CHP in the Hotel and Casino Market Sectors

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Note: This report was initially released in December 2005. In November 2007, EPA completed an addendum to this report containing updated market information. The 2007 addendum can be found on the CHP Partnership Web site at www.epa.gov/chp/documents/hotel_casino_addendum.pdf.

EXECUTIVE SUMMARY

Hotels and casinos have a number of characteristics that make them good targets for installing combined heat and power (CHP) systems. The facilities operate around the clock year-round; a portion of the industry has significant thermal and electric loads even at night: they have significant air conditioning requirements that could be met with thermally activated technologies running off the waste heat of an on-site generator; and there are establishments in every state in the U.S.

Hotel and Casino Industry Structure

The industry consists of nearly 48,000 establishments with over 4.4 million guest rooms. **Table ES1** shows the breakdown by size. The industry revenues for 2004 were $113.7 billion, up 8% from the previous year.

Table ES1 Number of Hotels and Lodging Establishments by Size

Number of Rooms	Property	Rooms	Average Rooms
<75	27,464	1,163,668	42
75-149	14,326	1,524,099	106
150-299	4,235	847,089	200
300-500	1,070	398,491	372
>500	503	478,561	951
Total	47,598	4,411,908	93

Source: American Hotel & Lodging Industry Association, *2005 Lodging Industry Profile*

Casinos and gaming overlap in the hotel and lodging industry to the extent that there are nearly 300 land-based casinos with associated lodging. There are commercial gaming operations in 11 states. The two largest commercial gaming centers are in Nevada (Las Vegas, Reno) and New Jersey (Atlantic City.) The Midwest commercial gaming industry consists exclusively of riverboat and dockside casinos (Illinois, Indiana, Iowa, Missouri) except for 3 land based casinos in Michigan. The next biggest gaming center is in the South with casinos in Louisiana and Mississippi. The Southern commercial gaming market is primarily riverboat and dockside with one land-based casino in Louisiana. Colorado and South Dakota in the West both allow limited stakes gambling casinos. These facilities bring in much less revenue than the unrestricted casinos in the larger markets.

In addition to the commercial industry there are Tribal casinos in 28 states (Class III casinos relevant to this study in 21 states.) **Figure ES1** shows the distribution of casino operations by state and type.

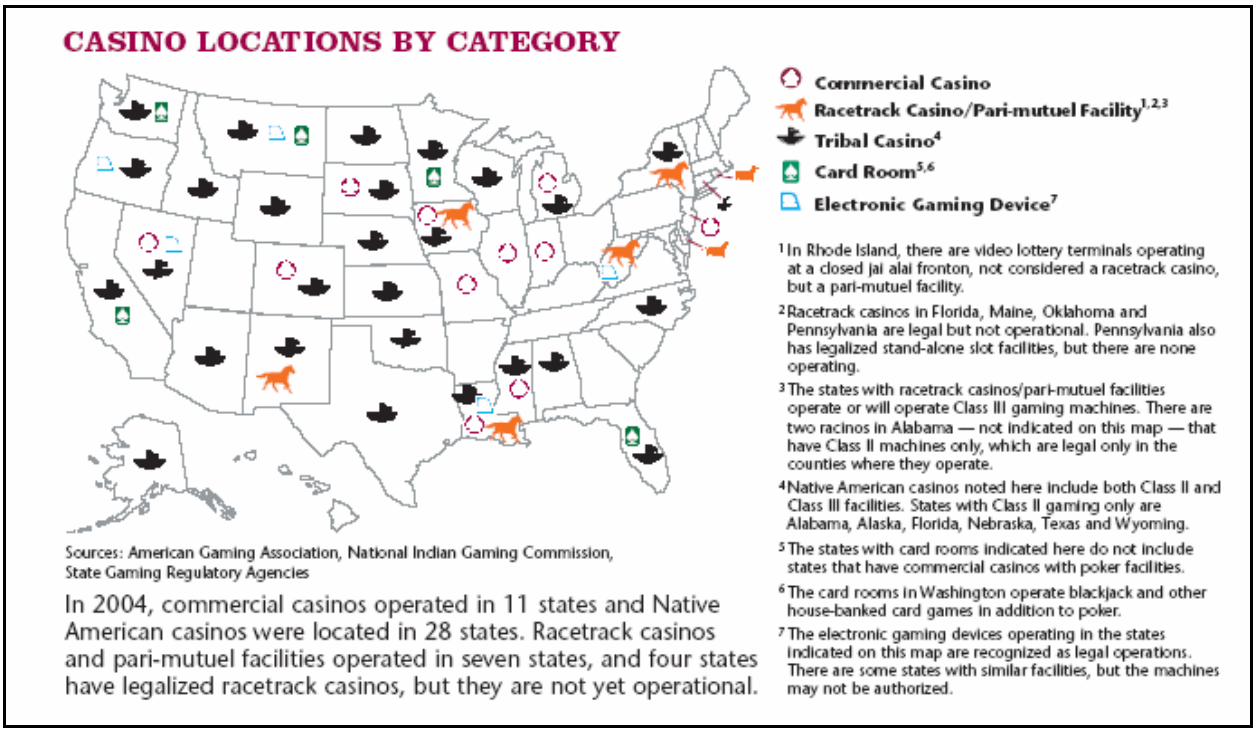


Figure ES1 Geographical Distribution of Casino Gaming by Type

Hotel Market Trends

The hotel industry is finally breaking out of the disastrous recession that followed the 9/11/2001 terrorist attacks on the World Trade Center and the Pentagon. In the three years following 9/11 the hotel industry had a 36.2% decline in profits. In 2004, this declining trend has turned around with a 7.6% increase in revenues and an 11.4 % increase in profits compared with 2003. Resort hotels achieved the greatest increase in profitability in 2004 with operating profits growing by 17.2%. Limited service hotels gained the least with profits up only 6.2%. Full service, suite, and convention hotels all saw profits rise by over 10%.

Luxury hotels (Four Seasons, Ritz Carlton, Fairmont) represent the fastest growing market segment. The worst performing segment is the economy segment (Motel 6, Red Roof, Days). Limited service hotels (Hampton Inn, Country Inns & Suites, HI Express) are gaining at the expense of full service mid-level chains (Holiday Inn, Ramada, Best Western).

Consistent with the strength of the luxury market sector, one of the top trends in the casino/resort segment of the lodging industry is known as *entertainment convergence*. Destination casinos and resorts seek to broaden the appeal of their facilities, i.e., attract more people, and to provide a variety of attractions so that guests will lengthen their stay. These new resorts offer gaming, shopping, golf, multiple entertainment venues, meeting and conference facilities, time-share condos, residential units, and other features. The addition of these multiple uses and components makes facilities much larger than

they used to be and creates a correspondingly larger but also more diverse energy load that can be met by CHP.

Existing CHP

There are currently 98 hotels in the U.S. with CHP systems, representing over 63 MW of capacity. California contains the most CHP equipped hotels in the country by a large margin with New Jersey and New York coming in second and third. Due to the load profiles of hotels the majority of CHP systems that are installed are under 500 kW. **Figure ES2 sh**ows this size dispersion with an equal amount of systems falling in the 0 to 100 kW and the 100 to 500 kW categories. The systems in the larger categories are mainly located at resort hotels with larger campuses that require more power. There are three hotel casino resorts with CHP systems, two of which are in the largest two categories with capacities of 4.9 MW and 5.2 MW.

Size Range	# Sites
0-99 kW	40
100-499 kW	39
500-999 kW	5
1,000-4,999 kW	10
>5 MW	4

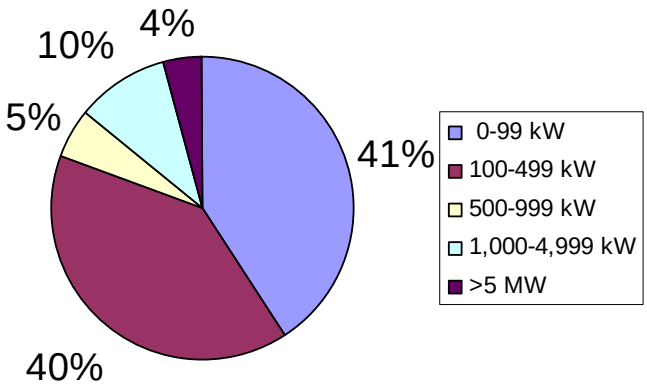


Figure ES2 CHP Systems in the Lodging Industry by Size

Energy Consumption in Hotels and Casinos

Figure ES3 shows annual energy costs per available room by type of hotel property.[1] Resort hotels pay the most per available room for energy -- $2,080 in 2003. Convention hotels are the next most energy intensive followed by full-service and all-suite hotels. Per available room energy costs for extended stay and limited service hotels are much less than resort hotels at $611 and $573 respectively. About three fourths of energy costs are for electricity and one fourth for fuel.

[1] Robert Mendelbaum, "Hotel Utility Costs Surge Protection is Needed," *Hotel Online Special Report*, PKF Hospitality Research March 2004.

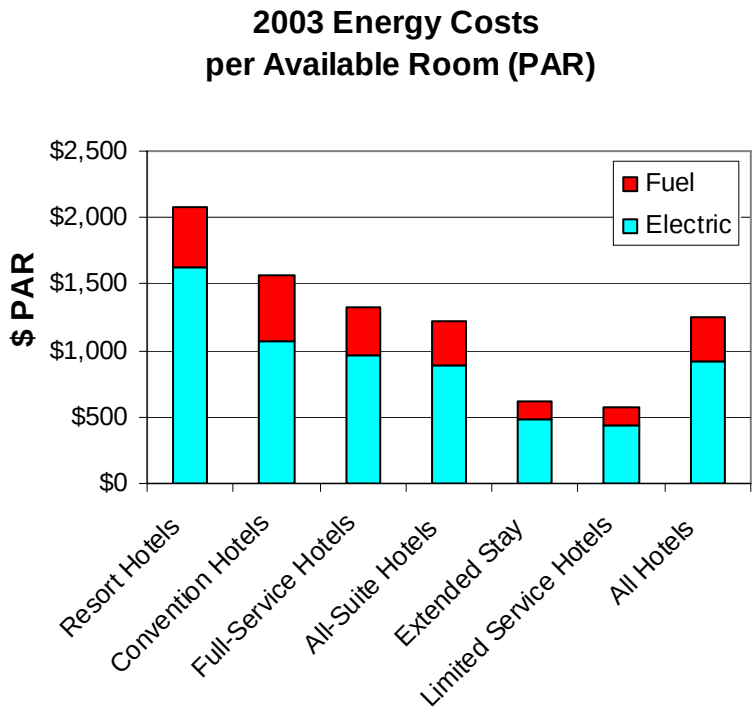


Figure ES3 2003 Energy Consumption Expenditures per Available Room by Type of Hotel

For the industry as a whole, energy costs (2003) were $1,254 per available room. Based on the 4.4 million available rooms for the industry, the total energy bill is $5.2 billion or about 5% of total industry revenues.

The EPA Energy Star Program has energy usage data for 1,222 hotels that are participating in the Energy Star labeling program. These data were analyzed for this study to provide insight on electric and natural gas utilization by hotels. **Table ES2** shows the results by chain scale for the hotels that recorded usage of both electricity and gas. There is a general trend of increasing energy intensity in all climates as the price and service classification increases. This trend is strongest in looking at the EUIs in the economy and limited service midscale hotel categories compared to full service hotels. The highest EUIs occur in the highest scale hotels. The impacts of climate on gas heating and electric air conditioning can be seen to some extent. The relationship is stronger for gas EUI which increases in most cases as the climate becomes colder. Climate impact on electric consumption is more difficult to see; in only three of the five hotel types is there a higher electric EUI in the hot climate compared to the cold climate.

Table ES2 Gas and Electric Energy Usage Intensities by Climate and Chain Scale

		Climate			Grand
Hotel Type	Data	Cold	Hot	Moderate	Total
Hotel (Economy and Budget)	# of Hotels	9	3	6	18
	Avg. Elec kWh/sf/yr	12.07	8.94	8.35	10.31
	Avg. Gas KBtu/sf	31.64	19.25	69.66	42.25
Hotel (Midscale w/o Food and Beverage)	# of Hotels	16	12	15	43
	Avg. Elec kWh/sf/yr	11.66	15.01	11.97	12.70
	Avg. Gas KBtu/sf	36.13	33.36	47.81	39.43
Hotel (Midscale w/Food and Beverage)	# of Hotels	127	55	83	265
	Avg. Elec kWh/sf/yr	18.02	15.62	15.00	16.57
	Avg. Gas KBtu/sf	70.67	24.49	48.18	54.04
Hotel (Upscale)	# of Hotels	92	145	210	447
	Avg. Elec kWh/sf/yr	16.21	16.65	13.24	14.96
	Avg. Gas KBtu/sf	52.44	35.67	38.76	40.57
Hotel (Upper Upscale)	# of Hotels	94	94	121	309
	Avg. Elec kWh/sf/yr	17.56	20.26	16.83	18.10
	Avg. Gas KBtu/sf	54.64	42.78	49.47	49.01
Total Number of Hotels		338	309	435	1082
Total Average of Elec kWh/sf/yr		16.94	17.43	14.46	16.08
Total Average of Gas KBtu/sf		58.58	35.59	44.27	46.26

Typical hotel characteristics for a 195,000 s.f., 230 room full-service hotel were developed for a range of climates. Energy consumption in Las Vegas and in Minneapolis was modeled to identify the energy consumption in hot and cold climates respectively. Anaheim, CA represents a mild climate. This comparison is shown in **Table ES3.**

Table ES3 Energy Consumption Breakdown by Climate for a 195,000 s.f. Full Service Hotel

Location Climate Type	Units	Anaheim Mild	Las Vegas Hot	Minneapolis Cold
Annual Electric Use	Thousand kWh	3,131	3,548	2,960
Annual Gas Use	Million Btu	7,836	8,780	19,660
Base Gas Demand	Million Btu	5,038	4,710	6,240
Electric EUII	kWh/s.f.	16.06	18.19	15.18
Gas EUI	kBtu/s.f.	40.18	45.03	100.82
Peak Demand	kW	745	840	832
Average Demand	kW	357	405	338
Minimum Demand	kW	250	260	240
Peak Load/Avg. Load	% of Avg	208%	207%	246%
Min Load/Avg. Load	% of Avg	70%	64%	71%
CHP Sizing Strategies				
100% Electric/80% Thermal Use (kW)		144	134	178
Max Size for 100% Electric Use (kW)		250	260	240

Energy consumption can be characterized as follows:

- Electric consumption ranges from 3 to 3.5 million kWh per year – hot climate cooling loads push total consumption up by 16% compared to mild and cold climate usage

- Annual gas demand in the cold climate application is more than twice that of the hot and mild climate applications.

