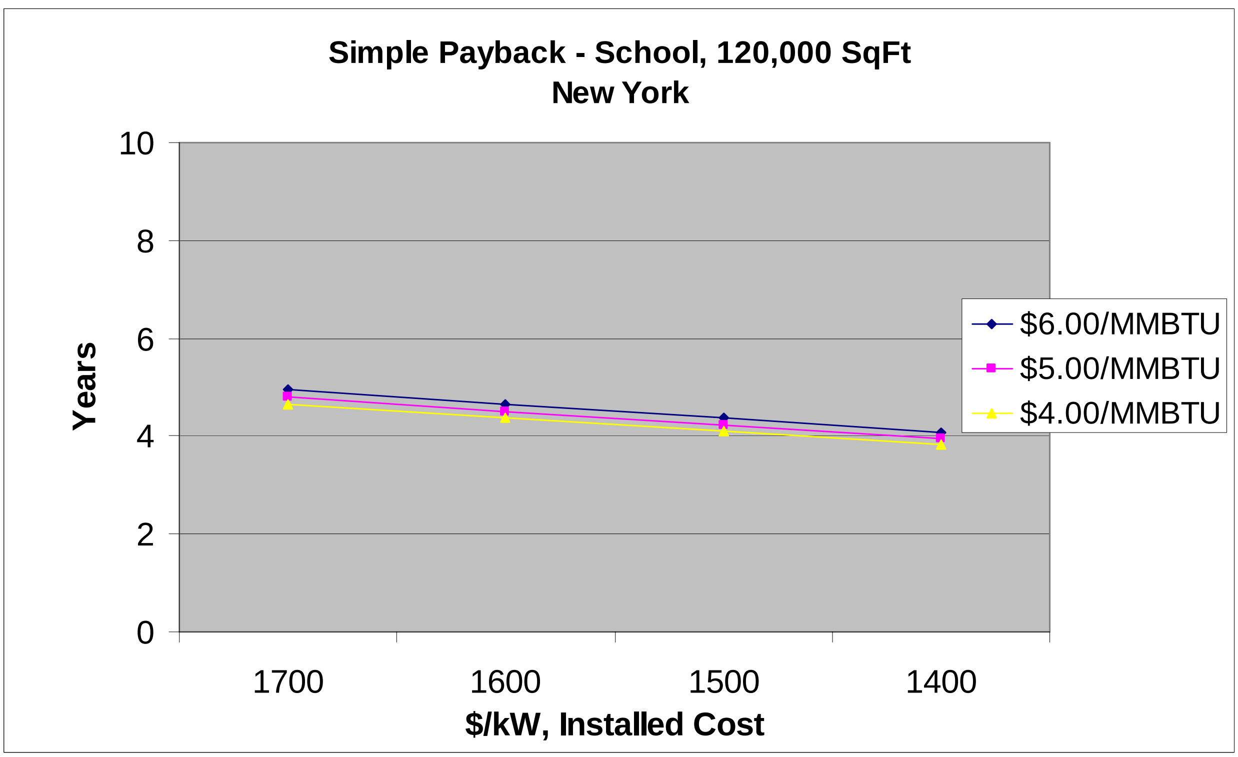


Figure 4: Payback Chart for New York School

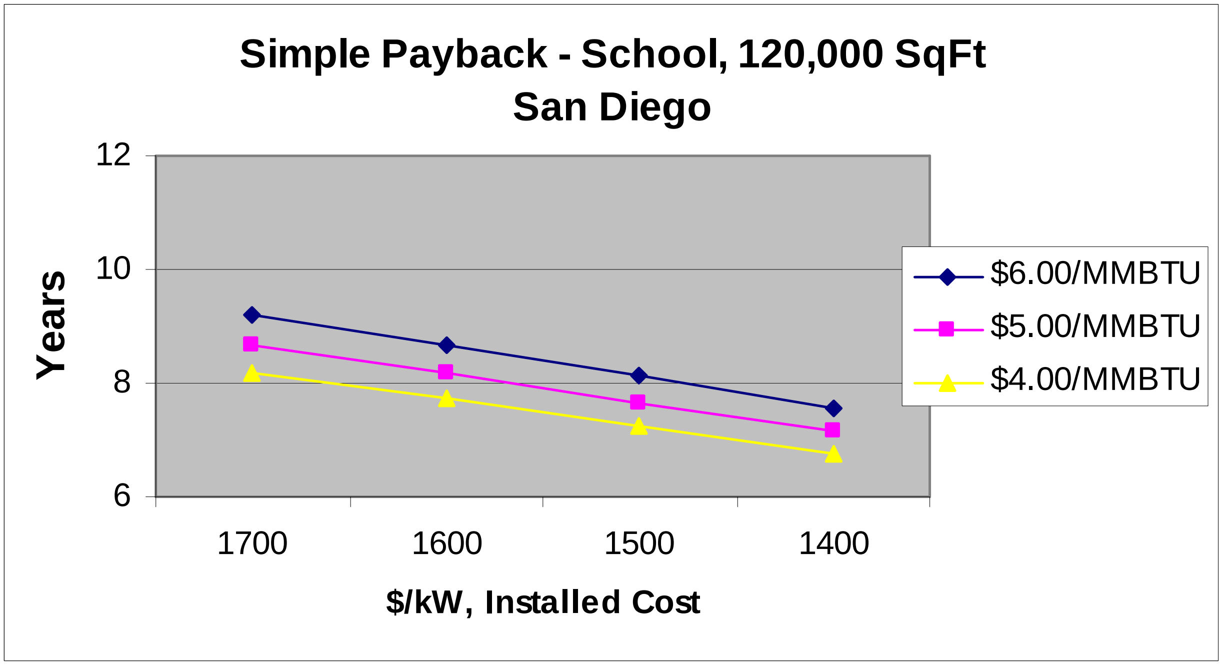


Figure 5: Payback Chart for San Diego School

Health Care

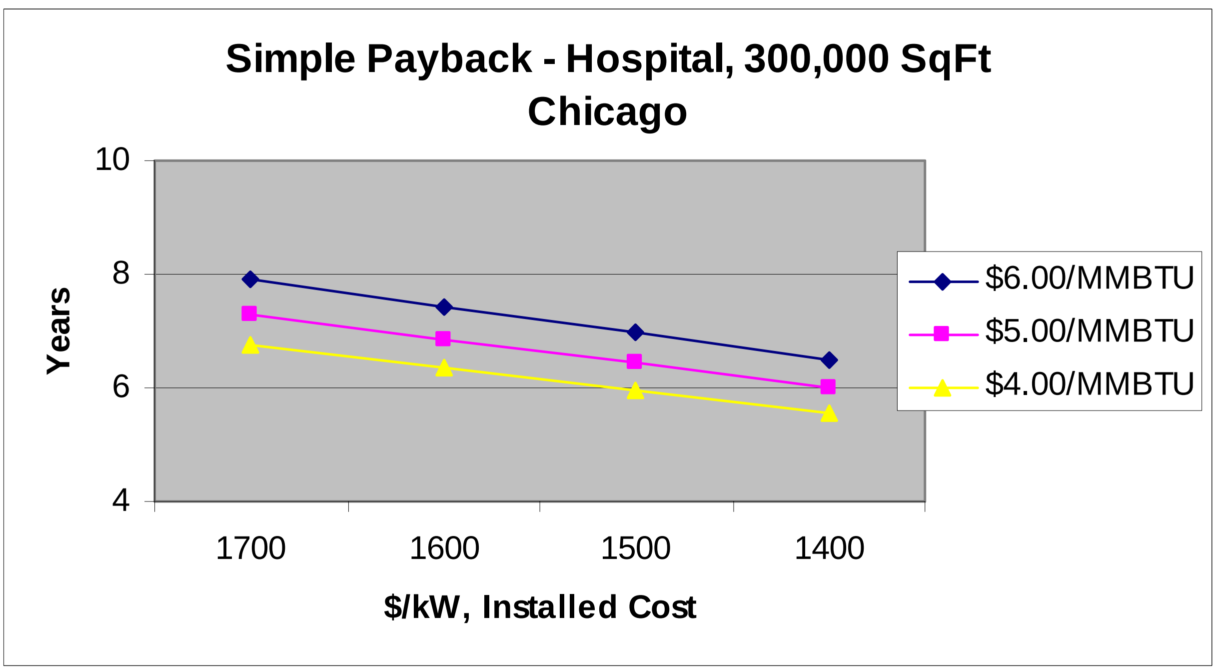


Figure 6: Payback Chart for Chicago Hospital

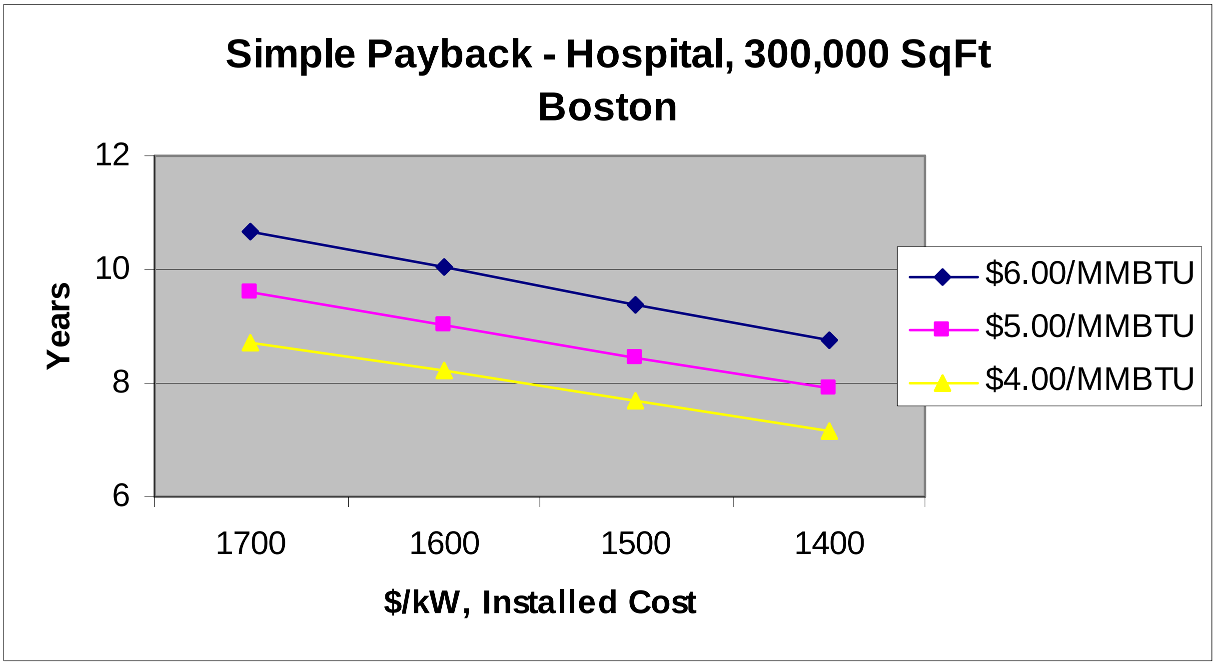


Figure 7: Payback Chart for Boston Hospital

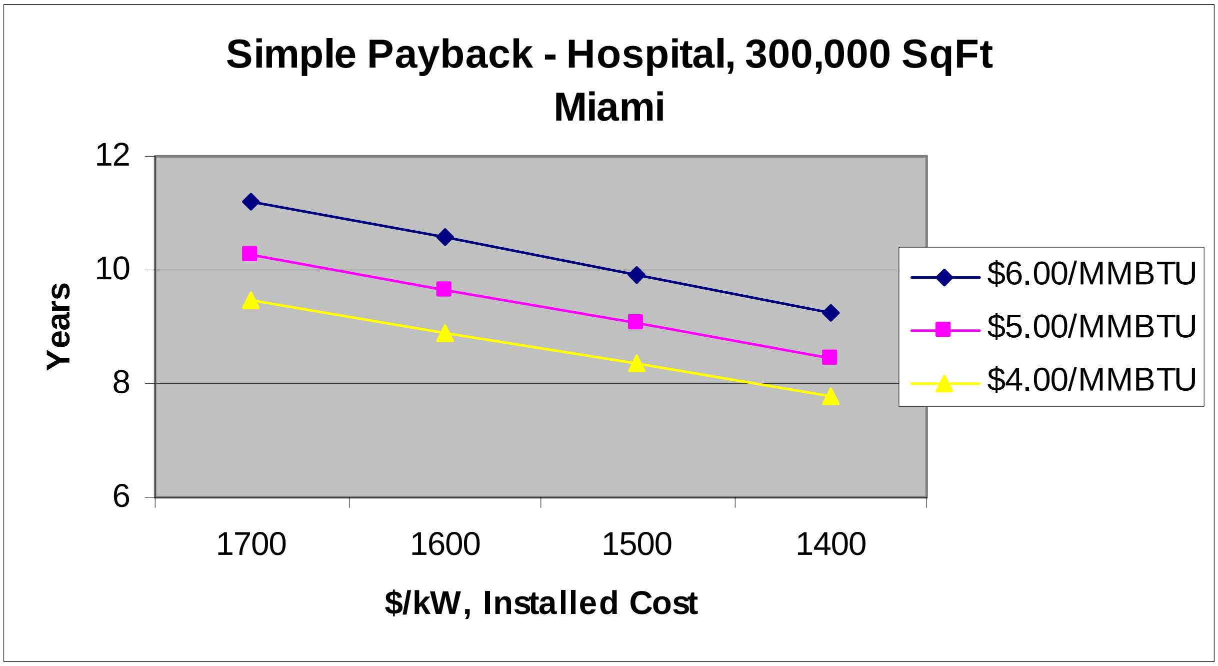


Figure 8: Payback Chart for Miami Hospital

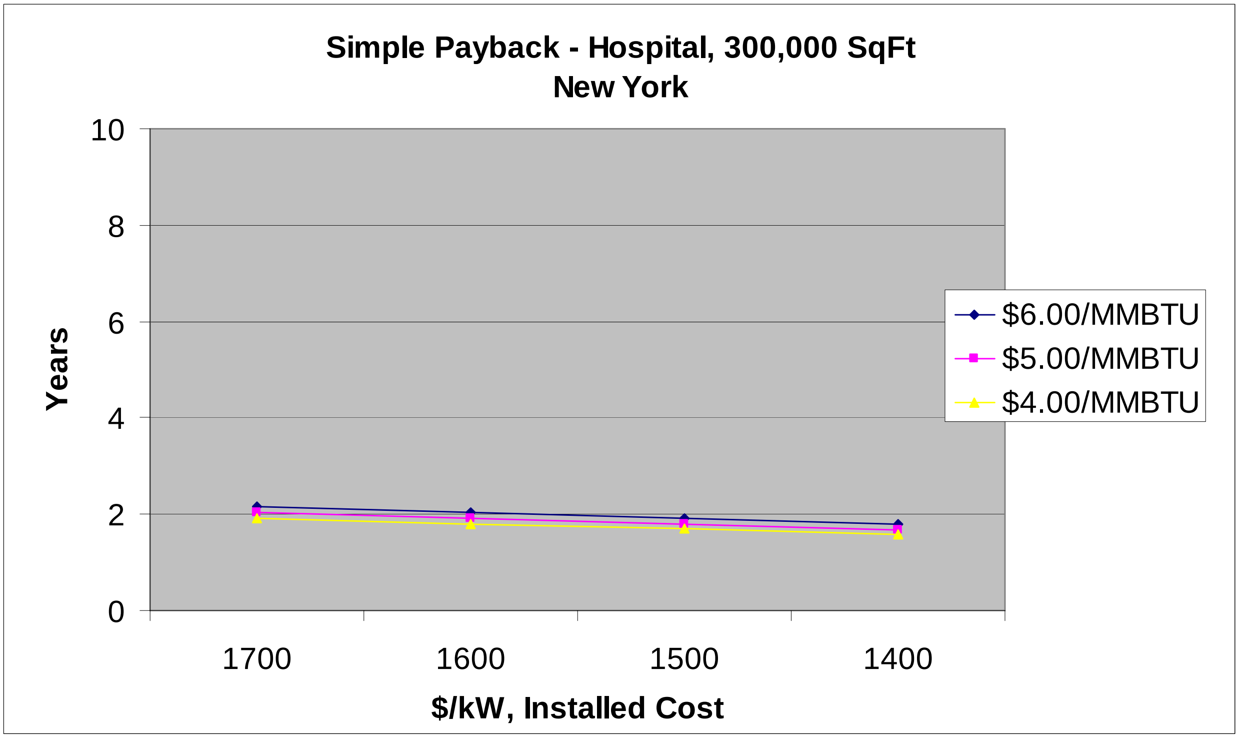


Figure 9: Payback Chart for New York Hospital

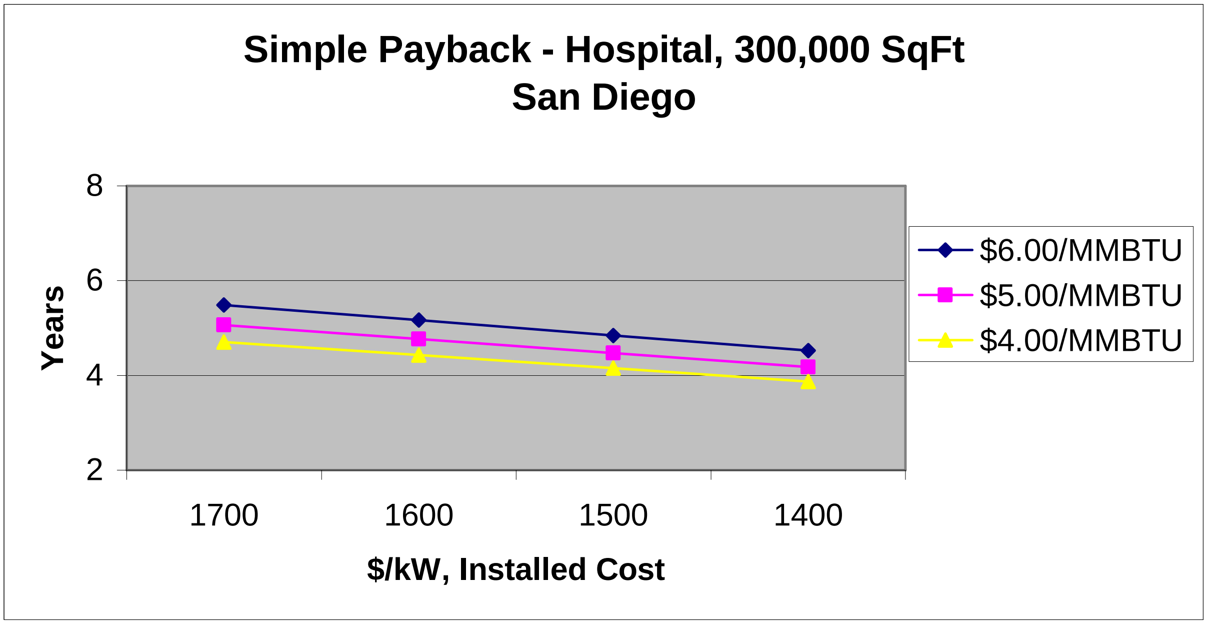


Figure 10: Payback Chart for San Diego Hospital

Large Retail

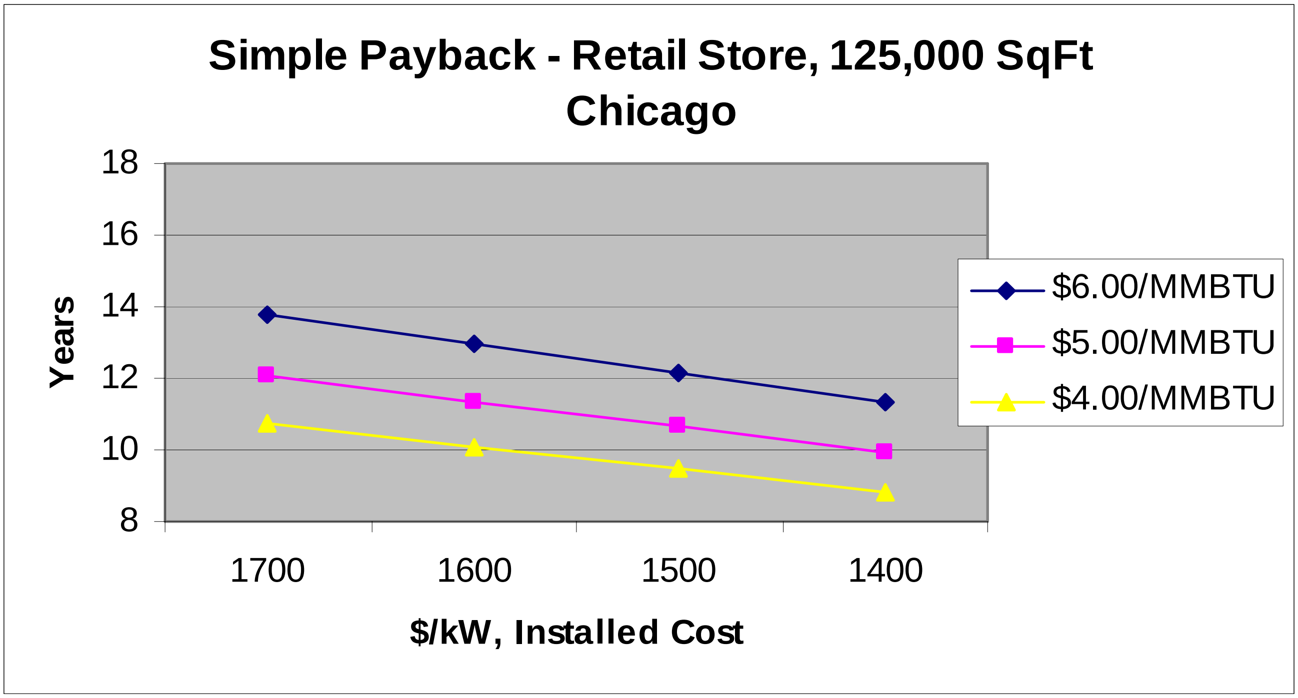


Figure 11: Payback Chart for Chicago Retail Store

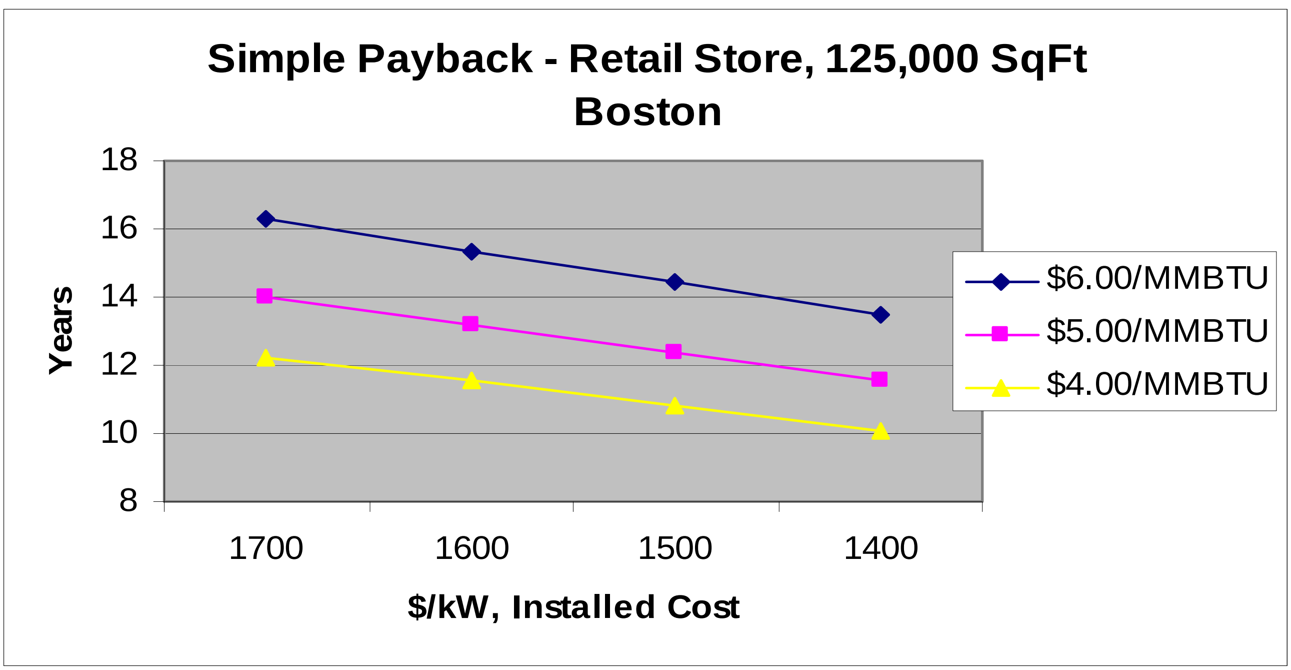


Figure 12: Payback Chart for Boston Retail Store

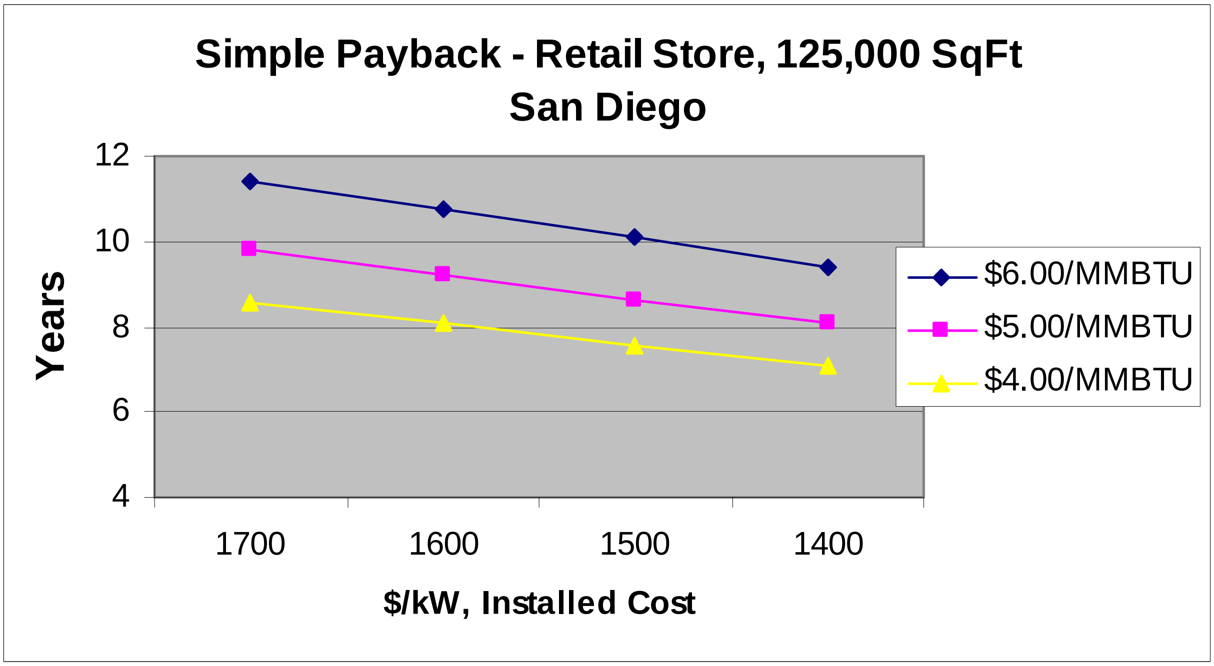


Figure 13: Payback Chart for San Diego Retail Store

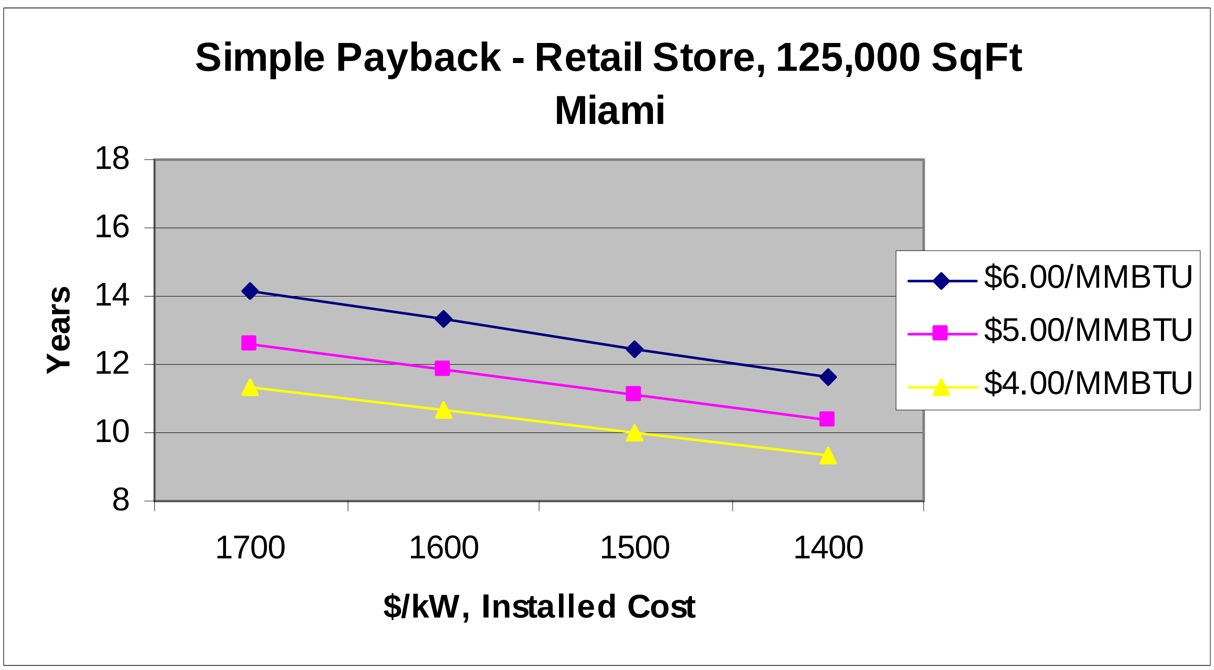


Figure 14: Payback Chart for Miami Retail Store

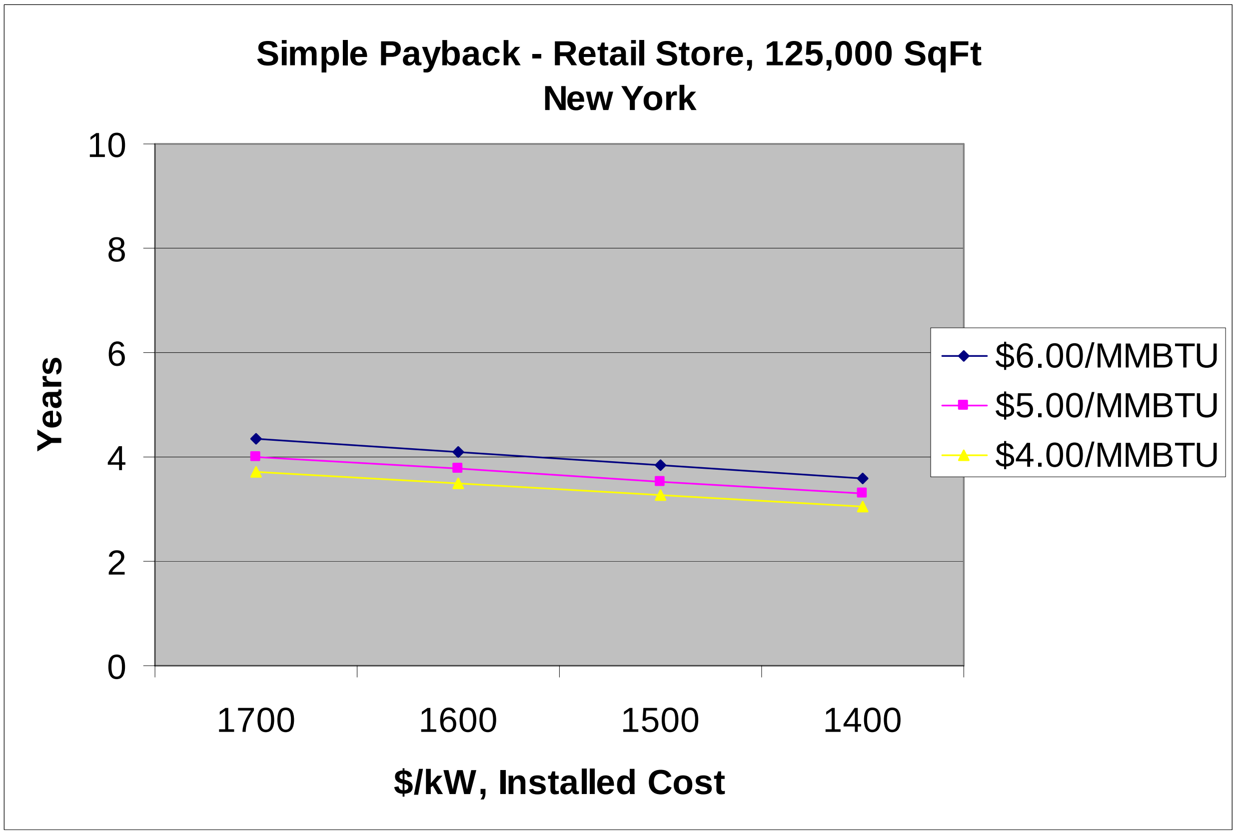


Figure 15: Payback Chart for New York Retail Store

Large Hotel

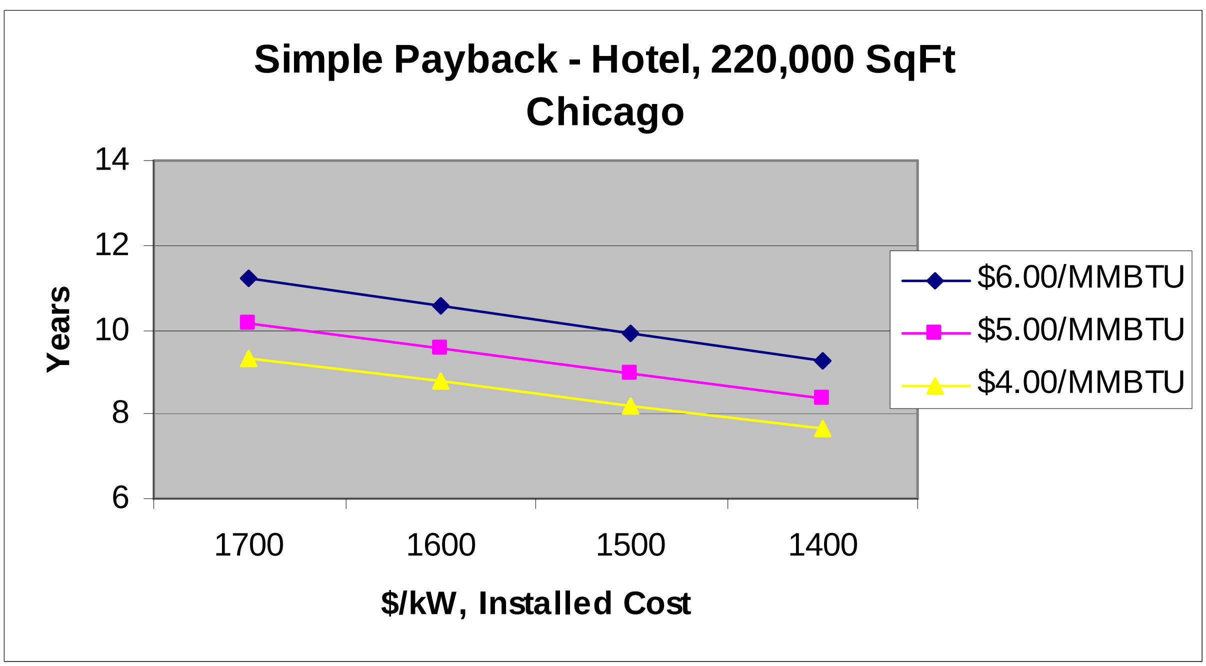


Figure 16: Payback Chart for Chicago Hotel

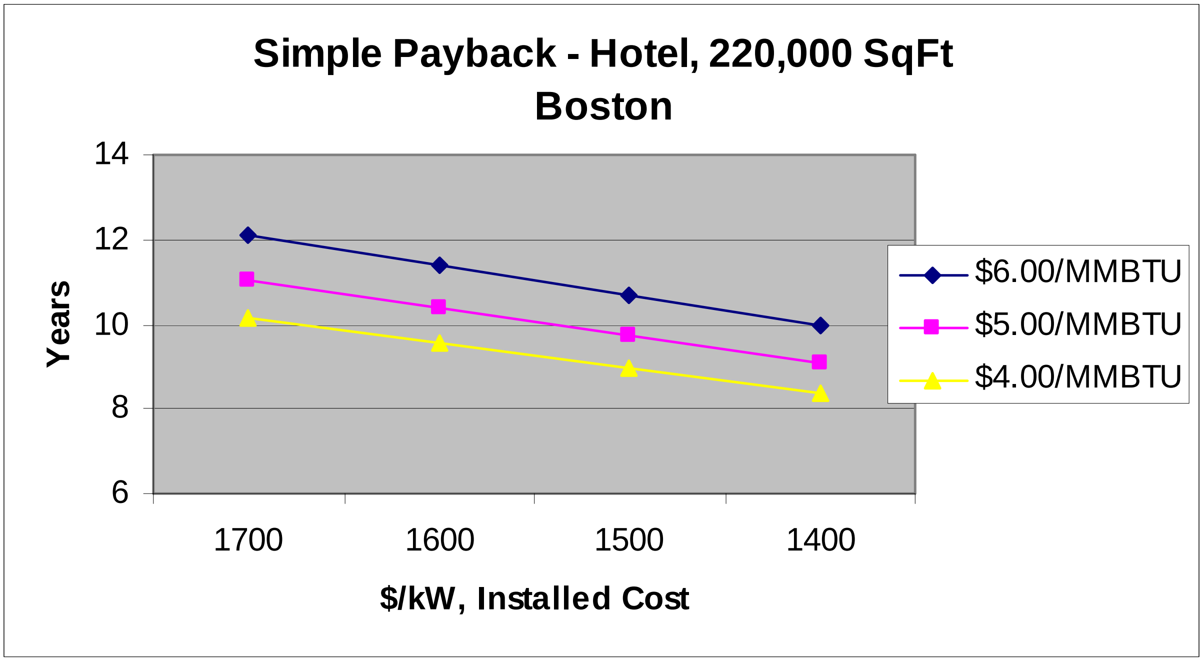


Figure 17: Payback Chart for Boston Hotel

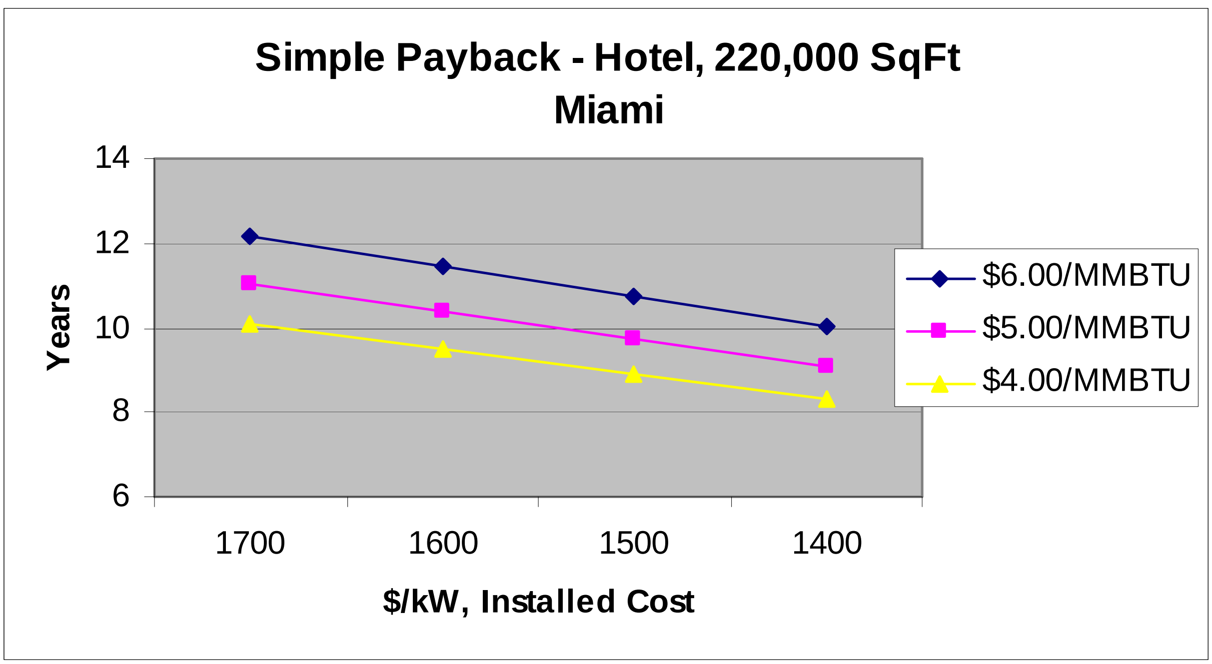


Figure 18: Payback Chart for Miami Hotel

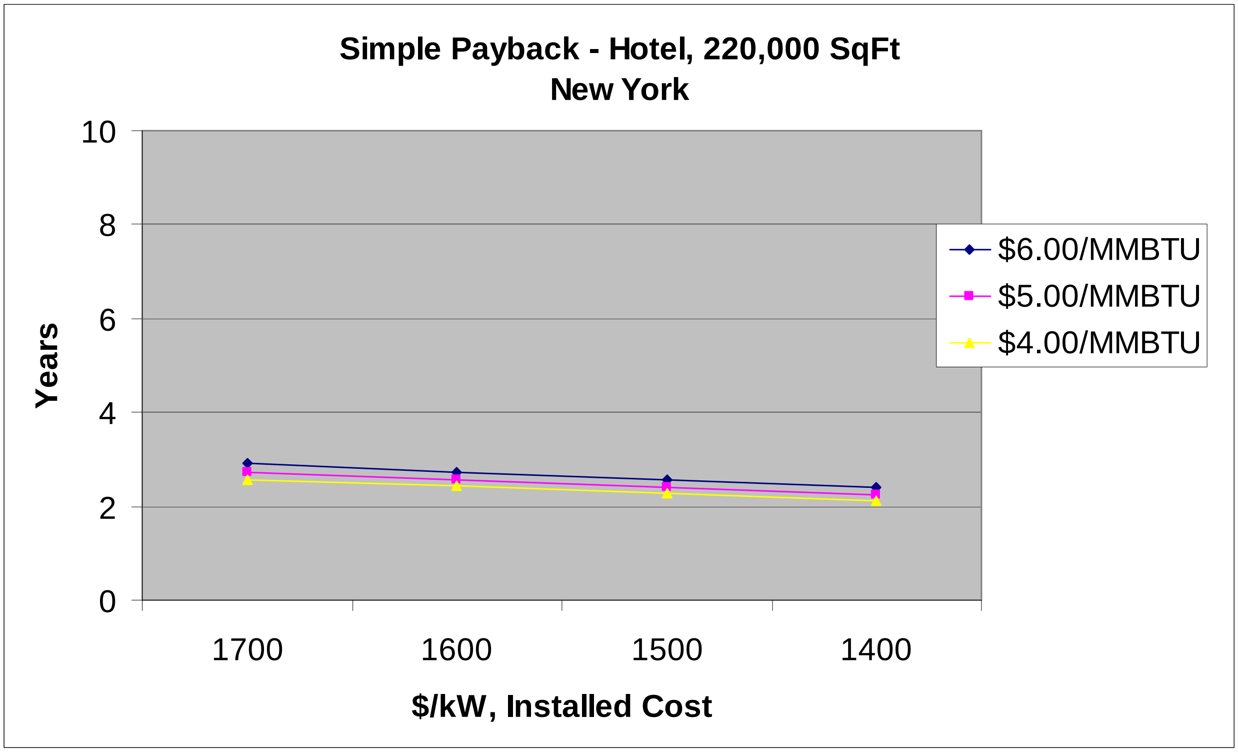


Figure 19: Payback Chart for New York Hotel

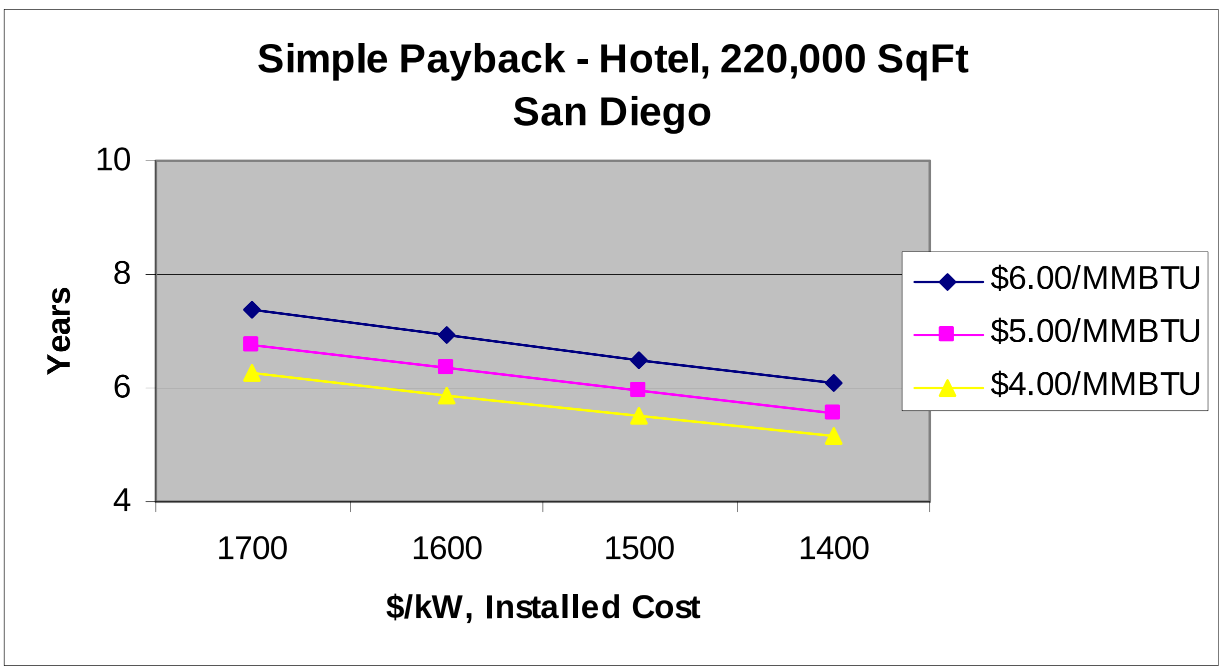


Figure 20: Payback Chart for San Diego Hotel

Detailed Data

School Building, Boston 110,000 sf

Baseline Configuration - No electric generation

	Electric Energy					Natural Gas Energy				Total Energy Cost
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	$
Jan	108950	460.2	1601	5311	7562	18935.6	1010.4	11361	11361	18,924
Feb	98233	467.8	1449	5398	7494	15481.7	943.2	9289	9289	16,783
Mar	118752	497.1	1779	5737	8208	14734.7	754.9	8841	8841	17,049
Apr	118708	540.2	1719	6234	8677	10008.0	625.1	6005	6005	14,681
May	135433	731.2	1966	8439	11299	5284.9	404.9	3171	3171	14,470
Jun	90877	577.2	1951	14267	17520	2520.2	238.0	1512	1512	19,032
Jul	106168	598.0	2326	14783	18473	1292.8	122.8	776	776	19,249
Aug	105674	581.1	2305	14364	18002	1510.8	105.8	906	906	18,909
Sep	130512	717.8	2752	17743	22097	2278.9	191.9	1367	1367	23,464
Oct	128263	526.9	1883	6081	8688	6698.3	413.5	4019	4019	12,707
Nov	108414	527.8	1643	6090	8441	11098.2	802.0	6659	6659	15,100
Dec	105089	488.1	1546	5633	7847	14971.5	1256.2	8983	8983	16,830
Tot.	**1,355,074**	**6,713**	**22,918**	**110,080**	**144,308**	**104,816**	**6,869**	**62,889**	**62,889**	**207,198**
Avr.	**112,923**	**559**	**1,910**	**9,173**	**12,026**	**8,735**	**572**	**5,241**	**5,241**	**17,266**
Max		**731**					**1,256**			

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

School Building, Boston 110,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	46,424	199	460	2,299	3,119	22,453	1,157	13,472	0	13,472	16,590	707	17,298
Feb	40,253	199	391	2,292	3,037	18,707	1,090	11,224	0	11,224	14,262	654	14,916
Mar	42,490	199	387	2,301	3,043	18,882	919	11,329	0	11,329	14,372	846	15,218
Apr	44,013	200	356	2,307	3,016	14,003	810	8,402	0	8,402	11,417	804	12,221
May	48,312	142	376	1,638	2,321	9,927	595	5,956	0	5,956	8,277	889	9,166
Jun	38,802	48	362	1,185	1,822	5,525	356	3,315	0	3,315	5,137	520	5,657
Jul	43,146	48	403	1,185	1,865	4,933	279	2,960	0	2,960	4,825	616	5,441
Aug	43,351	48	403	1,185	1,866	5,248	260	3,149	0	3,149	5,015	615	5,630
Sep	58,666	142	560	3,508	4,520	6,274	369	3,765	0	3,765	8,285	708	8,993
Oct	44,510	142	355	1,638	2,298	11,147	608	6,688	0	6,688	8,987	876	9,863
Nov	37,616	200	351	2,307	3,011	14,940	960	8,964	0	8,964	11,975	778	12,753
Dec	42,032	200	395	2,307	3,058	18,468	1,404	11,081	0	11,081	14,139	709	14,848
Tot.	**529,614**	**1,767**	**4,798**	**24,152**	**32,976**	**150,508**	**8,805**	**90,305**	**0**	**90,305**	**123,281**	**8,723**	**132,004**
Avr.	**44,135**	**147**	**400**	**2,013**	**2,748**	**12,542**	**734**	**7,525**	**0**	**7,525**	**10,273**	**727**	**11,000**
Max		**200**					**1,404**						

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School Building, Boston 110,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	64,293	64,293	64,293	7,945	3,631	3,631	100.0	181	181	181	24.3	27.6	73.3
Feb	59,476	59,476	59,476	7,287	3,330	3,330	100.0	161	161	161	24.0	27.8	73.5
Mar	76,942	76,942	76,942	9,335	4,266	4,254	99.7	199	199	199	26.7	28.1	73.7
Apr	73,050	73,050	73,050	8,822	4,032	3,958	98.2	185	185	185	25.7	28.3	73.1
May	80,822	80,822	80,822	9,699	4,432	4,147	93.6	199	199	199	26.7	28.4	71.2
Jun	47,285	47,285	47,285	5,975	2,730	2,435	89.2	147	147	147	20.4	27.0	67.8
Jul	55,996	55,996	55,996	6,807	3,111	2,597	83.5	147	147	147	19.8	28.1	66.2
Aug	55,885	55,885	55,885	6,939	3,171	2,625	82.8	161	161	161	21.6	27.5	65.3
Sep	64,368	64,368	64,368	7,654	3,498	3,000	85.8	152	152	152	21.1	28.7	67.9
Oct	79,659	79,659	79,659	9,622	4,397	4,242	96.5	202	202	202	27.2	28.2	72.3
Nov	70,764	70,764	70,764	8,617	3,938	3,916	99.4	186	186	186	25.8	28.0	73.5
Dec	64,474	64,474	64,474	7,884	3,603	3,598	99.8	173	173	173	23.3	27.9	73.5
Tot.	**793,015**	**793,015**	**793,015**	**96,586**	**44,140**	**41,733**		**2,093**	**2,093**	**2,093**			
Avr.	**66,085**	**66,085**	**66,085**	**8,049**	**3,678**	**3,478**	**94.0**	**174**	**174**	**174**	**24**	**28.0**	**70.9**
Max							**100.0**					**28.7**	**73.7**

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW

Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School Building, Boston 110,000 sf
Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	108,950	460	46,424	199	3,631	3,631	100.0	35.6	29.3	45.0	12.0	51.3	43	14
Feb	98,233	468	40,253	199	3,330	3,330	100.0	41.8	84.2	131.6	11.8	52.2	37	19
Mar	118,752	497	42,490	199	4,266	4,254	99.7	83.5	419.8	612.5	12.1	65.6	1,340	45
Apr	118,708	540	44,013	200	4,032	3,958	98.2	122.6	986.2	1,407.2	63.8	49.7	3,795	76
May	135,433	731	48,312	142	4,432	4,147	93.6	122.6	1,967.1	2,724.5	270.5	571.1	9,134	76
Jun	90,877	577	38,802	48	2,730	2,435	89.2	122.6	1,454.9	2,010.6	233.1	822.9	6,639	76
Jul	106,168	598	43,146	48	3,111	2,597	83.5	122.6	1,779.7	2,449.9	289.6	2,291.9	8,647	76
Aug	105,674	581	43,351	48	3,171	2,625	82.8	122.6	1,782.3	2,455.6	243.2	1,824.0	8,411	76
Sep	130,512	718	58,666	142	3,498	3,000	85.8	122.6	1,939.0	2,668.8	214.9	1,224.8	9,589	76
Oct	128,263	527	44,510	142	4,397	4,242	96.5	119.9	1,595.3	2,229.3	43.1	32.2	6,979	74
Nov	108,414	528	37,616	200	3,938	3,916	99.4	120.1	559.8	805.9	32.1	56.1	2,050	74
Dec	105,089	488	42,032	200	3,603	3,598	99.8	70.1	160.5	241.3	12.0	61.3	351	35
Tot.	**1,355,074**	**6,713**	**529,614**	**1,767**	**44,140**	**41,733**		**1,206.5**	**12,758**	**17,782**	**1,438.2**	**7,103**	**57,014**	
Avr.	**112,923**	**559**	**44,135**	**147**	**3,678**	**3,478**	**94.0**	**100.5**	**1,063**	**1,482**	**119.8**	**592**	**4,751**	**60**
Max		**731**		**200**										

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School Building, Boston 110,000 sf
Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.069	0.600
Feb	0.076	0.600
Mar	0.069	0.600
Apr	0.073	0.600
May	0.083	0.600
Jun	0.193	0.600
Jul	0.174	0.600
Aug	0.170	0.600
Sep	0.169	0.600
Oct	0.068	0.600
Nov	0.078	0.600
Dec	0.075	0.600
Avr.	**0.108**	**0.600**
Total		

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.067	0.600	0.085	2,179	0.051	0.1366
Feb	0.075	0.600	0.085	1,998	0.051	0.1295
Mar	0.072	0.600	0.084	2,552	0.051	0.1061
Apr	0.069	0.600	0.083	2,375	0.051	0.0841
May	0.048	0.600	0.083	2,488	0.052	0.0517
Jun	0.047	0.600	0.087	1,461	0.056	0.0487
Jul	0.043	0.600	0.084	1,558	0.056	0.0392
Aug	0.043	0.600	0.085	1,575	0.057	0.0409
Sep	0.077	0.600	0.082	1,800	0.054	0.0585
Oct	0.052	0.600	0.083	2,545	0.052	0.0589
Nov	0.080	0.600	0.084	2,350	0.051	0.0960
Dec	0.073	0.600	0.084	2,159	0.051	0.1191
Avr.	**0.062**	**0.600**	**0.084**	**2,087**	**0.053**	**0.081**
Total				**$25,040**		

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

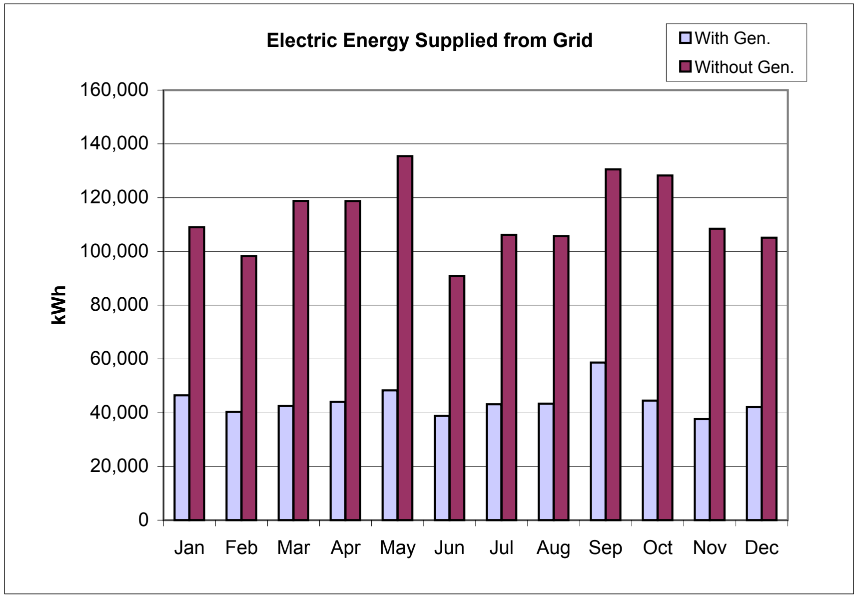
Baseline	On Site Generation
$207,198	**$132,004**

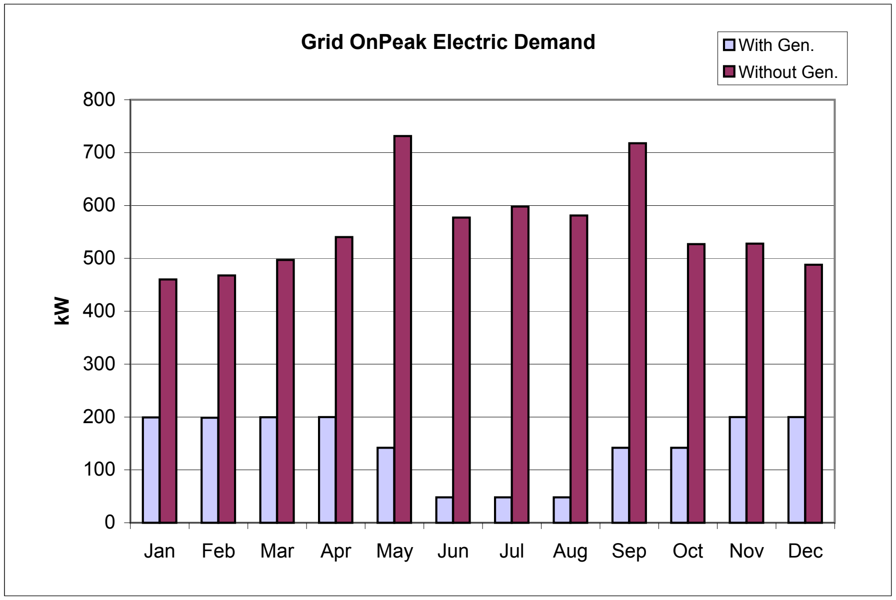
Annual Savings

$75,194

Note: * Cost of elctric generation including benefits of recoverable heat

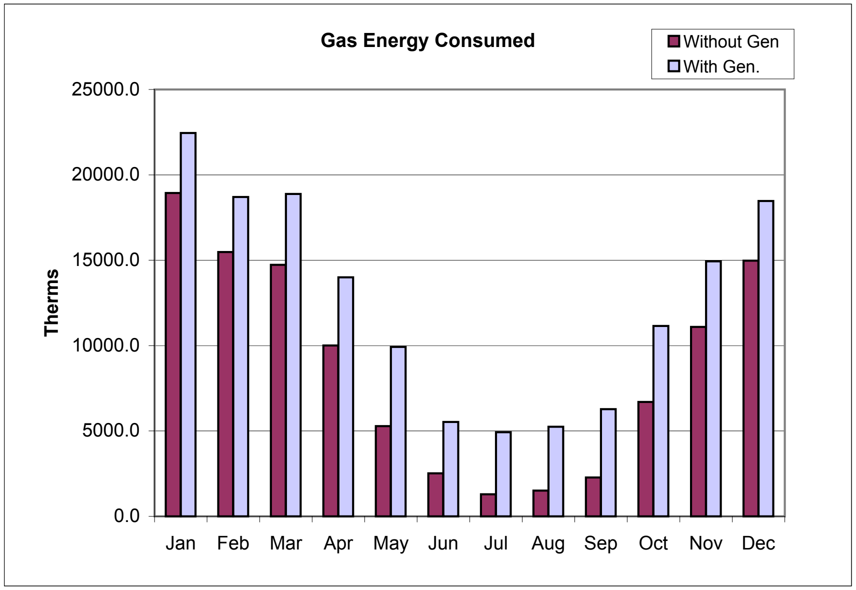
School Building, Boston 110,000 sf

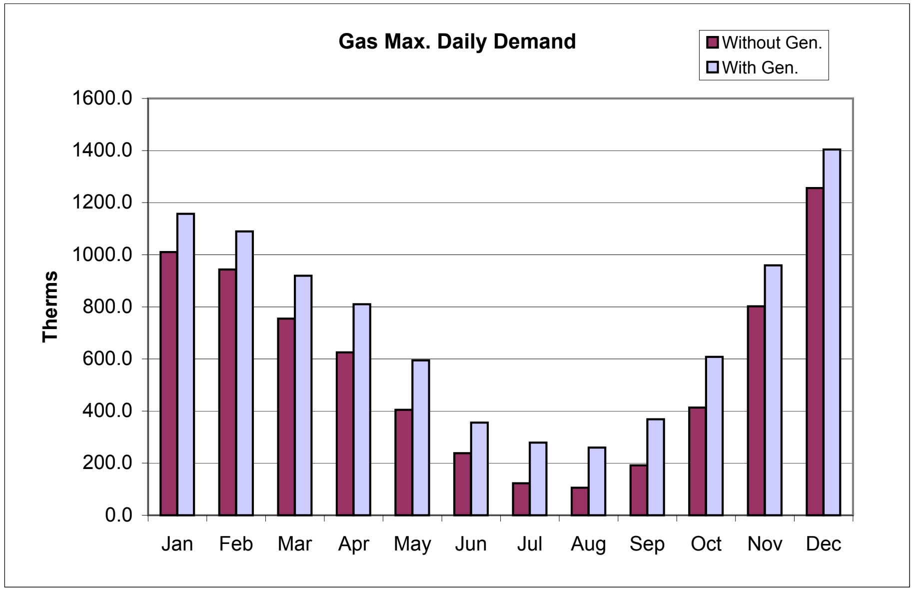




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Without (Boston Electric Rate T-2 TOU > 300 kW < 1000 kW

School Building, Boston 110,000 sf

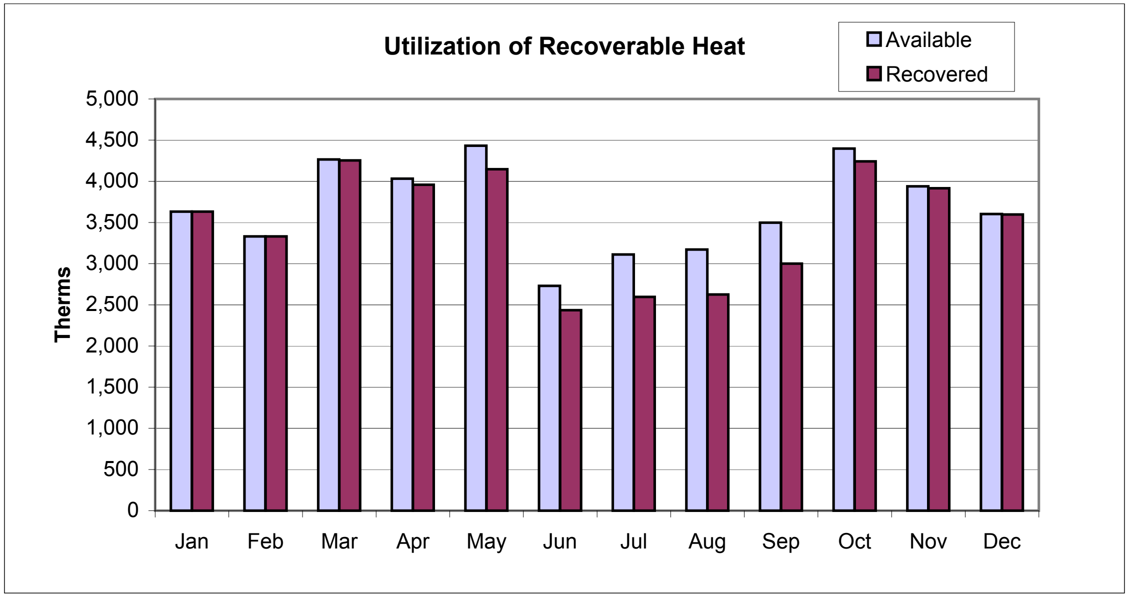




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

School Building, Boston 110,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

School Building, Chicago 120,000 sf

Baseline Configuration - No electric generation

	Electric Energy					Natural Gas Energy				Total Energy Cost
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	$
Jan	113266	475.3	5148	5291	11491	19465.1	1235.7	11679	11679	23,170
Feb	100044	465.9	4546	5186	10715	15567.3	972.0	9340	9340	20,055
Mar	118231	502.0	5463	5587	12162	14721.3	774.8	8833	8833	20,995
Apr	119664	510.7	5337	5684	12131	8865.8	726.1	5320	5320	17,450
May	141105	754.0	6271	8392	16125	4350.1	355.9	2610	2610	18,735
Jun	104684	708.1	4628	10083	16178	1441.4	142.4	865	865	17,043
Jul	115871	697.6	5109	9933	16541	1165.6	69.1	699	699	17,241
Aug	117707	671.2	5247	9558	16282	1362.6	87.8	818	818	17,099
Sep	134842	753.7	5962	10732	18353	2314.1	225.9	1388	1388	19,742
Oct	132286	566.5	5927	6305	13459	6377.1	467.0	3826	3826	17,285
Nov	110691	594.2	5160	6613	12955	11395.7	689.3	6837	6837	19,793
Dec	104425	463.0	4724	5153	10875	17119.2	1504.1	10272	10272	21,146
Tot.	**1,412,816**	**7,162**	**63,522**	**88,518**	**167,266**	**104,146**	**7,250**	**62,487**	**62,487**	**229,754**
Avr.	**117,735**	**597**	**5,293**	**7,376**	**13,939**	**8,679**	**604**	**5,207**	**5,207**	**19,146**
Max		**754**					**1,504**			

Energy Rates: Chicago Rate 6 TOU < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

School Building, Chicago 120,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	52,905	200	1,769	2,224	6,535	22,825	1,366	13,695	0	13,695	20,230	681	20,911
Feb	47,071	200	1,580	2,225	6,329	18,492	1,102	11,095	0	11,095	17,424	597	18,020
Mar	47,846	200	1,522	2,222	6,262	18,566	951	11,140	0	11,140	17,402	784	18,187
Apr	51,911	168	1,544	1,872	5,903	12,501	858	7,501	0	7,501	13,404	724	14,127
May	60,333	142	1,748	1,579	5,806	8,794	526	5,277	0	5,277	11,082	812	11,894
Jun	42,366	48	1,139	683	4,153	5,128	311	3,077	0	3,077	7,230	613	7,843
Jul	47,122	48	1,260	683	4,286	5,274	329	3,165	0	3,165	7,451	674	8,125
Aug	46,122	48	1,239	683	4,263	5,600	330	3,360	0	3,360	7,623	702	8,325
Sep	57,110	142	1,610	2,021	6,138	6,961	429	4,177	0	4,177	10,314	774	11,089
Oct	55,791	142	1,644	1,579	5,691	10,628	637	6,377	0	6,377	12,068	792	12,859
Nov	42,217	168	1,326	1,871	5,663	15,134	861	9,080	0	9,080	14,744	756	15,499
Dec	47,387	177	1,530	1,965	5,989	20,313	1,636	12,188	0	12,188	18,177	644	18,821
Tot.	**598,180**	**1,682**	**17,910**	**19,607**	**67,019**	**150,216**	**9,337**	**90,129**	**0**	**90,129**	**157,148**	**8,553**	**165,701**
Avr.	**49,848**	**140**	**1,493**	**1,634**	**5,585**	**12,518**	**778**	**7,511**	**0**	**7,511**	**13,096**	**713**	**13,808**
Max		**200**					**1,636**						

Energy Rates: Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School Building, Chicago 120,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	61,922	61,922	61,922	7,590	3,468	3,468	100.0	168	168	168	22.6	27.8	73.5
Feb	54,228	54,228	54,228	6,606	3,019	3,019	100.0	143	143	143	21.3	28.0	73.7
Mar	71,314	71,314	71,314	8,656	3,956	3,945	99.7	185	185	185	24.9	28.1	73.7
Apr	65,803	65,546	65,803	7,948	3,632	3,536	97.4	167	166	167	23.2	28.2	72.7
May	73,794	72,828	73,794	8,833	4,037	3,599	89.2	180	176	180	24.2	28.5	69.2
Jun	55,709	55,709	55,709	6,780	3,098	2,536	81.9	147	147	147	20.4	28.0	65.4
Jul	61,299	61,299	61,299	7,312	3,342	2,627	78.6	147	147	147	19.8	28.6	64.5
Aug	63,826	63,826	63,826	7,694	3,516	2,835	80.6	161	161	161	21.6	28.3	65.1
Sep	70,394	66,756	70,394	8,377	3,828	3,058	79.9	167	152	167	23.2	28.7	65.2
Oct	71,964	71,482	71,964	8,673	3,964	3,627	91.5	181	179	181	24.3	28.3	70.1
Nov	68,702	68,702	68,702	8,338	3,810	3,771	99.0	178	178	178	24.7	28.1	73.3
Dec	58,585	58,585	58,585	7,215	3,297	3,297	100.0	162	162	162	21.8	27.7	73.4
Tot.	**777,539**	**772,196**	**777,539**	**94,020**	**42,967**	**39,319**		**1,986**	**1,964**	**1,986**			
Avr.	**64,795**	**64,350**	**64,795**	**7,835**	**3,581**	**3,277**	**91.5**	**166**	**164**	**166**	**23**	**28.2**	**70.0**
Max							**100.0**					**28.7**	**73.7**

Energy Rates: Chicago Electric Rate 6 TOU - 18 Standby <1000 kW

Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School Building, Chicago 120,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	113,266	475	52,905	200	3,468	3,468	100.0	43.7	69.4	106.3	12.1	65.5	102	21
Feb	100,044	466	47,071	200	3,019	3,019	100.0	41.2	92.9	142.3	12.1	58.7	147	19
Mar	118,231	502	47,846	200	3,956	3,945	99.7	79.3	346.1	514.5	12.2	54.8	866	42
Apr	119,664	511	51,911	168	3,632	3,536	97.4	106.1	1,014.4	1,435.7	11.0	7.8	4,174	63
May	141,105	754	60,333	142	4,037	3,599	89.2	122.6	1,997.8	2,755.7	271.6	893.3	9,578	76
Jun	104,684	708	42,366	48	3,098	2,536	81.9	122.6	1,736.0	2,391.5	435.8	2,185.7	8,363	76
Jul	115,871	698	47,122	48	3,342	2,627	78.6	122.6	1,830.6	2,523.6	416.4	3,242.8	8,977	76
Aug	117,707	671	46,122	48	3,516	2,835	80.6	122.6	1,963.1	2,704.6	385.4	2,865.0	9,560	76
Sep	134,842	754	57,110	142	3,828	3,058	79.9	122.6	1,958.4	2,699.6	260.3	1,566.5	9,614	76
Oct	132,286	567	55,791	142	3,964	3,627	91.5	122.6	1,603.1	2,228.9	132.7	220.6	7,229	76
Nov	110,691	594	42,217	168	3,810	3,771	99.0	122.6	479.0	696.5	135.6	157.1	1,566	76
Dec	104,425	463	47,387	177	3,297	3,297	100.0	32.8	55.2	84.7	12.2	70.7	90	12
Tot.	**1,412,816**	**7,162**	**598,180**	**1,682**	**42,967**	**39,319**		**1,161.2**	**13,146**	**18,284**	**2,097.3**	**11,388**	**60,266**	
Avr.	**117,735**	**597**	**49,848**	**140**	**3,581**	**3,277**	**91.5**	**96.8**	**1,095**	**1,524**	**174.8**	**949**	**5,022**	**57**
Max		**754**		**200**										