- The CHP addressable thermal loads are the various water heating loads that are fairly constant throughout the year. These loads are fairly similar in the various climate applications varying only as a function of colder groundwater temperature in the cold climate application. In a warm climate application, 64% of the annual gas consumption represents the primary target for replacement with CHP supplied thermal energy.

- Minimum electric loads are similar for the applications across climate types of 240-260 kW. Minimum electric loads are important to CHP sizing and operating strategy because a system sized at or below this point can be run at full load continuously thereby maximizing the utilization of the equipment and minimizing operating complexity.

- Sizing a CHP system to the addressable thermal load results in a system sized below the minimum electric demand. Sizes range from 134-178 kW.

Energy consumption for large casino hotels was evaluated for two facilities, the Turning Stone Casino in New York and the Borgata in Atlantic City, New Jersey. Based on this energy consumption data, loads were estimated for casino hotels in both a Northeast climate (Atlantic City) and a hot climate (Las Vegas.) **Table ES4** summarizes energy consumption measures for a 2000 room casino hotel with and without absorption cooling for both a hot and cold climate.

Table ES4 Load Analysis for Mega-Hotel in Alternative Locations and Configurations

Energy Measure	Units	Actual	Estimate 1	Estimate 2	Estimate 3
Climate		Atlantic City	Atlantic City	Las Vegas	Las Vegas
Cooling		Absorption	Electric	Absorption	Electric
Annual Electric Consumption	Million kWh/year	86.1	99.4	86.1	104.9
Annual Gas Consumption	MMBtu/year	498,441	229,364	538,220	159,748
Electric Load Factor	Percent	61%	53%	61%	56%
Electric EUI	kWh/year/s.f.	28.7	33.1	28.7	35.0
Gas EUI	KBtu/year/s.f.	166.1	76.5	179.4	53.2
Peak Load	MW	16.1	21.3	16.1	21.3
Average Load	MW	9.8	11.3	9.8	12.0
Minimum Load	MW	7.0	7.4	7.0	7.4
Base Thermal Load	MMBtu/hour	30	12	29	12
Base Thermal Share of Total	Percent	53%	46%	47%	66%

Technical and Economic Market Potential for CHP in Hotels and Casinos

Table ES5 summarizes the results of the market screening. There are nearly 9,500 hotels of appropriate size to warrant consideration. To date, only 79 of the hotels within these size categories have installed CHP. Appropriately sized CHP systems installed in this target market provide a technical market potential of 2,773 MW. Based on a simple economic market screen undertaken using typical CHP cost and performance values for each size and average gas and electric prices by state, the economic market potential was estimated at 1,456 MW.

Table ES5 Summary of Hotel CHP Market Screening Results

Screening Approach	Number of Rooms					Total
	100-199	200-499	500-999	1000-1999	2000+	
Hotels in U.S.	6,323	2,614	379	116	32	9,464
Hotels with CHP	33	30	9	5	2	79
Remaining Market (sites)	6,290	2,584	370	111	30	9,385
Appropriate CHP Size (kW)	90	380	1,000	5,000	10,000	
Technical Market Potential (MW)	566	982	370	555	300	2,773
Economic Market Potential (MW)	130	371	170	495	290	1,456
% of Market Economic	22.9%	37.8%	45.9%	89.2%	96.7%	52.5%

Conclusions

This analysis has shown that there is significant market potential for CHP in the hotel and casino market. This market potential is concentrated in the larger, full-service facilities. While there are nearly 48,000 hotels in the U.S., less than 10,000 of them have the usage and energy characteristics suitable for CHP using current technology. The economic cut-off for this analysis was set at 100-rooms or greater.

The large mega-resort hotels of 1,000 rooms or greater represent a distinct and very important market segment. These huge facilities have more in common from an energy standpoint with a small university than with a small business hotel or roadside motel. These facilities are typically, though not exclusively, associated with the casino gaming. There are multiple restaurants, nightclubs and other entertainment venues, spas, casinos, health clubs, movie theaters, shops, and often large attractions – zoos, aquaria, fountains, even an “active” volcano. The facilities occupy millions of square feet of building space and the energy usage intensity per square foot is much higher than for the typical business hotel.

There are 148 hotels in the U.S. with more than 1,000 rooms. The economic market potential for CHP in these mega-sites represents 54% of the total economic potential for CHP in the hotel industry. There are 32 hotels with more than 2,000 rooms and 75% of them are on the Las Vegas strip. These facilities could support CHP systems with an average size of 10 MW each representing 20% of the economic potential.

One of the big drivers for CHP in these large facilities is to provide the thousands of tons of air conditioning needed using the waste heat from the on-site electric generation. Industrial gas turbine generators can produce power for the facility baseload needs and the high temperature exhaust can be converted to steam in heat recovery steam generators that can be used to drive a central heating and cooling plant.

The remaining identified market is in hotels with 100 to 999 rooms. These facilities are less energy intensive than the large casino and resort hotels, but they still have round-the-clock electric and thermal loads that can effectively support CHP. As the hotel sizes get smaller, the cost of absorption chillers goes up, and their effectiveness goes down. It is not considered cost-effective with current technology to try to include absorption cooling in a hotel system until the generator size reaches about 300 kW. This size can support about a 100-ton absorption system. Hotels need to have more than 200 rooms before such a system would be warranted.

In smaller hotel sizes, without adding cooling, it is very important to size the system to the available thermal load. As shown in Section 4, a system with 70-80% seasonal utilization of the available thermal load is going to be utilizing only about 60% the capacity of a system that is sized to the minimum facility electric load. The problem is that there are fairly wide swings in thermal energy consumption during the day, with nighttime values dropping considerably. The key thermal load is the hot water for the guest rooms, though it may be possible to augment these loads with hot water needs for the kitchen, laundry, pools, and even space heating seasonally.

CHP in the Hotel and Casino Market Sectors

1. INTRODUCTION

Hotels and casinos have a number of characteristics that make them good targets for installing an economic combined heat and power (CHP) system. They operate around the clock year-round; a portion of the industry has significant thermal and electric loads even at night: they have significant air conditioning requirements that could be met with thermally activated technologies running off the waste heat of an on-site generator; and there are establishments in every state in the U.S. There are 98 hotels in 21 states that have operating CHP systems; these systems have an electric capacity of 63 MW.

This report describes the hotel and casino industry characteristics and trends and provides an evaluation of energy consumption by facility type and location. This characterization is the basis for a technical and economic screening of CHP market potential. The analysis was conducted to support the Environmental Protection Agency's Combined Heat and Power Partnership Program as a means to provide information and tools to industry in order to encourage cost effective implementation of CHP in applications that provide economic, efficiency, and environmental benefits.

The report is organized in the following sections:

2. *Overview of the Hotel and Casino Industries* –an analysis of the industry structure, geographical distribution and trends.

3. *Existing CHP in Hotels and Casinos* –the current inventory of operating CHP systems.

4. *Energy Consumption and Load Profiles* –energy usage characteristics related to CHP implementation including electric and thermal energy usage intensities, load shapes, and electric and thermal energy coincidence.

5. *CHP Technical and Economic Potential* – a screening model of CHP market potential by size and state

6. *Conclusions* – overall evaluation of the competitiveness of CHP in the industry.

2. OVERVIEW OF THE HOTEL AND CASINO INDUSTRIES

Hotels and other lodging industry accommodations vary greatly in size and in the services they provide:

Large hotels and motels offer a variety of services for their guests, including coffee shops, restaurants, cocktail lounges with live entertainment, retail shops, barber and beauty shops, laundry and valet services, swimming pools, fitness centers and health spas. Hotels and motels often have banquet rooms, exhibit halls, and ballrooms to accommodate conventions, business meetings, wedding receptions, and other social gatherings. Conventions and business meetings are major sources of revenue for these hotels and motels.

Resort hotels and motels offer luxurious surroundings with a variety of recreational facilities such as swimming pools, golf courses, tennis courts, game rooms, and health spas, as well as planned social activities and entertainment. Resorts are located primarily in vacation destinations near mountains, the seashore, or other attractions. As a result, the business of many resorts fluctuates with the season. Some resort hotels and motels provide additional convention and conference facilities to encourage customers to combine business with pleasure.

Extended-stay hotels combine features of a resort and a residential hotel. Typically, guests use these hotels for a minimum of five consecutive nights. These facilities usually provide rooms with fully equipped kitchens, entertainment systems, ironing boards and irons, office spaces with computer and telephone lines, access to fitness centers, and other amenities.

Residential hotels provide living quarters for permanent and semi-permanent residents. They combine the comfort of apartment living with the convenience of hotel services. Many have dining rooms and restaurants that also are open to the general public.

Casino hotels provide lodging in hotel facilities with a casino on the premises. The casino provides table wagering games and may include other gambling activities, such as slot machines and sports betting. Casino hotels generally offer a full range of services and amenities and may also contain conference and convention facilities.

In addition to hotels and motels, the industry includes bed-and-breakfast inns, recreational vehicle (RV) parks, campgrounds, and rooming and boarding houses that provide lodging for overnight guests. Other short-term lodging facilities in this industry include guesthouses, or small cottages located on the same property as a main residence, and youth hostels—dormitory-style hotels with few frills, occupied mainly by students traveling on low budgets. Also included are rooming and boarding houses, such as fraternity houses, sorority houses, off-campus dormitories, and workers' camps. These establishments provide temporary or longer-term accommodations that may serve as a principal residence for the period of occupancy. These establishments also may provide services such as housekeeping, meals, and laundry services.

Hotels and motels make up the majority of lodging establishments and tend to provide more services than other lodging options.

2.1 Lodging Industry Market Data Sources

There are a number of government and private data sources that publish statistics for the lodging industry; however, the definition of the industry and the inclusion or exclusion of certain sub-sectors is not uniform. The industry is variously defined to include all types of lodging, from upscale hotels to RV parks. Motels, resorts, casino hotels, bed-and-breakfast inns, boarding houses, dormitories, and nursing homes are also are included in some government statistics. **Table 1** shows the data sources that were used in this study to define the scope of the lodging industry and the sectors of most interest to CHP development.

Table 1 Data Sources Used, Establishments Included, and Data Available

Data Source	Base Year	Establishments Included	Target Establishments	Market Segments Included (Relevant Segments)	Data Included
U.S. Economic Census	2002 Partial; 1997	60,870 (2002)	46,446 (2002)	11 (6)	Sales, Payroll, Employees
U.S. EIA/CBECS	1999 Complete 2003 Summary	153,000 (1999)	89,000 (1999)	5 (2)	building size, age, energy equipment, energy consumption, employment
American Hotel & Lodging Industry Association	2004	47,584	47,584	5 (5)	rooms, RevPAR, occupancy rates, promotional spending, other marketing statistics
PKF Hospitality Research (proprietary)	2004	sample 5,000	n.a.	6 (6)	Financial statistics -- published utility consumption costs by type of facility
Smith Travel Research, Inc. (proprietary)	2004 Updated yearly	49,122	all	7 (7)	Establishments by state and by chain scale[2]I – additional detailed data available by subscription
EPA Energy Star Database	Applications to date	1222	1222	6	Hotels applying for Energy star labeling provide size, chain scale, number of rooms, electric and gas usage
Meeting Industry Megasite[3]	2005	24,563	17,423	8(2)	Website designed to allow meeting planners to screen facilities by location, number of rooms, meeting space and other factors

U.S. Economic Census – The Economic Census provides state-by-state (and more specific) geographical detail on businesses defined as *accommodations.* Within this classification system (NAICS 721) there are 11 submarkets – the first five submarkets are the focus of this assessment:

[2] *Chain scale* refers to the type of hotel chain. There are seven categories: luxury, upper upscale, upscale, midscale with food and beverage, midscale without food and beverage, economy, and independent.
[3] http://www.mimegasite.com/mimegasite/index.jsp

1. hotels more than 25 rooms,
2. hotels less than 25 rooms,
3. motels,
4. motor hotels,
5. casino hotels,
6. organization (membership) hotels,
7. bed & breakfast inns,
8. other traveler accommodations,
9. RV parks and campgrounds,
10. recreational camps except campgrounds, and
11. rooming & boarding houses.

The number of establishments, revenues, and employment by sector are provided. The advantage of this data series is that it provides good geographical detail and highlights larger facilities, particularly casinos that would be targets for CHP. Partial data are available from the 2002 Economic Census. Full state-by-state data from 2002 have not been published[4], but are available from the 1997 Census. A key disadvantage of the data series is that there is no information on building size or number of guest rooms.

EIA Commercial Buildings Energy Consumption Survey – The CBECS data series has a variety of useful energy consumption and equipment characteristics statistics. The Lodging sector of CBECS is rather uniquely defined in that it includes nursing homes, and college dormitories – two sectors that are not generally considered part of the lodging industry. In addition to the inclusion of these sectors, there is not a good separation of the market segments of interest – hotels, motel, inn, resort, and other. There are only two submarkets that are considered part of the industry under consideration for this study – hotel and motel/inn/resort. There are complete tabulations of the data but cross tabulations are often not available in the public data. For example, there are breakdowns by type of equipment, building size, by subsector, and by region, but getting the type of equipment for a certain market segment and a specific building size isn't available. The geographic detail only goes down to a multi-state regional level and the 1999 CBECS is somewhat out of date. There are very preliminary data available for the 2003 CBECS, though there was not enough detail to be of use for this study.