Energy Rates: Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School Building, Chicago 120,000 sf
Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

	Baseline		**On Site Generation**					
	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.101	0.600	0.124	0.600	0.085	2,081	0.051	0.1640
Feb	0.107	0.600	0.134	0.600	0.084	1,811	0.051	0.1600
Mar	0.103	0.600	0.131	0.600	0.084	2,367	0.051	0.1328
Apr	0.101	0.600	0.114	0.600	0.083	2,122	0.051	0.1020
May	0.114	0.600	0.096	0.600	0.083	2,159	0.054	0.0726
Jun	0.155	0.600	0.098	0.600	0.084	1,522	0.057	0.0644
Jul	0.143	0.600	0.091	0.600	0.083	1,576	0.057	0.0604
Aug	0.138	0.600	0.092	0.600	0.083	1,701	0.057	0.0603
Sep	0.136	0.600	0.107	0.600	0.082	1,835	0.056	0.0726
Oct	0.102	0.600	0.102	0.600	0.083	2,176	0.053	0.0836
Nov	0.117	0.600	0.134	0.600	0.084	2,263	0.051	0.1193
Dec	0.104	0.600	0.126	0.600	0.085	1,978	0.051	0.1589
Avr.	**0.118**	**0.600**	**0.112**	**0.600**	**0.084**	**1,966**	**0.053**	**0.104**
Total						**$23,591**		

Chicago Rate 6 TOU < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

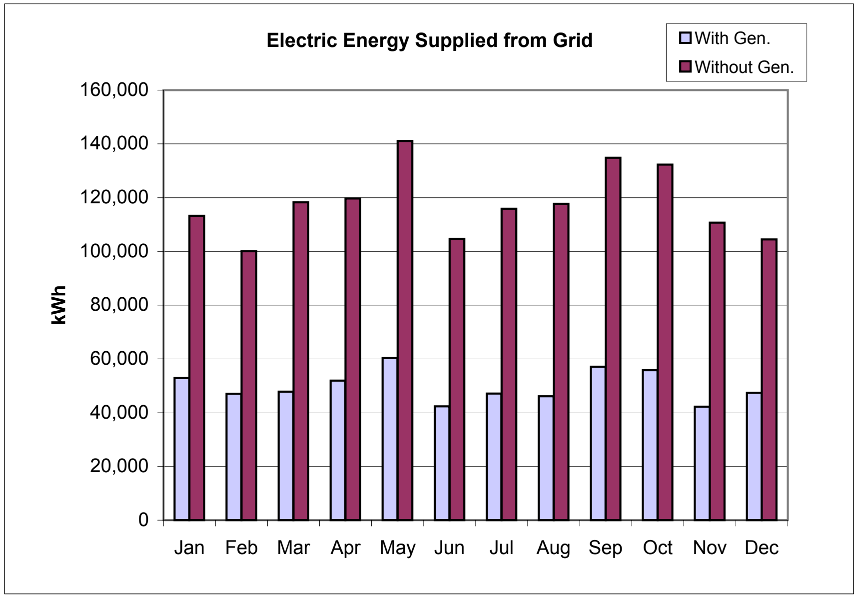
Baseline	On Site Generation
$229,754	**$165,701**

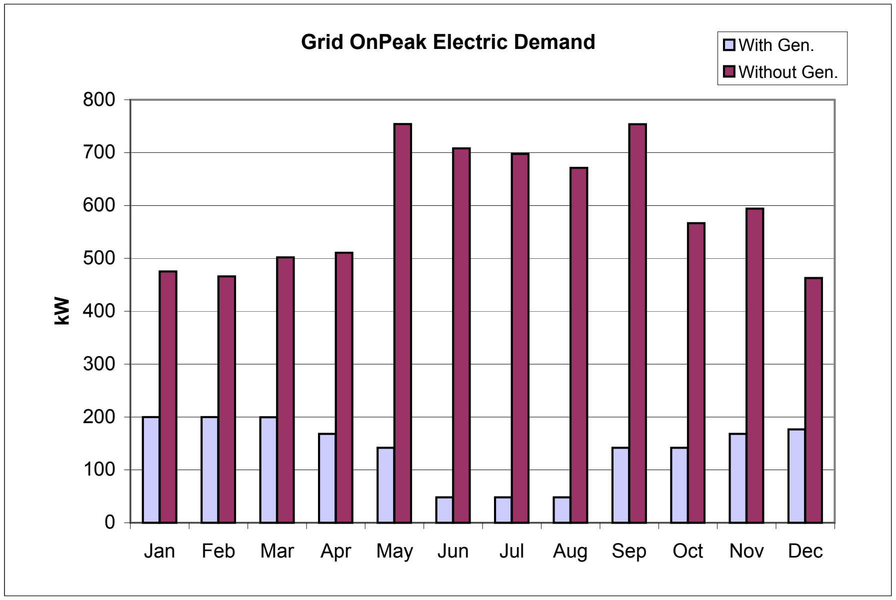
Annual Savings

$64,053

Note: * Cost of elctric generation including benefits of recoverable heat

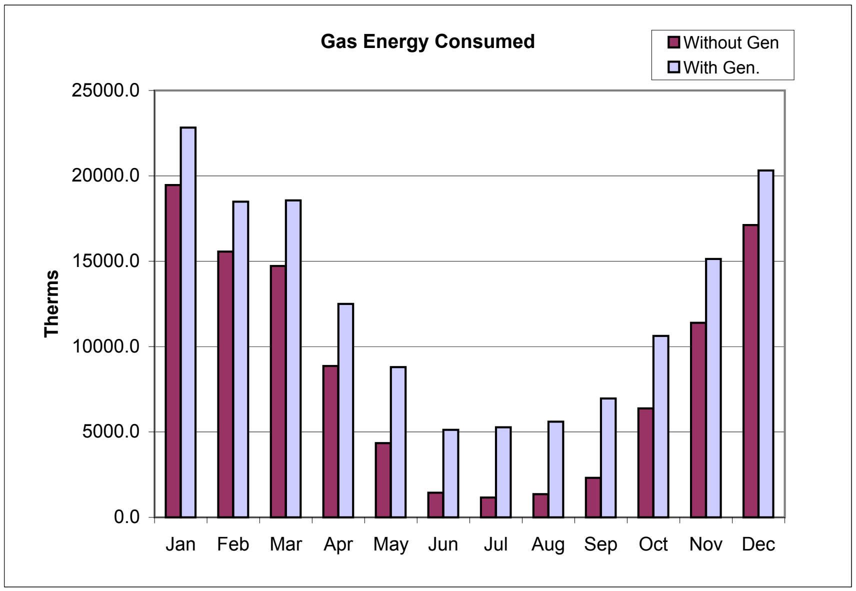
School Building, Chicago 120,000 sf

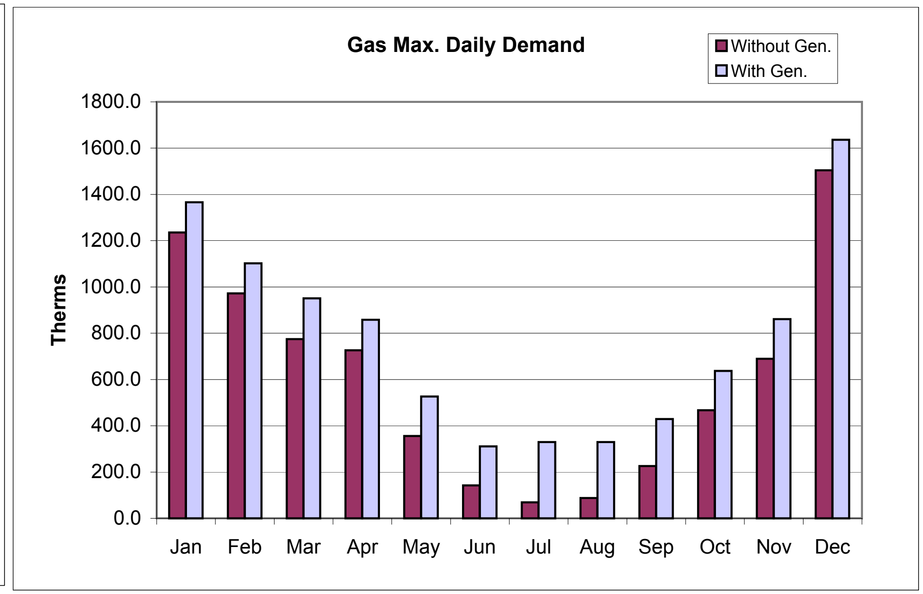




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Without (Chicago Rate 6 TOU < 1000 kW

School Building, Chicago 120,000 sf

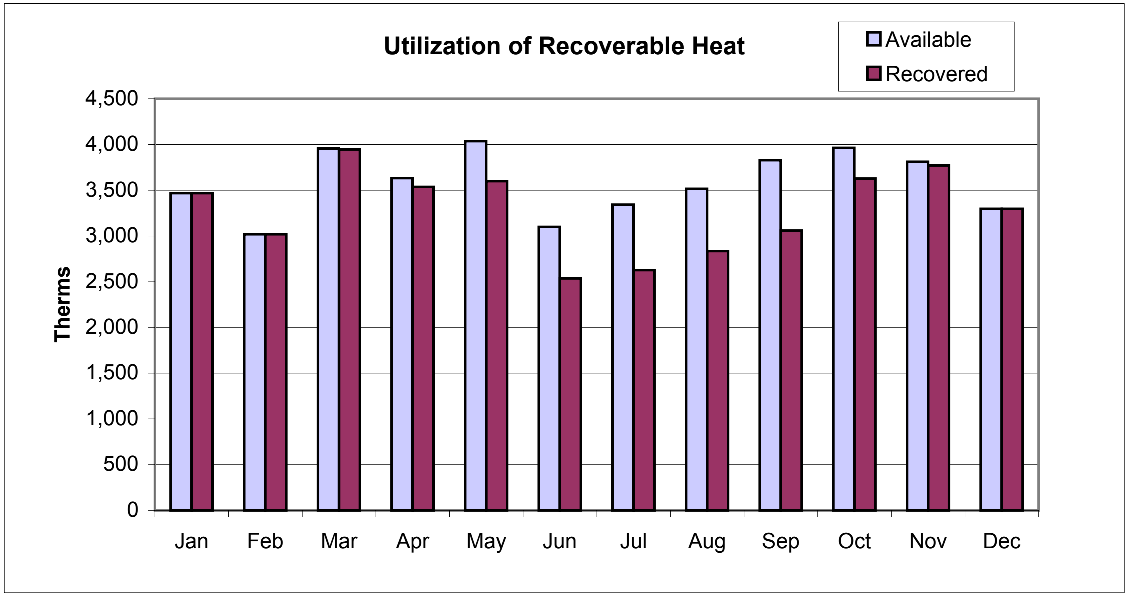




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

School Building, Chicago 120,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

School, Miami 110,000 sf

Baseline Configuration - No electric generation

	Electric Energy					**Natural Gas Energy**				**Total Energy Cost**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	**$**
Jan	170772	729.7	8543	7539	17245	2519.7	276.0	1512	1512	18,757
Feb	151854	760.9	7604	7822	16544	1668.6	172.1	1001	1001	17,545
Mar	183029	810.5	9175	8141	18566	1952.6	215.2	1172	1172	19,737
Apr	191105	871.9	9933	7149	18316	1349.7	88.8	810	810	19,126
May	236238	933.6	12223	7655	21308	1307.1	58.4	784	784	22,092
Jun	166285	803.8	8467	6609	16169	1037.1	45.0	622	622	16,791
Jul	180422	767.6	9148	6331	16600	1038.7	44.8	623	623	17,224
Aug	188105	813.8	9541	6673	17387	1107.6	44.7	665	665	18,052
Sep	230910	935.0	11838	7667	20908	1128.5	53.4	677	677	21,585
Oct	228503	911.5	11867	7474	20733	1295.9	63.9	778	778	21,511
Nov	179970	812.1	8999	8186	18426	1248.2	71.5	749	749	19,175
Dec	156799	729.2	7848	7542	16505	1556.6	125.4	934	934	17,439
Tot.	**2,263,992**	**9,880**	**115,183**	**88,788**	**218,707**	**17,210**	**1,259**	**10,326**	**10,326**	**229,033**
Avr.	**188,666**	**823**	**9,599**	**7,399**	**18,226**	**1,434**	**105**	**861**	**861**	**19,086**
Max		**935**					**276**			

Energy Rates: Miami FPL Rate GSLDT-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

School, Miami 110,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	126,698	192	5,738	3,860	11,936	5,310	388	3,186	0	3,186	15,122	453	15,575
Feb	112,210	142	5,081	3,355	10,692	4,221	256	2,533	0	2,533	13,225	406	13,630
Mar	134,498	142	6,086	3,672	12,106	5,152	329	3,091	0	3,091	15,197	497	15,694
Apr	124,968	199	5,724	3,194	11,207	5,882	303	3,529	0	3,529	14,737	670	15,407
May	160,737	260	7,418	3,691	13,552	6,544	309	3,926	0	3,926	17,478	768	18,246
Jun	112,521	138	5,045	2,738	9,993	4,547	228	2,728	0	2,728	12,721	538	13,260
Jul	125,766	130	5,669	2,626	10,541	4,628	222	2,777	0	2,777	13,318	548	13,866
Aug	129,159	147	5,790	2,676	10,724	4,954	226	2,973	0	2,973	13,697	590	14,286
Sep	162,989	262	7,515	3,728	13,696	5,901	335	3,541	0	3,541	17,237	693	17,929
Oct	152,323	238	7,019	3,517	12,939	6,589	339	3,953	0	3,953	16,892	775	17,667
Nov	133,501	142	6,042	3,711	12,101	4,379	251	2,627	0	2,627	14,728	472	15,201
Dec	115,570	142	5,224	3,075	10,546	4,235	239	2,541	0	2,541	13,086	421	13,507
Tot.	**1,590,940**	**2,133**	**72,350**	**39,844**	**140,032**	**62,343**	**3,425**	**37,406**	**0**	**37,406**	**177,438**	**6,830**	**184,268**
Avr.	**132,578**	**178**	**6,029**	**3,320**	**11,669**	**5,195**	**285**	**3,117**	**0**	**3,117**	**14,786**	**569**	**15,356**
Max		**262**					**388**						

Energy Rates: Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School, Miami 110,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	41,213	41,213	41,213	4,994	2,282	1,807	79.2	106	106	106	14.2	28.2	64.3
Feb	36,898	36,898	36,898	4,452	2,035	1,558	76.6	93	93	93	13.8	28.3	63.3
Mar	45,146	45,146	45,146	5,394	2,465	1,800	73.0	109	109	109	14.7	28.6	61.9
Apr	60,922	60,922	60,922	7,057	3,225	2,070	64.2	126	126	126	17.5	29.5	58.8
May	69,809	69,809	69,809	7,954	3,635	2,228	61.3	132	132	132	17.7	29.9	58.0
Jun	48,928	48,928	48,928	5,485	2,507	1,619	64.6	84	84	84	11.7	30.4	60.0
Jul	49,796	49,796	49,796	5,566	2,544	1,621	63.7	84	84	84	11.3	30.5	59.6
Aug	53,623	53,623	53,623	6,010	2,747	1,774	64.6	92	92	92	12.4	30.4	60.0
Sep	62,978	62,978	62,978	7,130	3,259	1,933	59.3	115	115	115	16.0	30.1	57.2
Oct	70,414	70,414	70,414	8,053	3,680	2,263	61.5	136	136	136	18.3	29.8	57.9
Nov	42,952	42,952	42,952	5,092	2,327	1,608	69.1	100	100	100	13.9	28.8	60.4
Dec	38,254	38,254	38,254	4,653	2,126	1,620	76.2	100	100	100	13.4	28.1	62.9
Tot.	**620,932**	**620,932**	**620,932**	**71,842**	**32,832**	**21,902**		**1,277**	**1,277**	**1,277**			
Avr.	**51,744**	**51,744**	**51,744**	**5,987**	**2,736**	**1,825**	**67.8**	**106**	**106**	**106**	**15**	**29.4**	**60.4**
Max							**79.2**					**30.5**	**64.3**

Energy Rates:	Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
	Gen. Service, Natural Gas - $0.6/therm (flat)
Generator Type:	VGF36GLD Engine Generator, 615 kWe

School, Miami 110,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	170,772	730	126,698	192	2,282	1,807	79.2	113.0	973.6	1,376.0	260.3	744.3	4,455	68
Feb	151,854	761	112,210	142	2,035	1,558	76.6	113.0	911.1	1,286.2	293.5	767.0	4,228	68
Mar	183,029	811	134,498	142	2,465	1,800	73.0	113.0	1,075.8	1,519.4	368.2	1,345.5	5,000	68
Apr	191,105	872	124,968	199	3,225	2,070	64.2	113.0	1,413.9	1,992.3	408.4	3,089.7	6,821	68
May	236,238	934	160,737	260	3,635	2,228	61.3	113.0	1,525.1	2,149.2	491.2	4,648.4	7,431	68
Jun	166,285	804	112,521	138	2,507	1,619	64.6	113.0	1,129.1	1,588.6	531.3	3,618.9	5,670	68
Jul	180,422	768	125,766	130	2,544	1,621	63.7	113.0	1,132.7	1,591.2	487.6	3,996.4	5,693	68
Aug	188,105	814	129,159	147	2,747	1,774	64.6	113.0	1,240.6	1,742.2	543.7	4,117.4	6,235	68
Sep	230,910	935	162,989	262	3,259	1,933	59.3	113.0	1,326.6	1,870.3	517.1	4,620.1	6,466	68
Oct	228,503	911	152,323	238	3,680	2,263	61.5	113.0	1,550.9	2,185.9	460.7	4,306.2	7,526	68
Nov	179,970	812	133,501	142	2,327	1,608	69.1	113.0	1,053.5	1,486.0	369.2	1,618.1	4,989	68
Dec	156,799	729	115,570	142	2,126	1,620	76.2	113.0	988.9	1,395.6	261.2	653.1	4,595	68
Tot.	**2,263,992**	**9,880**	**1,590,940**	**2,133**	**32,832**	**21,902**		**1,355.7**	**14,322**	**20,183**	**4,992.2**	**33,525**	**69,109**	
Avr.	**188,666**	**823**	**132,578**	**178**	**2,736**	**1,825**	**67.8**	**113.0**	**1,193**	**1,682**	**416.0**	**2,794**	**5,759**	**68**
Max		**935**		**262**										

Energy Rates: Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School, Miami 110,000 sf

Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.101	0.600
Feb	0.109	0.600
Mar	0.101	0.600
Apr	0.096	0.600
May	0.090	0.600
Jun	0.097	0.600
Jul	0.092	0.600
Aug	0.092	0.600
Sep	0.091	0.600
Oct	0.091	0.600
Nov	0.102	0.600
Dec	0.105	0.600
Avr.	**0.097**	**0.600**
Total		

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.094	0.600	0.084	1,084	0.057	0.0863
Feb	0.095	0.600	0.083	935	0.058	0.0851
Mar	0.090	0.600	0.083	1,080	0.059	0.0814
Apr	0.090	0.600	0.081	1,242	0.060	0.0762
May	0.084	0.600	0.079	1,337	0.060	0.0733
Jun	0.089	0.600	0.078	972	0.058	0.0761
Jul	0.084	0.600	0.078	973	0.059	0.0734
Aug	0.083	0.600	0.078	1,065	0.058	0.0723
Sep	0.084	0.600	0.079	1,160	0.061	0.0742
Oct	0.085	0.600	0.080	1,358	0.060	0.0732
Nov	0.091	0.600	0.082	965	0.060	0.0807
Dec	0.091	0.600	0.084	972	0.059	0.0815
Avr.	**0.088**	**0.600**	**0.081**	**1,095**	**0.059**	**0.078**
Total				**$13,141**		

Miami FPL Rate GSLDT-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

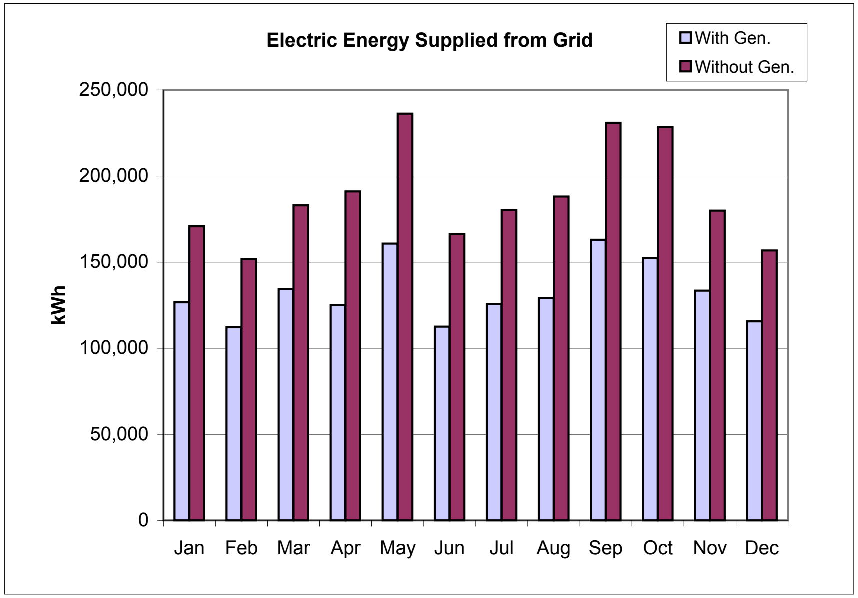
Baseline	On Site Generation
$229,033	**$184,268**

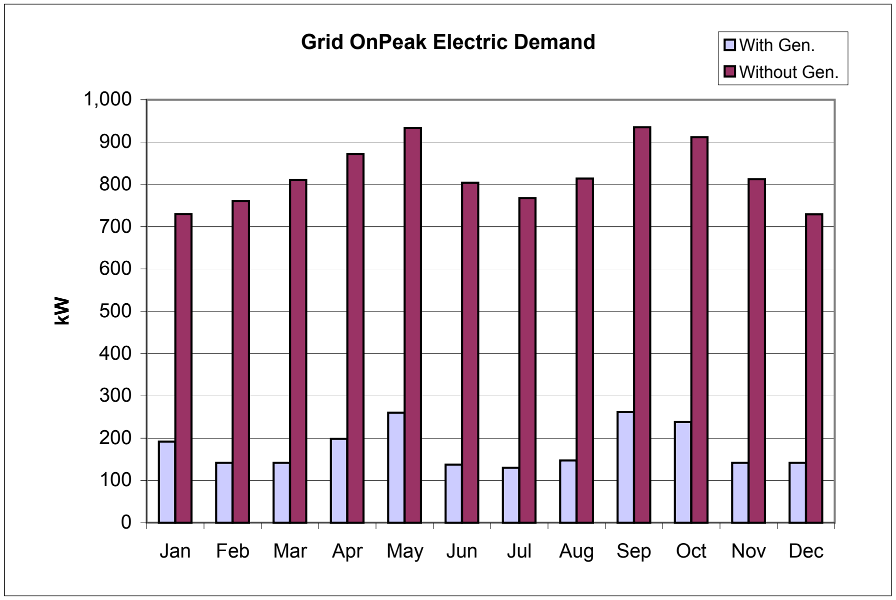
Annual Savings

$44,765

Note: * Cost of elctric generation including benefits of recoverable heat

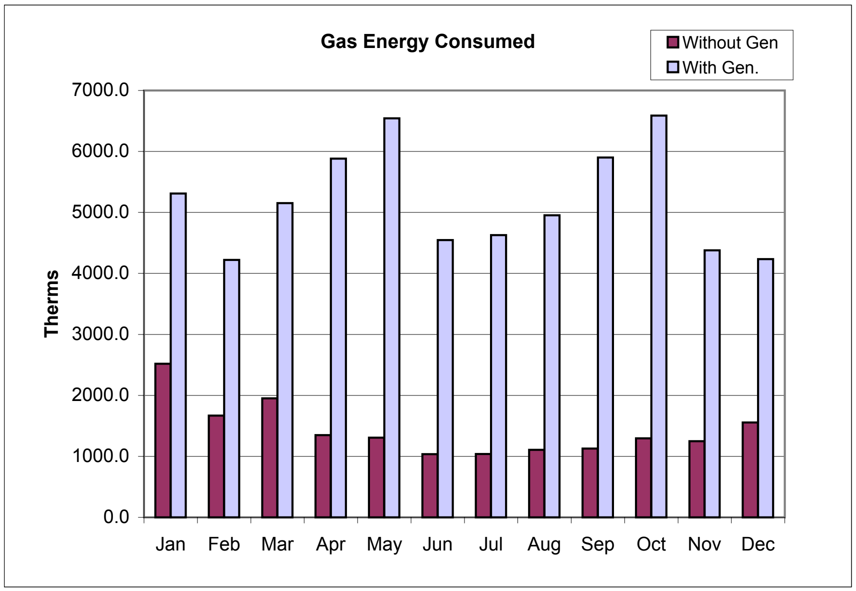
School, Miami 110,000 sf

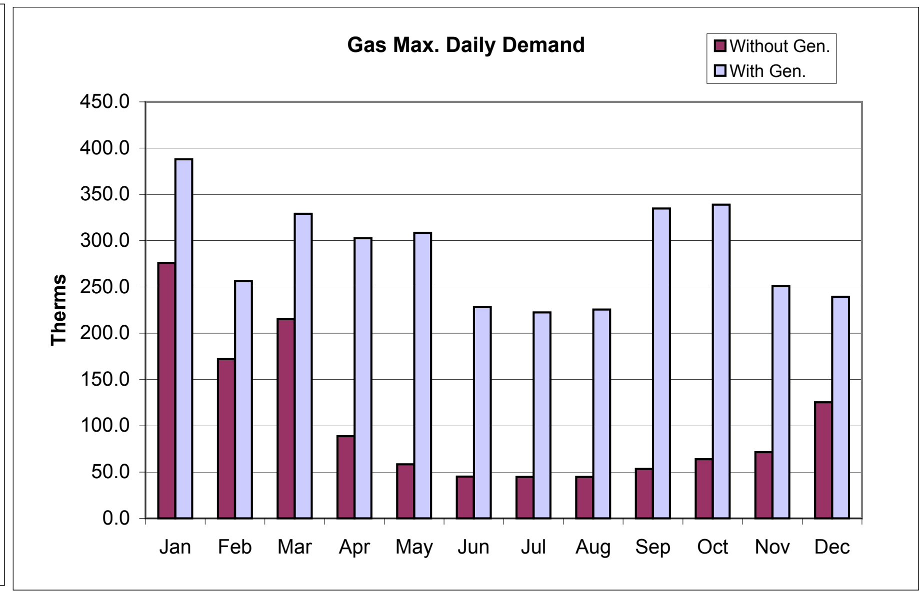




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Without (Miami FPL Rate GSLDT-1 TOU > 500 kW

School, Miami 110,000 sf

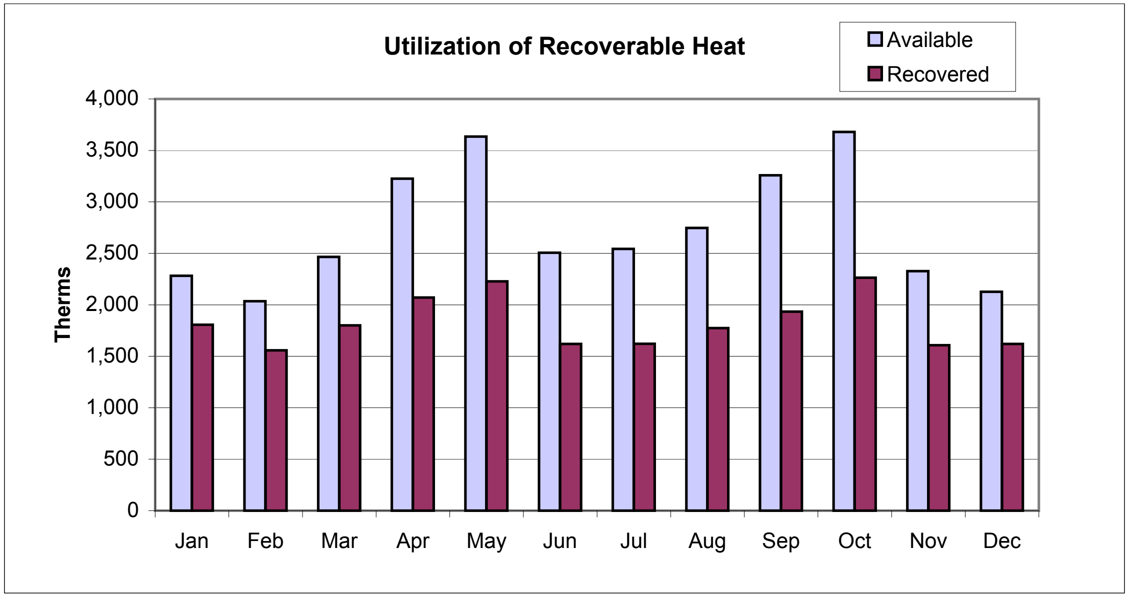




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

School, Miami 110,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

School, San Diego 110,000 sf

Baseline Configuration - No electric generation

	Electric Energy					Natural Gas Energy				Total Energy Cost
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	$
Jan	129631	259.2	11698	6491	19658	5073.5	300.5	3044	3044	22,702
Feb	115750	257.0	10445	6315	18129	3625.7	223.8	2175	2175	20,305
Mar	134577	268.6	12142	6460	20100	3815.0	240.3	2289	2289	22,389
Apr	131908	216.9	11840	7685	21088	3033.1	197.1	1820	1820	22,908
May	137914	544.0	13669	8878	24321	3170.6	191.8	1902	1902	26,223
Jun	90220	520.0	8937	8487	18840	1632.1	112.7	979	979	19,819
Jul	101637	540.7	10083	8858	20463	1217.4	79.1	730	730	21,193
Aug	109169	532.1	10886	8811	21272	1189.6	53.6	714	714	21,985
Sep	143353	704.7	14259	11500	27758	1329.2	81.3	798	798	28,555
Oct	145016	263.1	13020	8254	22958	1964.0	117.9	1178	1178	24,137
Nov	125015	281.0	11286	6910	19666	3003.1	208.0	1802	1802	21,468
Dec	122373	260.5	11039	6617	19088	4402.7	371.6	2642	2642	21,729
Tot.	**1,486,562**	**4,648**	**139,303**	**95,267**	**253,340**	**33,456**	**2,178**	**20,074**	**20,074**	**273,413**
Avr.	**123,880**	**387**	**11,609**	**7,939**	**21,112**	**2,788**	**181**	**1,673**	**1,673**	**22,784**
Max		**705**					**372**			

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

School, San Diego 110,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	27,069	142	2,506	3,264	7,488	10,558	530	6,335	0	6,335	13,823	1,059	14,882
Feb	23,224	142	2,139	3,284	6,990	8,543	477	5,126	0	5,126	12,116	938	13,053
Mar	26,102	142	2,406	3,294	7,456	9,691	473	5,815	0	5,815	13,270	1,098	14,368
Apr	23,140	142	2,196	3,310	7,229	8,990	450	5,394	0	5,394	12,624	1,092	13,716
May	22,681	142	2,070	3,626	7,633	9,366	461	5,620	0	5,620	13,253	1,154	14,407
Jun	12,830	48	1,162	2,325	4,827	6,131	335	3,679	0	3,679	8,505	774	9,279
Jul	12,921	48	1,175	782	3,308	6,495	361	3,897	0	3,897	7,205	876	8,081
Aug	12,697	48	1,155	1,346	3,980	7,003	362	4,202	0	4,202	8,182	950	9,132
Sep	22,964	142	2,085	5,663	9,890	8,808	539	5,285	0	5,285	15,174	1,202	16,376
Oct	22,409	142	2,124	4,958	9,055	9,188	459	5,513	0	5,513	14,567	1,224	15,792
Nov	23,769	142	2,181	3,358	7,202	8,584	477	5,151	0	5,151	12,353	1,020	13,373
Dec	26,270	142	2,408	3,284	7,324	9,651	598	5,791	0	5,791	13,115	981	14,096
Tot.	**256,075**	**1,421**	**23,607**	**38,492**	**82,383**	**103,007**	**5,523**	**61,804**	**0**	**61,804**	**144,187**	**12,368**	**156,556**
Avr.	**21,340**	**118**	**1,967**	**3,208**	**6,865**	**8,584**	**460**	**5,150**	**0**	**5,150**	**12,016**	**1,031**	**13,046**
Max		**142**					**598**						

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School, San Diego 110,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	96,257	6,637	96,257	11,804	5,394	5,182	96.1	260	28	260	34.9	27.8	71.7
Feb	85,264	6,443	85,264	10,517	4,806	4,592	95.5	236	27	236	35.1	27.7	71.3
Mar	99,826	7,403	99,632	12,309	5,625	5,275	93.8	276	31	275	37.1	27.7	70.5
Apr	99,274	3,564	92,998	12,243	5,595	5,154	92.1	275	15	246	38.2	27.7	69.8
May	104,919	48,975	97,180	12,994	5,938	5,575	93.9	296	132	260	39.8	27.5	70.5
Jun	70,333	32,476	66,346	8,988	4,108	3,681	89.6	229	105	210	31.8	26.7	67.7
Jul	79,633	36,719	74,946	9,897	4,523	3,788	83.8	231	105	210	31.0	27.5	65.7
Aug	86,403	41,144	81,544	10,768	4,921	4,063	82.6	253	115	230	34.0	27.4	65.1
Sep	109,241	53,136	100,647	13,067	5,971	4,582	76.7	265	114	227	36.8	28.5	63.6
Oct	111,281	5,008	103,316	13,627	6,228	5,251	84.3	300	21	263	40.3	27.9	66.4
Nov	92,767	7,676	92,366	11,442	5,229	4,806	91.9	257	32	255	35.7	27.7	69.7
Dec	89,209	6,863	89,209	10,971	5,014	4,693	93.6	244	29	244	32.8	27.7	70.5
Tot.	**1,124,406**	**256,045**	**1,079,705**	**138,629**	**63,353**	**56,644**		**3,122**	**754**	**2,916**			
Avr.	**93,701**	**21,337**	**89,975**	**11,552**	**5,279**	**4,720**	**89.5**	**260**	**63**	**243**	**36**	**27.6**	**68.5**
Max							**96.1**					**28.5**	**71.7**

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges

Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School, San Diego 110,000 sf
Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	129,631	259	27,069	142	5,394	5,182	96.1	113.0	2,294.1	3,239.7	56.5	63.9	10,202	68
Feb	115,750	257	23,224	142	4,806	4,592	95.5	113.0	2,359.0	3,320.3	40.6	59.6	10,900	68
Mar	134,577	269	26,102	142	5,625	5,275	93.8	113.0	2,790.6	3,925.6	48.6	199.1	12,937	68
Apr	131,908	217	23,140	142	5,595	5,154	92.1	113.0	2,894.5	4,069.2	160.0	557.0	13,619	68
May	137,914	544	22,681	142	5,938	5,575	93.9	113.0	3,138.8	4,412.0	76.1	495.2	14,815	68
Jun	90,220	520	12,830	48	4,108	3,681	89.6	113.0	2,262.5	3,175.4	197.7	1,179.7	10,271	68
Jul	101,637	541	12,921	48	4,523	3,788	83.8	113.0	2,539.4	3,561.2	240.2	2,559.3	11,947	68
Aug	109,169	532	12,697	48	4,921	4,063	82.6	113.0	2,774.1	3,890.8	234.9	2,916.5	13,017	68
Sep	143,353	705	22,964	142	5,971	4,582	76.7	113.0	3,012.0	4,233.8	254.1	3,025.3	14,453	68
Oct	145,016	263	22,409	142	6,228	5,251	84.3	113.0	3,283.1	4,615.3	214.8	1,639.3	15,616	68
Nov	125,015	281	23,769	142	5,229	4,806	91.9	113.0	2,651.6	3,730.8	85.3	393.3	12,411	68
Dec	122,373	260	26,270	142	5,014	4,693	93.6	113.0	2,294.6	3,236.1	67.2	165.6	10,478	68
Tot.	**1,486,562**	**4,648**	**256,075**	**1,421**	**63,353**	**56,644**		**1,355.7**	**32,294**	**45,410**	**1,676.2**	**13,254**	**150,666**	
Avr.	**123,880**	**387**	**21,340**	**118**	**5,279**	**4,720**	**89.5**	**113.0**	**2,691**	**3,784**	**139.7**	**1,104**	**12,555**	**68**
Max		**705**		**142**										