American Hotel and Lodging Industry Association Lodging Industry Profile – The AH&LA annual industry trends publication provides good information on the annual trends in the lodging industry. The market is made up of 5 segments: suburban, highway, urban, airport, and resort. Facility sizes are characterized by number of guest rooms, though this information is not reported by sub-market. Some trends are called out by region or state, but the basic data series is for the total U.S. The AH&LA does not report energy statistics but their research group provided references to other sources. The information is reported every year.

PKF Hospitality Research – PKF publishes a survey of financial trends for 5,000 of the largest hotels in the U.S. This series is available on a subscription basis. Energy and utility expenditure information and hotel revenue and profitability data are used in this report based on publicly available articles and press releases concerning the detailed survey.

[4] as of October, 2005.

Smith Travel Research, Inc. – STR provides a number of industry statistical reports on a subscription basis. Customized reports for individual metropolitan areas are available that provide physical and financial information on hotels within a local market. The data set used for this study was a comparison of hotels (number of hotels and number of rooms) by chain scale and state.

EPA Energy Star Database – There are approximately 1200 hotels that are participating in EPA's *Energy Star* program. Approximately 10% of the hotels participating have received *Energy Star* certification. These data were used for this study to evaluate gas and electricity consumption in hotels by size, number of rooms, and geographic location. This analysis is presented in **Section 4.**

Meeting Industry Megasite – A website designed for meeting planners, the MIMegasite allows a registered user to search their database of nearly 25,000 meeting facilities. The site includes information on hotels, golf resorts, convention centers, conference centers, bed and breakfasts, convention & visitors' bureaus, tourism bureaus, and other venues. Only the first two categories were searched for this report. Search criteria include country, state, major market, hotel size, largest meeting room, room rates, and available dates for meetings. The number of rooms criteria is very sensitive with 20 categories to search from *less than 25* to *2500+*. Based on a particular screen, individual facilities are identified by name, with additional information provided on other amenities at the site.

A number of other marketing firms sell industry statistics – Mintel, Standard & Poor, Datamonitor Business Information Center, Factiva, Business Source Premier, etc. The main disadvantage of these data series is the high cost and the limited focus on energy and utility issues.

Data sources used for the casino hotel market segment, not shown in Table 1, are statistics and membership data maintained by the American Gaming Association and the National Indian Gaming Association.

The remaining overview of the lodging market provides detail on the applications, sizes, geographic distribution, energy equipment, and energy use characteristics. Due to the lack of consistency in the source data described in Table 1, it was not possible to create a single internally consistent structure for the industry that covers all of these market characteristics.

2.2 Lodging Industry Market Size

As of the last *Economic Census* in 2002, there were 50,877 establishments in the economic category of *travelers' accommodations* (NAICS 7211). The number of establishments by type is shown in **Table 2**. The detailed breakdown by state is not available yet for 2002 data, but the 1997 data are shown in **Table 3** by type of facility and by state.

Table 2 Economic Census Figures for Lodging (Accommodations) Industry 2002 and 1997

Market Categories	2002	1997	Annualized Growth Rates %/yr

	Sites	Sales ($million)	Sites	Sales ($million)	Sites	Sales
Hotels (except casino hotels) with 25 guestrooms or more	46,163	90,541	16,782	61,333	1.34%	4.27%
Hotels with less than 25 guestrooms			2,386	582		
Motels			21,829	9,206		
Motor hotels			2,139	2,206		
Organization hotels			52	124		
Casino hotels	283	34,385	257	20,652	1.95%	10.73%
Bed & breakfast inns	3,537	890	2,898	687	4.07%	5.30%
All other traveler accommodation	894	175	736	175	3.97%	-0.02%
RV (recreational vehicle) parks & campgrounds	4,157	1,733	4,085	1,394	0.35%	4.45%
Recreational & vacation camps (except campgrounds)	3,177	1,740	3,513	1,341	-1.99%	5.35%
Rooming & boarding houses	2,659	719	3,485	757	-5.27%	-1.02%
Total Accommodations	60,870	130,320	58,162	98,457	0.91%	5.77%

Figure 1 shows the real revenue growth for the accommodations industry from 1997 to 2003. The total industry had revenues of just under $90 billion 2000 dollars. There was a small 1% recession in 1998 and a larger 6% recession in 2001 caused by 9/11. About 70% of revenue in this sector is concentrated in the South and West. In addition, the Northeast and Midwest regions suffered greater declines in the recessionary periods and less robust recoveries indicating a continued shift in travel to the South and West.

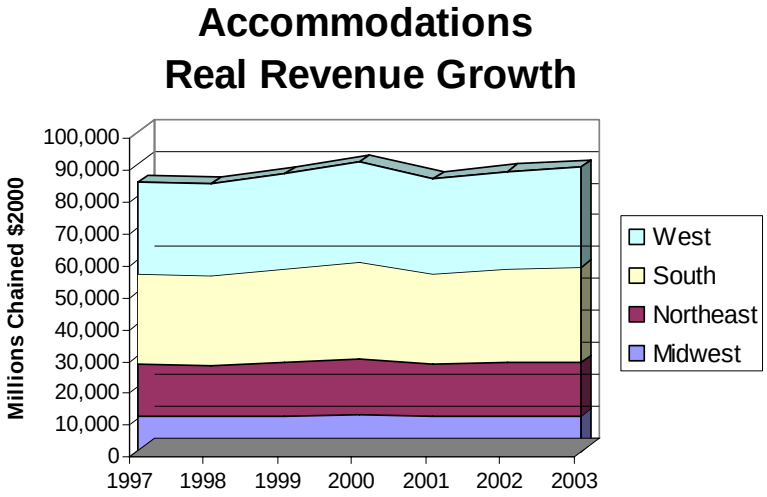


Figure 1 Growth in Accommodations Revenues by Region (Millions of Chained $2000)

Table 3 1997 Economic Census of Lodging Industry (NAIC 7211 Travelers' Accommodations) Number of Establishments by Type and State

State	Hotels >25rooms	Hotels <25rooms	Motels	Casino Hotels	Motor Hotels	Other	Travelers' Accommo-dations
Alabama	257	17	304	0	29	10	617
Alaska	111	30	86	0	6	48	281
Arizona	340	32	436	2	46	61	917
Arkansas	200	26	304	0	18	48	596
California	1,856	292	2,384	1	236	396	5,165
Colorado	389	86	540	14	56	150	1,235
Connecticut	143	13	102	0	24	20	302
D.C.	88	2	10	0	3	11	114
Delaware	37	6	74	0	5	6	128
Florida	1,382	156	1,436	2	111	123	3,210
Georgia	641	42	606	0	57	65	1,411
Hawaii	241	23	16	0	0	14	294
Idaho	93	19	181	1	20	20	334
Illinois	514	46	553	0	59	37	1,209
Indiana	281	26	320	1	30	48	706
Iowa	148	26	335	1	45	29	584
Kansas	146	17	281	0	19	18	481
Kentucky	234	15	303	0	27	24	603
Louisiana	253	18	246	5	30	35	587
Maine	138	53	326	0	28	185	730
Maryland	264	18	209	0	24	38	553
Massachusetts	315	63	322	1	38	188	927
Michigan	455	100	705	1	53	131	1,445
Minnesota	328	110	444	6	23	122	1,033
Mississippi	181	16	246	11	20	39	513
Missouri	383	45	514	3	52	79	1,076
Montana	125	31	310	6	20	32	524
Nebraska	93	11	247	0	12	14	377
Nevada	87	16	254	170	20	7	554
New Hampshire	114	22	157	0	21	106	420
New Jersey	365	53	580	12	67	76	1,153
New Mexico	170	36	359	0	28	77	670
New York	759	119	811	0	71	162	1,922
North Carolina	603	67	656	0	50	145	1,521
North Dakota	59	14	143	0	15	2	233
Ohio	444	32	556	0	65	62	1,159
Oklahoma	172	14	318	0	17	15	536
Oregon	196	51	517	6	44	72	886
Pennsylvania	536	104	479	0	67	120	1,306
Rhode Island	43	13	44	0	9	45	154
South Carolina	386	41	479	1	44	48	999
South Dakota	84	26	272	10	16	17	425
Tennessee	504	31	552	1	50	69	1,207
Texas	1,018	93	1,384	0	236	128	2,859
Utah	149	21	248	0	20	32	470
Vermont	103	51	140	0	20	137	451
Virginia	487	32	563	0	59	96	1,237
Washington	341	56	511	0	52	131	1,091
West Virginia	96	19	161	0	15	23	314
Wisconsin	351	108	555	2	48	120	1,184
Wyoming	79	28	250	0	14	16	387
Total U.S.	16,782	2,386	21,829	257	2,139	3,697	47,090

The statistics reported by the American Hotel & Lodging Industry Association (**Table 4**) show that as of year-end 2004, there were 47,598 properties with over 4.4 million guestrooms. The industry revenues for 2004 were $113.7 billion, up 8% from the previous year.

Table 4 Number of Hotels and Lodging Establishments by Size

Number of Rooms	Property	Rooms	Average Rooms
<75	27,464	1,163,668	42
75-149	14,326	1,524,099	106
150-299	4,235	847,089	200
300-500	1,070	398,491	372
>500	503	478,561	951
Total	47,598	4,411,908	93

Source: American Hotel & Lodging Industry Association, *2005 Lodging Industry Profile*

As will be discussed later, the larger the hotel, the greater the energy consumption, both overall and in terms of energy usage intensity per square foot. The high energy consumption in the roughly 1500 hotels larger than 300 rooms represents the priority target for CHP development.

Table 5 shows the distribution of hotels by state and by chain scale. *Chain scale* refers to the classification of hotel chains by the services offered and by cost ranging from luxury at the high end to economy and independent at the lower end. As shown in the table, the luxury and upper upscale chains both average more than 300 rooms/hotel nationally. **Table 6** shows the total number of hotel rooms by state. Taken together these data can be analyzed to identify where the highest concentration of high end and large hotels reside.

Table 7 shows the top ten markets for high end hotels, first by most luxury and upper upscale hotels per state and then the top ten states in terms of largest average size for upper upscale hotels. Luxury and upscale hotels are concentrated in two areas: resort areas like California, Florida, Nevada, Louisiana, and Arizona and in large metropolitan areas – convention centers in states with large metropolitan areas: California (Los Angeles and San Francisco), Texas (Houston), New York (New York City), Illinois (Chicago), Massachusetts (Boston.), and Washington, DC.

Table 5 Number of Hotels by State and by Chain Scale

State	Hotels							
	Luxury	Upper Upscale	Upscale	Midscale w/ F&B	Midscale w/o F&B	Economy	Independent	Total
Alabama	**1**	**9**	**30**	**73**	**147**	**212**	**292**	764
Alaska	1	4	8	22	5	17	195	252
Arizona	6	43	70	110	135	231	431	1026
Arkansas	1	5	15	67	99	143	322	652
California	43	203	249	516	381	942	3,094	5,428
Colorado	8	37	56	104	143	188	634	1,170
Connecticut	-	16	38	35	33	65	151	338
Delaware	1	5	9	13	20	20	76	144
District of Columbia	11	21	11	8	1	7	52	111
Florida	30	132	200	307	421	538	1,983	3,611
Georgia	7	49	101	150	352	582	514	1,755
Hawaii	18	25	43	30	-	-	199	315
Idaho	1	1	6	42	39	45	131	265
Illinois	12	61	90	125	271	311	507	1,377
Indiana	1	18	50	81	223	224	294	891
Iowa	-	6	12	51	121	194	220	604
Kansas	-	7	22	57	81	138	221	526
Kentucky	-	13	31	80	137	203	261	725
Louisiana	7	19	34	106	106	126	328	726
Maine	-	4	4	25	21	37	410	501
Maryland	2	30	39	72	90	122	235	590
Massachusetts	9	37	65	74	68	88	479	820
Michigan	3	28	65	135	237	266	615	1,349
Minnesota	3	17	45	61	110	253	349	838
Mississippi	-	4	6	66	121	151	266	614
Missouri	5	32	35	96	184	264	518	1,134
Montana	-	2	1	38	46	84	271	442
Nebraska	-	7	7	32	62	107	171	386
Nevada	3	15	18	42	29	67	449	623
New Hampshire	-	4	11	15	21	20	270	341
New Jersey	-	44	61	82	77	123	674	1,061
New Mexico	1	10	20	61	88	141	324	645
New York	21	52	70	171	129	233	1,012	1,688
North Carolina	2	35	81	144	350	376	684	1,672
North Dakota	-	-	3	13	27	51	110	204
Ohio	4	40	96	125	323	366	414	1,368
Oklahoma	-	13	23	71	87	151	314	659
Oregon	-	12	26	98	104	114	490	844
Pennsylvania	4	39	85	153	225	260	465	1,231
Rhode Island	-	5	10	7	12	12	82	128
South Carolina	1	20	36	77	204	226	523	1,087
South Dakota	-	1	4	30	51	108	180	374
Tennessee	3	31	47	115	256	367	477	1,296
Texas	14	110	224	370	623	818	1,519	3,678
Utah	1	11	16	61	73	111	252	525
Vermont	1	1	5	14	18	22	238	299
Virginia	4	51	88	167	255	343	434	1,342
Washington	5	21	36	113	107	146	547	975
West Virginia	-	2	5	25	53	70	157	312
Wisconsin	1	10	37	99	140	208	561	1,056
Wyoming	2	-	10	35	24	73	216	360
National Total	**237**	**1,362**	**2,354**	**4,664**	**6,930**	**9,964**	**23,611**	**49,122**
Avg. Rooms/Hotel	**320**	**386**	**158**	**125**	**89**	**78**	**66**	**92**

Source: Smith Travel Research, Inc.