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

School, San Diego 110,000 sf

Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.152	0.600
Feb	0.157	0.600
Mar	0.149	0.600
Apr	0.160	0.600
May	0.176	0.600
Jun	0.209	0.600
Jul	0.201	0.600
Aug	0.195	0.600
Sep	0.194	0.600
Oct	0.158	0.600
Nov	0.157	0.600
Dec	0.156	0.600
Avr.	**0.172**	**0.600**
Total		

On Site Generation

Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
0.277	0.600	0.085	3,109	0.052	0.0955
0.301	0.600	0.085	2,755	0.053	0.0949
0.286	0.600	0.085	3,165	0.053	0.0890
0.312	0.600	0.085	3,093	0.054	0.0868
0.336	0.600	0.085	3,345	0.053	0.0867
0.376	0.600	0.088	2,209	0.056	0.0850
0.256	0.600	0.086	2,273	0.057	0.0627
0.313	0.600	0.086	2,438	0.058	0.0676
0.430	0.600	0.083	2,749	0.058	0.1031
0.404	0.600	0.084	3,151	0.056	0.0946
0.303	0.600	0.085	2,884	0.054	0.0900
0.279	0.600	0.085	2,816	0.053	0.0977
0.323	**0.600**	**0.085**	**2,832**	**0.055**	**0.088**
			$33,986		

SDG&E AL-TOU_DER + EECC > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

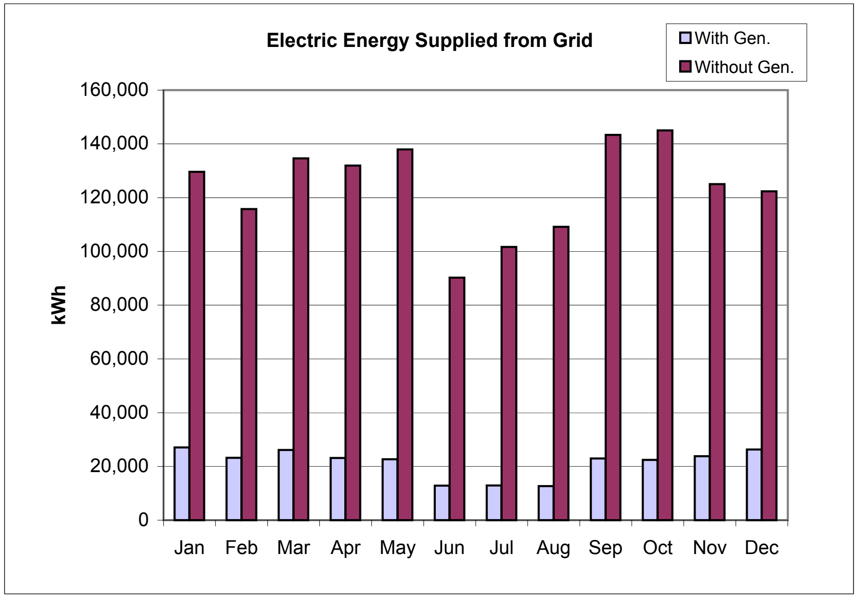
Baseline	On Site Generation
$273,413	**$156,556**

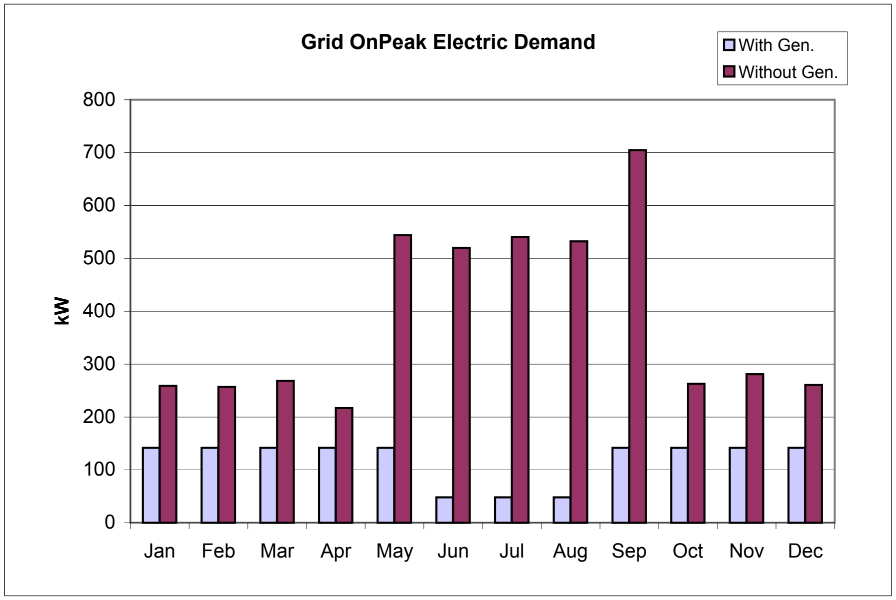
Annual Savings

$116,857

Note: * Cost of elctric generation including benefits of recoverable heat

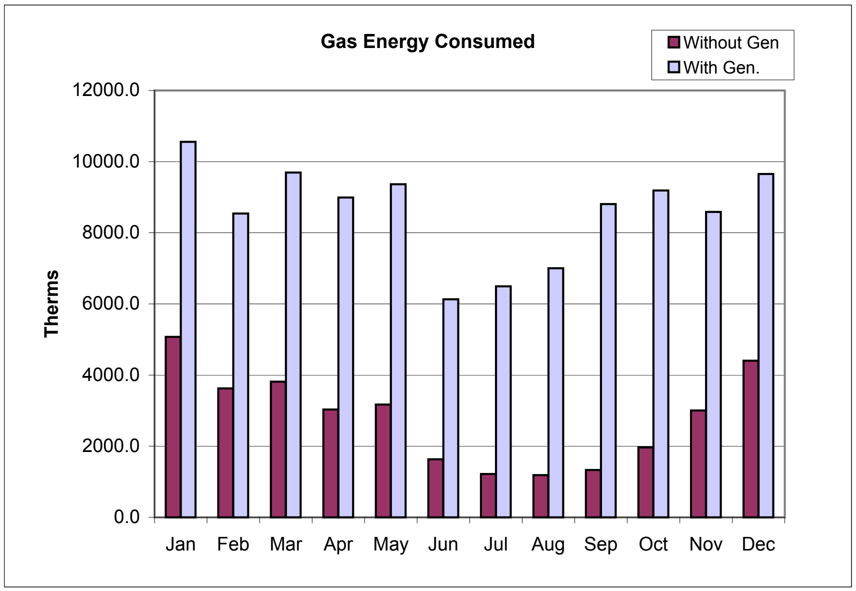
School, San Diego 110,000 sf

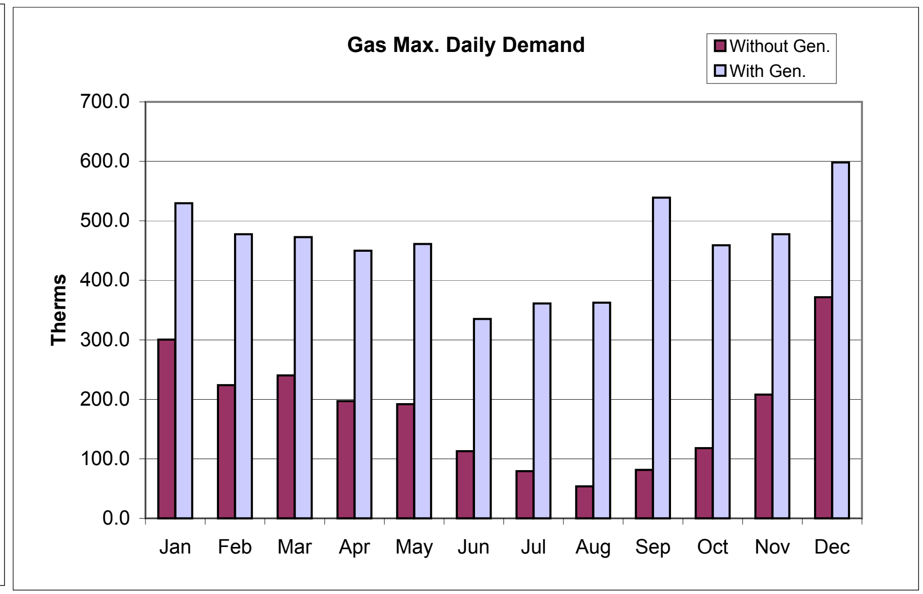




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Without (SDG&E AL-TOU_DER + EECC > 500 kW

School, San Diego 110,000 sf

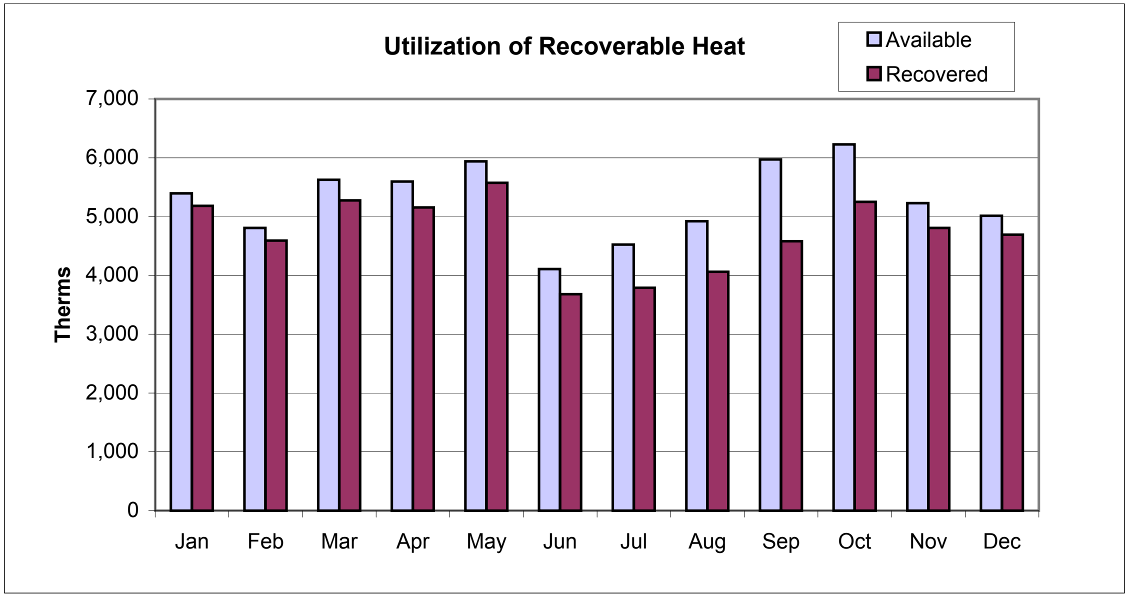




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - \$0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - \$0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

School, San Diego 110,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Hospital, Boston 300,000 sf

Baseline Configuration - No electric generation

	Electric Energy					**Natural Gas Energy**				**Total Energy Cost**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	**$**
Jan	549122	971.9	6136	11216	18941	56193.9	2578.9	33716	33716	52,658
Feb	493772	940.9	5411	10858	17783	47838.2	2341.2	28703	28703	46,486
Mar	549887	1083.0	6018	12498	20186	47553.8	2460.0	28532	28532	48,718
Apr	539691	1155.3	5797	13333	20843	33637.5	1794.7	20182	20182	41,025
May	617853	1266.9	6866	14620	23365	27759.3	1423.0	16656	16656	40,021
Jun	652728	1276.3	9955	31550	44784	24383.2	1195.2	14630	14630	59,414
Jul	718670	1293.7	11047	31981	46415	28883.3	1291.3	17330	17330	63,745
Aug	704917	1269.4	11089	31378	45814	26414.6	1205.5	15849	15849	61,663
Sep	637745	1245.5	9665	30788	43659	23803.7	1070.9	14282	14282	57,941
Oct	585388	1167.3	6486	13471	21729	27593.0	1199.2	16556	16556	38,284
Nov	536488	1165.0	5958	13444	21136	37347.5	1931.6	22409	22409	43,544
Dec	548303	982.8	5845	11341	18764	47186.3	2535.6	28312	28312	47,076
Tot.	**7,134,564**	**13,818**	**90,273**	**226,479**	**343,419**	**428,594**	**21,027**	**257,157**	**257,157**	**600,576**
Avr.	**594,547**	**1,152**	**7,523**	**18,873**	**28,618**	**35,716**	**1,752**	**21,430**	**21,430**	**50,048**
Max		**1,294**					**2,579**			

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Hospital, Boston 300,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	369,168	383	2,852	4,426	8,161	65,436	2,972	39,262	0	39,262	47,423	2,023	49,446
Feb	337,534	347	2,560	4,008	7,402	55,905	2,734	33,543	0	33,543	40,945	1,759	42,704
Mar	378,891	414	2,897	4,783	8,592	56,771	2,460	34,063	0	34,063	42,654	1,935	44,589
Apr	376,283	487	2,815	5,617	9,397	43,927	2,188	26,356	0	26,356	35,753	1,847	37,600
May	429,517	598	3,429	6,905	11,432	38,840	1,824	23,304	0	23,304	34,736	2,023	36,759
Jun	529,467	608	6,194	15,023	23,076	30,846	1,475	18,507	0	18,507	41,584	1,279	42,862
Jul	586,318	625	7,009	15,454	24,410	35,144	1,578	21,087	0	21,087	45,497	1,339	46,836
Aug	566,761	601	6,874	14,851	23,621	33,044	1,494	19,826	0	19,826	43,447	1,400	44,847
Sep	518,103	577	6,015	14,261	22,070	29,551	1,360	17,731	0	17,731	39,801	1,218	41,018
Oct	402,426	499	3,147	5,756	9,900	39,432	1,635	23,659	0	23,659	33,560	2,023	35,583
Nov	365,487	496	2,838	5,729	9,541	47,768	2,325	28,660	0	28,661	38,202	1,935	40,136
Dec	385,103	394	2,867	4,550	8,311	56,432	2,929	33,859	0	33,859	42,170	1,847	44,017
Tot.	**5,245,058**	**6,031**	**49,495**	**101,363**	**165,913**	**533,097**	**24,974**	**319,858**	**0**	**319,858**	**485,771**	**20,626**	**506,398**
Avr.	**437,088**	**503**	**4,125**	**8,447**	**13,826**	**44,425**	**2,081**	**26,655**	**0**	**26,655**	**40,481**	**1,719**	**42,200**
Max		**625**					**2,972**						

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Hospital, Boston 300,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	183,885	183,885	183,885	20,425	9,334	9,170	98.2	299	299	299	40.2	30.7	75.6
Feb	159,900	159,900	159,900	17,761	8,117	7,949	97.9	260	260	260	38.7	30.7	75.5
Mar	175,890	175,890	175,890	19,537	8,928	8,462	94.8	286	286	286	38.4	30.7	74.0
Apr	167,895	167,895	167,895	18,649	8,523	6,855	80.4	273	273	273	37.9	30.7	67.5
May	183,885	183,885	183,885	20,425	9,334	7,662	82.1	299	299	299	40.2	30.7	68.2
Jun	116,235	116,235	116,235	12,911	5,900	5,288	89.6	189	189	189	26.3	30.7	71.7
Jul	121,770	121,770	121,770	13,526	6,181	5,957	96.4	198	198	198	26.6	30.7	74.8
Aug	127,305	127,305	127,305	14,140	6,462	6,159	95.3	207	207	207	27.8	30.7	74.3
Sep	110,700	110,700	110,700	12,296	5,619	5,370	95.6	180	180	180	25.0	30.7	74.4
Oct	183,885	183,885	183,885	20,425	9,334	7,040	75.4	299	299	299	40.2	30.7	65.2
Nov	175,890	175,890	175,890	19,537	8,928	7,476	83.7	286	286	286	39.7	30.7	69.0
Dec	167,895	167,895	167,895	18,649	8,523	7,711	90.5	273	273	273	36.7	30.7	72.1
Tot.	**1,875,135**	**1,875,135**	**1,875,135**	**208,281**	**95,184**	**85,098**		**3,049**	**3,049**	**3,049**			
Avr.	**156,261**	**156,261**	**156,261**	**17,357**	**7,932**	**7,091**	**90.0**	**254**	**254**	**254**	**35**	**30.7**	**71.8**
Max							**98.2**					**30.7**	**75.6**

Energy Rates:	Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
	Gen. Service, Natural Gas - $0.6/therm (flat)
Generator Type:	VGF36GLD Engine Generator, 615 kWe

Hospital, Boston 300,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	549,122	972	369,168	383	9,334	9,170	98.2	18.4	6.0	9.6	6.1	0.7	-6	0
Feb	493,772	941	337,534	347	8,117	7,949	97.9	0.0	0.0	0.0	0.0	0.0	0	0
Mar	549,887	1,083	378,891	414	8,928	8,462	94.8	122.6	58.8	81.1	56.7	22.5	254	63
Apr	539,691	1,155	376,283	487	8,523	6,855	80.4	122.6	433.5	601.6	143.0	266.7	1,765	63
May	617,853	1,267	429,517	598	9,334	7,662	82.1	122.6	2,586.2	3,588.2	265.9	2,203.5	10,530	63
Jun	652,728	1,276	529,467	608	5,900	5,288	89.6	122.6	2,389.3	3,304.1	282.4	2,904.2	10,023	63
Jul	718,670	1,294	586,318	625	6,181	5,957	96.4	122.6	2,911.7	4,011.8	344.3	5,262.6	12,565	63
Aug	704,917	1,269	566,761	601	6,462	6,159	95.3	122.6	3,045.1	4,195.7	371.8	4,810.2	13,142	63
Sep	637,745	1,245	518,103	577	5,619	5,370	95.6	122.6	2,607.6	3,593.8	261.9	3,068.9	11,232	63
Oct	585,388	1,167	402,426	499	9,334	7,040	75.4	122.6	1,500.4	2,085.4	165.5	808.5	6,043	63
Nov	536,488	1,165	365,487	496	8,928	7,476	83.7	122.6	283.5	402.2	167.9	184.3	959	63
Dec	548,303	983	385,103	394	8,523	7,711	90.5	122.6	25.2	37.1	12.5	18.6	42	63
Tot.	**7,134,564**	**13,818**	**5,245,058**	**6,031**	**95,184**	**85,098**		**1,244.3**	**15,847**	**21,910**	**2,078.2**	**19,551**	**66,549**	
Avr.	**594,547**	**1,152**	**437,088**	**503**	**7,932**	**7,091**	**90.0**	**103.7**	**1,321**	**1,826**	**173.2**	**1,629**	**5,546**	**53**
Max		**1,294**		**625**										

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Hospital, Boston 300,000 sf
Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.034	0.600
Feb	0.036	0.600
Mar	0.037	0.600
Apr	0.039	0.600
May	0.038	0.600
Jun	0.069	0.600
Jul	0.065	0.600
Aug	0.065	0.600
Sep	0.068	0.600
Oct	0.037	0.600
Nov	0.039	0.600
Dec	0.034	0.600
Avr.	**0.047**	**0.600**
Total		

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.022	0.600	0.078	5,502	0.048	0.0795
Feb	0.022	0.600	0.078	4,769	0.048	0.0763
Mar	0.023	0.600	0.078	5,077	0.049	0.0712
Apr	0.025	0.600	0.078	4,113	0.053	0.0615
May	0.027	0.600	0.078	4,597	0.053	0.0524
Jun	0.044	0.600	0.078	3,173	0.050	0.0615
Jul	0.042	0.600	0.078	3,574	0.048	0.0611
Aug	0.042	0.600	0.078	3,696	0.049	0.0593
Sep	0.043	0.600	0.078	3,222	0.049	0.0601
Oct	0.025	0.600	0.078	4,224	0.055	0.0535
Nov	0.026	0.600	0.078	4,486	0.052	0.0659
Dec	0.022	0.600	0.078	4,626	0.050	0.0712
Avr.	**0.030**	**0.600**	**0.078**	**4,255**	**0.050**	**0.064**
Total				**$51,059**		

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

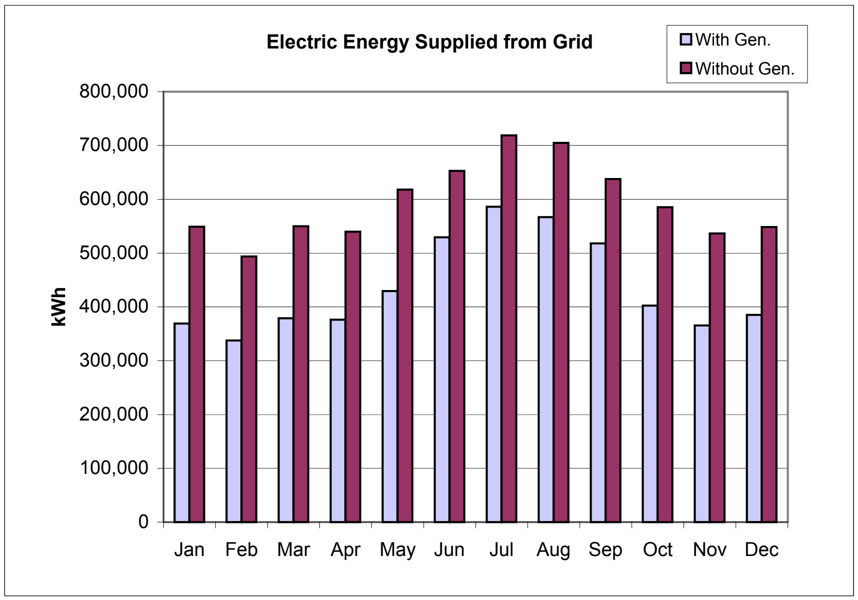
Total Annual Energy Costs

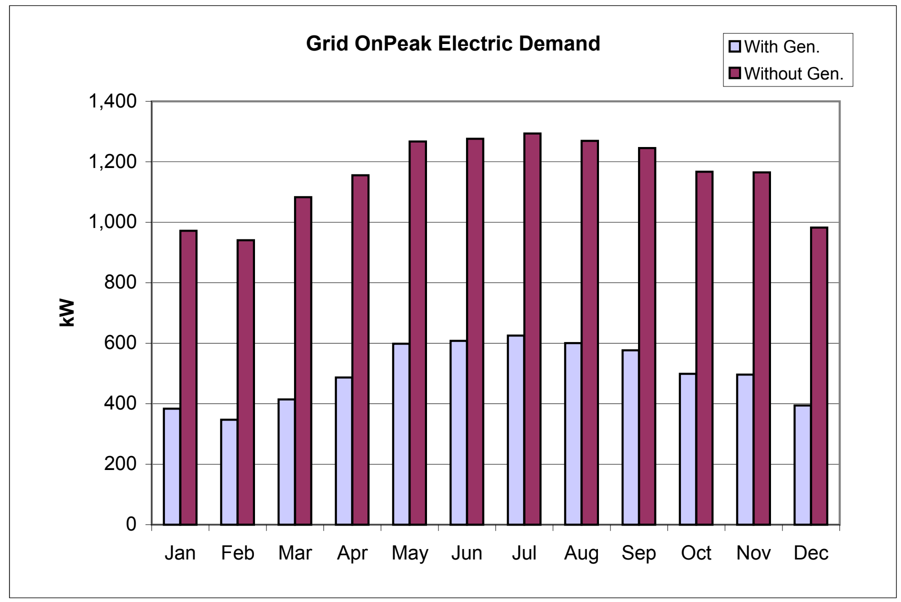
Baseline	On Site Generation
$600,576	**$506,398**

Annual Savings
$94,178

Note: * Cost of elctric generation including benefits of recoverable heat

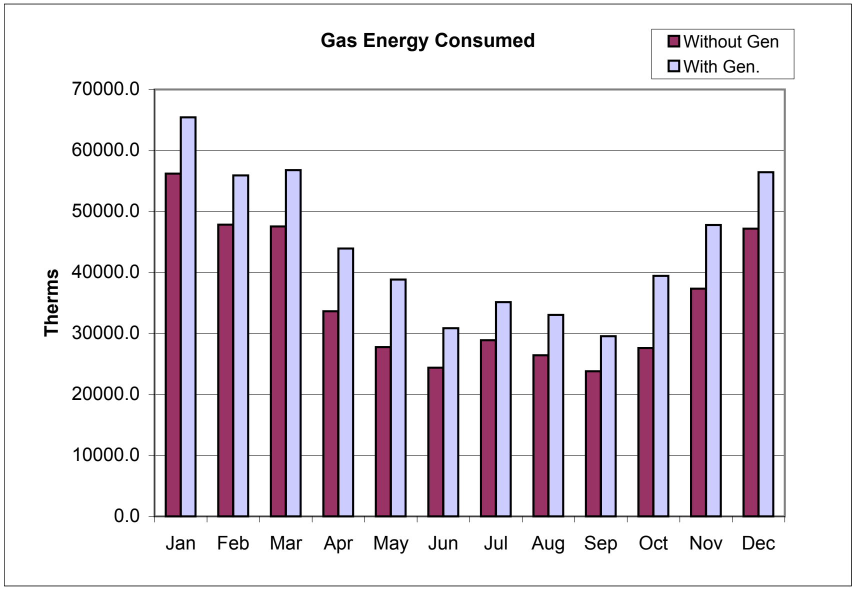
Hospital, Boston 300,000 sf

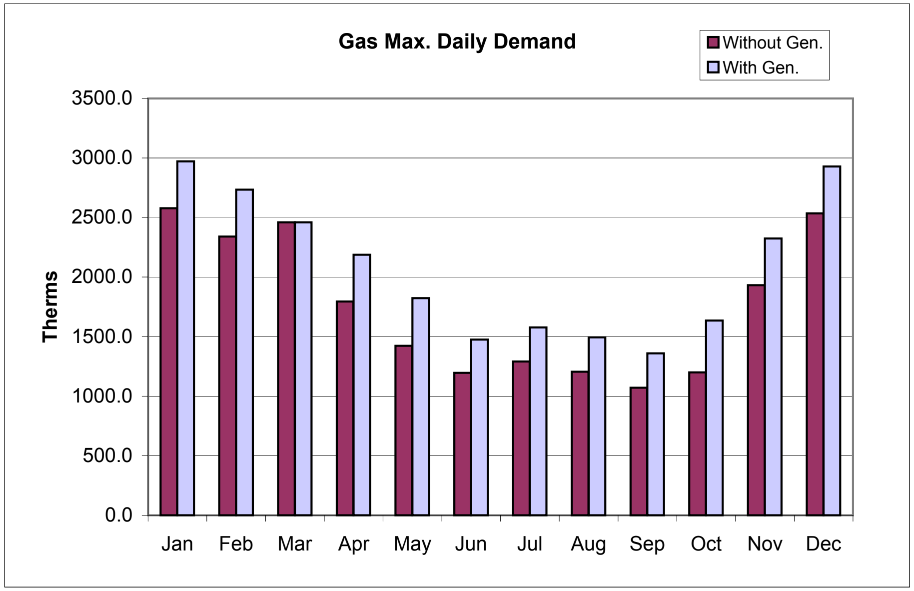




Electric			
Energy Rates		Gen:	VGF36GLD Engine Generator, 615 kWe
With Gen	Boston Electric Rate T-2 TOU > 300 kW < 1000 kW		
Without (	Boston Electric Rate T-2 TOU > 300 kW < 1000 kW		

Hospital, Boston 300,000 sf

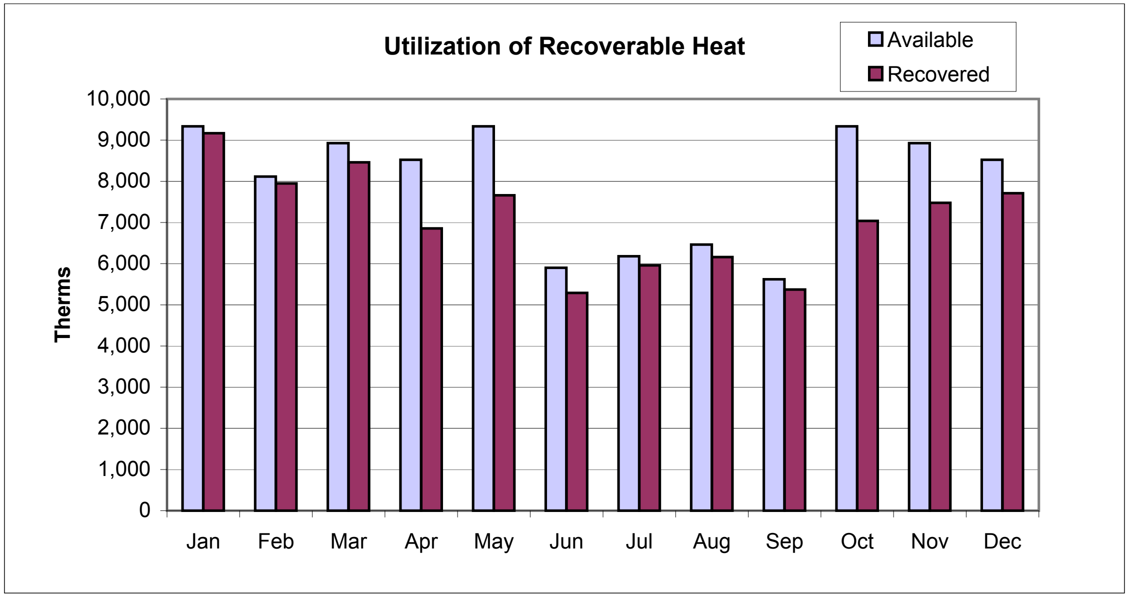




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Hospital, Boston 300,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Retail Store, Boston 125,000 sf

Baseline Configuration - No electric generation

	Electric Energy					Natural Gas Energy				Total Energy Cost
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	$
Jan	186406	362.7	2353	4185	7162	15883.5	835.5	9530	9530	16,693
Feb	167798	359.1	2074	4145	6820	12905.1	737.2	7743	7743	14,563
Mar	187375	430.5	2298	4968	7941	11372.3	770.2	6823	6823	14,765
Apr	181046	468.1	2219	5402	8321	5970.7	436.6	3582	3582	11,903
May	210053	609.3	2684	7031	10562	1436.5	198.4	862	862	11,424
Jun	235700	604.2	3921	14936	20344	81.8	10.2	49	49	20,393
Jul	276606	629.4	4692	15560	21836	49.1	2.2	29	29	21,866
Aug	267772	629.7	4655	15567	21804	48.0	2.0	29	29	21,833
Sep	227436	589.4	3830	14570	19855	146.3	25.8	88	88	19,943
Oct	194857	484.8	2472	5594	8797	1916.7	168.3	1150	1150	9,947
Nov	179435	484.3	2262	5589	8568	7725.6	577.9	4635	4635	13,203
Dec	185329	363.0	2222	4189	7027	12251.0	900.3	7351	7351	14,378
Tot.	**2,499,814**	**6,015**	**35,682**	**101,737**	**149,038**	**69,787**	**4,665**	**41,872**	**41,872**	**190,910**
Avr.	**208,318**	**501**	**2,974**	**8,478**	**12,420**	**5,816**	**389**	**3,489**	**3,489**	**15,909**
Max		**630**					**900**			

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Retail Store, Boston 125,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	79,309	0	398	0	593	23,195	1,096	13,917	0	13,917	14,510	1,225	15,735
Feb	74,711	0	375	0	568	19,779	998	11,867	0	11,867	12,435	1,068	13,504
Mar	84,774	0	426	0	622	20,512	841	12,307	0	12,307	12,930	1,188	14,117
Apr	82,024	0	412	0	607	16,587	801	9,952	0	9,952	10,559	1,150	11,709
May	86,886	0	436	0	633	13,320	730	7,992	0	7,992	8,626	1,353	9,979
Jun	148,194	0	1,251	0	1,505	6,766	424	4,060	0	4,060	5,565	907	6,472
Jul	169,781	0	1,433	0	1,700	6,405	342	3,843	0	3,843	5,543	1,049	6,592
Aug	159,246	0	1,344	0	1,605	6,788	335	4,073	0	4,073	5,677	1,078	6,755
Sep	140,857	0	1,189	0	1,439	6,108	366	3,665	0	3,665	5,103	881	5,984
Oct	82,076	133	414	1,540	2,257	14,664	706	8,799	0	8,799	11,055	1,295	12,350
Nov	76,542	0	384	0	578	17,533	861	10,520	0	10,520	11,098	1,191	12,288
Dec	87,676	0	440	0	638	20,395	1,161	12,237	0	12,237	12,875	1,126	14,001
Tot.	**1,272,076**	**133**	**8,501**	**1,540**	**12,744**	**172,053**	**8,662**	**103,232**	**0**	**103,232**	**115,976**	**13,510**	**129,487**
Avr.	**106,006**	**11**	**708**	**128**	**1,062**	**14,338**	**722**	**8,603**	**0**	**8,603**	**9,665**	**1,126**	**10,791**
Max		**133**					**1,161**						

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, Boston 125,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	111,345	111,345	111,345	13,646	6,236	5,194	83.3	299	299	299	40.2	27.8	65.9
Feb	97,129	97,129	97,129	11,896	5,436	4,118	75.7	260	260	260	38.7	27.9	62.5
Mar	107,958	107,958	107,958	13,192	6,029	3,322	55.1	286	286	286	38.4	27.9	53.1
Apr	104,513	104,513	104,513	12,730	5,818	1,733	29.8	273	273	273	37.9	28.0	41.6
May	123,033	123,033	123,033	14,740	6,736	2,342	34.8	299	299	299	40.2	28.5	44.4
Jun	82,480	82,480	82,480	9,759	4,460	2,521	56.5	189	189	189	26.3	28.8	54.7
Jul	95,402	95,402	95,402	11,067	5,057	3,863	76.4	198	198	198	26.6	29.4	64.3
Aug	97,980	97,980	97,980	11,405	5,212	3,826	73.4	207	207	207	27.8	29.3	62.9
Sep	80,047	80,047	80,047	9,430	4,310	2,845	66.0	180	180	180	25.0	29.0	59.1
Oct	117,721	117,721	117,721	14,233	6,505	1,218	18.7	298	298	298	40.1	28.2	36.8
Nov	108,228	108,228	108,228	13,217	6,040	2,796	46.3	286	286	286	39.7	27.9	49.1
Dec	102,389	102,389	102,389	12,529	5,726	3,595	62.8	273	273	273	36.7	27.9	56.6
Tot.	**1,228,224**	**1,228,224**	**1,228,224**	**147,844**	**67,565**	**37,374**		**3,048**	**3,048**	**3,048**			
Avr.	**102,352**	**102,352**	**102,352**	**12,320**	**5,630**	**3,114**	**56.6**	**254**	**254**	**254**	**35**	**28.4**	**54.2**
Max							**83.3**					**29.4**	**65.9**

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, Boston 125,000 sf
Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	186,406	363	79,309	0	6,236	5,194	83.3	0.0	0.0	0.0	0.0	0.0	0	0
Feb	167,798	359	74,711	0	5,436	4,118	75.7	0.0	0.0	0.0	0.0	0.0	0	0
Mar	187,375	431	84,774	0	6,029	3,322	55.1	40.6	13.9	20.8	0.0	0.0	36	18
Apr	181,046	468	82,024	0	5,818	1,733	29.8	111.0	165.0	229.5	7.4	1.6	733	67
May	210,053	609	86,886	0	6,736	2,342	34.8	122.6	1,501.0	2,086.1	148.9	369.2	7,004	76
Jun	235,700	604	148,194	0	4,460	2,521	56.5	122.6	1,816.5	2,505.7	141.1	565.7	8,797	76
Jul	276,606	629	169,781	0	5,057	3,863	76.4	122.6	2,795.7	3,848.0	179.0	1,769.3	14,237	76
Aug	267,772	630	159,246	0	5,212	3,826	73.4	122.6	2,766.8	3,810.6	181.2	1,410.2	13,889	76
Sep	227,436	589	140,857	0	4,310	2,845	66.0	122.6	2,051.4	2,831.5	111.8	566.5	9,958	76
Oct	194,857	485	82,076	133	6,505	1,218	18.7	112.8	617.3	871.9	28.8	12.6	2,584	68
Nov	179,435	484	76,542	0	6,040	2,796	46.3	112.7	92.9	129.8	29.0	9.1	417	68
Dec	185,329	363	87,676	0	5,726	3,595	62.8	0.0	0.0	0.0	0.0	0.0	0	0
Tot.	**2,499,814**	**6,015**	**1,272,076**	**133**	**67,565**	**37,374**		**990.1**	**11,820**	**16,334**	**827.1**	**4,704**	**57,657**	
Avr.	**208,318**	**501**	**106,006**	**11**	**5,630**	**3,114**	**56.6**	**82.5**	**985**	**1,361**	**68.9**	**392**	**4,805**	**50**
Max		**630**		**133**										

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, Boston 125,000 sf

Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.038	0.600
Feb	0.041	0.600
Mar	0.042	0.600
Apr	0.046	0.600
May	0.050	0.600
Jun	0.086	0.600
Jul	0.079	0.600
Aug	0.081	0.600
Sep	0.087	0.600
Oct	0.045	0.600
Nov	0.048	0.600
Dec	0.038	0.600
Avr.	**0.057**	**0.600**
Total		

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.007	0.600	0.085	3,116	0.057	0.0662
Feb	0.008	0.600	0.084	2,471	0.059	0.0642
Mar	0.007	0.600	0.084	1,993	0.066	0.0629
Apr	0.007	0.600	0.084	1,040	0.074	0.0572
May	0.007	0.600	0.083	1,405	0.071	0.0408
Jun	0.010	0.600	0.082	1,513	0.064	0.0215
Jul	0.010	0.600	0.081	2,318	0.056	0.0161
Aug	0.010	0.600	0.081	2,296	0.057	0.0173
Sep	0.010	0.600	0.082	1,707	0.060	0.0194
Oct	0.027	0.600	0.084	731	0.077	0.0582
Nov	0.008	0.600	0.084	1,677	0.069	0.0574
Dec	0.007	0.600	0.084	2,157	0.063	0.0623
Avr.	**0.010**	**0.600**	**0.083**	**1,869**	**0.065**	**0.045**
Total				**$22,424**		

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

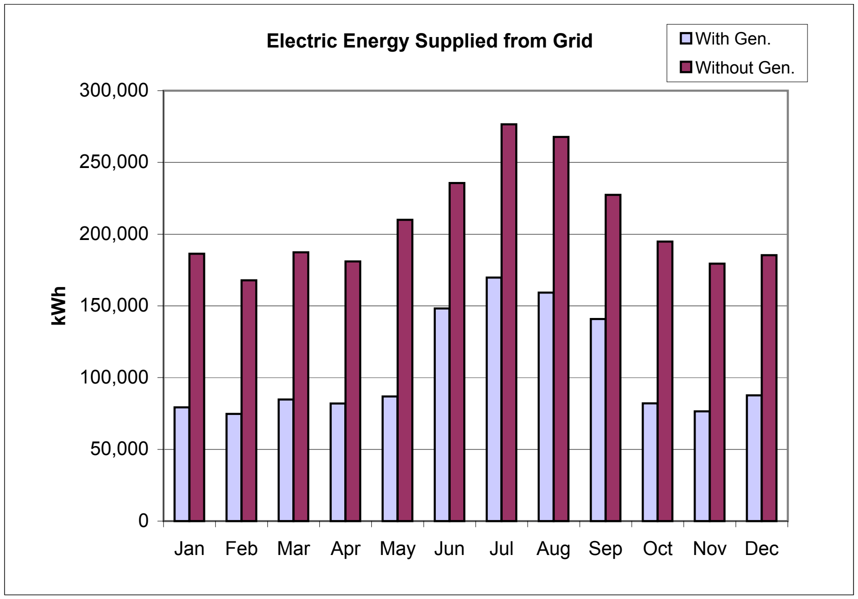
Baseline	On Site Generation
$190,910	**$129,487**

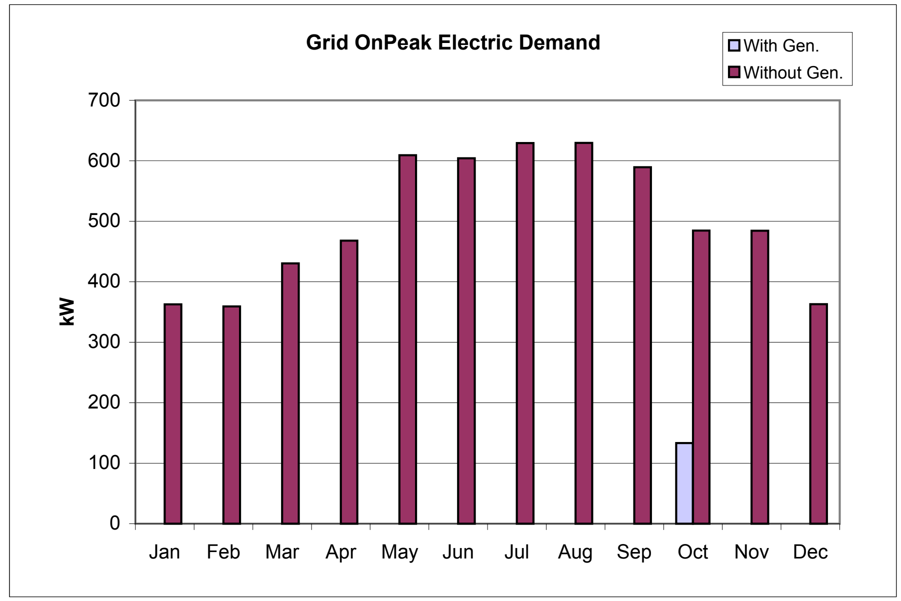
Annual Savings

$61,423

Note: * Cost of elctric generation including benefits of recoverable heat

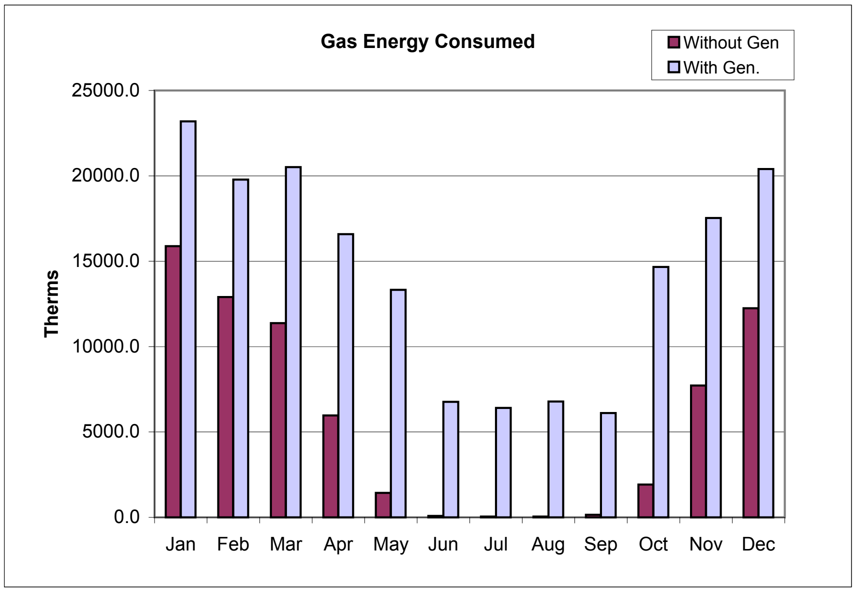
Retail Store, Boston 125,000 sf

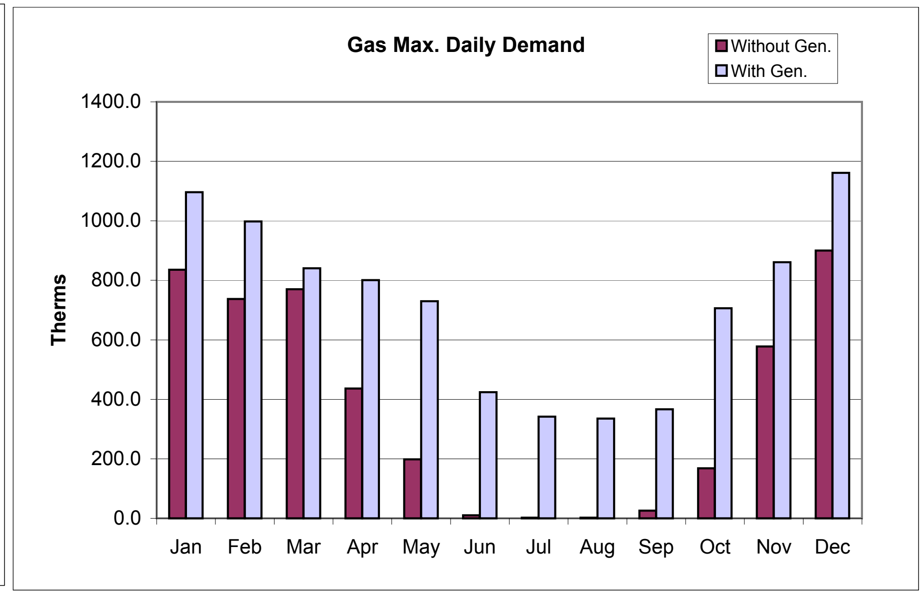




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Without (Boston Electric Rate T-2 TOU > 300 kW < 1000 kW

Retail Store, Boston 125,000 sf

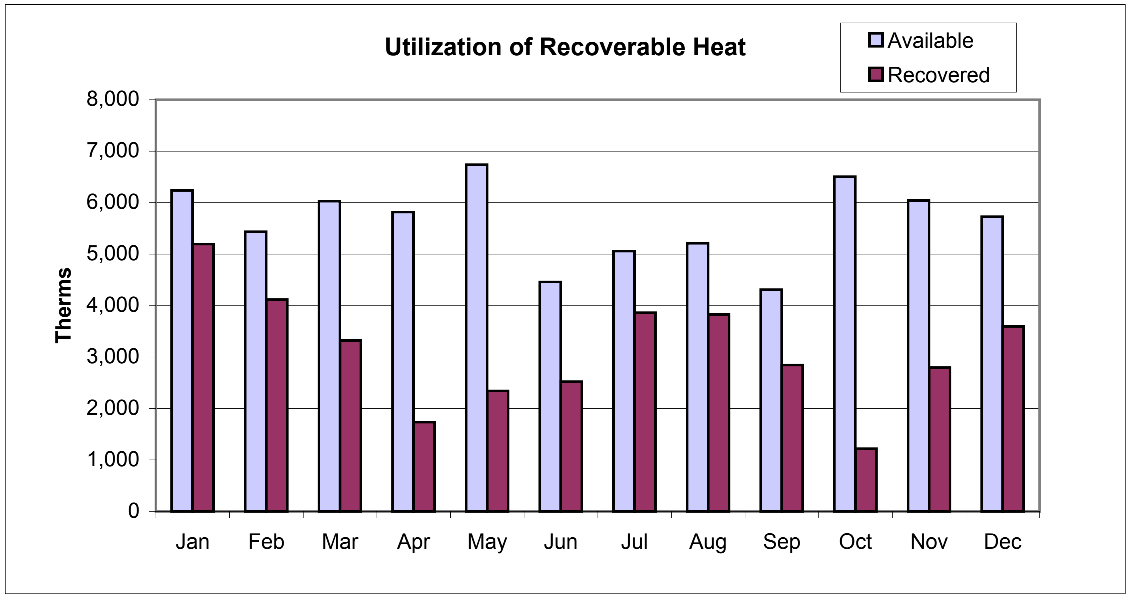




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Retail Store, Boston 125,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Retail Store Chicago 125,000 sf

Baseline Configuration - No electric generation

	Electric Energy					Natural Gas Energy				Total Energy Cost
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	$
Jan	187501	364.6	7888	4058	13145	16751.5	1035.3	10051	10051	23,196
Feb	168693	360.7	6988	4015	12110	13261.3	697.6	7957	7957	20,067
Mar	189250	428.3	7796	4766	13820	11264.2	637.4	6759	6759	20,579
Apr	183515	450.5	7452	5014	13715	4946.3	498.9	2968	2968	16,683
May	216520	621.0	9090	6912	17595	836.6	95.1	502	502	18,097
Jun	254399	695.9	10483	9910	22412	129.5	26.4	78	78	22,489
Jul	286752	694.2	11766	9886	23792	50.7	2.4	30	30	23,822
Aug	284695	694.2	11844	9886	23878	52.6	3.3	32	32	23,909
Sep	233317	606.6	9371	8638	19795	148.7	18.2	89	89	19,885
Oct	201575	522.1	8492	5811	15730	2331.9	238.0	1399	1399	17,129
Nov	181295	521.9	7616	5809	14767	7583.0	483.9	4550	4550	19,317
Dec	186370	365.0	7557	4062	12786	15047.9	1206.7	9029	9029	21,815
Tot.	**2,573,881**	**6,325**	**106,344**	**78,766**	**203,545**	**72,404**	**4,943**	**43,442**	**43,442**	**246,988**
Avr.	**214,490**	**527**	**8,862**	**6,564**	**16,962**	**6,034**	**412**	**3,620**	**3,620**	**20,582**
Max		**696**					**1,207**			

Energy Rates: Chicago Rate 6 TOU < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Retail Store Chicago 125,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					Natural Gas Energy					Total	Gen.	Total
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	Energy
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	Cost $
Jan	80,260	0	1,883	0	4,221	24,546	1,214	14,727	0	14,727	18,949	1,229	20,178
Feb	75,542	0	1,773	0	4,100	20,130	959	12,078	0	12,078	16,178	1,069	17,247
Mar	85,957	0	2,012	0	4,363	20,244	861	12,146	0	12,146	16,509	1,194	17,703
Apr	86,660	0	2,029	0	4,381	15,911	798	9,547	0	9,547	13,927	1,133	15,061
May	93,079	0	2,179	0	4,545	12,210	665	7,326	0	7,326	11,872	1,349	13,220
Jun	115,527	36	2,708	509	5,684	9,373	541	5,624	0	5,624	11,308	1,421	12,728
Jul	131,930	32	3,098	455	6,052	9,753	539	5,852	0	5,852	11,904	1,563	13,467
Aug	125,887	30	2,953	433	5,869	10,180	557	6,108	0	6,108	11,977	1,610	13,587
Sep	113,466	0	2,660	0	5,074	8,924	586	5,355	0	5,355	10,428	1,250	11,679
Oct	85,884	0	2,015	0	4,365	14,293	732	8,576	0	8,576	12,941	1,306	14,247
Nov	78,082	0	1,837	0	4,170	17,549	803	10,529	0	10,529	14,700	1,192	15,892
Dec	88,471	0	2,076	0	4,432	22,314	1,471	13,388	0	13,388	17,820	1,123	18,943
Tot.	**1,160,746**	**98**	**27,222**	**1,397**	**57,257**	**185,426**	**9,725**	**111,256**	**0**	**111,256**	**168,512**	**15,439**	**183,952**
Avr.	**96,729**	**8**	**2,269**	**116**	**4,771**	**15,452**	**810**	**9,271**	**0**	**9,271**	**14,043**	**1,287**	**15,329**
Max		**36**					**1,471**						

Energy Rates: Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store Chicago 125,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	111,723	77,724	111,723	13,673	6,248	4,820	77.1	298	207	298	40.1	27.9	63.1
Feb	97,172	67,643	97,172	11,890	5,434	4,118	75.8	259	180	259	38.5	27.9	62.5
Mar	108,563	75,079	108,563	13,249	6,055	3,501	57.8	286	198	286	38.4	28.0	54.4
Apr	103,021	73,708	103,021	12,587	5,752	1,330	23.1	273	189	273	37.9	27.9	38.5
May	122,618	89,198	122,618	14,678	6,708	2,710	40.4	298	207	298	40.1	28.5	47.0
Jun	129,141	93,945	129,141	15,022	6,865	4,738	69.0	273	189	273	37.9	29.3	60.9
Jul	142,113	103,320	142,113	16,368	7,480	5,466	73.1	285	198	285	38.3	29.6	63.0
Aug	146,357	105,948	146,357	16,915	7,730	5,565	72.0	299	207	299	40.2	29.5	62.4
Sep	113,660	82,917	113,660	13,407	6,127	3,798	62.0	258	180	258	35.8	28.9	57.3
Oct	118,726	85,200	118,726	14,307	6,538	1,924	29.4	297	207	297	39.9	28.3	41.8
Nov	108,405	75,875	108,405	13,212	6,038	2,662	44.1	284	198	284	39.4	28.0	48.1
Dec	102,082	71,035	102,082	12,490	5,708	4,284	75.1	272	189	272	36.6	27.9	62.2
Tot.	**1,403,581**	**1,001,591**	**1,403,581**	**167,798**	**76,684**	**44,916**		**3,382**	**2,349**	**3,382**			
Avr.	**116,965**	**83,466**	**116,965**	**13,983**	**6,390**	**3,743**	**58.2**	**282**	**196**	**282**	**39**	**28.5**	**55.1**
Max							**77.1**					**29.6**	**63.1**

Energy Rates: Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store Chicago 125,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	187,501	365	80,260	0	6,248	4,820	77.1	0.0	0.0	0.0	0.0	0.0	0	0
Feb	168,693	361	75,542	0	5,434	4,118	75.8	0.0	0.0	0.0	0.0	0.0	0	0
Mar	189,250	428	85,957	0	6,055	3,501	57.8	39.4	24.3	35.9	0.0	0.0	57	13
Apr	183,515	451	86,660	0	5,752	1,330	23.1	80.4	116.0	169.7	11.9	6.5	275	35
May	216,520	621	93,079	0	6,708	2,710	40.4	122.6	1,913.5	2,651.5	158.6	393.9	7,521	63
Jun	254,399	696	115,527	36	6,865	4,738	69.0	122.6	3,423.9	4,719.2	273.1	1,921.7	14,285	63
Jul	286,752	694	131,930	32	7,480	5,466	73.1	122.6	3,954.1	5,447.8	264.0	2,986.8	16,775	63
Aug	284,695	694	125,887	30	7,730	5,565	72.0	122.6	4,026.5	5,547.0	265.0	2,717.5	17,012	63
Sep	233,317	607	113,466	0	6,127	3,798	62.0	122.6	2,743.7	3,782.4	131.0	823.4	11,218	63
Oct	201,575	522	85,884	0	6,538	1,924	29.4	121.4	1,132.6	1,581.7	63.5	85.1	4,107	63
Nov	181,295	522	78,082	0	6,038	2,662	44.1	121.4	154.3	212.4	63.3	41.1	642	63
Dec	186,370	365	88,471	0	5,708	4,284	75.1	0.0	0.0	0.0	0.0	0.0	0	0
Tot.	**2,573,881**	**6,325**	**1,160,746**	**98**	**76,684**	**44,916**		**975.5**	**17,489**	**24,148**	**1,230.3**	**8,976**	**71,894**	
Avr.	**214,490**	**527**	**96,729**	**8**	**6,390**	**3,743**	**58.2**	**81.3**	**1,457**	**2,012**	**102.5**	**748**	**5,991**	**41**
Max		**696**		**36**										

Energy Rates: Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store Chicago 125,000 sf
<u>Basline/Alt. Config. Energy Cost Comparison</u>

Specific Energy Costs

	Baseline Grid Elec. Energy $/kWh	Baseline Utility Gas Energy $/therm	On Site Generation Grid Elec. Energy $/kWh	On Site Generation Utility Gas Energy $/therm	On Site Generation Gen Elec. Energy $/kWh	On Site Generation Rec. Heat Value $	On Site Generation Gen* Elec. Energy $/kWh	On Site Generation Avr. Elec. Energy $/kWh
Jan	0.070	0.600	0.053	0.600	0.084	2,892	0.059	0.0900
Feb	0.072	0.600	0.054	0.600	0.084	2,471	0.059	0.0856
Mar	0.073	0.600	0.051	0.600	0.084	2,101	0.065	0.0802
Apr	0.075	0.600	0.051	0.600	0.084	798	0.077	0.0752
May	0.081	0.600	0.049	0.600	0.083	1,626	0.070	0.0538
Jun	0.088	0.600	0.049	0.600	0.081	2,843	0.059	0.0404
Jul	0.083	0.600	0.046	0.600	0.080	3,279	0.057	0.0372
Aug	0.084	0.600	0.047	0.600	0.080	3,339	0.058	0.0376
Sep	0.085	0.600	0.045	0.600	0.082	2,279	0.062	0.0414
Oct	0.078	0.600	0.051	0.600	0.083	1,154	0.074	0.0640
Nov	0.081	0.600	0.053	0.600	0.084	1,597	0.069	0.0767
Dec	0.069	0.600	0.050	0.600	0.084	2,570	0.059	0.0859
Avr.	**0.078**	**0.600**	**0.050**	**0.600**	**0.083**	**2,246**	**0.064**	**0.064**
Total						**$26,950**		

Chicago Rate 6 TOU < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

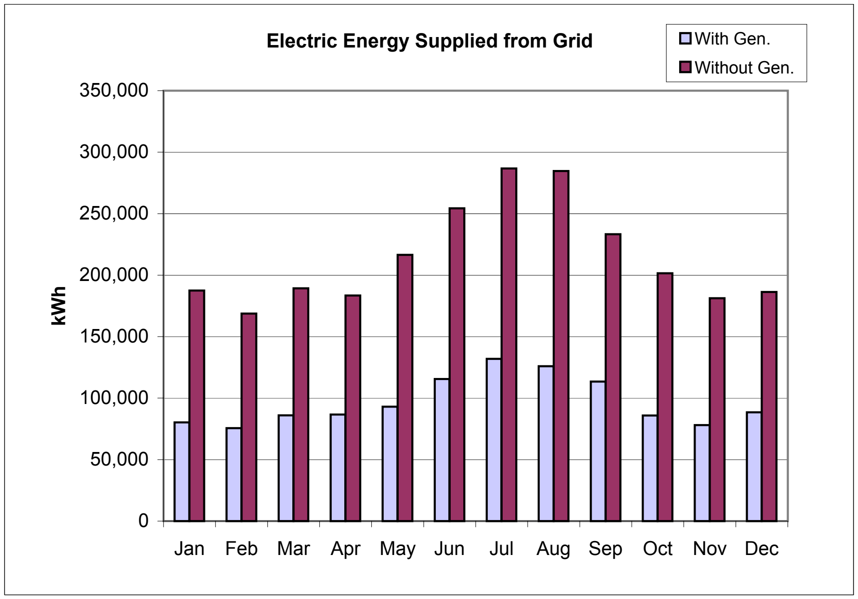
<u>Total Annual Energy Costs</u>

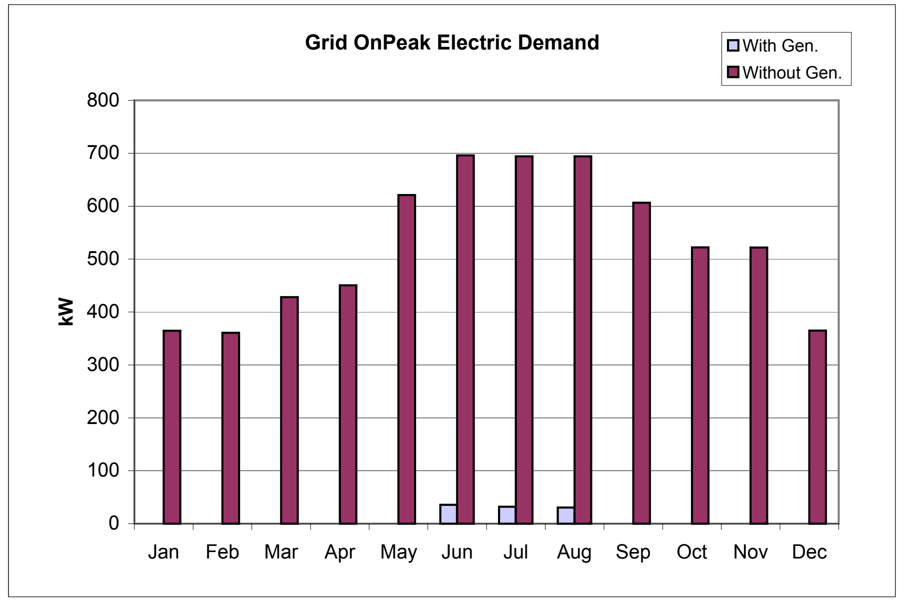
Baseline	On Site Generation
$246,988	**$183,952**

Annual Savings
$63,036

Note: * Cost of elctric generation including benefits of recoverable heat

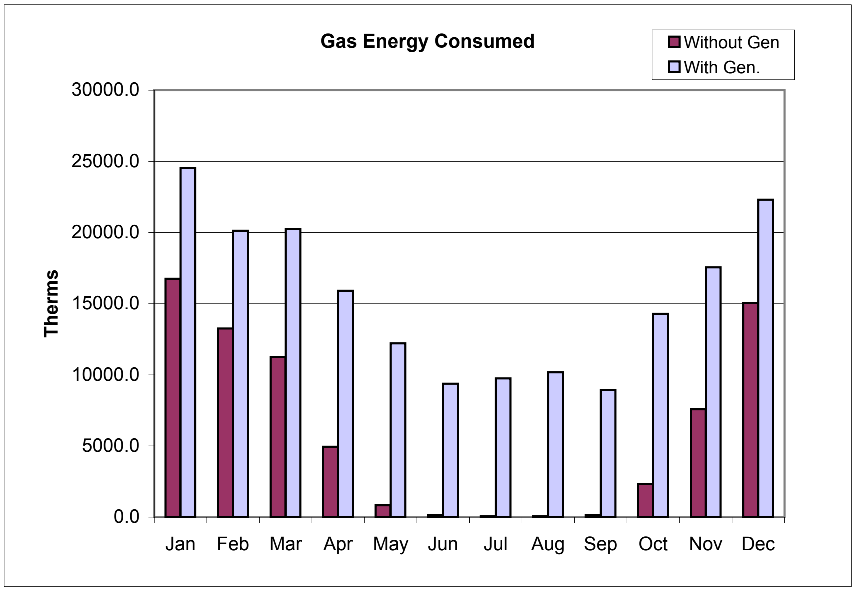
Retail Store Chicago 125,000 sf

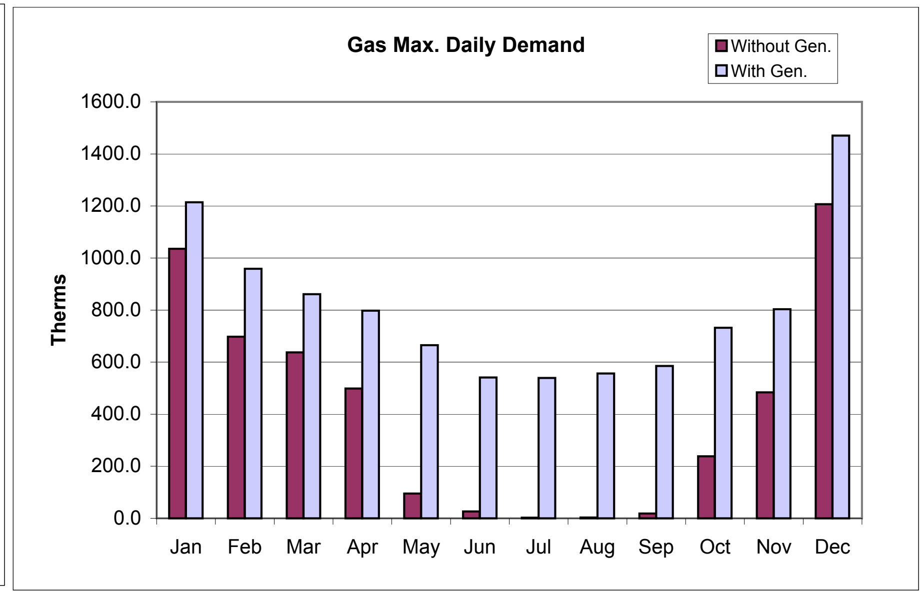




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Chicago Electric Rate 6 TOU - 18 Standby <1000 kW
Without (Chicago Rate 6 TOU < 1000 kW

Retail Store Chicago 125,000 sf

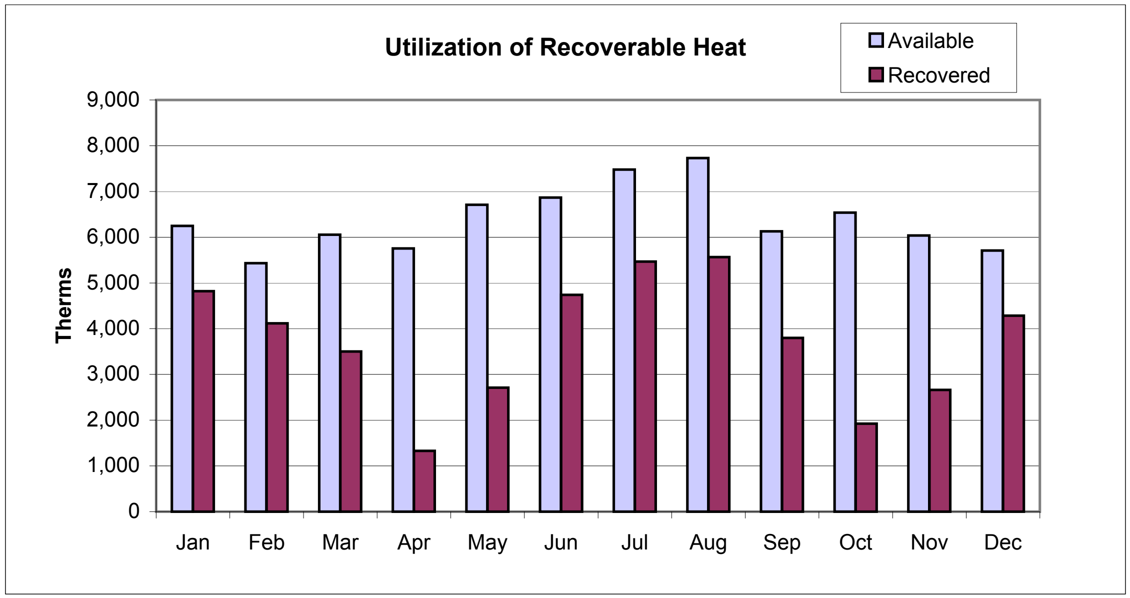




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Retail Store Chicago 125,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Retail Store, Miami 125,000 sf

Baseline Configuration - No electric generation

	Electric Energy					Natural Gas Energy				Total Energy Cost
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	$
Jan	274579	626.0	13722	8859	24200	199.0	62.6	119	119	24,319
Feb	250672	646.8	12516	9106	23173	67.1	12.4	40	40	23,213
Mar	286109	674.1	14265	9312	25266	100.0	38.6	60	60	25,326
Apr	295628	684.4	15147	5612	22251	39.3	2.0	24	24	22,274
May	345325	716.0	17793	5887	25376	38.4	1.3	23	23	25,399
Jun	348445	771.8	17796	6328	25851	36.4	1.3	22	22	25,873
Jul	374681	749.0	19115	6154	27076	35.7	1.2	21	21	27,098
Aug	374266	770.4	19205	6317	27347	35.9	1.2	22	22	27,369
Sep	350957	731.6	17774	5999	25475	33.9	1.2	20	20	25,496
Oct	337361	700.4	17374	5774	24807	36.1	1.2	22	22	24,829
Nov	287950	665.9	14410	9300	25408	37.5	1.9	22	22	25,431
Dec	267513	625.5	13291	8753	23625	48.1	4.8	29	29	23,654
Tot.	**3,793,485**	**8,362**	**192,408**	**87,403**	**299,855**	**708**	**130**	**425**	**425**	**300,280**
Avr.	**316,124**	**697**	**16,034**	**7,284**	**24,988**	**59**	**11**	**35**	**35**	**25,023**
Max		**772**					**63**			

Energy Rates: Miami FPL Rate GSLDT-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Retail Store, Miami 125,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	189,581	171	8,313	2,590	13,332	6,660	382	3,996	0	3,996	17,328	880	18,208
Feb	173,510	0	7,605	1,591	11,505	5,585	342	3,351	0	3,351	14,855	790	15,645
Mar	199,053	1	8,725	1,607	12,720	6,333	369	3,800	0	3,800	16,520	891	17,411
Apr	185,103	11	8,113	1,695	12,160	7,092	397	4,255	0	4,255	16,415	1,103	17,518
May	212,330	43	9,330	1,975	13,761	8,798	407	5,279	0	5,279	19,040	1,332	20,373
Jun	223,229	105	9,827	2,383	14,730	8,391	413	5,034	0	5,034	19,764	1,257	21,021
Jul	242,670	78	10,714	2,254	15,541	8,847	407	5,308	0	5,308	20,849	1,326	22,175
Aug	235,988	104	10,405	2,331	15,293	9,266	410	5,560	0	5,560	20,853	1,388	22,241
Sep	231,844	60	10,193	2,069	14,786	7,958	406	4,775	0	4,775	19,561	1,195	20,756
Oct	207,120	27	9,086	1,862	13,380	8,542	406	5,125	0	5,125	18,505	1,303	19,808
Nov	197,874	129	8,678	2,371	13,488	5,811	334	3,487	0	3,487	16,975	901	17,876
Dec	188,491	0	8,262	1,568	12,183	5,492	326	3,295	0	3,295	15,478	804	16,282
Tot.	**2,486,794**	**728**	**109,250**	**24,296**	**162,879**	**88,776**	**4,599**	**53,265**	**0**	**53,265**	**216,144**	**13,171**	**229,315**
Avr.	**207,233**	**61**	**9,104**	**2,025**	**13,573**	**7,398**	**383**	**4,439**	**0**	**4,439**	**18,012**	**1,098**	**19,110**
Max		**171**					**413**						

Energy Rates: Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, Miami 125,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	80,041	80,041	80,041	9,455	4,321	2,455	56.8	183	183	183	24.6	28.9	54.8
Feb	71,777	71,777	71,777	8,436	3,855	2,393	62.1	160	160	160	23.8	29.0	57.4
Mar	80,969	80,969	80,969	9,469	4,327	2,653	61.3	176	176	176	23.7	29.2	57.2
Apr	100,278	100,278	100,278	11,422	5,220	3,582	68.6	189	189	189	26.3	30.0	61.3
May	121,133	121,133	121,133	13,572	6,202	3,946	63.6	207	207	207	27.8	30.5	59.5
Jun	114,300	114,300	114,300	12,735	5,820	3,592	61.7	189	189	189	26.3	30.6	58.8
Jul	120,509	120,509	120,509	13,410	6,128	3,771	61.5	198	198	198	26.6	30.7	58.8
Aug	126,223	126,223	126,223	14,042	6,417	3,946	61.5	207	207	207	27.8	30.7	58.8
Sep	108,644	108,644	108,644	12,108	5,534	3,431	62.0	180	180	180	25.0	30.6	59.0
Oct	118,458	118,458	118,458	13,318	6,086	3,946	64.8	207	207	207	27.8	30.3	60.0
Nov	81,903	81,903	81,903	9,532	4,356	3,082	70.7	174	174	174	24.2	29.3	61.6
Dec	73,099	73,099	73,099	8,640	3,948	2,621	66.4	168	168	168	22.6	28.9	59.2
Tot.	**1,197,333**	**1,197,333**	**1,197,333**	**136,139**	**62,216**	**39,418**		**2,238**	**2,238**	**2,238**			
Avr.	**99,778**	**99,778**	**99,778**	**11,345**	**5,185**	**3,285**	**63.4**	**187**	**187**	**187**	**26**	**29.9**	**58.9**
Max							**70.7**					**30.7**	**61.6**