Table 6 Number of Hotel Rooms by State and by Chain Scale

State	Rooms							
	Luxury	Upper Upscale	Upscale	Midscale w/ F&B	Midscale w/o F&B	Economy	Independent	Total
Alabama	329	2,968	3,579	7,428	12,303	14,778	18,224	59,609
Alaska	547	1,616	1,043	2,616	509	1,220	11,027	18,578
Arizona	2,525	13,527	10,605	12,342	13,335	19,740	28,966	101,040
Arkansas	418	1,295	1,714	6,425	8,010	9,654	16,202	43,718
California	12,550	82,332	43,333	59,872	33,988	72,181	176,516	480,772
Colorado	1,901	11,357	9,048	11,854	12,912	13,069	37,158	97,299
Connecticut	-	4,904	5,047	4,469	3,528	5,206	10,391	33,545
Delaware	216	1,039	1,098	1,399	1,718	1,664	4,060	11,194
District of Columbia	2,919	10,704	2,646	2,136	100	898	6,764	26,167
Florida	10,924	49,618	35,148	48,851	45,368	55,142	147,923	392,974
Georgia	2,495	20,717	14,284	17,154	30,574	45,793	34,860	165,877
Hawaii	6,441	18,191	8,484	6,989	-	-	23,620	63,725
Idaho	337	303	879	4,445	2,989	3,281	6,007	18,241
Illinois	5,026	27,389	14,611	18,754	23,924	24,922	33,557	148,183
Indiana	99	6,170	6,823	9,574	18,304	18,132	18,670	77,772
Iowa	-	1,547	1,649	6,395	9,012	10,889	12,042	41,534
Kansas	-	2,256	2,898	6,143	6,372	9,105	10,520	37,294
Kentucky	-	3,599	4,272	9,124	10,666	15,487	16,945	60,093
Louisiana	2,739	9,781	5,972	14,854	10,302	11,621	23,668	78,937
Maine	-	714	394	2,965	1,993	2,753	18,389	27,208
Maryland	412	9,067	6,447	11,096	9,528	11,210	15,589	63,349
Massachusetts	1,925	14,438	10,241	9,739	7,497	7,068	26,266	77,174
Michigan	1,140	8,003	8,645	16,870	20,842	20,640	33,575	109,715
Minnesota	677	6,019	7,164	8,634	9,536	15,751	19,154	66,935
Mississippi	-	955	717	6,407	9,835	9,949	27,155	55,018
Missouri	1,244	12,045	6,617	12,628	16,549	19,004	32,698	100,785
Montana	-	453	79	4,208	3,419	5,471	12,387	26,017
Nebraska	-	1,996	966	3,872	4,847	6,217	7,975	25,873
Nevada	974	18,208	8,145	7,687	3,268	7,499	138,019	183,800
New Hampshire	-	926	1,547	1,904	2,036	1,457	11,987	19,857
New Jersey	-	15,152	10,971	11,303	8,608	10,343	45,291	101,668
New Mexico	59	2,867	2,833	5,787	7,268	9,763	16,110	44,687
New York	7,903	26,781	12,793	24,561	12,385	17,087	72,139	173,649
North Carolina	406	10,414	10,357	16,861	31,681	31,550	36,471	137,740
North Dakota	-	-	466	2,074	2,067	3,167	6,311	14,085
Ohio	815	12,197	12,222	17,795	25,995	30,332	24,082	123,438
Oklahoma	-	4,801	3,160	7,539	6,696	10,461	16,209	48,866
Oregon	-	4,255	3,776	8,785	8,652	8,032	25,411	58,911
Pennsylvania	1,553	12,920	14,558	20,277	21,173	20,297	26,250	117,028
Rhode Island	-	1,502	1,377	948	1,463	964	3,539	9,793
South Carolina	255	5,903	4,940	8,956	18,054	18,461	41,495	98,064
South Dakota	-	184	442	3,437	3,500	6,011	7,614	21,188
Tennessee	925	11,880	5,988	14,355	21,901	27,947	29,169	112,165
Texas	4,545	42,491	34,823	40,533	56,108	65,770	89,657	333,927
Utah	170	3,679	1,929	7,393	6,497	8,047	13,454	41,169
Vermont	113	309	635	1,489	1,705	1,240	11,546	17,037
Virginia	1,448	16,832	13,290	23,568	23,627	28,592	26,825	134,182
Washington	1,138	8,185	5,627	13,320	10,587	12,251	27,216	78,324
West Virginia	-	605	700	2,991	4,774	5,191	10,727	24,988
Wisconsin	307	3,242	5,098	11,166	11,023	14,210	31,343	76,389
Wyoming	285	-	2,443	4,173	1,820	4,358	9,747	22,826
National Total	**75,760**	**526,336**	**372,523**	**584,145**	**618,848**	**773,875**	**1,550,920**	**4,502,407**

Source: Smith Travel Research, Inc.

Table 7 Top Ten States by Number of High End Hotels and by Largest Average Size for High End Hotels

Most Luxury and Upper Upscale Hotels	Hotels	Largest Average Upper Upscale Hotels	Avg. Rooms / Hotel
California	246	Nevada	1,214
Florida	162	Hawaii	728
Texas	124	New York	515
New York	73	Louisiana	515
Illinois	73	District of Columbia	510
Georgia	56	Illinois	449
Virginia	55	Georgia	423
Arizona	49	California	406
Massachusetts	46	Alaska	404
Colorado	45	Massachusetts	390
Percent of U.S.	58.1%	Average Rest of U.S.	338

Table 8 shows the number of hotels by state and by number of rooms for hotels having 100 or more guest rooms. The table breaks down hotels by five size categories. As will be described later, 100-room hotels were chosen as the minimum size category for a hotel to economically consider CHP. There are nearly 9,500 hotels in the U.S. with 100 rooms or more. There are 527 hotels with 500 rooms or more. In the largest size category, there are only 32 hotels in the U.S. with 2000 rooms or more. Most of these mega-resorts have casinos and three-fourths of these hotels are in Nevada.

2.3 Casino Industry Focus

The U.S. casino industry, which includes land-based commercial casinos, riverboat casinos, tribal-run casinos, racetrack casinos, and card rooms, generated approximately $45.9 billion in revenue in 2003, a 5.7% increase compared with 2002 revenues. In 2004, industry revenue is projected to grow 5.1%, to reach $48.3 billion.

There are 48 U.S. states (except Hawaii and Utah) that have some form of legal gambling. Casino gambling was legalized in Nevada in 1931 and the state did not experience any competition until 1976 when New Jersey legalized gambling. The rapid spread of casinos started in the late 1980s and early 1990s when a number of states including Iowa, Illinois, Colorado, Connecticut and Indiana, began legislative initiatives to allow commercial and/or tribal casinos to open. Between 1989 and 1998 nine states legalized casino gambling. In 2004, casino gambling (including commercial casinos, tribal casinos, racetrack casinos and card rooms) was legal in 34 states.

Table 8 Number of Hotels by State and by Number of Guest Rooms

State	Number of Rooms					Total
	100-199	200-499	500-999	1000-1999	2000+	
Alabama	110	24	1			135
Alaska	22	11	2			35
Arizona	198	57	12			267
Arkansas	46	18				64
California	581	337	51	12		981
Colorado	155	66	9	2		232
Connecticut	87	21	1	2		111
DC	32	35	8	2		77
Delaware	18	6				24
Florida	606	285	57	22	4	974
Georgia	229	79	7	5		320
Hawaii	9	43	21	5	1	79
Idaho	31	5	1			37
Illinois	220	115	16	5	1	357
Indiana	102	33	5			140
Iowa	64	17				81
Kansas	58	14				72
Kentucky	69	29	2	1		101
Louisiana	122	54	9	4		189
Maine	40	8				48
Maryland	135	47	4	1		187
Massachusetts	139	73	5	2		219
Michigan	187	56	5	1		249
Minnesota	103	53	6			162
Mississippi	51	17	7	5		80
Missouri	139	60	11			210
Montana	26	7	1			34
Nebraska	33	10				43
Nevada	53	61	29	20	24	187
New Hampshire	36	13				49
New Jersey	153	63	9	5	1	231
New Mexico	68	18				86
New York	225	101	29	10		365
North Carolina	232	40	4	1		277
North Dakota	18	4				22
Ohio	198	77	4			279
Oklahoma	41	21	1			63
Oregon	91	26	2			119
Pennsylvania	230	76	8	1		315
Rhode Island	17	12				29
South Carolina	113	41	12	1		167
South Dakota	19	7				26
Tennessee	170	57	2		1	230
Texas	411	209	20	6		646
Utah	71	17	4	1		93
Vermont	28	6		1		35
Virginia	241	95	6			342
Washington	131	39	4			174
West Virginia	43	7	1	1		52
Wisconsin	100	35	3			138
Wyoming	22	9				31
U.S. Total	6323	2614	379	116	32	9464

Casinos and gaming overlap the hotel and lodging industry to the extent that there are nearly 300 land-based casinos with associated lodging. The casino industry also includes land-based casinos without lodging, racetracks, riverboat and dockside casinos. The industry is further split into the commercial gaming industry with operations in 11 states and the Indian casino operations operating in 28 states (Class III Tribal Casinos in 21 states.) **Figure 2** shows the distribution of casino operations by state and type.

Commercial gaming is permitted in 11 states. The two largest commercial gaming centers are in Nevada (Las Vegas, Reno) and New Jersey (Atlantic City.) The Midwest commercial gaming industry consists exclusively of riverboat and dockside casinos (Illinois, Indiana, Iowa, Missouri) except for 3 land based casinos in Michigan. The next biggest gaming center is in the South with casinos in Louisiana and Mississippi. The Southern commercial gaming market is primarily riverboat and dockside with one land-based casino in Louisiana. Colorado and South Dakota in the West both allow limited stakes gambling casinos. These facilities bring in much less revenue than the unrestricted casinos in the larger markets. **Table 9** shows the breakdown of the commercial gaming industry by state.

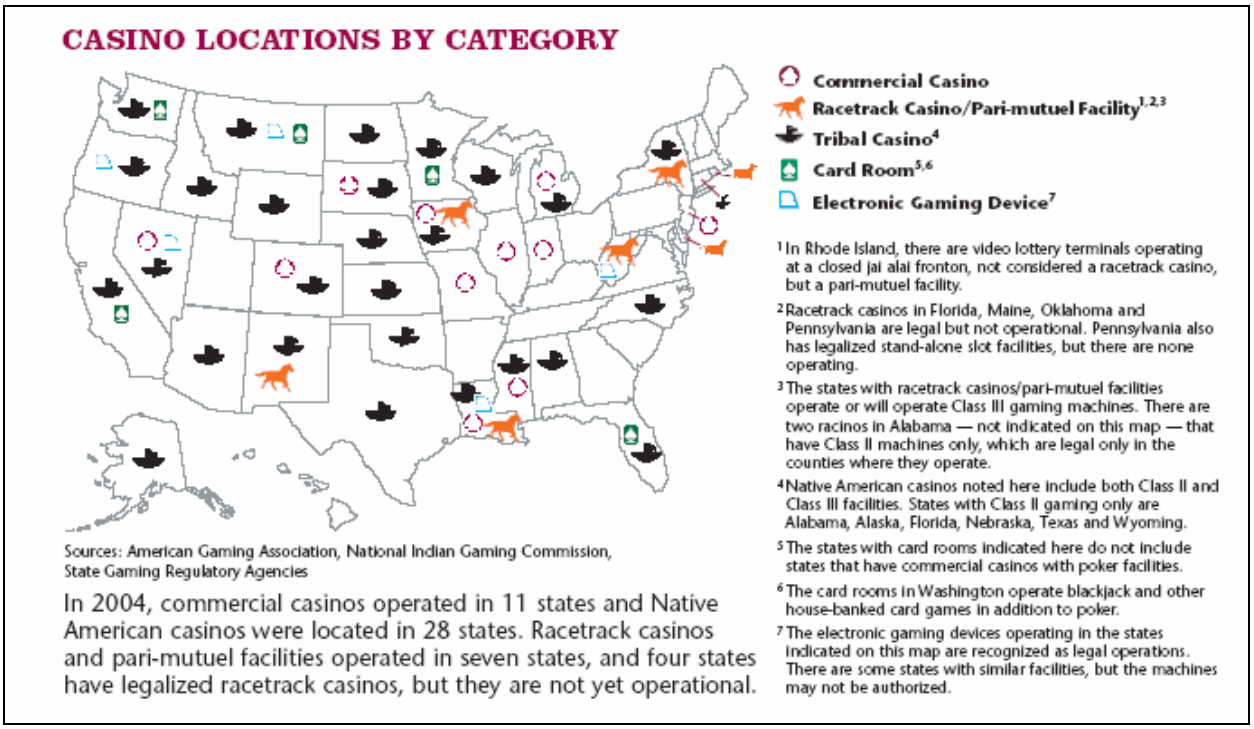


Figure 2 Geographical Distribution of Casino Gaming by Type

Table 9 Commercial Gaming Facilities and Revenues by State

State	Employee Wages $millions	Gross Revenue $millions	Tax Revenue $millions	Year of first Operation	Type of Casino		
					Land	Race-Track	River-boat
Nevada	$6,954	$9,625	$777	1931	256		
New Jersey	$1,239	$4,490	$415	1978	12		
Mississippi	$1,028	$2,700	$325	1992			29
Indiana	$590	$2,229	$703	1995			10
Louisiana	$453	$2,017	$449	1993	1	3	14
Illinois	$377	$1,709	$720	1991			9
Missouri	$310	$1,330	$369	1994			11
Michigan	$368	$1,130	$250	1999	3		
Iowa	$279	$1,024	$210	1991		3	10
Colorado	$207	$609	$96	1991	44		
South Dakota	$35	$70	$11	1989	38		
Total	$11,839	$26,934	$4,323		354	6	83

Since 1988, when the Indian Gaming Regulatory Act was passed, 224 of the 562 recognized Indian nations have pursued development of Class II or Class III casinos. The Indian gaming industry has grown from $212 million in 1988 to over $14 billion in 2004. **Table 10** shows the number of Indian casinos with associated lodging by state. There are a total of 97 Indian casino hotels.