Energy Rates: Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, Miami 125,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	274,579	626	189,581	171	4,321	2,455	56.8	113.0	1,719.5	2,415.2	134.1	989.0	8,432	68
Feb	250,672	647	173,510	0	3,855	2,393	62.1	113.0	1,696.4	2,382.4	160.6	927.6	8,263	68
Mar	286,109	674	199,053	1	4,327	2,653	61.3	113.0	1,871.0	2,628.5	215.4	1,259.0	9,218	68
Apr	295,628	684	185,103	11	5,220	3,582	68.6	113.0	2,545.5	3,572.4	235.2	2,551.5	12,790	68
May	345,325	716	212,330	43	6,202	3,946	63.6	113.0	2,803.9	3,935.7	274.3	4,439.1	14,111	68
Jun	348,445	772	223,229	105	5,820	3,592	61.7	113.0	2,548.4	3,583.2	341.6	4,713.9	12,809	68
Jul	374,681	749	242,670	78	6,128	3,771	61.5	113.0	2,678.9	3,761.9	311.5	5,489.3	13,478	68
Aug	374,266	770	235,988	104	6,417	3,946	61.5	113.0	2,803.6	3,936.5	353.3	5,556.8	14,109	68
Sep	350,957	732	231,844	60	5,534	3,431	62.0	113.0	2,438.5	3,422.9	296.7	4,462.3	12,273	68
Oct	337,361	700	207,120	27	6,086	3,946	64.8	113.0	2,804.2	3,935.9	251.3	4,006.2	14,113	68
Nov	287,950	666	197,874	129	4,356	3,082	70.7	113.0	2,191.0	3,075.5	198.1	1,564.4	10,855	68
Dec	267,513	626	188,491	0	3,948	2,621	66.4	113.0	1,861.8	2,614.6	133.0	710.9	9,058	68
Tot.	**3,793,485**	**8,362**	**2,486,794**	**728**	**62,216**	**39,418**		**1,355.7**	**27,963**	**39,265**	**2,905.3**	**36,670**	**139,510**	
Avr.	**316,124**	**697**	**207,233**	**61**	**5,185**	**3,285**	**63.4**	**113.0**	**2,330**	**3,272**	**242.1**	**3,056**	**11,626**	**68**
Max		**772**		**171**										

Energy Rates: Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, Miami 125,000 sf
Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.088	0.600
Feb	0.092	0.600
Mar	0.088	0.600
Apr	0.075	0.600
May	0.073	0.600
Jun	0.074	0.600
Jul	0.072	0.600
Aug	0.073	0.600
Sep	0.073	0.600
Oct	0.074	0.600
Nov	0.088	0.600
Dec	0.088	0.600
Avr.	**0.080**	**0.600**
Total		

On Site Generation

Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
0.070	0.600	0.082	1,473	0.063	0.0621
0.066	0.600	0.082	1,436	0.062	0.0579
0.064	0.600	0.081	1,592	0.062	0.0565
0.066	0.600	0.079	2,149	0.058	0.0539
0.065	0.600	0.078	2,368	0.059	0.0540
0.066	0.600	0.078	2,155	0.059	0.0559
0.064	0.600	0.078	2,263	0.059	0.0548
0.065	0.600	0.078	2,368	0.059	0.0549
0.064	0.600	0.078	2,059	0.059	0.0549
0.065	0.600	0.078	2,367	0.058	0.0536
0.068	0.600	0.081	1,849	0.058	0.0573
0.065	0.600	0.082	1,572	0.060	0.0562
0.066	**0.600**	**0.080**	**1,971**	**0.060**	**0.056**
			$23,651		

Miami FPL Rate GSLDT-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

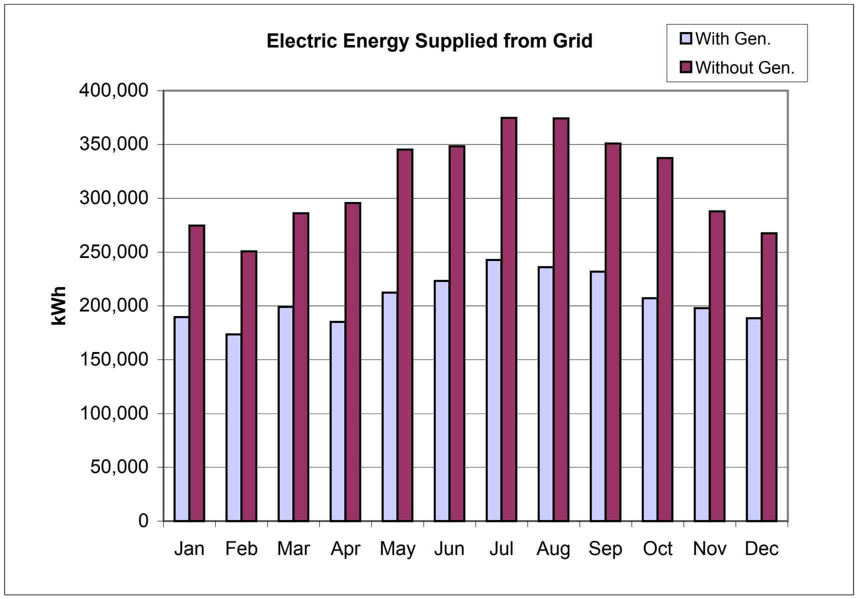
Baseline	On Site Generation
$300,280	**$229,315**

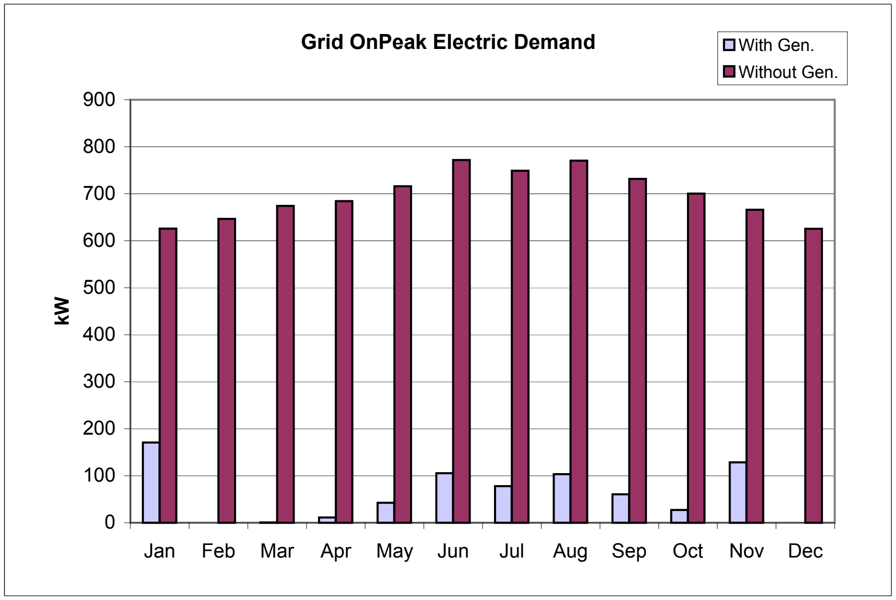
Annual Savings

$70,965

Note: * Cost of elctric generation including benefits of recoverable heat

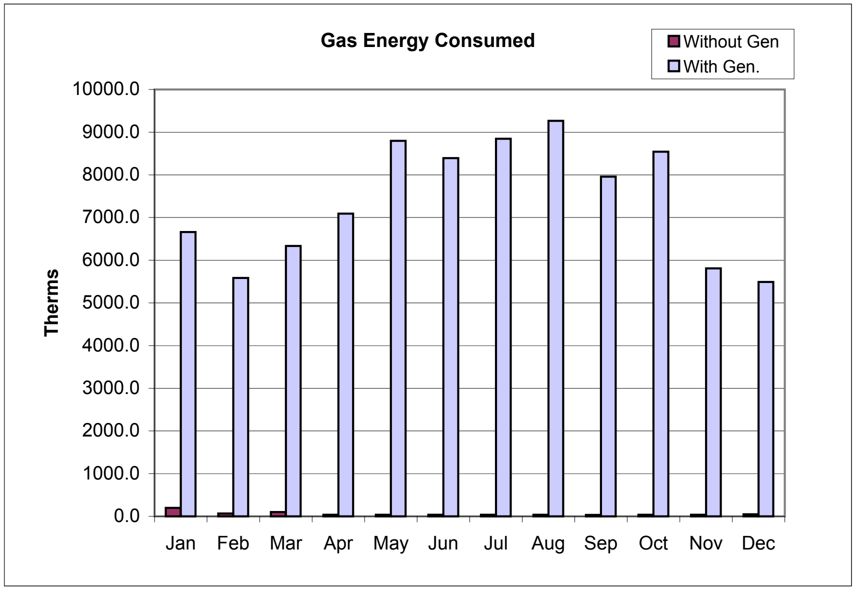
Retail Store, Miami 125,000 sf

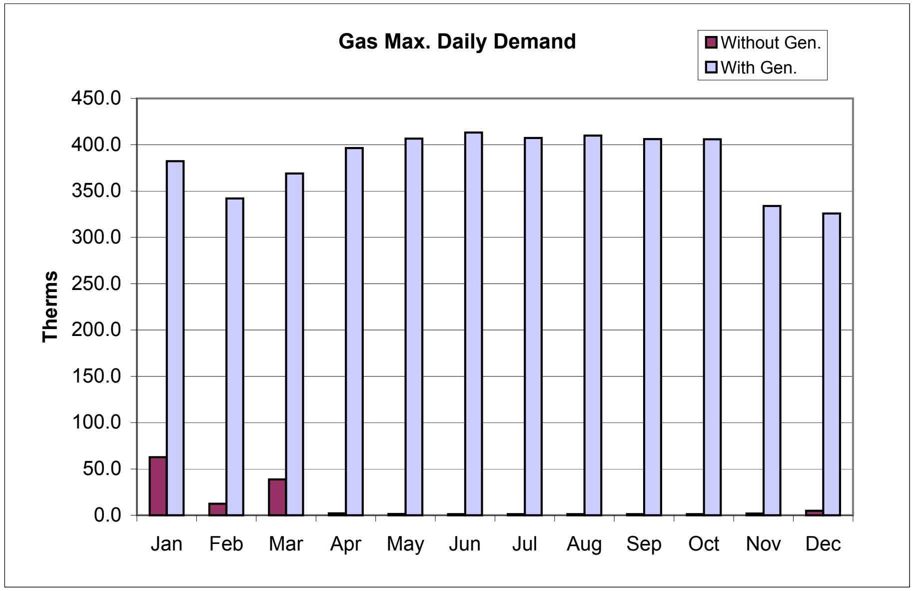




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Without (Miami FPL Rate GSLDT-1 TOU > 500 kW

Retail Store, Miami 125,000 sf

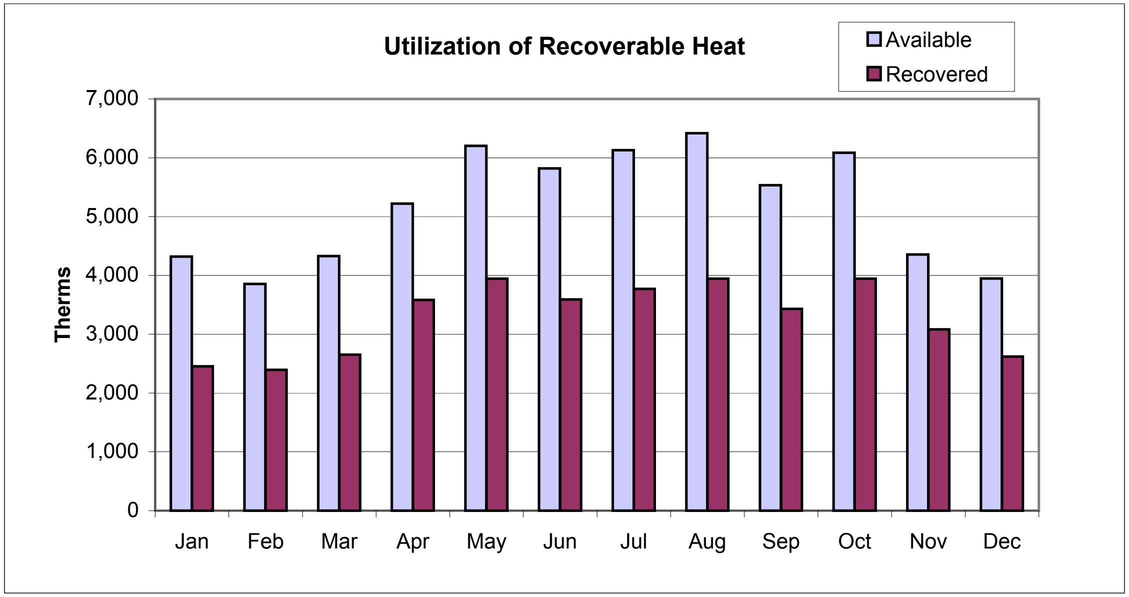




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Retail Store, Miami 125,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Retail Store, San Diego 125,000 sf

Baseline Configuration - No electric generation

	Electric Energy					**Natural Gas Energy**				**Total Energy Cost**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	**$**
Jan	192005	429.9	17465	6481	25818	527.1	61.3	316	316	26,134
Feb	182336	426.9	16566	6451	24824	161.2	18.8	97	97	24,920
Mar	204400	440.1	18580	6500	27032	145.6	26.4	87	87	27,119
Apr	207581	476.4	18859	7510	28410	77.2	11.7	46	46	28,456
May	213096	459.9	20541	7505	30205	59.8	3.8	36	36	30,241
Jun	235755	566.9	22580	9252	34256	44.4	1.9	27	27	34,283
Jul	261107	582.0	25015	9499	37125	42.6	1.5	26	26	37,151
Aug	270682	573.8	26038	9554	38280	43.0	1.4	26	26	38,306
Sep	248812	566.4	23734	9322	35566	40.5	1.4	24	24	35,590
Oct	240573	516.2	21879	7864	32020	48.3	3.3	29	29	32,049
Nov	206586	456.2	18813	6814	27617	101.6	12.9	61	61	27,678
Dec	196223	435.0	17786	6592	26280	471.7	99.8	283	283	26,563
Tot.	**2,659,156**	**5,930**	**247,857**	**93,343**	**367,434**	**1,763**	**244**	**1,058**	**1,058**	**368,491**
Avr.	**221,596**	**494**	**20,655**	**7,779**	**30,619**	**147**	**20**	**88**	**88**	**30,708**
Max		**582**					**100**			

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Retail Store, San Diego 125,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					Natural Gas Energy					Total	Gen.	Total
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	Energy
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	Cost $
Jan	54,276	0	4,720	4,768	12,046	16,541	779	9,925	0	9,925	21,970	1,583	23,554
Feb	55,840	0	4,856	4,820	12,072	13,476	725	8,085	0	8,085	20,157	1,420	21,577
Mar	62,406	0	5,427	4,608	12,626	14,578	761	8,747	0	8,747	21,373	1,580	22,953
Apr	65,429	0	5,690	4,764	13,039	13,145	735	7,887	0	7,887	20,926	1,546	22,472
May	59,864	0	5,204	4,707	12,737	14,331	737	8,599	0	8,599	21,336	1,673	23,008
Jun	72,949	0	6,341	5,788	15,083	11,190	616	6,714	0	6,714	21,797	1,653	23,449
Jul	75,616	0	6,573	5,943	15,716	11,755	597	7,053	0	7,053	22,768	1,848	24,616
Aug	71,674	0	6,231	6,266	15,843	12,452	587	7,471	0	7,471	23,315	1,975	25,289
Sep	83,411	0	7,251	6,076	16,361	10,651	586	6,391	0	6,391	22,751	1,652	24,403
Oct	67,716	0	5,889	5,892	14,678	11,926	593	7,155	0	7,155	21,834	1,755	23,588
Nov	60,461	0	5,258	4,917	12,768	12,978	721	7,787	0	7,787	20,555	1,570	22,125
Dec	66,277	0	5,764	4,645	12,896	14,248	790	8,549	0	8,549	21,445	1,458	22,903
Tot.	**795,918**	**0**	**69,204**	**63,195**	**165,865**	**157,271**	**8,228**	**94,363**	**0**	**94,363**	**260,227**	**19,711**	**279,939**
Avr.	**66,326**	**0**	**5,767**	**5,266**	**13,822**	**13,106**	**686**	**7,864**	**0**	**7,864**	**21,686**	**1,643**	**23,328**
Max		**0**					**790**						

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, San Diego 125,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	143,943	26,186	138,549	17,655	8,068	1,345	16.7	388	69	366	52.2	27.8	35.4
Feb	129,097	23,617	124,297	15,717	7,182	1,970	27.4	337	60	318	50.1	28.0	40.6
Mar	143,608	26,460	137,801	17,473	7,985	2,493	31.2	374	66	352	50.3	28.0	42.3
Apr	140,543	25,815	135,221	17,002	7,770	3,225	41.5	357	63	336	49.6	28.2	47.2
May	152,074	66,150	146,620	18,418	8,417	3,400	40.4	388	161	366	52.2	28.2	46.6
Jun	150,231	64,740	141,679	18,035	8,242	5,650	68.5	370	147	336	51.4	28.4	59.7
Jul	167,986	71,088	155,422	20,031	9,154	6,822	74.5	402	154	351	54.0	28.6	62.7
Aug	179,533	77,133	164,846	21,411	9,785	7,382	75.4	431	161	368	57.9	28.6	63.1
Sep	150,150	64,789	139,113	17,971	8,213	6,036	73.5	366	140	319	50.8	28.5	62.1
Oct	159,505	28,414	150,990	19,249	8,797	6,044	68.7	402	69	367	54.0	28.3	59.7
Nov	142,732	26,745	137,420	17,329	7,919	3,650	46.1	368	66	348	51.1	28.1	49.2
Dec	132,541	24,226	127,642	16,223	7,414	2,006	27.1	354	63	334	47.6	27.9	40.2
Tot.	**1,791,942**	**525,363**	**1,699,600**	**216,512**	**98,946**	**50,023**		**4,537**	**1,219**	**4,161**			
Avr.	**149,329**	**43,780**	**141,633**	**18,043**	**8,246**	**4,169**	**49.3**	**378**	**102**	**347**	**52**	**28.2**	**50.7**
Max							**75.4**					**28.6**	**63.1**

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, San Diego 125,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	192,005	430	54,276	0	8,068	1,345	16.7	106.5	834.6	1,195.2	12.9	3.6	3,455	63
Feb	182,336	427	55,840	0	7,182	1,970	27.4	106.3	1,342.1	1,921.4	3.6	0.4	5,524	63
Mar	204,400	440	62,406	0	7,985	2,493	31.2	106.8	1,724.1	2,456.5	9.6	3.7	7,248	63
Apr	207,581	476	65,429	0	7,770	3,225	41.5	113.0	2,252.2	3,201.5	74.8	101.1	9,657	68
May	213,096	460	59,864	0	8,417	3,400	40.4	106.9	2,373.0	3,377.4	15.4	16.1	10,060	63
Jun	235,755	567	72,949	0	8,242	5,650	68.5	113.0	4,006.7	5,629.6	125.7	995.6	19,107	68
Jul	261,107	582	75,616	0	9,154	6,822	74.5	113.0	4,848.1	6,802.7	145.6	2,206.0	23,700	68
Aug	270,682	574	71,674	0	9,785	7,382	75.4	113.0	5,248.8	7,362.6	135.6	2,471.0	25,797	68
Sep	248,812	566	83,411	0	8,213	6,036	73.5	113.0	4,289.4	6,018.4	124.8	1,682.3	20,923	68
Oct	240,573	516	67,716	0	8,797	6,044	68.7	113.0	4,291.0	6,023.5	101.7	740.0	20,512	68
Nov	206,586	456	60,461	0	7,919	3,650	46.1	109.9	2,561.4	3,615.9	35.9	73.2	11,531	66
Dec	196,223	435	66,277	0	7,414	2,006	27.1	107.6	1,304.0	1,844.2	22.5	30.0	5,769	64
Tot.	**2,659,156**	**5,930**	**795,918**	**0**	**98,946**	**50,023**		**1,321.8**	**35,075**	**49,449**	**808.1**	**8,323**	**163,283**	
Avr.	**221,596**	**494**	**66,326**	**0**	**8,246**	**4,169**	**49.3**	**110.1**	**2,923**	**4,121**	**67.3**	**694**	**13,607**	**66**
Max		**582**		**0**										

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Retail Store, San Diego 125,000 sf

Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.134	0.600
Feb	0.136	0.600
Mar	0.132	0.600
Apr	0.137	0.600
May	0.142	0.600
Jun	0.145	0.600
Jul	0.142	0.600
Aug	0.141	0.600
Sep	0.143	0.600
Oct	0.133	0.600
Nov	0.134	0.600
Dec	0.134	0.600
Avr.	**0.138**	**0.600**
Total		

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.222	0.600	0.085	807	0.079	0.1148
Feb	0.216	0.600	0.084	1,182	0.075	0.1103
Mar	0.202	0.600	0.084	1,496	0.074	0.1042
Apr	0.199	0.600	0.084	1,935	0.070	0.0997
May	0.213	0.600	0.084	2,040	0.070	0.0989
Jun	0.207	0.600	0.083	3,390	0.060	0.0899
Jul	0.208	0.600	0.083	4,093	0.058	0.0842
Aug	0.221	0.600	0.083	4,429	0.058	0.0830
Sep	0.196	0.600	0.083	3,621	0.059	0.0890
Oct	0.217	0.600	0.083	3,627	0.061	0.0879
Nov	0.211	0.600	0.084	2,190	0.068	0.0981
Dec	0.195	0.600	0.084	1,203	0.075	0.1091
Avr.	**0.209**	**0.600**	**0.084**	**2,501**	**0.067**	**0.097**
Total				**$30,014**		

SDG&E AL-TOU_DER + EECC > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

$368,491

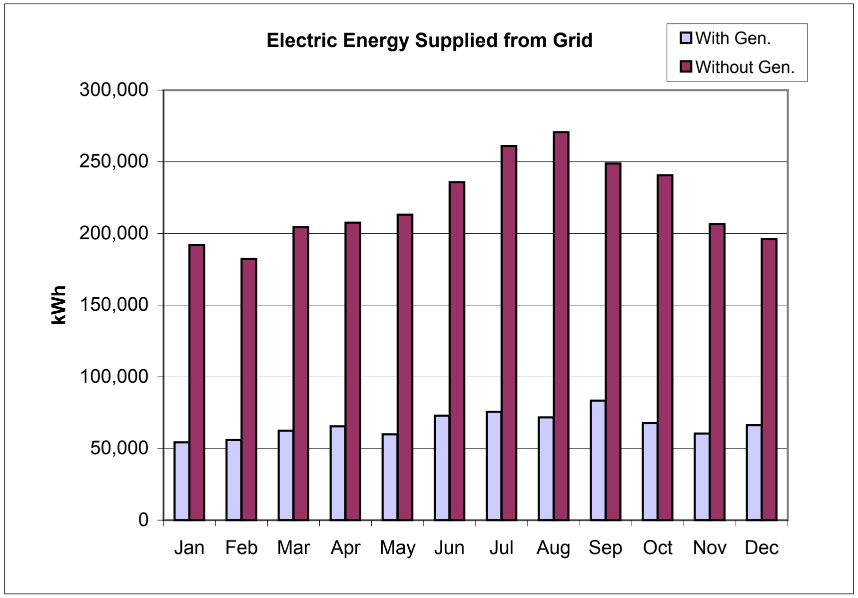
$279,939

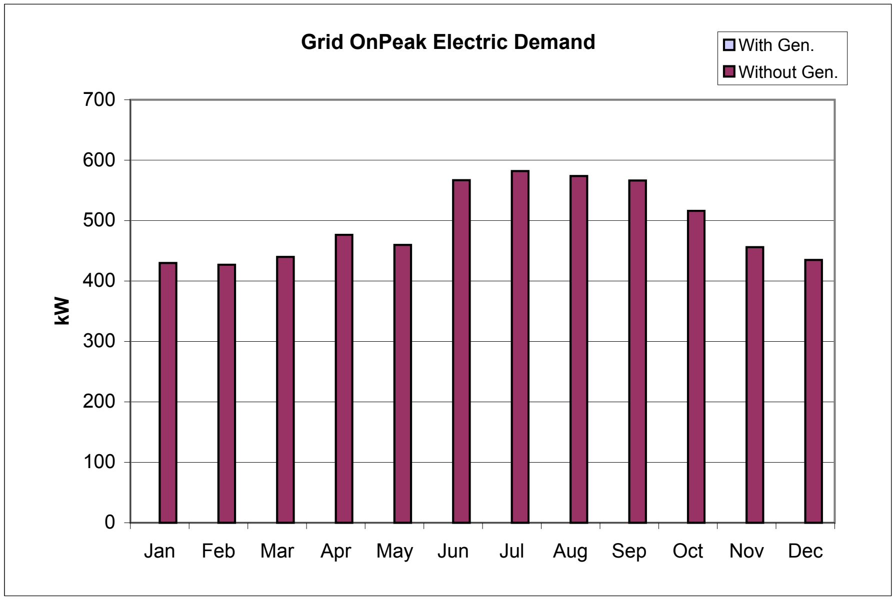
Annual Savings

$88,553

Note: * Cost of elctric generation including benefits of recoverable heat

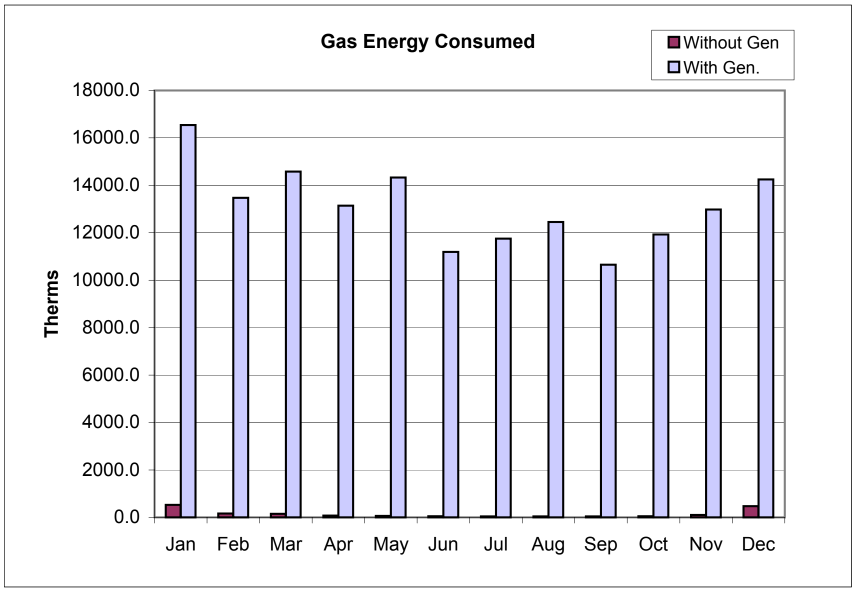
Retail Store, San Diego 125,000 sf

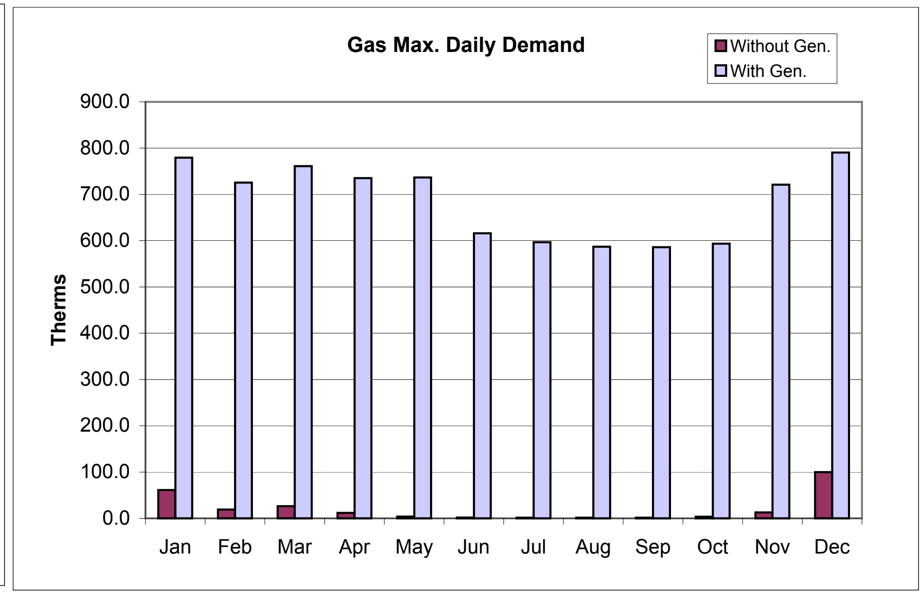




Electric			
Energy Rates		Gen:	VGF36GLD Engine Generator, 615 kWe
With Gen	SDG&E AL-TOU_DER + EECC	> 500 kW + Energy Generation Charges	
Without (	SDG&E AL-TOU_DER + EECC	> 500 kW	

Retail Store, San Diego 125,000 sf

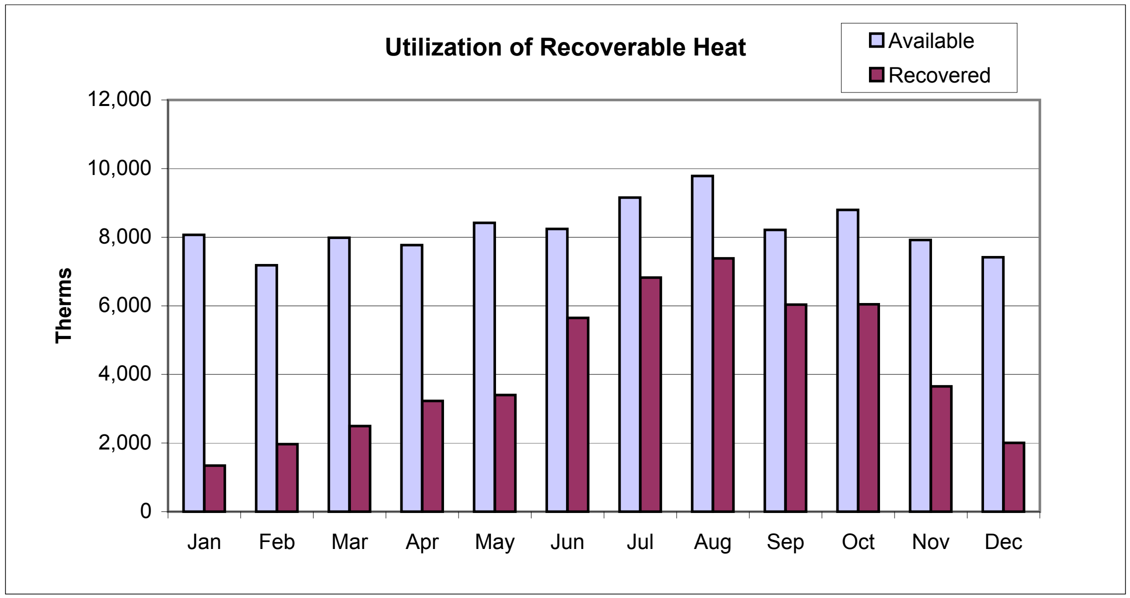




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Retail Store, San Diego 125,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf

Baseline Configuration - No electric generation

	Electric Energy					**Natural Gas Energy**				**Total Energy Cost**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	**$**
Jan	261060	629.6	2859	7265	11000	26988.8	1209.7	16193	16193	27,193
Feb	241350	636.0	2598	7340	10800	22950.3	1120.1	13770	13770	24,570
Mar	275087	653.9	2954	7546	11402	21671.7	1066.9	13003	13003	24,405
Apr	281558	667.3	2992	7701	11608	15393.8	729.9	9236	9236	20,844
May	311355	798.9	3403	9219	13672	8645.7	483.5	5187	5187	18,860
Jun	323066	712.6	4590	17616	23927	5417.9	310.8	3251	3251	27,177
Jul	363679	735.9	5283	18190	25283	4221.1	179.3	2533	2533	27,816
Aug	351482	704.5	5193	17416	24358	4407.6	190.3	2645	2645	27,002
Sep	311902	684.8	4395	16927	22982	5459.2	285.0	3275	3276	26,257
Oct	298879	672.6	3249	7762	11948	10193.7	472.2	6116	6116	18,065
Nov	268102	643.1	2892	7421	11202	16992.0	906.0	10195	10195	21,397
Dec	266541	635.8	2791	7337	11004	23430.2	1370.1	14058	14058	25,062
Tot.	**3,554,061**	**8,175**	**43,198**	**131,742**	**189,186**	**165,772**	**8,324**	**99,463**	**99,463**	**288,649**
Avr.	**296,172**	**681**	**3,600**	**10,979**	**15,766**	**13,814**	**694**	**8,289**	**8,289**	**24,054**
Max		**799**					**1,370**			

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Large Hotel Building, Boston 220,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	144,206	30	727	348	1,316	33,857	1,470	20,314	0	20,314	21,630	1,326	22,956
Feb	137,047	40	694	461	1,403	29,089	1,397	17,453	0	17,453	18,856	1,183	20,040
Mar	156,845	42	796	485	1,537	28,871	1,145	17,323	0	17,323	18,860	1,334	20,194
Apr	162,885	43	826	492	1,577	22,684	1,033	13,610	0	13,610	15,187	1,310	16,497
May	173,161	130	881	1,504	2,719	17,290	837	10,374	0	10,374	13,092	1,462	14,554
Jun	238,766	44	2,018	1,089	3,491	10,405	557	6,243	0	6,243	9,734	866	10,599
Jul	277,905	706	2,666	17,450	21,690	9,042	426	5,425	0	5,425	27,115	859	27,974
Aug	250,852	36	2,123	889	3,389	10,152	422	6,091	0	6,091	9,480	1,011	10,491
Sep	232,057	16	1,959	400	2,691	10,210	506	6,126	0	6,126	8,817	815	9,632
Oct	167,112	23	844	265	1,354	19,067	858	11,440	0	11,440	12,794	1,431	14,225
Nov	151,670	39	767	449	1,468	24,791	1,211	14,875	0	14,875	16,343	1,318	17,661
Dec	157,204	39	796	453	1,503	30,334	1,654	18,200	0	18,200	19,703	1,244	20,947
Tot.	**2,249,709**	**1,188**	**15,096**	**24,285**	**44,138**	**245,791**	**11,517**	**147,474**	**0**	**147,474**	**191,612**	**14,159**	**205,771**
Avr.	**187,476**	**99**	**1,258**	**2,024**	**3,678**	**20,483**	**960**	**12,290**	**0**	**12,290**	**15,968**	**1,180**	**17,148**
Max		**706**					**1,654**						

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	120,552	120,552	120,552	14,480	6,617	6,241	94.3	299	299	299	40.2	28.4	71.5
Feb	107,566	107,566	107,566	12,854	5,874	5,507	93.7	260	260	260	38.7	28.6	71.4
Mar	121,314	121,314	121,314	14,424	6,592	5,924	89.9	286	286	286	38.4	28.7	69.8
Apr	119,050	119,050	119,050	14,082	6,436	5,570	86.5	273	273	273	37.9	28.8	68.4
May	132,876	132,876	132,876	15,657	7,155	5,750	80.4	299	299	299	40.2	29.0	65.7
Jun	78,708	78,708	78,708	9,405	4,298	3,623	84.3	189	189	189	26.3	28.6	67.1
Jul	78,079	78,079	78,079	9,152	4,182	3,552	84.9	171	171	171	23.0	29.1	67.9
Aug	91,912	91,912	91,912	10,832	4,950	4,172	84.3	207	207	207	27.8	29.0	67.5
Sep	74,073	74,073	74,073	8,874	4,056	3,381	83.4	180	180	180	25.0	28.5	66.6
Oct	130,133	130,133	130,133	15,399	7,038	5,351	76.0	299	299	299	40.2	28.8	63.6
Nov	119,832	119,832	119,832	14,284	6,528	5,317	81.5	286	286	286	39.7	28.6	65.9
Dec	113,052	113,052	113,052	13,506	6,172	5,414	87.7	273	273	273	36.7	28.6	68.6
Tot.	**1,287,147**	**1,287,147**	**1,287,147**	**152,948**	**69,897**	**59,802**		**3,022**	**3,022**	**3,022**			
Avr.	**107,262**	**107,262**	**107,262**	**12,746**	**5,825**	**4,984**	**85.6**	**252**	**252**	**252**	**35**	**28.7**	**67.8**
Max							**94.3**					**29.1**	**71.5**

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	261,060	630	144,206	30	6,617	6,241	94.3	31.0	17.9	28.4	12.0	137.0	-19	8
Feb	241,350	636	137,047	40	5,874	5,507	93.7	43.3	128.8	197.3	12.0	124.2	112	16
Mar	275,087	654	156,845	42	6,592	5,924	89.9	97.8	571.6	834.4	12.1	86.0	1,315	47
Apr	281,558	667	162,885	43	6,436	5,570	86.5	122.6	1,433.5	2,040.4	47.7	59.2	4,368	63
May	311,355	799	173,161	130	7,155	5,750	80.4	122.6	2,849.3	3,954.2	204.5	764.4	10,810	63
Jun	323,066	713	238,766	44	4,298	3,623	84.3	122.6	2,162.0	2,982.0	201.0	989.6	8,637	63
Jul	363,679	736	277,905	706	4,182	3,552	84.9	122.6	2,335.4	3,214.4	239.1	2,295.4	9,835	63
Aug	351,482	705	250,852	36	4,950	4,172	84.3	122.6	2,751.1	3,785.4	202.8	2,183.4	11,476	63
Sep	311,902	685	232,057	16	4,056	3,381	83.4	122.6	2,158.2	2,971.0	171.3	906.1	8,659	63
Oct	298,879	673	167,112	23	7,038	5,351	76.0	122.6	2,217.0	3,104.0	43.6	29.6	7,563	63
Nov	268,102	643	151,670	39	6,528	5,317	81.5	102.7	606.4	888.1	38.5	92.6	1,417	50
Dec	266,541	636	157,204	39	6,172	5,414	87.7	61.0	218.6	333.0	12.2	112.2	197	27
Tot.	**3,554,061**	**8,175**	**2,249,709**	**1,188**	**69,897**	**59,802**		**1,193.9**	**17,450**	**24,332**	**1,196.9**	**7,780**	**64,368**	
Avr.	**296,172**	**681**	**187,476**	**99**	**5,825**	**4,984**	**85.6**	**99.5**	**1,454**	**2,028**	**99.7**	**648**	**5,364**	**49**
Max		**799**		**706**										

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW

Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf
Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.042	0.600
Feb	0.045	0.600
Mar	0.041	0.600
Apr	0.041	0.600
May	0.044	0.600
Jun	0.074	0.600
Jul	0.070	0.600
Aug	0.069	0.600
Sep	0.074	0.600
Oct	0.040	0.600
Nov	0.042	0.600
Dec	0.041	0.600
Avr.	**0.052**	**0.600**
Total		

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.009	0.600	0.083	3,745	0.052	0.0726
Feb	0.010	0.600	0.083	3,304	0.052	0.0684
Mar	0.010	0.600	0.082	3,554	0.053	0.0598
Apr	0.010	0.600	0.082	3,342	0.054	0.0467
May	0.016	0.600	0.082	3,450	0.056	0.0363
Jun	0.015	0.600	0.083	2,174	0.055	0.0265
Jul	0.078	0.600	0.081	2,131	0.054	0.0726
Aug	0.014	0.600	0.082	2,503	0.054	0.0233
Sep	0.012	0.600	0.083	2,029	0.055	0.0248
Oct	0.008	0.600	0.082	3,211	0.057	0.0371
Nov	0.010	0.600	0.083	3,190	0.056	0.0533
Dec	0.010	0.600	0.083	3,248	0.054	0.0655
Avr.	**0.017**	**0.600**	**0.082**	**2,990**	**0.054**	**0.049**
Total				**$35,881**		

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

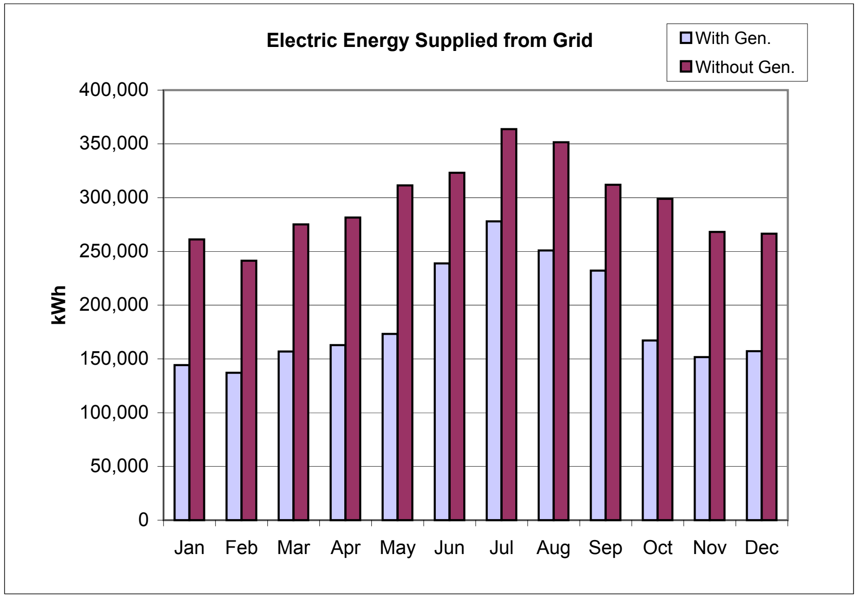
Baseline	On Site Generation
$288,649	**$205,771**

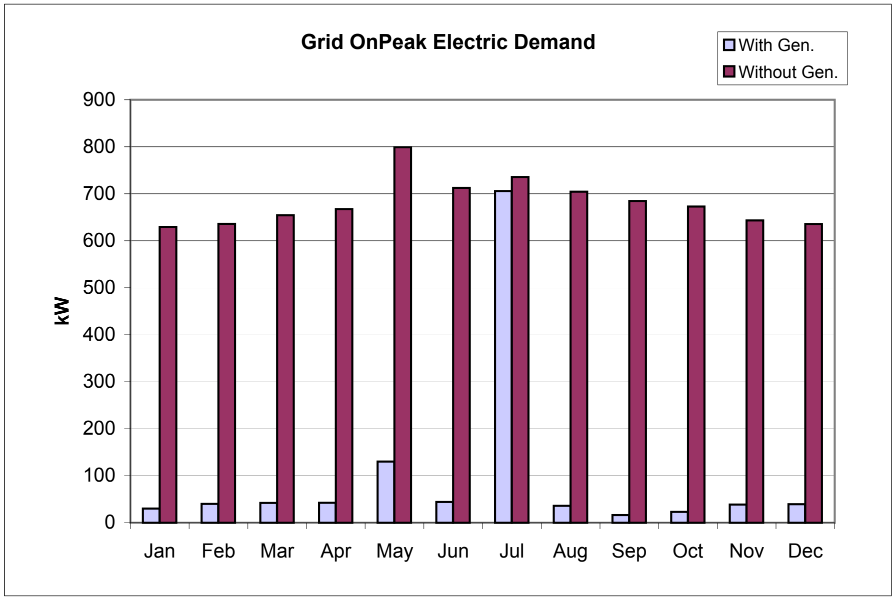
Annual Savings

$82,878

Note: * Cost of elctric generation including benefits of recoverable heat

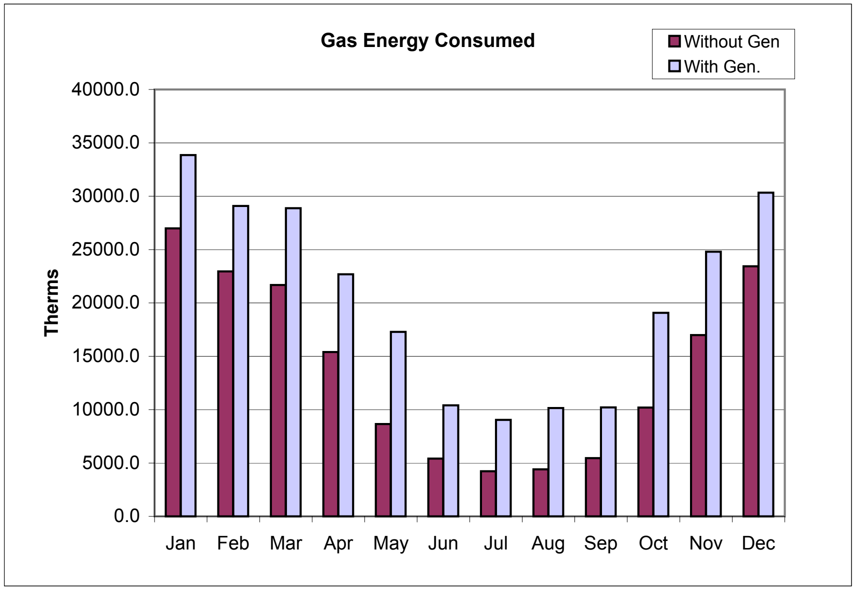
Large Hotel Building, Boston 220,000 sf

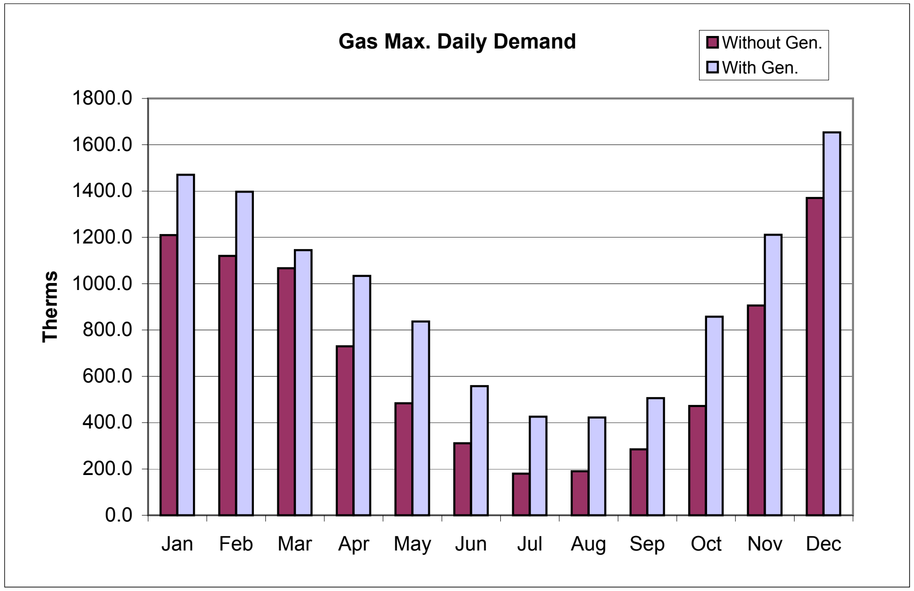




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Without (Boston Electric Rate T-2 TOU > 300 kW < 1000 kW

Large Hotel Building, Boston 220,000 sf

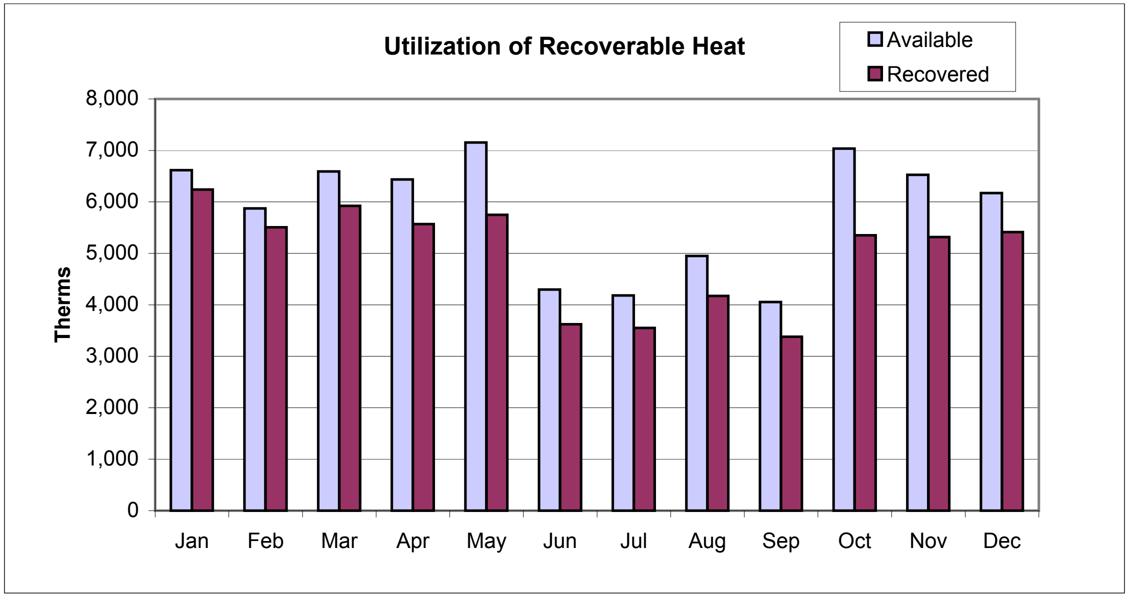




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf

Baseline Configuration - No electric generation

	Electric Energy					**Natural Gas Energy**				**Total Energy Cost**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	**$**
Jan	260384	434.6	9890	4837	16196	30308.4	1600.2	18185	18185	34,381
Feb	238765	443.1	8963	4931	15282	24412.7	1175.8	14648	14648	29,930
Mar	276004	449.4	10329	5002	16857	22121.6	990.6	13273	13273	30,130
Apr	284344	553.9	10581	6165	18411	14061.3	735.4	8437	8437	26,848
May	316145	682.0	12048	7590	21583	8553.3	449.5	5132	5132	26,715
Jun	339607	739.3	12819	10527	25651	4984.9	288.5	2991	2991	28,642
Jul	374997	775.1	14125	11038	27643	4272.2	162.6	2563	2563	30,207
Aug	368794	814.2	14105	11595	28232	4388.6	199.2	2633	2633	30,865
Sep	317529	708.1	11652	10083	23883	5674.8	305.2	3405	3405	27,288
Oct	301009	570.6	11464	6351	19583	10866.6	592.2	6520	6520	26,103
Nov	270520	495.9	10170	5520	17251	17980.4	813.4	10788	10788	28,039
Dec	257296	425.6	9475	4737	15630	27551.2	1676.2	16531	16531	32,161
Tot.	**3,605,394**	**7,092**	**135,621**	**88,375**	**246,202**	**175,176**	**8,989**	**105,106**	**105,106**	**351,308**
Avr.	**300,450**	**591**	**11,302**	**7,365**	**20,517**	**14,598**	**749**	**8,759**	**8,759**	**29,276**
Max		**814**					**1,676**			

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Large Hotel Building, Boston 220,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	144,226	0	3,387	0	5,870	37,042	1,664	22,225	0	22,225	28,096	1,317	29,413
Feb	135,612	0	3,188	0	5,652	30,541	1,465	18,325	0	18,325	23,977	1,170	25,147
Mar	158,089	0	3,727	0	6,243	29,295	1,246	17,577	0	17,577	23,820	1,334	25,154
Apr	164,463	0	3,869	0	6,400	21,860	1,037	13,116	0	13,116	19,516	1,323	20,839
May	174,154	13	4,098	149	6,814	17,005	796	10,203	0	10,203	17,017	1,480	18,497
Jun	193,332	71	4,629	1,018	8,350	13,408	618	8,045	0	8,045	16,395	1,477	17,872
Jul	215,745	108	5,208	1,539	9,556	13,519	641	8,111	0	8,111	17,668	1,602	19,269
Aug	205,474	151	4,961	2,145	9,950	13,862	648	8,317	0	8,317	18,267	1,645	19,912
Sep	189,373	40	4,476	562	7,683	13,362	722	8,017	0	8,017	15,700	1,314	17,014
Oct	166,062	0	3,909	0	6,443	19,764	961	11,858	0	11,859	18,302	1,455	19,756
Nov	153,421	0	3,613	0	6,119	25,692	1,120	15,415	0	15,415	21,534	1,326	22,861
Dec	151,611	0	3,557	0	6,058	34,016	1,944	20,409	0	20,409	26,467	1,201	27,668
Tot.	**2,051,563**	**383**	**48,622**	**5,413**	**85,138**	**269,367**	**12,863**	**161,620**	**0**	**161,620**	**246,758**	**16,644**	**263,403**
Avr.	**170,964**	**32**	**4,052**	**451**	**7,095**	**22,447**	**1,072**	**13,468**	**0**	**13,468**	**20,563**	**1,387**	**21,950**
Max		**151**					**1,944**						

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	119,723	71,424	119,723	14,394	6,578	6,281	95.5	299	207	299	40.2	28.4	72.0
Feb	106,397	63,800	106,397	12,738	5,821	5,420	93.1	260	180	260	38.7	28.5	71.0
Mar	121,284	72,864	121,284	14,419	6,589	5,942	90.2	286	198	286	38.4	28.7	69.9
Apr	120,291	74,317	120,291	14,199	6,489	5,248	80.9	273	189	273	37.9	28.9	65.9
May	134,534	84,481	134,534	15,816	7,228	6,039	83.5	299	207	299	40.2	29.0	67.2
Jun	134,308	87,187	134,308	15,514	7,090	5,815	82.0	273	189	273	37.9	29.5	67.0
Jul	145,600	95,309	145,600	16,712	7,638	6,122	80.2	286	198	286	38.4	29.7	66.4
Aug	149,569	97,133	149,569	17,223	7,871	6,354	80.7	299	207	299	40.2	29.6	66.5
Sep	119,438	75,448	119,438	13,981	6,389	5,160	80.8	260	180	260	36.1	29.1	66.1
Oct	132,265	81,977	132,265	15,603	7,131	5,498	77.1	299	207	299	40.2	28.9	64.2
Nov	120,574	73,389	120,574	14,355	6,560	5,447	83.0	286	198	286	39.7	28.7	66.6
Dec	109,145	65,292	109,145	13,128	5,999	5,464	91.1	273	189	273	36.7	28.4	70.0
Tot.	**1,513,127**	**942,621**	**1,513,127**	**178,082**	**81,384**	**68,791**		**3,393**	**2,349**	**3,393**			
Avr.	**126,094**	**78,552**	**126,094**	**14,840**	**6,782**	**5,733**	**84.8**	**283**	**196**	**283**	**39**	**29.0**	**67.7**
Max							**95.5**					**29.7**	**72.0**

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW

Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	260,384	435	144,226	0	6,578	6,281	95.5	53.4	106.5	162.4	11.7	96.1	93	23
Feb	238,765	443	135,612	0	5,821	5,420	93.1	58.2	164.5	252.4	12.1	98.4	125	26
Mar	276,004	449	158,089	0	6,589	5,942	90.2	101.5	454.0	673.1	12.2	96.0	841	49
Apr	284,344	554	164,463	0	6,489	5,248	80.9	105.2	1,531.4	2,170.8	11.4	11.2	4,773	52
May	316,145	682	174,154	13	7,228	6,039	83.5	122.6	3,260.1	4,502.9	203.3	902.5	12,795	63
Jun	339,607	739	193,332	71	7,090	5,815	82.0	122.6	3,733.6	5,142.3	349.9	3,329.6	15,738	63
Jul	374,997	775	215,745	108	7,638	6,122	80.2	122.6	4,024.1	5,544.6	329.9	4,788.8	17,119	63
Aug	368,794	814	205,474	151	7,871	6,354	80.7	122.6	4,159.1	5,729.2	349.3	4,286.7	17,626	63
Sep	317,529	708	189,373	40	6,389	5,160	80.8	122.6	3,192.5	4,399.6	185.9	1,515.7	13,033	63
Oct	301,009	571	166,062	0	7,131	5,498	77.1	122.6	2,406.2	3,359.7	86.5	206.1	8,513	63
Nov	270,520	496	153,421	0	6,560	5,447	83.0	122.6	525.3	769.1	90.9	172.9	1,213	63
Dec	257,296	426	151,611	0	5,999	5,464	91.1	45.7	50.6	76.8	12.0	97.6	72	18
Tot.	**3,605,394**	**7,092**	**2,051,563**	**383**	**81,384**	**68,791**		**1,222.1**	**23,608**	**32,783**	**1,655.1**	**15,602**	**91,942**	
Avr.	**300,450**	**591**	**170,964**	**32**	**6,782**	**5,733**	**84.8**	**101.8**	**1,967**	**2,732**	**137.9**	**1,300**	**7,662**	**51**
Max		**814**		**151**										

Energy Rates: Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf

Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.062	0.600
Feb	0.064	0.600
Mar	0.061	0.600
Apr	0.065	0.600
May	0.068	0.600
Jun	0.076	0.600
Jul	0.074	0.600
Aug	0.077	0.600
Sep	0.075	0.600
Oct	0.065	0.600
Nov	0.064	0.600
Dec	0.061	0.600
Avr.	**0.068**	**0.600**
Total		

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.041	0.600	0.083	3,769	0.052	0.0972
Feb	0.042	0.600	0.083	3,252	0.052	0.0905
Mar	0.039	0.600	0.082	3,565	0.053	0.0773
Apr	0.039	0.600	0.082	3,149	0.056	0.0621
May	0.039	0.600	0.082	3,623	0.055	0.0482
Jun	0.043	0.600	0.080	3,489	0.054	0.0439
Jul	0.044	0.600	0.080	3,673	0.055	0.0432
Aug	0.048	0.600	0.080	3,813	0.055	0.0453
Sep	0.041	0.600	0.081	3,096	0.055	0.0451
Oct	0.039	0.600	0.082	3,299	0.057	0.0552
Nov	0.040	0.600	0.082	3,268	0.055	0.0715
Dec	0.040	0.600	0.083	3,278	0.053	0.0935
Avr.	**0.041**	**0.600**	**0.082**	**3,440**	**0.054**	**0.064**
Total				**$41,275**		

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

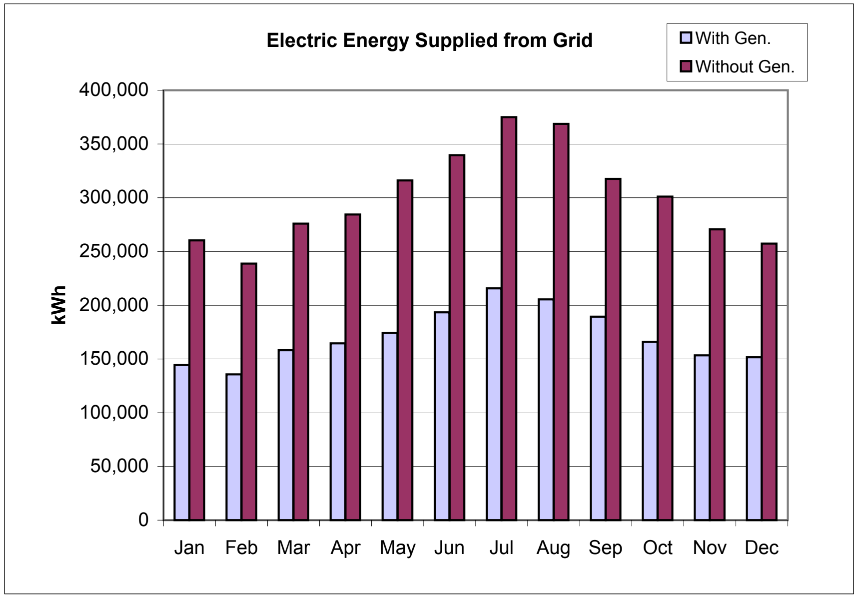
Baseline	On Site Generation
$351,308	**$263,403**

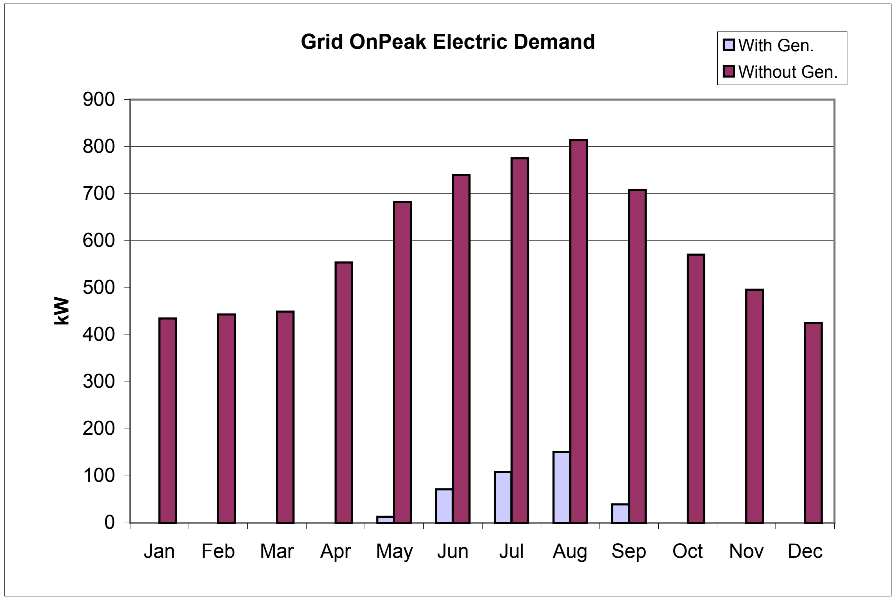
Annual Savings

$87,905

Note: * Cost of elctric generation including benefits of recoverable heat

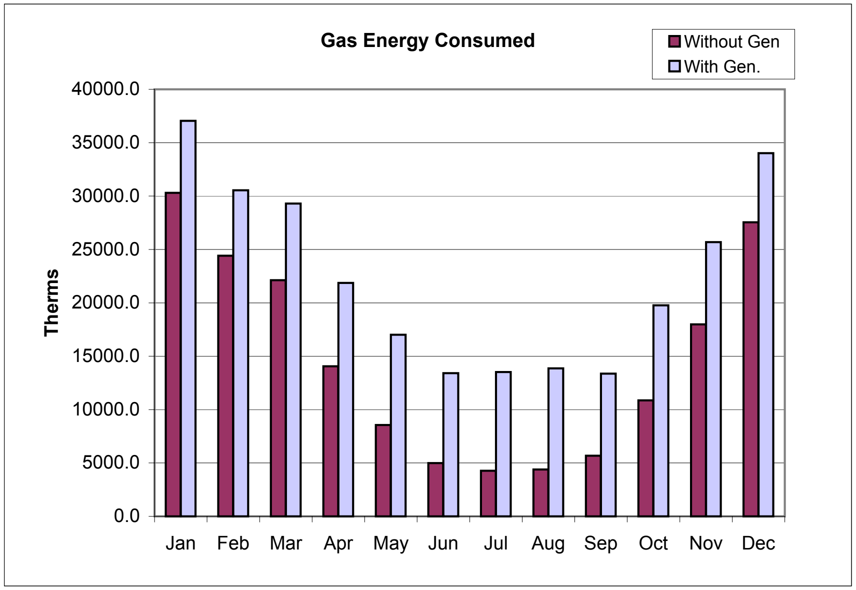
Large Hotel Building, Boston 220,000 sf

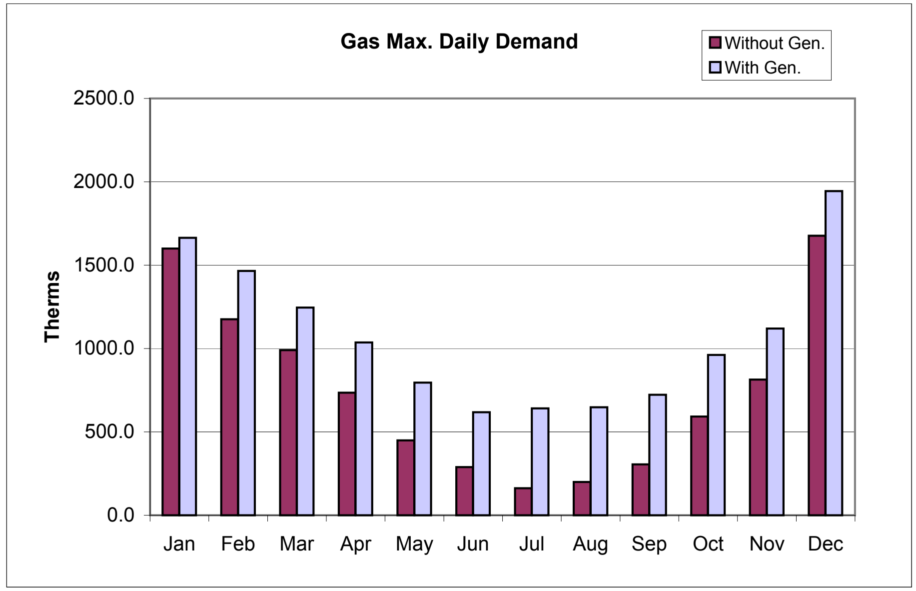




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Boston Electric Rate T-2 TOU > 300 kW < 1000 kW
Without (Boston Electric Rate T-2 TOU > 300 kW < 1000 kW

Large Hotel Building, Boston 220,000 sf

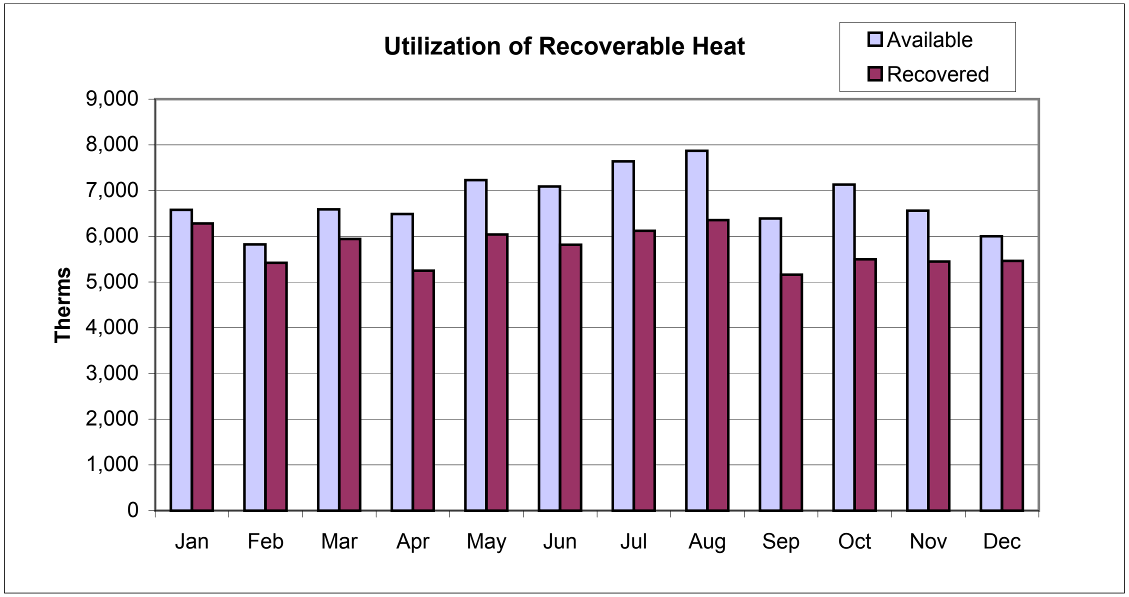




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Large Hotel Building, Boston 220,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Hotel, Miami 220,000 sf

Baseline Configuration - No electric generation

	Electric Energy					Natural Gas Energy				Total Energy Cost
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	$
Jan	359280	837.6	17909	10598	30540	4970.5	353.3	2982	2982	33,523
Feb	328596	849.9	16316	10958	29221	4109.7	275.4	2466	2466	31,686
Mar	371105	862.1	18422	11226	31761	4292.4	281.1	2575	2575	34,337
Apr	380601	879.8	18975	7215	28061	3531.4	149.8	2119	2119	30,180
May	445179	930.3	22290	7629	32051	3476.4	117.5	2086	2086	34,137
Jun	450095	955.9	22394	7839	32387	3288.9	110.0	1973	1973	34,360
Jul	489169	947.7	24284	7771	34337	3358.1	108.8	2015	2015	36,352
Aug	483610	935.8	24147	7673	34086	3335.6	107.9	2001	2001	36,087
Sep	457730	925.1	22578	7586	32313	3221.5	107.9	1933	1933	34,246
Oct	433920	906.9	21719	7436	31234	3415.2	127.2	2049	2049	33,283
Nov	368672	878.3	18337	11491	31953	3555.5	147.8	2133	2133	34,087
Dec	348230	822.4	17207	10417	29597	4244.6	203.2	2547	2547	32,143
Tot.	**4,916,187**	**10,732**	**244,578**	**107,838**	**377,542**	**44,800**	**2,090**	**26,880**	**26,880**	**404,422**
Avr.	**409,682**	**894**	**20,382**	**8,986**	**31,462**	**3,733**	**174**	**2,240**	**2,240**	**33,702**
Max		**956**					**353**			

Energy Rates: Miami FPL Rate GSLDT-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Hotel, Miami 220,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	253,794	164	11,196	2,631	16,460	11,506	609	6,904	0	6,904	23,364	1,077	24,441
Feb	235,015	177	10,360	2,935	15,892	9,859	507	5,915	0	5,915	21,807	948	22,754
Mar	266,345	189	11,755	3,203	17,671	10,759	543	6,455	0	6,455	24,126	1,061	25,187
Apr	270,628	207	11,977	3,139	17,839	10,187	471	6,112	0	6,112	23,952	1,094	25,046
May	315,496	257	14,037	3,503	20,433	11,542	491	6,925	0	6,925	27,358	1,294	28,653
Jun	327,949	285	14,621	3,627	21,191	11,026	506	6,616	0	6,616	27,806	1,223	29,029
Jul	359,199	274	16,013	3,661	22,716	11,642	497	6,985	0	6,985	29,702	1,303	31,004
Aug	348,814	262	15,569	3,565	22,138	11,899	500	7,140	0	7,140	29,278	1,350	30,628
Sep	341,437	252	15,177	3,490	21,639	10,581	490	6,349	0	6,349	27,987	1,164	29,151
Oct	306,741	234	13,625	3,326	19,802	11,306	481	6,784	0	6,784	26,586	1,269	27,855
Nov	263,388	205	11,636	3,373	17,725	10,012	452	6,007	0	6,007	23,732	1,057	24,789
Dec	252,295	149	11,102	2,658	16,389	10,052	479	6,031	0	6,031	22,420	969	23,389
Tot.	**3,541,101**	**2,654**	**157,068**	**39,110**	**229,895**	**130,372**	**6,026**	**78,223**	**0**	**78,223**	**308,118**	**13,808**	**321,926**
Avr.	**295,092**	**221**	**13,089**	**3,259**	**19,158**	**10,864**	**502**	**6,519**	**0**	**6,519**	**25,676**	**1,151**	**26,827**
Max		**285**					**609**						

Energy Rates: Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Hotel, Miami 220,000 sf