Table 10 Indian Casinos with Associated Hotels, Resorts, or Lodges

Northeast		Midwest	
Connecticut	2	Iowa	1
New York	1	Kansas	0
Northeast Total	3	Michigan	9
		Minnesota	14
		Nebraska	1
		North Dakota	5
		Oklahoma	3
		South Dakota	5
		Wisconsin	8
		Midwest Total	46
South		**West**	
Alabama	1	Arizona	7
Florida	1	California	10
Louisiana	2	Colorado	1
Mississippi	1	Idaho	1
North Carolina	1	Montana	2
South Carolina	0	Nevada	1
Texas	0	New Mexico	7
South Total	6	Oregon	9
		Washington	4
		Wyoming	0
		West Total	42

For purposes of evaluating the applicability of CHP, the unrestricted land-based casinos, both commercial and tribal, represent the best target. However, the riverboat and dockside casino activities have evolved such that there are no cruising requirements in the six states. "Riverboat" casinos in these states (except for Iowa that only lifted cruising requirements in 2004) are in permanently moored barges. Such facilities could receive electric and thermal energy services in the same way as permanent buildings, and therefore it is conceivable that CHP could be applied.

2.4 Industry Trends

The hotel industry is finally breaking out of the disastrous recession that followed the 9/11 terrorist attacks on the World Trade Center and the Pentagon. In the three years following 9/11 the hotel industry had a 36.2 decline in profits. In 2004, this declining trend has turned around with a 7.6%

increase in revenues and an 11.4 % increase in profits compared with 2003.[5] Resort hotels achieved the greatest increase in profitability in 2004 with operating profits growing by 17.2%. Limited service hotels gained the least with profits up only 6.2%. Full service, suite, and convention hotels all saw profits rise by over 10%.

The number of occupied rooms grew by only 4.3% so the much higher increase in profitability is due to increased usage of other hotel amenities such as restaurants, lounges, retail shops, and recreational facilities. Energy costs have fluctuated up in 2001, down in 2002, and up again the last two years. The rising oil prices in 2005 are creating concern within the industry for not only increased operating costs, but decreased travel as well.

Increased competition among establishments in this industry has spurred many independently owned and operated hotels and other lodging places to join national or international reservation systems, which allow travelers to make multiple reservations for lodging, airlines, and car rentals with one telephone call. Nearly all hotel chains operate online reservation systems through the Internet. There is a shift in the demand by type of traveler and by type of facility.

Younger travelers (generation X) are eclipsing baby-boomers as the number one travel segment.

Leisure travel hotel stays, historically subordinate to business travelers' needs, has now equaled business travel stays and should become the number one reason for hotel stays in the U.S.

Luxury hotels (Four Seasons, Ritz Carlton, Fairmont) represent the fastest growing market segment. The worst performing segment is the economy segment (Motel 6, Red Roof, Days). Limited service hotels (Hampton Inn, Country Inns & Suites, HI Express) are gaining at the expense of full service mid-level chains (Holiday Inn, Ramada, Best Western). **Figure 3** shows the change in rooms supplied and demanded for five categories of hotel properties.

[5] *Trends in the Hotel Industry*, PKF Hospitality Research, 2005. (cited statistics from PKF press release.)

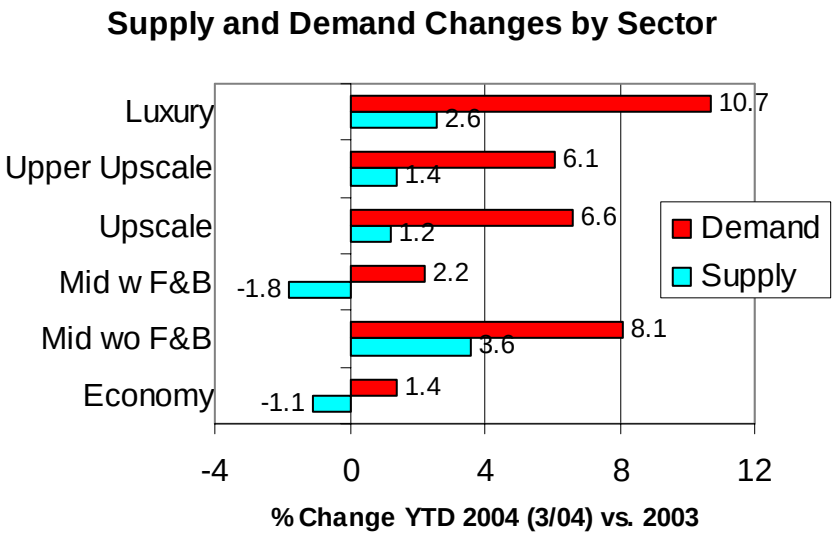


Figure 3 Change in Room Supply and Demand by Market Sector[6]

About 70% of all motel and hotel rooms are associated with franchises and national chains. **Table 11** shows the largest 15 hotel corporations by number of available rooms in the U.S[7]. These large corporations can provide centralized decision making for CHP project development. The top national chains account for the majority of the development through new construction or "reflagging" of existing facilities that are acquired. **Table 12** shows the growth in progress for the five top chains in the U.S. New construction represents the best opportunity for making a CHP decision. Reflagging also represents an opportunity for facility upgrades during remodeling.

[6] Mark V. Lommano, "U.S. Lodging Industry Overview," *AH&LA 2004 Travel Industry Summit*, Smith Travel Research, May 14, 2004.

[7] In recent years, hotels, motels, camps, and recreational and RV parks affiliated with national chains have been growing rapidly. To the traveler, familiar chain establishments represent dependability and quality at predictable rates. National corporations own many chains, although several others are independently owned but affiliated with a chain through a franchise agreement.

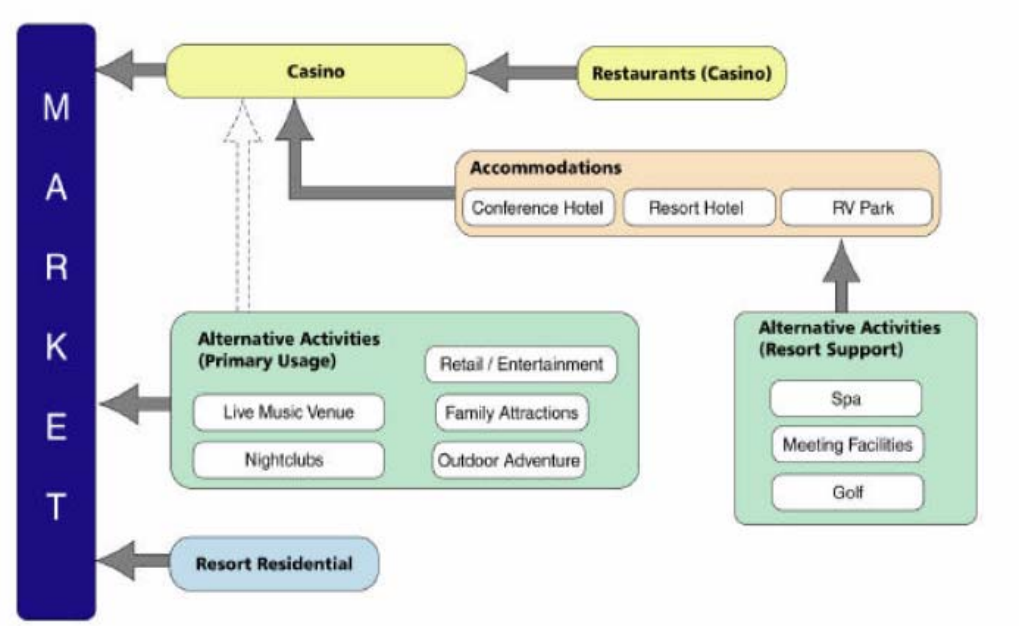
Table 11 Top 15 National Chains by Number of Available Rooms in the U.S.

Top 15 Domestic Hotel Chains by Number of Rooms	Domestic Rooms	Domestic Hotels	International Rooms	International Hotels	Brands
[2] Cendant Corporation	439,279	5,622	64,581	839	Amerihost Inn, Days Inn, Days Serviced Apartments, Howard Johnson, Howard Johnson Express, Knights Inn, Ramada, Ramada Limited, Super 8, Thriftlodge, Travelodge & Wingate Inn
[3] Marriott International, Inc.	380,218	2,236	120,970	563	Courtyard by Marriott, Fairfield Inn by Marriott, Marriott Conference Centers, Marriott Executive Apartments, Marriott Hotels and Resorts, Ramada Int'l Plaza, Ramada International Hotels & Resorts, Renaissance Hotels & Resorts, & Residence Inn
[5] Hilton Hotels Corporation	357,332	2,184	17,218	75	Conrad, Doubletree, Doubletree Club, Embassy Suites, Embassy Vacation Resort, Hampton Inn, Hampton Inn & Suites, Hilton, Hilton Gaming, Hilton Garden Inn, & Homewood Suites
[1] Inter-Continental Hotel Group	337,643	2,523	214,295	1,133	Candlewood, Centra, Crowne Plaza, Forum Hotel, Holiday Inn, Holiday Inn Express, Holiday Inn Garden Court, Holiday Inn Select, Inter Continental, Parkroyal, Posthouse, Staybridge Suites by Holiday Inn, & Sunspree Resorts
[4] Choice Hotels International, Inc.	313,982	3,891	78,615	878	Clarion, Comfort Inn, Hotel & Suites, Econo Lodge, MainStay Suites, Quality Inn, Hotel & Suites, Rodeway Inn, & Sleep Inn
[6] Best Western International	186,422	2,181	116,924	1,783	Best Western
[10] Accor North America	134,803	1,252	4,167	26	Coralia, Hotel Novotel, Hotel Sofitel, Mercure Hotel, Motel 6, Red Roof Inn, & Studio 6
[7] Starwood Hotels & Resorts Worldwide, Inc.	123,747	355	103,543	377	Four Points Hotel by Sheraton, Sheraton, St. Regis/Luxury Collection, W Hotels, & Westin
[9] Carlson Hospitality Worldwide	82,739	566	70,703	379	Country Inns & Suites by Carlson, Park Inns & Suites, Park Plaza Suites, Radisson, & Regent Hotels
[12] HVM, L.L.C.	72,961	654	0	0	Extended StayAmerica Efficiency Studios®, Homestead Studio Suites Hotels®, StudioPLUS Deluxe Studios® and Crossland Economy Studios® properties.
[14] La Quinta Corporation	65,384	592	50	1	Baymont Inn & Suites, La Quinta Inns, La Quinta Inn & Suites, Woodfield Suites and Budgetel.
[13] Interstate Hotel & Resorts	64,909	288	573	3	Hotel Operator
[15] Hyatt Hotels Corporation	57,085	115	4,500	12	Hyatt®, Hyatt Regency®, Grand Hyatt® and Park Hyatt® brands, just added Amerisuites
[16] Host Marriott	51,721	101	1,641	4	Marriott, Ritz-Carlton, Fairmont, Hyatt Regency, Westfields, Westin, Swissotel, Four Seasons
[17] FelCor Lodging Trust, Incorporated	40,137	148	814	2	REIT. FelCor maintains a strong relationship with InterContinental Hotels Group (NYSE: IHG), Hilton Hotels Corporation (NYSE: HLT) and Starwood Hotels & Resorts (NYSE: HOT).

Table 12 National Chains Share of Industry Growth[8]

Leading Chains	Rooms Under Development			2004 Growth Rate %
	New Construct	Reflags	Total	
Marriott	41,905	6,204	48,109	4.1
Hilton	37,755	2,679	40,434	4.4
InterContinental	26,235	4,450	30,685	3.8
Cendant	24,695	7,209	31,904	2.1
Choice	9,896	4,110	14,006	3.0
Total Leading Cos.	140,486	24,652	165,138	3.4
% of Industry	54.70%	69.90%	56.50%	

Consistent with the strength of the luxury market sector, one of the top trends in the casino/resort segment of the lodging industry is known as *entertainment convergence*. Destination casinos and resorts seek to broaden the appeal of their facilities, i.e., attract more people, and to provide a variety of attractions so that guests will lengthen their stay. **Figure 4** shows the components that are going into the development of a modern casino/resort property. The addition of these multiple uses and components makes facilities much larger than they used to be and creates a correspondingly larger but also more diverse energy load that can be met by CHP.



Source: Economics Research Associates[9]

Figure 4 Casino/Resort Use and Services Model

[8] Patrick Ford, "New Construction, Top Markets, Leading Companies, Real Estate Transactions," AH&LA *2004 Travel Industry Summit*, Lodging Econometrics, May 14, 2004.
[9] Mark E. Dvorchak, *From Casino to Resort: Understanding the Entertainment Heirarchy*, ERA White Paper, July 2002.

In this expanded use model, hotel and entertainment companies are seeing the most revenue opportunities from the expansion of retail facilities, resort residential development, theme parks, and spas. An example of this model for new resort facilities is the Atlantic City's Marina District, Borgata Hotel Casino and Spa. The Borgata is the first new casino/hotel/shopping destination built in Atlantic City in more than a decade. This facility features more than 2,000 guest rooms, 135,000 square feet of gaming, 11 restaurants, 4 bars, a 35,000 sq ft spa, 8 retail stores, 30,000 sq ft event center for concerts and conference exhibitions that is part of a total of 70,000 sq ft of conference space, a 1,000 seat theater, and other entertainment facilities. The facility is served by a state-of-the-art district heating and cooling plant with 8 MW of backup power. Having centralized heating and cooling makes it easier to add CHP at a later date.

3. EXISTING CHP IN HOTELS/CASINOS

There are currently 98 hotels in the U.S. with CHP systems, representing over 63 MW of capacity. California contains the most CHP equipped hotels in the country by a large margin with New Jersey and New York coming in second and third. This distribution of CHP hotels throughout the U.S. follows very closely with the proportion of total CHP installations by state. **Table 13** shows the number of CHP hotels that are located in each state.

Table 13 State Distribution of Hotels with CHP Systems

State	# Sites	Capacity (kW)
AK	2	5,950
AZ	1	1,650
CA	57	27,003
CT	2	550
FL	1	125
HI	3	1,550
IN	1	90
MA	5	560
MI	1	125
MO	1	150
ND	1	30
NE	1	82
NJ	8	1,710
NM	1	28
NV	1	4,900
NY	6	7,935
OH	1	100
TN	1	5,200
TX	2	355
UT	1	1,950
WV	1	3,150
Total	98	63,193

Of the existing CHP systems in the hotel/casino sector, the majority are reciprocating engine systems. Many of these systems were put in during the late 1980s. **Table 14** shows the distribution of

systems by prime mover and **Figure 5** shows the start year for each system. In recent years the industry has installed a number of microturbine and fuel cell systems, with a particularly busy installation year in 2003.

Table 14 Hotel CHP Systems by Prime Mover

Prime Mover	# Sites	Capacity (kW)
Combustion Turbine	4	12,450
Reciprocating Engine	78	48,255
Fuel Cell	5	1,350
Microturbine	11	1,138
Total	98	63,193

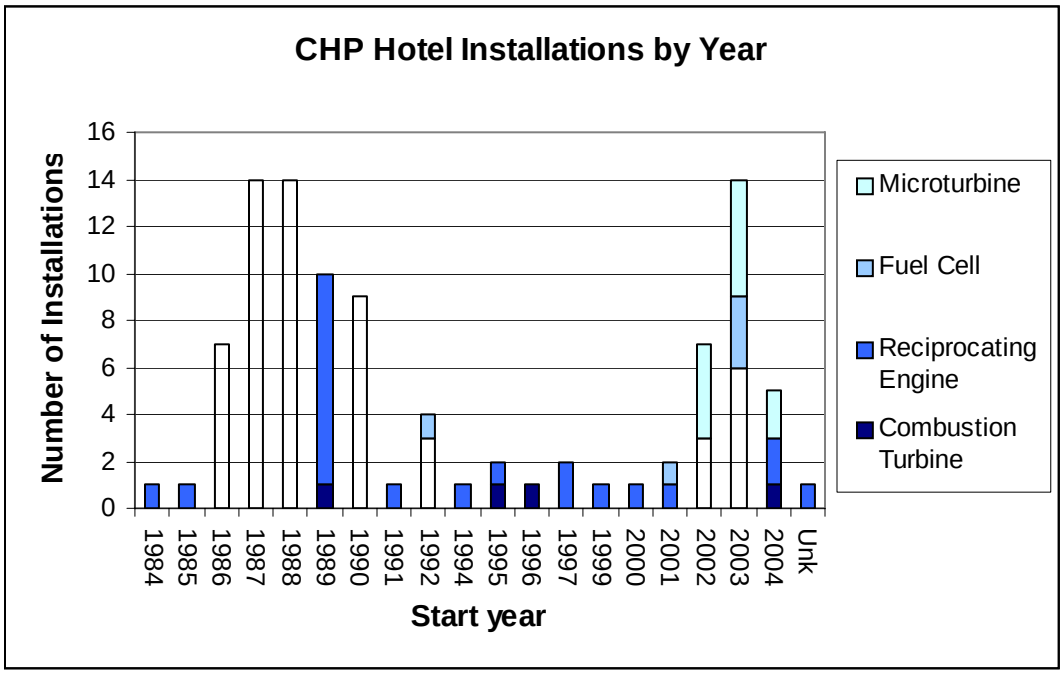


Figure 5 Hotel CHP System Installations by Start Year and Prime Mover

Due to the load profiles of hotels the majority of CHP systems that are installed are under 500 kW. **Figure 6** shows this size dispersion with an equal amount of systems falling in the 0 to 100 kW category and the 100 to 500 kW category. The systems in the larger categories are mainly located at resort hotels with larger campuses that require more power. There are three hotel casino resorts with CHP systems, two of which are in the largest two categories with capacities of 4.9 MW and 5.2 MW.

Size Range	# Sites
0-100 kW	40
100-500 kW	39
500-1000 kW	5
1-5 MW	10
>5 MW	4

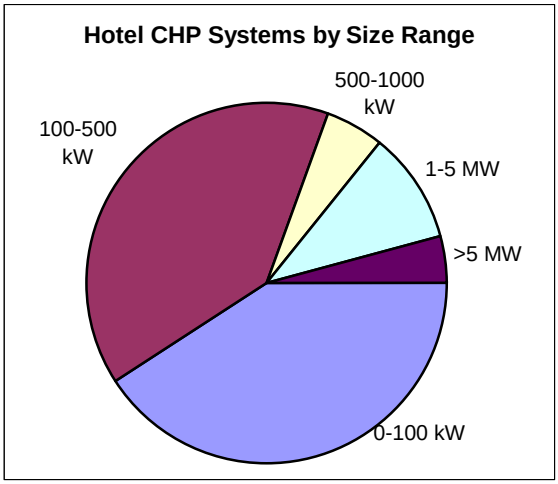


Figure 6 CHP Systems in the Lodging Industry by Size

Examples of CHP systems in hotels are described in the following sections.

Mohegan Sun Casino and Hotel

The Mohegan Sun Casino and Hotel is a unique casino destination in southeastern Connecticut that is owned by the Mohegan Tribal Nation. The hotel has almost 1,200 guest rooms and includes a spa, business center, and several fine and casual dining restaurants.

In 2001 International Fuel Cells sold two PC25TM fuel cells to the Mohegan Tribal Nation for the hotel casino. The units each produce 200 kilowatts of electricity and 900,000 BTUs of heat, providing reliable energy for the Mohegan Sun. The heat is used to meet space heating as well as domestic hot water needs.

The purchase of the fuel cells is part of a larger effort by the tribe to make the hotel casino as environmentally friendly as possible. "The environment has always been a traditional Mohegan priority. We are pleased to be able to implement this environmentally sound system at Mohegan Sun," said Jayne Fawcett, Tribal Ambassador. The Department of Energy and the Environmental Protection Agency Combined Heat and Power Partnership recognized the Mohegan Sun project's pollution reduction and energy efficiency with a 2005 CHP Certificate of Recognition.

The tribe also intends to run a public awareness program by inviting outside groups including school classes to view the fuel cells and learn about how they operate with significantly reduced emissions. Real-time operating data from the fuel cells will also be available for visitors to view.

Harrah's Rio All Suite Hotel and Casino

The Rio All Suite Hotel and Casino is a high-end casino resort located in Las Vegas less than a mile from the Las Vegas Strip. The hotel offers 2,800 suites, shows and lounges, nonstop gaming, as well as many luxuries associated with top resorts. The Rio also contains five fine dining restaurants with another ten casual dining restaurants.

The Rio was installed a CHP system, the first system at a Las Vegas casino, in order to reduce its $9 million annual energy bill. This was accomplished by installing six Caterpillar 3516 natural gas gen-sets that produce 4.9 MW of electricity for the hotels needs. The system started operation on May 1, 2004 and generates 40 percent of the electricity, 60 percent of the hot water, and 65 percent of the heating requirements of the resort. Through generating power and thermal energy more efficiently than the hotel can purchase from the local utility, the Rio has an annual energy savings of $1.5 million. The system will pay for itself in just over four and a half years.

The CHP system operates around 75 percent overall efficiency and uses 34 percent less fuel than on-site thermal generation and purchased electricity. The Department of Energy and the Environmental Protection Agency Combined Heat and Power Partnership recognized the Rio project's pollution reduction and energy efficiency with a 2003 CHP Certificate of Recognition.

Radisson Santa Maria

The Radisson Hotel of Santa Maria is a 185 room hotel located adjacent to the Santa Maria Airport. The hotel has conference and meeting rooms, a spa, exercise area with pool, and an 80-seat gourmet restaurant/lounge. The hotel has served the Santa Maria and Vandenberg communities with lodging, dining, and business services for almost 30 years but was driven to look into CHP because of high energy and operating costs.

The hotel installed two Capstone microturbine C60-ICHP systems to reduce the hotel's cost of electricity, hot water, and space heating. The microturbines each produce 60 kW of electrical energy and 115 kW of thermal energy. The system was installed in parallel to the utility connection and runs continuously to offset the hotel's average demand of 160 kW. Almost 800,000 Btu/hr of heat is obtained from the heat recovery units and is used to heat water in the domestic, laundry, and kitchen water loops with excess heat being utilized for space heating. During the winter months the microturbines provide for a majority of the hotel's hot water needs, which are supplemented by the existing boilers, however the system provides all the hot water during the summer months.

The system installation went very smoothly at the Radisson Santa Maria. The system is located in an easily viewable area adjacent to the mechanical room and is connected to a 200-amp electrical sub-panel and extended gas service. Since the Capstone systems are precertified to the California Air Resources Board 2003 DG emissions standards and also to California's statewide Rule 21 interconnection requirements, the installation and startup were quick and easy, and had no impact on hotel operations.

4. ENERGY CONSUMPTION AND LOAD PROFILES

This section provides some general energy consumption figures and then explores specific energy use load profiles for specific hotel types that have enough thermal and electric load to support an economically sized CHP system. These electric and thermal load relationships are used in the technical and economic screening of CHP potential in *Section 5.*

4.1 Energy Consumption Trends

The energy consumption characteristics of the lodging industry have a direct bearing on the applicability of CHP and the total technical market potential. . This section provides some overall energy use indicators.

Figure 7 shows annual energy costs per available room by type of hotel property.[10] Resort hotels pay the most per available room for energy -- $2,080 in 2003. Convention hotels are the next most energy intensive followed by full-service and all-suite hotels. Per available room energy costs for extended stay and limited service hotels are much less than resort hotels at $611 and $573 respectively. About three fourths of energy costs are for electricity and one fourth for fuel.

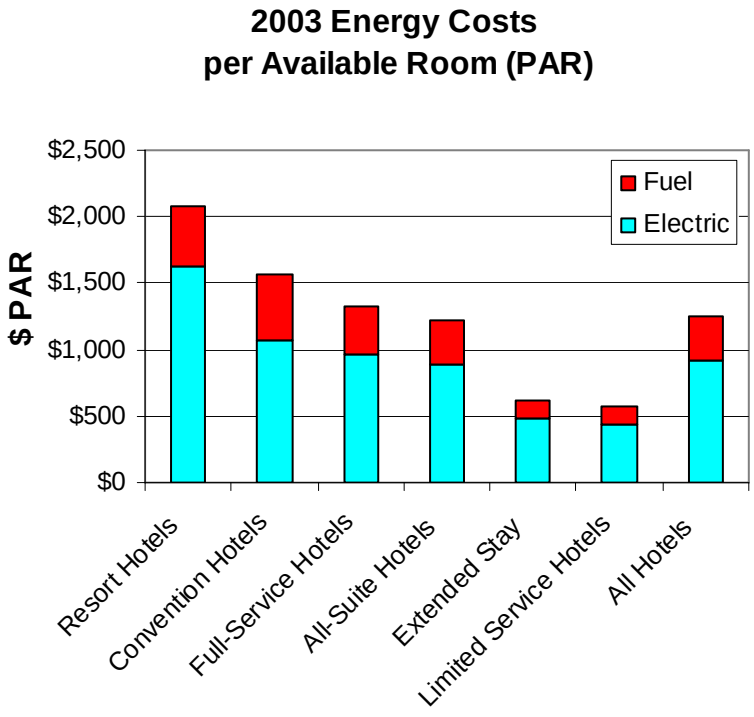


Figure 7 2003 Energy Consumption Expenditures per Available Room by Type of Hotel

For the industry as a whole, energy costs (2003) were $1,254 per available room. Based on the 4.4 million available rooms for the industry, the total energy bill is $5.2 billion or about 5% of total industry revenues.

[10] Robert Mendelbaum, "Hotel Utility Costs Surge Protection is Needed," *Hotel Online Special Report*, PKF Hospitality Research March 2004.

The energy costs reported by PKF Hospitality Research were divided by the average large commercial energy costs for 2003 reported by EIA. The resulting estimates of energy consumption per available room are shown in **Figure 8.** In terms of energy consumed, electricity and fuel consumption is roughly equal overall. Based on the total industry figures, the total energy consumption for the industry in 2003 was an estimated 394 trillion Btu/year. (When using a more inclusive EIA definition of the industry with dormitories and nursing homes included the estimate rises to 450 trillion/Btu per year.)

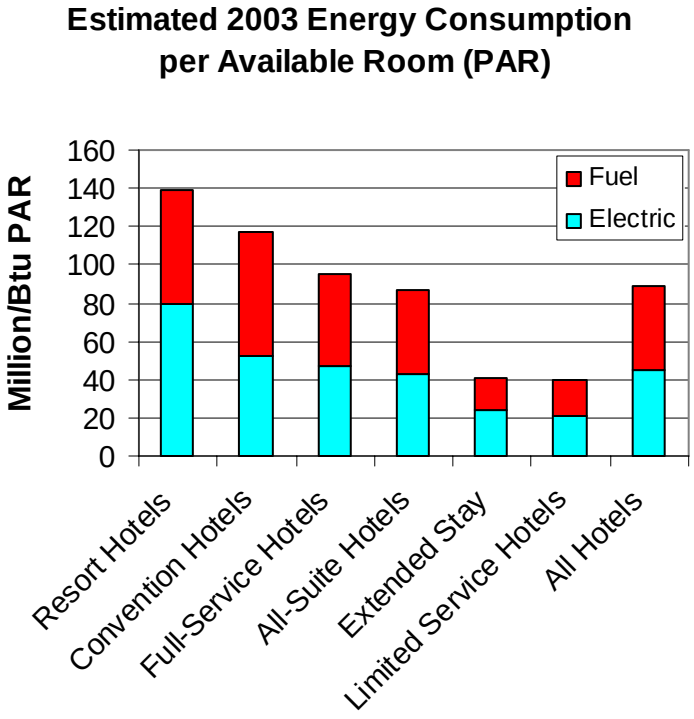


Figure 8 2003 Estimated Energy Consumption per Available Room by Type of Hotel

Using the per room estimates shown above, the annual energy costs of different types of hotels can be compared. A 2,000 room resort hotel would have a typical annual energy bill of over $4 million and might have a peak electric demand of 7 to 10 MW. A typical 100 room limited service hotel would have an annual energy budget of $57,000 with a corresponding peak demand of 100 to 150 kW. These examples show the importance of segmenting the lodging market when evaluating the market potential for CHP.