<u>Generator Performance Details</u>

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	97,879	97,879	97,879	11,141	5,091	3,776	74.2	184	184	184	24.7	30.0	63.9
Feb	86,165	86,165	86,165	9,785	4,472	3,310	74.0	160	160	160	23.8	30.0	63.9
Mar	96,425	96,425	96,425	10,919	4,990	3,652	73.2	176	176	176	23.7	30.1	63.6
Apr	99,478	99,478	99,478	11,349	5,187	3,849	74.2	189	189	189	26.3	29.9	63.8
May	117,662	117,662	117,662	13,247	6,054	4,248	70.2	207	207	207	27.8	30.3	62.4
Jun	111,214	111,214	111,214	12,450	5,690	3,865	67.9	189	189	189	26.3	30.5	61.5
Jul	118,447	118,447	118,447	13,222	6,043	4,049	67.0	198	198	198	26.6	30.6	61.2
Aug	122,742	122,742	122,742	13,723	6,271	4,230	67.5	207	207	207	27.8	30.5	61.3
Sep	105,799	105,799	105,799	11,846	5,414	3,679	68.0	180	180	180	25.0	30.5	61.5
Oct	115,334	115,334	115,334	13,030	5,955	4,214	70.8	207	207	207	27.8	30.2	62.5
Nov	96,083	96,083	96,083	10,888	4,976	3,634	73.0	176	176	176	24.4	30.1	63.5
Dec	88,065	88,065	88,065	10,049	4,592	3,478	75.7	168	168	168	22.6	29.9	64.5
Tot.	**1,255,294**	**1,255,294**	**1,255,294**	**141,650**	**64,734**	**45,984**		**2,241**	**2,241**	**2,241**			
Avr.	**104,608**	**104,608**	**104,608**	**11,804**	**5,395**	**3,832**	**71.3**	**187**	**187**	**187**	**26**	**30.2**	**62.8**
Max							**75.7**					**30.6**	**64.5**

Energy Rates: Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Hotel, Miami 220,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	359,280	838	253,794	164	5,091	3,776	74.2	113.0	2,162.6	3,042.2	222.1	1,686.1	10,574	68
Feb	328,596	850	235,015	177	4,472	3,310	74.0	113.0	2,009.3	2,822.3	238.9	1,626.1	9,951	68
Mar	371,105	862	266,345	189	4,990	3,652	73.2	113.0	2,220.4	3,119.0	259.8	2,142.1	11,012	68
Apr	380,601	880	270,628	207	5,187	3,849	74.2	113.0	2,527.2	3,545.5	286.6	3,768.5	12,671	68
May	445,179	930	315,496	257	6,054	4,248	70.2	113.0	2,800.7	3,930.9	355.6	6,099.8	14,091	68
Jun	450,095	956	327,949	285	5,690	3,865	67.9	113.0	2,548.4	3,583.2	437.2	6,511.8	12,809	68
Jul	489,169	948	359,199	274	6,043	4,049	67.0	113.0	2,680.4	3,764.1	381.0	7,432.2	13,488	68
Aug	483,610	936	348,814	262	6,271	4,230	67.5	113.0	2,803.6	3,936.5	408.4	7,448.6	14,109	68
Sep	457,730	925	341,437	252	5,414	3,679	68.0	113.0	2,439.8	3,424.7	362.0	6,119.2	12,281	68
Oct	433,920	907	306,741	234	5,955	4,214	70.8	113.0	2,791.3	3,917.2	320.7	5,578.0	14,030	68
Nov	368,672	878	263,388	205	4,976	3,634	73.0	113.0	2,328.8	3,268.6	276.1	2,515.4	11,646	68
Dec	348,230	822	252,295	149	4,592	3,478	75.7	113.0	2,153.6	3,023.1	213.3	1,290.2	10,686	68
Tot.	**4,916,187**	**10,732**	**3,541,101**	**2,654**	**64,734**	**45,984**		**1,355.7**	**29,466**	**41,377**	**3,761.8**	**52,218**	**147,347**	
Avr.	**409,682**	**894**	**295,092**	**221**	**5,395**	**3,832**	**71.3**	**113.0**	**2,456**	**3,448**	**313.5**	**4,351**	**12,279**	**68**
Max		**956**		**285**										

Energy Rates: Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW

Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Hotel, Miami 220,000 sf
Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.085	0.600
Feb	0.089	0.600
Mar	0.086	0.600
Apr	0.074	0.600
May	0.072	0.600
Jun	0.072	0.600
Jul	0.070	0.600
Aug	0.070	0.600
Sep	0.071	0.600
Oct	0.072	0.600
Nov	0.087	0.600
Dec	0.085	0.600
Avr.	**0.078**	**0.600**
Total		

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.065	0.600	0.079	2,265	0.056	0.0631
Feb	0.068	0.600	0.079	1,986	0.056	0.0647
Mar	0.066	0.600	0.079	2,191	0.056	0.0634
Apr	0.066	0.600	0.079	2,309	0.056	0.0614
May	0.065	0.600	0.079	2,549	0.057	0.0603
Jun	0.065	0.600	0.078	2,319	0.057	0.0608
Jul	0.063	0.600	0.078	2,430	0.057	0.0598
Aug	0.063	0.600	0.078	2,538	0.057	0.0596
Sep	0.063	0.600	0.078	2,207	0.057	0.0602
Oct	0.065	0.600	0.079	2,528	0.057	0.0600
Nov	0.067	0.600	0.079	2,181	0.056	0.0629
Dec	0.065	0.600	0.079	2,087	0.056	0.0626
Avr.	**0.065**	**0.600**	**0.079**	**2,299**	**0.057**	**0.062**
Total				**$27,590**		

Miami FPL Rate GSLDT-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

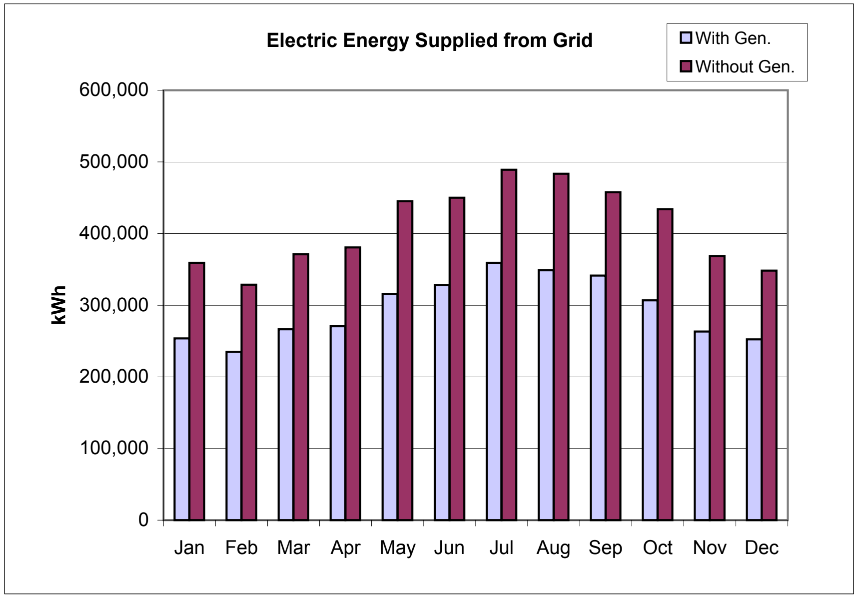
$404,422 **$321,926**

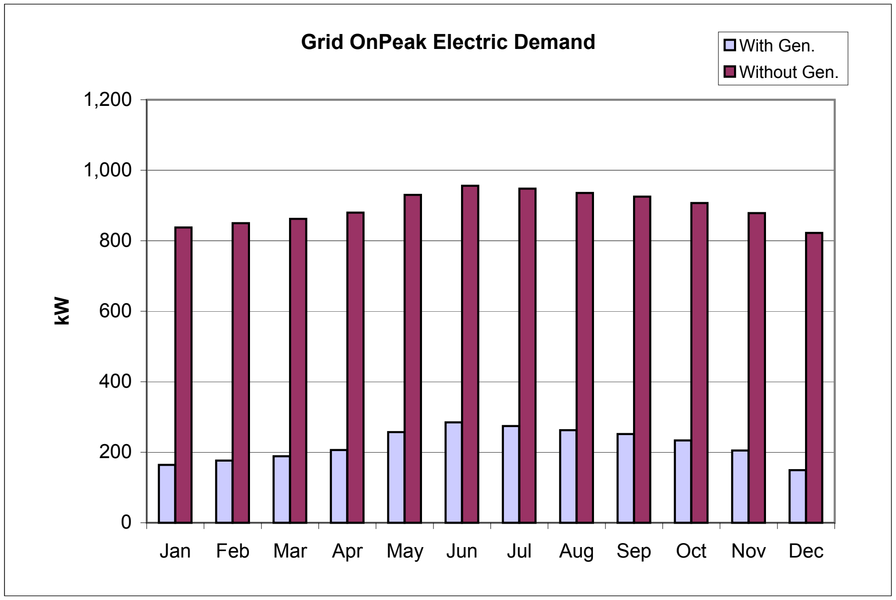
Annual Savings

$82,496

Note: * Cost of elctric generation including benefits of recoverable heat

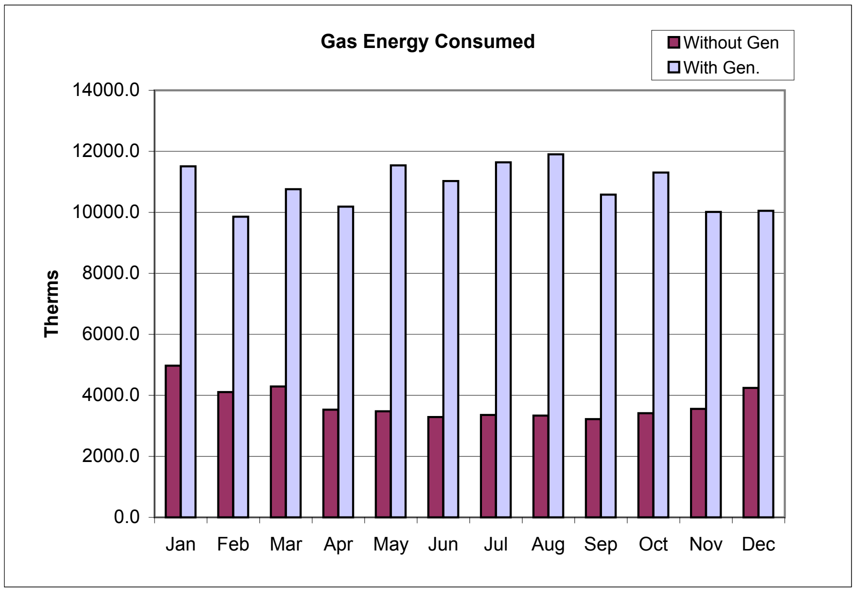
Hotel, Miami 220,000 sf

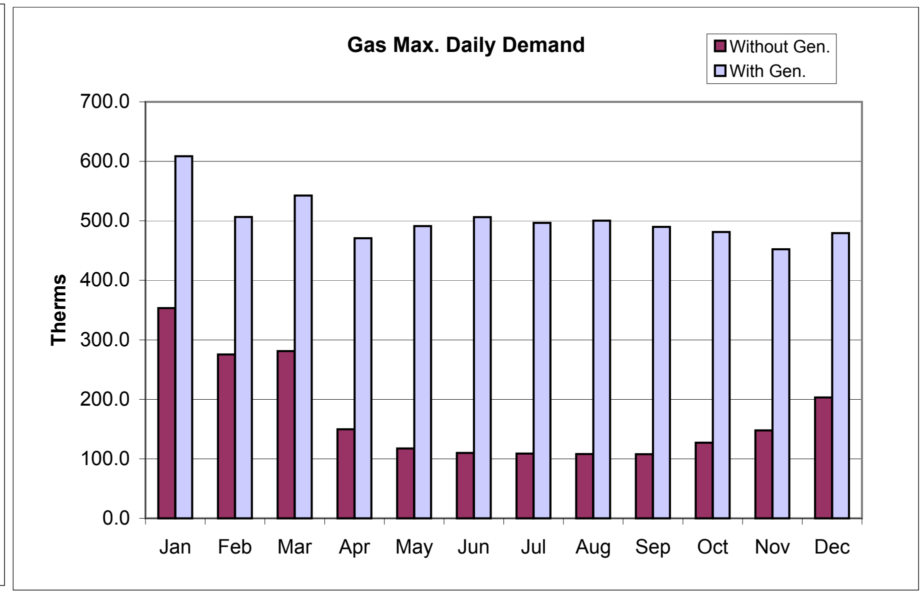




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen Miami FPL Rate GSLDT-1 & SST-1 TOU > 500 kW
Without (Miami FPL Rate GSLDT-1 TOU > 500 kW

Hotel, Miami 220,000 sf

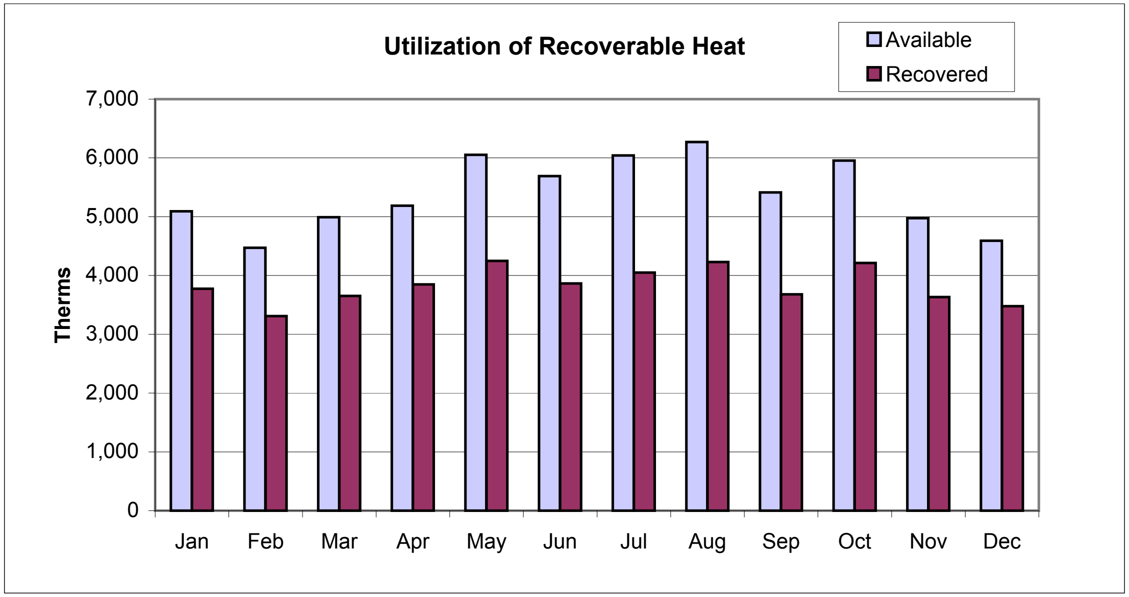




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Hotel, Miami 220,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe

Hotel, San Diego 220,000 sf

Baseline Configuration - No electric generation

	Electric Energy					Natural Gas Energy				Total Energy Cost
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs		
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Tot. Gas $	$
Jan	294474	634.1	26656	9286	38654	9073.3	382.6	5444	5444	44,098
Feb	268672	636.6	24287	9385	36225	6719.1	293.1	4031	4031	40,256
Mar	299010	649.3	27039	9572	39370	6996.3	280.8	4198	4198	43,567
Apr	293785	718.7	26703	10356	39849	5881.8	242.3	3529	3529	43,378
May	302125	572.2	28204	10548	41661	6085.6	240.7	3651	3651	45,312
Jun	314080	670.8	29275	12090	44456	4569.1	176.0	2741	2741	47,198
Jul	346239	671.7	32292	12123	47720	4055.0	157.2	2433	2433	50,153
Aug	354311	667.9	33159	11946	48458	3978.2	138.9	2387	2387	50,845
Sep	328713	683.6	30555	12208	45952	3898.0	152.4	2339	2339	48,291
Oct	321542	736.1	29244	10608	42837	4694.5	186.5	2817	2817	45,654
Nov	292706	672.9	26478	9746	38955	6206.9	286.0	3724	3724	42,679
Dec	294998	634.8	26618	9349	38680	8636.0	434.7	5182	5182	43,862
Tot.	**3,710,656**	**7,949**	**340,510**	**127,215**	**502,816**	**70,794**	**2,971**	**42,476**	**42,476**	**545,293**
Avr.	**309,221**	**662**	**28,376**	**10,601**	**41,901**	**5,899**	**248**	**3,540**	**3,540**	**45,441**
Max		**736**					**435**			

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

Hotel, San Diego 220,000 sf

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Energy					**Natural Gas Energy**					Total	**Gen.**	**Total**
	Elec. Grid Load		Electr. Costs			Gas Utility Load		Natural Gas Costs			Utility	Gen.	**Energy**
	Energy kWh	Demand kW	Energy $	Demand $	Tot. Elec. $	Energy therms	Demand therms/day	Energy $	Demand $	Tot. Gas $	Cost $	O&M $	**Cost $**
Jan	73,607	0	6,401	6,073	16,055	23,658	1,062	14,195	0	14,195	30,250	2,394	32,644
Feb	74,079	0	6,442	6,134	15,832	19,179	924	11,507	0	11,507	27,339	2,078	29,417
Mar	83,158	0	7,232	6,136	16,905	20,788	988	12,473	0	12,473	29,378	2,292	31,670
Apr	84,947	68	7,396	6,598	17,488	19,042	936	11,425	0	11,425	28,914	2,200	31,114
May	75,379	0	6,553	6,257	16,534	20,474	918	12,284	0	12,284	28,818	2,394	31,212
Jun	90,657	9	7,883	7,119	18,772	17,780	852	10,668	0	10,668	29,440	2,290	31,731
Jul	98,096	10	8,531	7,138	19,741	18,773	879	11,264	0	11,264	31,005	2,521	33,526
Aug	93,422	6	8,125	7,485	19,821	19,312	863	11,587	0	11,587	31,408	2,645	34,053
Sep	108,376	22	9,424	7,521	20,802	16,959	854	10,176	0	10,176	30,978	2,242	33,220
Oct	82,724	80	7,223	7,548	18,589	18,962	803	11,377	0	11,377	29,966	2,457	32,423
Nov	75,846	22	6,597	6,460	16,566	19,814	916	11,888	0	11,888	28,454	2,287	30,742
Dec	91,612	0	7,967	6,032	17,466	21,498	1,043	12,899	0	12,899	30,364	2,184	32,549
Tot.	**1,031,903**	**215**	**89,773**	**80,500**	**214,572**	**236,240**	**11,039**	**141,744**	**0**	**141,744**	**356,316**	**27,984**	**384,299**
Avr.	**85,992**	**18**	**7,481**	**6,708**	**17,881**	**19,687**	**920**	**11,812**	**0**	**11,812**	**29,693**	**2,332**	**32,025**
Max		**80**					**1,062**						

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Hotel, San Diego 220,000 sf

Generator Performance Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Total electricity Produced kWh	Dem peak electricity Produced kWh	Energ Peak electricity Produced kWh	generator gas use therms	Heat Avail. therms	Heat Used therms	Heat Rec. %	Gen Total Run Hours	Demand Peak Run Hours	Energy Peak Run Hours	Gen. Time Util Factor %	Generation Elec. Eff. HHV %	Generation Overall. Eff. HHV %
Jan	217,619	33,741	159,072	26,282	12,011	9,592	79.9	552	69	368	74.2	28.3	64.7
Feb	188,877	29,234	138,001	22,821	10,429	8,496	81.5	480	60	320	71.4	28.2	65.5
Mar	208,365	32,663	152,725	25,160	11,498	9,322	81.1	528	66	352	71.0	28.3	65.3
Apr	199,998	36,589	147,587	24,120	11,023	8,987	81.5	504	63	336	70.0	28.3	65.5
May	217,610	61,805	160,134	26,282	12,011	9,753	81.2	552	161	368	74.2	28.3	65.4
Jun	208,219	61,172	154,156	24,889	11,374	9,577	84.2	504	147	336	70.0	28.5	67.0
Jul	229,174	67,624	168,927	27,110	12,389	10,162	82.0	528	154	352	71.0	28.8	66.3
Aug	240,438	72,638	178,345	28,417	12,986	10,728	82.6	552	161	368	74.2	28.9	66.6
Sep	203,809	61,076	150,758	24,217	11,067	9,148	82.7	480	140	320	66.7	28.7	66.5
Oct	223,353	39,365	164,634	26,824	12,258	10,296	84.0	552	69	368	74.2	28.4	66.8
Nov	207,941	31,967	151,771	25,120	11,480	9,441	82.2	528	66	352	73.3	28.2	65.8
Dec	198,561	30,741	145,105	23,984	10,961	9,120	83.2	504	63	336	67.7	28.2	66.3
Tot.	**2,543,964**	**558,615**	**1,871,216**	**305,226**	**139,488**	**114,620**		**6,264**	**1,219**	**4,176**			
Avr.	**211,997**	**46,551**	**155,935**	**25,436**	**11,624**	**9,552**	**82.2**	**522**	**102**	**348**	**71**	**28.4**	**66.0**
Max							**84.2**					**28.9**	**67.0**

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Hotel, San Diego 220,000 sf

Absorber Heat Recovery Details

Alternative Configuration -System Supplemented with 615 kWe IC Generator with Heat Recovery to Heating, DHW, and Abs. Chiller

	Electric Grid Load				Gen. Total Heat Recovery			Absorption Chiller			Electric Chiller			
	No Generation Elec. Grid Load		Generation Elec. Grid Load											
	Energy kWh	Demand kW	Energy kWh	Demand kW	Heat Avail. therms	Heat Used therms	Heat Rec. %	Absorb Max Capacity RT	Absorb Cooling Load therms	Absorber Heat In therms	Electric Cooling Max RT	Electric Cooling Load therms	Electric Chiller Reduced kWh	Electric Chiller Reduced kW
Jan	294,474	634	73,607	0	12,011	9,592	79.9	113.0	3,993.6	5,684.6	36.4	29.2	13,564	57
Feb	268,672	637	74,079	0	10,429	8,496	81.5	113.0	4,106.6	5,799.0	21.8	24.7	14,748	57
Mar	299,010	649	83,158	0	11,498	9,322	81.1	113.0	4,749.7	6,699.0	35.6	110.5	17,425	57
Apr	293,785	719	84,947	68	11,023	8,987	81.5	113.0	4,875.8	6,861.7	122.8	372.9	18,218	57
May	302,125	572	75,379	0	12,011	9,753	81.2	113.0	5,291.4	7,442.4	54.6	139.1	19,574	57
Jun	314,080	671	90,657	9	11,374	9,577	84.2	113.0	5,886.1	8,254.9	175.4	2,313.6	23,370	57
Jul	346,239	672	98,096	10	12,389	10,162	82.0	113.0	6,520.8	9,145.0	188.0	4,606.7	26,458	57
Aug	354,311	668	93,422	6	12,986	10,728	82.6	113.0	6,900.2	9,677.2	174.1	4,962.8	28,131	57
Sep	328,713	684	108,376	22	11,067	9,148	82.7	113.0	5,856.5	8,212.3	184.4	3,395.3	23,661	57
Oct	321,542	736	82,724	80	12,258	10,296	84.0	113.0	6,302.3	8,840.2	133.7	1,805.2	24,852	57
Nov	292,706	673	75,846	22	11,480	9,441	82.2	113.0	4,991.2	7,030.0	60.8	289.9	18,620	57
Dec	294,998	635	91,612	0	10,961	9,120	83.2	113.0	3,974.1	5,631.3	45.6	117.5	13,922	57
Tot.	**3,710,656**	**7,949**	**1,031,903**	**215**	**139,488**	**114,620**		**1,355.7**	**63,448**	**89,278**	**1,233.3**	**18,168**	**242,543**	
Avr.	**309,221**	**662**	**85,992**	**18**	**11,624**	**9,552**	**82.2**	**113.0**	**5,287**	**7,440**	**102.8**	**1,514**	**20,212**	**57**
Max		**736**		**80**										

Energy Rates: SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Gen. Service, Natural Gas - $0.6/therm (flat)

Generator Type: VGF36GLD Engine Generator, 615 kWe

Hotel, San Diego 220,000 sf

Basline/Alt. Config. Energy Cost Comparison

Specific Energy Costs

Baseline

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm
Jan	0.131	0.600
Feb	0.135	0.600
Mar	0.132	0.600
Apr	0.136	0.600
May	0.138	0.600
Jun	0.142	0.600
Jul	0.138	0.600
Aug	0.137	0.600
Sep	0.140	0.600
Oct	0.133	0.600
Nov	0.133	0.600
Dec	0.131	0.600
Avr.	**0.135**	**0.600**
Total		

On Site Generation

	Grid Elec. Energy $/kWh	Utility Gas Energy $/therm	Gen Elec. Energy $/kWh	Rec. Heat Value $	**Gen*** Elec. Energy $/kWh	**Avr.** Elec. Energy $/kWh
Jan	0.218	0.600	0.083	5,755	0.057	0.0923
Feb	0.214	0.600	0.083	5,098	0.057	0.0925
Mar	0.203	0.600	0.083	5,593	0.057	0.0895
Apr	0.206	0.600	0.083	5,392	0.056	0.0903
May	0.219	0.600	0.083	5,852	0.057	0.0866
Jun	0.207	0.600	0.083	5,746	0.055	0.0869
Jul	0.201	0.600	0.082	6,097	0.055	0.0838
Aug	0.212	0.600	0.082	6,437	0.055	0.0827
Sep	0.192	0.600	0.082	5,489	0.055	0.0888
Oct	0.225	0.600	0.083	6,178	0.055	0.0857
Nov	0.218	0.600	0.083	5,664	0.056	0.0884
Dec	0.191	0.600	0.083	5,472	0.056	0.0933
Avr.	**0.209**	**0.600**	**0.083**	**5,731**	**0.056**	**0.088**
Total				**$68,772**		

SDG&E AL-TOU_DER + EECC > 500 kW
Gen. Service, Natural Gas - $0.6/therm (flat)

SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation
Gen. Service, Natural Gas - $0.6/therm (flat)

VGF36GLD Engine Generator, 615 kWe

Total Annual Energy Costs

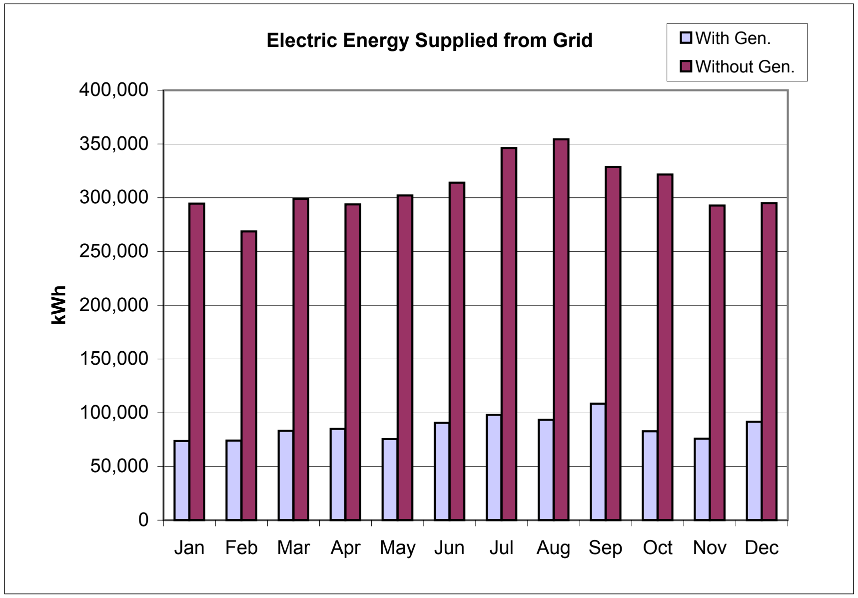
Baseline	On Site Generation
$545,293	**$384,299**

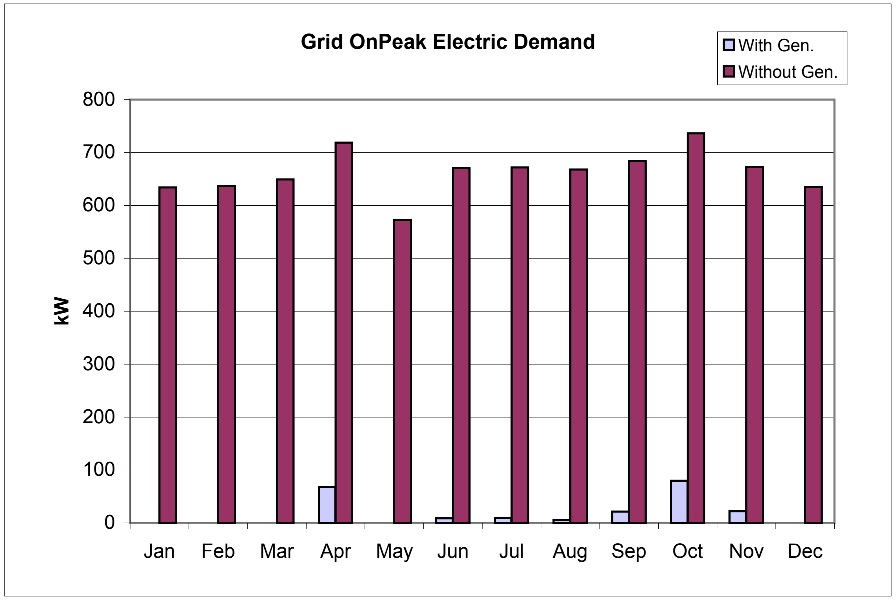
Annual Savings

$160,993

Note: * Cost of elctric generation including benefits of recoverable heat

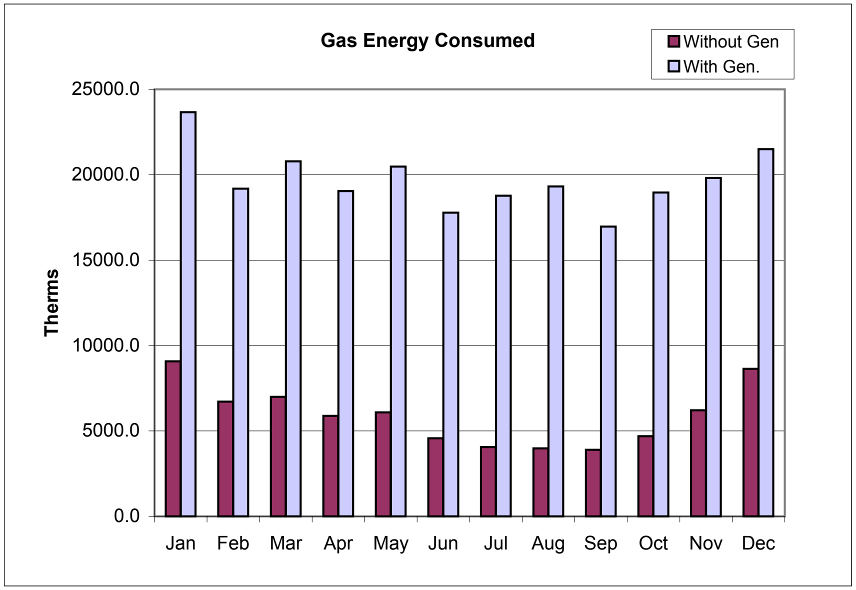
Hotel, San Diego 220,000 sf

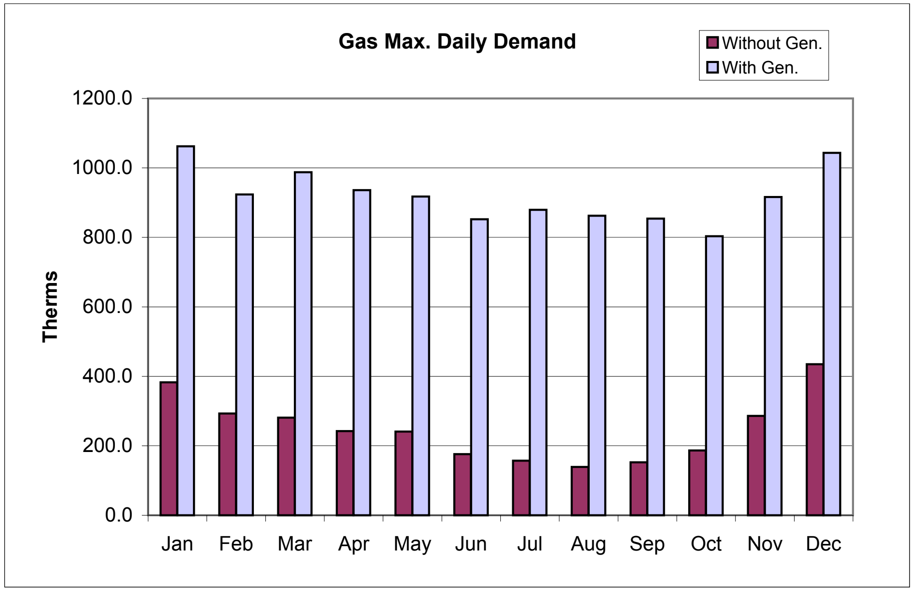




Electric
Energy Rates Gen: VGF36GLD Engine Generator, 615 kWe
With Gen SDG&E AL-TOU_DER + EECC > 500 kW + Energy Generation Charges
Without (SDG&E AL-TOU_DER + EECC > 500 kW

Hotel, San Diego 220,000 sf

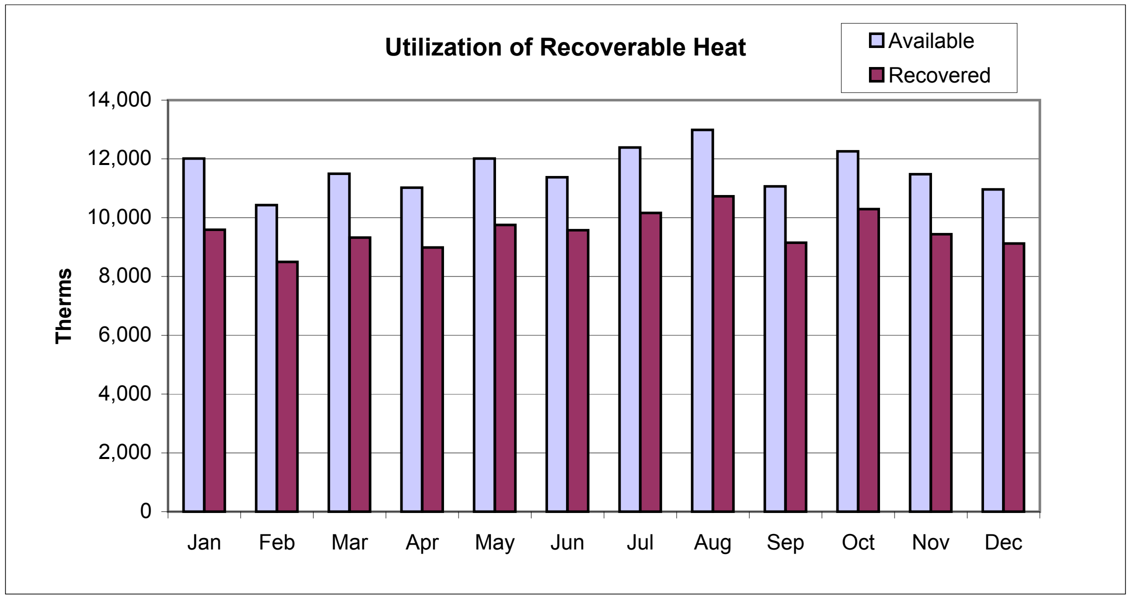




Natural Gas
Energy Rates
With Gen: Gen. Service, Natural Gas - $0.6/therm (flat)
Without Gen.: Gen. Service, Natural Gas - $0.6/therm (flat)

Gen: VGF36GLD Engine Generator, 615 kWe

Hotel, San Diego 220,000 sf



Gen: VGF36GLD Engine Generator, 615 kWe