The ability of lodging facilities to utilize CHP depends not only on the amount of energy utilized but the ways in which the energy is utilized. **Figure 9,** based on the EIA CBECS data for the lodging sector, shows the breakdown of electric and gas consumption by end-use for the industry as a whole. Space heating and water heating are the two largest consumers of energy; both of these end-uses predominantly use natural gas. Air conditioning is the next biggest end-use followed by lighting. Together these four end uses account for three quarters of the total energy needs for the industry.

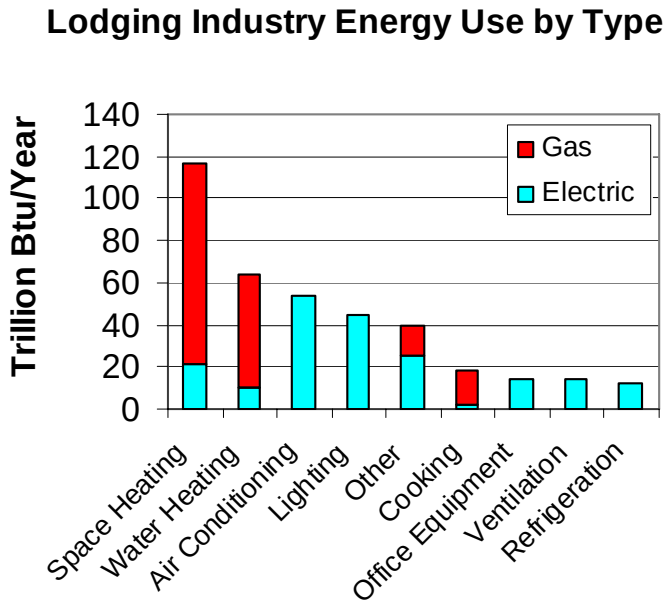


Figure 9 1999 Energy Consumption by End-Use for the Lodging Industry (EIA Data)

4.2 Energy Consumption Analysis for EPA Energy Star Hotel Participants

The EPA Energy Star Program has had energy usage data submitted by 1222 hotels[11]. These data were analyzed for this study to provide insight on electric and natural gas utilization by hotels.

Of the 1200 hotels analyzed, the breakdown by chain scale and by size class of the hotel is shown in **Table 15**. About two-thirds of the hotels participating in the Energy Star program are in the Upscale and higher chains. There are 146 hotels with more than 500 rooms representing 30% of the total market as reported by the AH&LA.

Hotel size as a function of the number of rooms varies by chain scale. Using a linear trend line analysis, the average total square footage per hotel room is given for each type of hotel. As hotels increase in services and price level, the total average square footage per room increases from 535 s.f. for an economy hotel to 905 s.f. for an upper upscale hotel as shown in **Table 16.**

[11] Twenty-two hotels were eliminated from the analysis for a variety of reasons: no information on number of rooms, no floor space given, located in a U.S. territory, one duplicate, and cases where the square footage given for the hotel was too small for the number of rooms. A total of 1200 hotels were analyzed from the EPA database.

Table 15 Breakdown of EPA Energy Star Hotel Database by Size Class and Chain Scale

	Size Class (Number of Rooms)					
Hotel Type	<75	75-149	150-299	300-500	>500	Total
Hotel (Economy and Budget)	18	7	2			27
Hotel (Midscale w/o Food and Beverage)	6	50	8			64
Hotel (Midscale w/Food and Beverage)	3	186	73	13	4	279
Hotel (Upscale)	3	238	165	54	24	484
Hotel (Upper Upscale)	3	7	82	136	118	346
Grand Total	33	488	330	203	146	1200

Table 16 Average Hotel Size per Room in Square Feet

Hotel Chain Scale	Total s.f./ # rooms
Economy and Budget	535
Midscale w/o Food and Beverage	549
Midscale w/ Food and Beverage	656
Upscale	842
Upper Upscale	905

The EPA data were identified by state using the zip codes provided. These states were split into three rough climate categories, hot, moderate, and cold, in order to evaluate the changes in electric and gas energy usage intensities (EUI). **Table 17** shows the results by chain scale for the hotels that recorded usage of both electricity and gas. There is a general trend of increasing energy intensity in all climates as the price and service classification increases. This trend is strongest in looking at the EUIs in the economy and limited service midscale hotel categories compared to full service hotels. The highest EUIs occur in the highest scale hotels. The impacts of climate on gas heating and electric air conditioning can be seen to some extent. The relationship is stronger for gas EUI which increases in most cases as the climate becomes colder. Climate impact on electric consumption is more difficult to see; in only three of the five hotel types are there higher electric EUIs in the hot climate compared to the cold climate.

In order to control the impact that size of the hotel has on energy consumption, and to focus in on the target market for CHP applications, the same analysis was undertaken for hotels in the 300-500 room class. There are no economy or limited service hotels in this size range in the EPA database. **Figures 10 and 11** show the changes in electric and gas EUI respectively. The electric consumption shows a slight trend toward greater electric EUI in hot climates. Midscale hotels show the highest EUIs, but there are only 11 represented in this size class compared to 41 upscale and 123 upper upscale hotels. Gas consumption shows the effects of reduced space heating requirements in midscale and upper upscale hotels but not in upscale hotels.

The database does provide a strong indication of the level of energy usage in large hotels and provides a starting point for CHP sizing.

Table 17 Gas and Electric Energy Usage Intensities by Climate and Chain Scale

Hotel Type	Data	Climate			Grand Total
		Cold	Hot	Moderate	
Hotel (Economy and Budget)	# of Hotels	9	3	6	18
	Avg. Elec kWh/sf/yr	12.07	8.94	8.35	10.31
	Avg. Gas KBtu/sf	31.64	19.25	69.66	42.25
Hotel (Midscale w/o Food and Beverage)	# of Hotels	16	12	15	43
	Avg. Elec kWh/sf/yr	11.66	15.01	11.97	12.70
	Avg. Gas KBtu/sf	36.13	33.36	47.81	39.43
Hotel (Midscale w/Food and Beverage)	# of Hotels	127	55	83	265
	Avg. Elec kWh/sf/yr	18.02	15.62	15.00	16.57
	Avg. Gas KBtu/sf	70.67	24.49	48.18	54.04
Hotel (Upscale)	# of Hotels	92	145	210	447
	Avg. Elec kWh/sf/yr	16.21	16.65	13.24	14.96
	Avg. Gas KBtu/sf	52.44	35.67	38.76	40.57
Hotel (Upper Upscale)	# of Hotels	94	94	121	309
	Avg. Elec kWh/sf/yr	17.56	20.26	16.83	18.10
	Avg. Gas KBtu/sf	54.64	42.78	49.47	49.01
Total Number of Hotels		338	309	435	1082
Total Average of Elec kWh/sf/yr		16.94	17.43	14.46	16.08
Total Average of Gas KBtu/sf		58.58	35.59	44.27	46.26

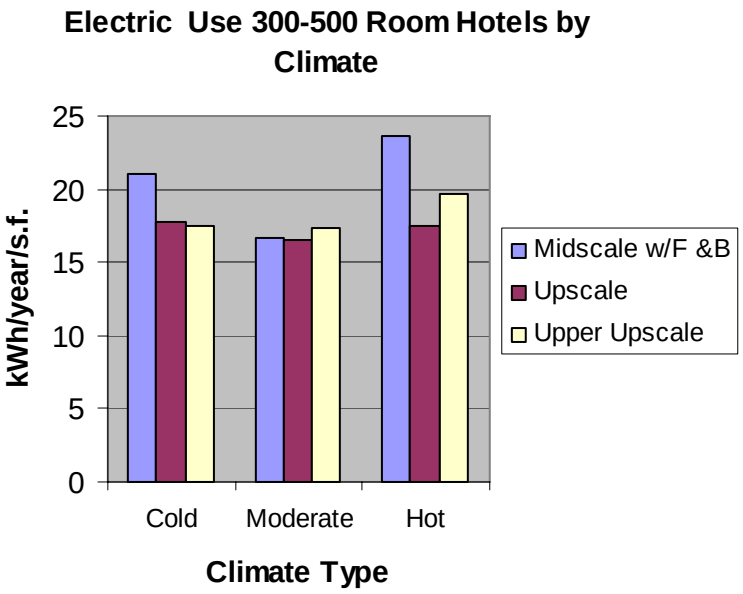


Figure 10 Electric EUI for 400-500 Room Hotels by Climate

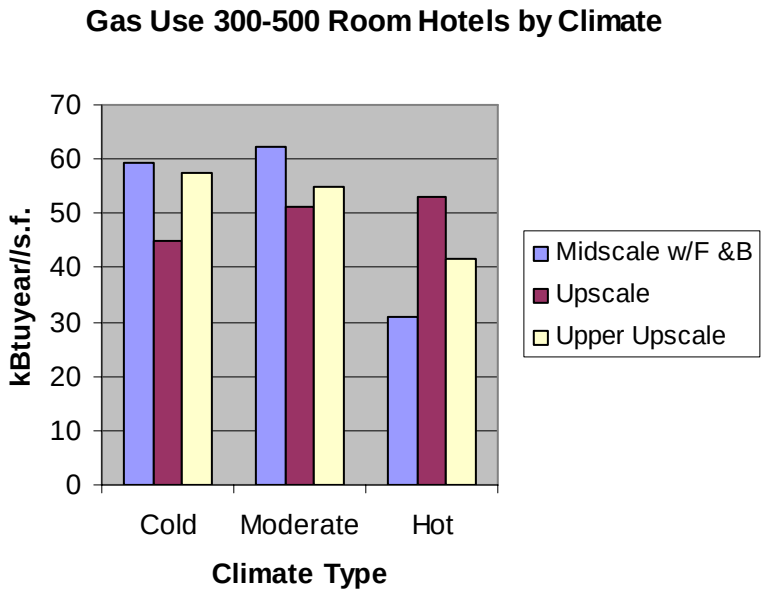


Figure 11 Gas EUI for 400-500 Room Hotels by Climate

The thermal to electric ratio for each of these hotels ranges from 0.9 to 2.6 with a class weighted average of 1.25. This means that for every kWh of electricity consumed, 2700 Btu of natural gas is consumed. Reciprocating engine and microturbines produce up to twice this amount of recoverable waste heat, so size matching for CHP will need take into account the thermal requirements at the site. Thermal requirements can be increased, however, by converting all or a portion of the air conditioning load to a thermally activated technology.

4.3 Hotel Load Analysis and Examples

Small and limited service hotels and motels do not have the load needed to support an economically sized CHP system. A 40-unit two story motel in Atlantic City, New Jersey might have a peak summer electric load of 65 kW, however, the minimum nighttime electric loads are less than 10 kW and thermal loads are limited. Economics depends not only on the characteristics of the hotel but also on the cost and performance of the CHP equipment itself. While there is a lot of development work underway on small electric generators, these systems are currently too costly for all but specific niche applications.

For this study, an economic cut-off for CHP systems was set at full service hotels with 100 rooms or more.

4.3.1 Large Full Service Hotel

A CHP system developer, PowerHouse Energy, Inc. (PHE), provided energy consumption for a full service hotel that was retrofitted with CHP.[12] PHE has installed a number of CHP systems in hotels in California. The hotel is an Embassy Suites in Brea, California located in North Orange County. The hotel has 228 guest rooms, a 400-seat restaurant, meeting rooms, a laundry, and an outdoor swimming pool and spa.

During the site evaluation, PHE did instrumented electric and load consumption monitoring for a number of days to determine the appropriate sizing and operating strategy for the CHP system. The primary focus of this monitoring was to determine the minimum nighttime electric loads and the coincident thermal loads. PHE wanted to size the system for continuous base-load operation with a high degree of thermal utilization.

Figure 12 shows a portion of the results of monitoring the hotel electric use for a period of almost two weeks during the summer of 2002. The minimum nighttime electric load was 304 kW and the maximum peak electric use occurred at 10:00pm, July 17th, (not shown) of 540 kW. The minimum electric loads during the winter months are 5-10% lower.

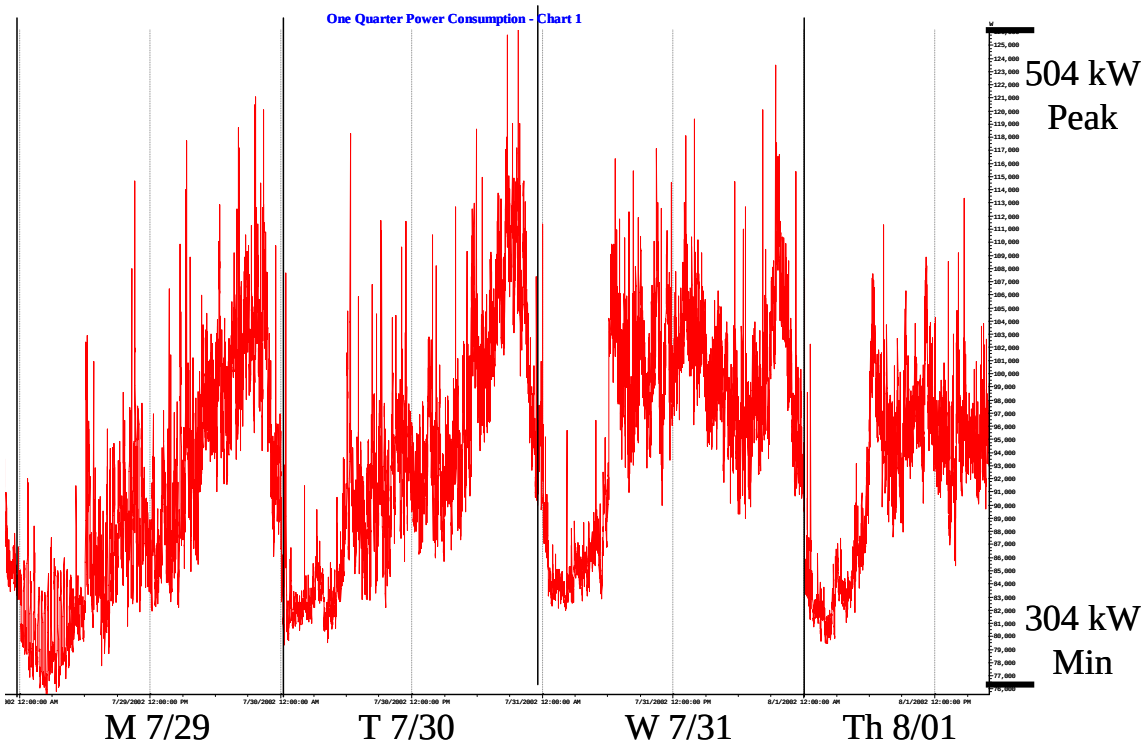


Figure 12 Electric Load Monitoring for Brea Embassy Suites prior to Installation of CHP System

The key to designing an economically viable CHP system is to design a system with high thermal utilization. PHE evaluated the thermal loads for the building. The addressable thermal loads were hot water for the guest rooms, space heating, kitchen hot water, the laundry water heater, and the pool and spa heater. Physical location of the facilities in an existing hotel is as important as the size and timing of the loads.

[12] David Moard, President, Powerhouse Energy, Inc., personal communication.

PHE monitored the thermal consumption of the domestic hot water for guest use. The existing pair of 1.2 MMBtu/hr boilers operated for 8-12 hours per day providing about 1.0 MMBtu/hr of useful heat energy to the hot water. The average energy required by the guests for hot water was 9.72 MMBtu/day (averaging 0.34mmBtu/hr).

PHE installed Capstone microturbines in parallel with the hotel's existing electrical utility connection. The microturbines are run continuously to provide approximately 115 kWh of electrical power to offset the hotel's average 300 kWh electrical demand. Approximately 750,000 Btu/hr thermal heat output of the microturbines is recovered and circulated through a Unifin heat recovery unit and supplied to the domestic hot water storage tanks to offset the guest rooms, laundry and kitchen thermal requirements. The captured thermal heat, using a 40^{o}F temperature rise in the water that is pumped at 80 gpm through the heat recovery unit of the turbines and into the domestic hot water storage tank, reduces the operational run time of the hotel's two existing 1.2 million Btu/hr water heating boilers. The boilers remained in a reserve or backup capacity to the CHP system, running only a couple hours per day in the winter months. The CHP system provides virtually all the domestic water heating needs during the summer months.

The outdoor pool heating is integrated into the CHP system by a thermal heat exchanger, tying the domestic and pool hot water heating loops. The excess thermal heat, not utilized by the day or nighttime domestic demand of the hotel, is diverted to preheat the pool hot water loop. This ensures maximum usage of thermal energy available from the system; in this case about 90% of the thermal heat generated by the microturbines is used 100% of the time.

Based on a number of applications provided by PHE and supplementary analysis, a thermal load analysis by end-use is provided in **Table 18** for a hotel that is based on the requirements of a hotel the size of the Brea Embassy Suites – 230 guest rooms and estimated to be about 195,000 square feet. **Figure 13** shows a graphic representation of loads compared to alternative CHP sizing. Water heating loads are the most important for CHP size matching. These loads are steady throughout the year but have two large peaks during the day and drop down to maintenance loads only during the middle of the night. Space heating loads can fill in the nighttime thermal use, but only in the wintertime. Kitchen loads peak with each meal. Laundries typically run a single shift starting early in the morning and stopping in early afternoon. Pool heating loads can be shifted to nighttime thereby creating higher utilization of the CHP system at night. The key for a developer such as PHE is that each hot water application that is added to the system requires another heat exchanger loop and associated piping at a cost of about $7,000 per added heat exchanger. This fact limits the attractiveness of linking up several different loads within the hotel.

Table 18 Thermal Energy Requirements for 228-Room Full Service Hotel

Thermal Load	Boiler Capacity kBtu/hr	Average Use kBtu/hr	Annual Use MMBtu	Typical Schedule
Guest Hot Water	1,200	340	2,978	Peak morning and evening
Laundry/Kitchen	750	90	788	Daytime/meal prep.
Pool	300	50	438	Can be shifted to night-time
Spa	300	90	788	Steady
Space Heating	2,000	Variable		Climate driven, highest at night
Cooking	Non-boiler	230	2,015	Meal prep.
Total Thermal		800	7,008	plus space heating
CHP Addressable		570	4,993	plus some space heating

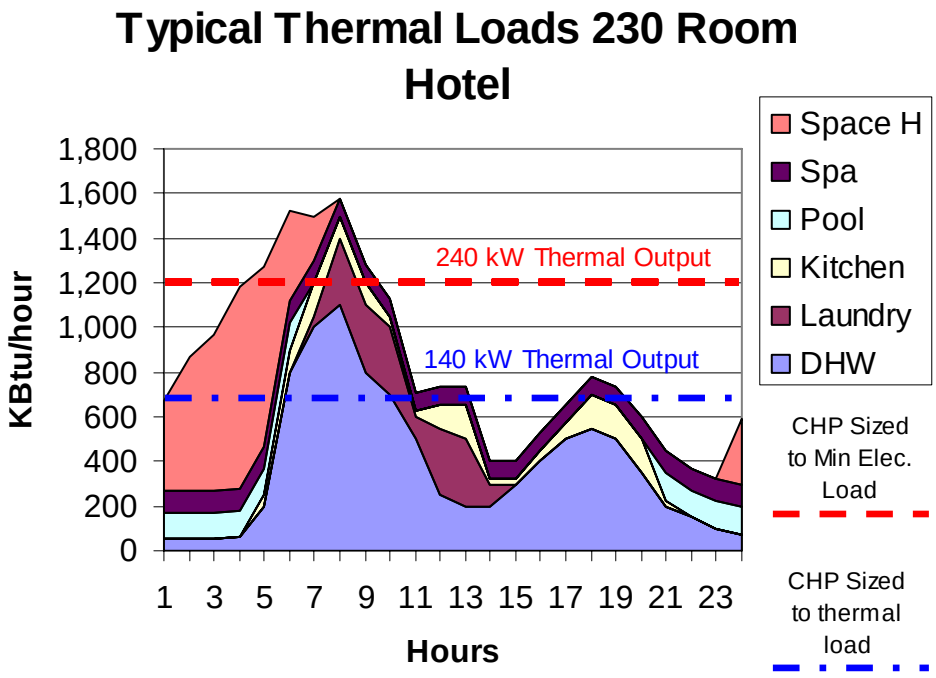


Figure 13 Thermal Load Breakdown for Typical 230 Room Hotel

Typical hotel characteristics for a 195,000 s.f., 230 room full-service hotel were developed, based in part on partial data provided for the Brea Embassy Suites. These characteristics were put into an

energy load model.[13] The modeling allowed the hotel to be "moved" around the country to determine the impact of climate on energy loads. Orange County is a comparatively mild climate. Energy consumption in Las Vegas and in Minneapolis was modeled to identify the energy consumption in hot and cold climates respectively. This comparison is shown in **Table 19.**

Table 19 Energy Consumption Breakdown by Climate for a 195,000 s.f. Full Service Hotel

Location Climate Type	Units	Anaheim Mild	Las Vegas Hot	Minneapolis Cold
Annual Electric Use	Thousand kWh	3,131	3,548	2,960
Annual Gas Use	Million Btu	7,836	8,780	19,660
Base Gas Demand	Million Btu	5,038	4,710	6,240
Electric EUII	kWh/s.f.	16.06	18.19	15.18
Gas EUI	kBtu/s.f.	40.18	45.03	100.82
Peak Demand	kW	745	840	832
Average Demand	kW	357	405	338
Minimum Demand	kW	250	260	240
Peak Load/Avg. Load	% of Avg	208%	207%	246%
Min Load/Avg. Load	% of Avg	70%	64%	71%
CHP Sizing Strategies				
100% Electric/80% Thermal Use (kW)		144	134	178
Max Size for 100% Electric Use (kW)		250	260	240

Energy consumption can be characterized as follows:

- Electric consumption ranges from 3 to 3.5 million kWh per year – hot climate cooling loads push total consumption up by 16% compared to mild and cold climate usage

- Annual gas demand in the cold climate application is more than twice that of the hot and mild climate applications.

- The CHP addressable thermal loads are the various water heating loads that are fairly constant throughout the year. These loads are fairly similar in the various climate applications varying only as a function of colder groundwater temperature in the cold climate application. In a warm climate application, 64% of the annual gas consumption represents the primary target for replacement with CHP supplied thermal energy.

- Minimum electric loads are similar for the applications across climate types of 240-260 kW. Minimum electric loads are important to CHP sizing and operating strategy because a system sized at or below this point can be run at full load continuously thereby maximizing the utilization of the equipment and minimizing operating complexity.

- Sizing a CHP system to the addressable thermal load results in a system sized below the minimum electric demand. Sizes range from 134-178 kW.

[13] The Model used was EQuest 3.5 an energy simulation model for commercial buildings. EQuest was funded under the California Public Interest Energy Research Program and is publicly available.

- A CHP system sized at the minimum electric load would be able to meet an air conditioning load that was converted to absorption cooling or some other thermally activated technology and also space heating loads.

The energy and sizing relationships shown in the table were used in the market screening approach described in **Section 5**.

4.3.2 Very Large Resort/Casino Hotel

Turning Stone Resort and Casino

An example of a very large casino resort is the Turning Stone Resort and Casino in upstate New York. This resort operated by the Oneida Indian Nation recently underwent a $310 million expansion that will ultimately double the space to nearly 2 million square feet. This expansion included a $13.1 million gas turbine combined cooling heating and power facility that provides 5.5 MW of power on a continuous basis. The turbine exhaust heat is recovered using a heat recovery steam generator (HRSG) producing steam at 125psig for service hot water, space heating, and 2,000 tons of absorption chiller capacity to provide space cooling.

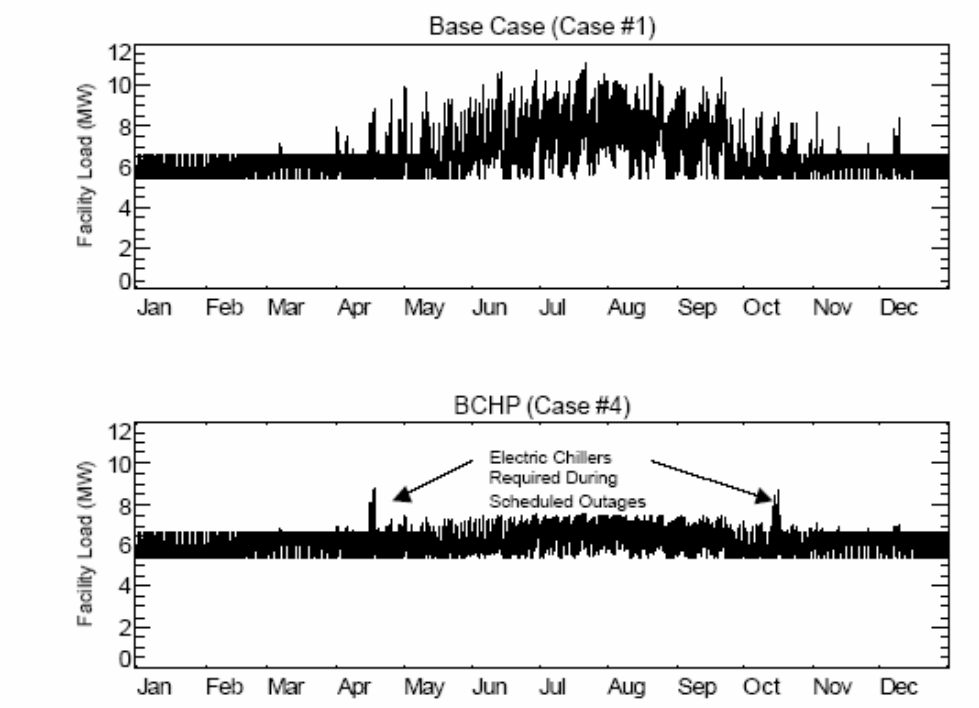
The resort consists of 4 separate lodging accommodations with over 750 rooms and suites These accommodations include the original 4-story, 271 room, 20 suite hotel, the new 19-story 287 room, 7 suite Tower, a 4-story 88 room all suite Lodge, and a no-frills 2-story 63 room inn. There is a 500,000 square foot casino with 2400 slot machines, over 100 table games, and a 1300 seat Bingo parlor. There are 11 restaurants and coffee shops, a fitness facility with 65' indoor pool, a 30,000 s.f. Event Center for entertainment and trade shows, a 2400 car parking garage, and a large Clubhouse serving the three golf courses that has additional banquet and meeting facilities. There is also an RV park and a soon to be completed spa. The resort employs 4200 people and has over 4.5 million visitors per year.

Before the current expansion, the facility used 28.7 million kWh per year at a cost of $2.4 million and 94,000 MMBtu/year of natural gas at a cost of $500,000. The peak load on the facility was 6 MW with a minimum demand of 2.5 MW. The expansion, most of which is completed, will more than double the consumption of both gas (200,000 MMBtu/year) and electricity (57.6 million kWh) with a corresponding peak demand 11.1 MW and minimum demand of over 5 MW. Peak cooling load will increase to nearly 4,000 tons.[14]

[14] *BCHP Feasibility Study for Turning Stone Casino*, CDH Energy Corporation, March 2003.

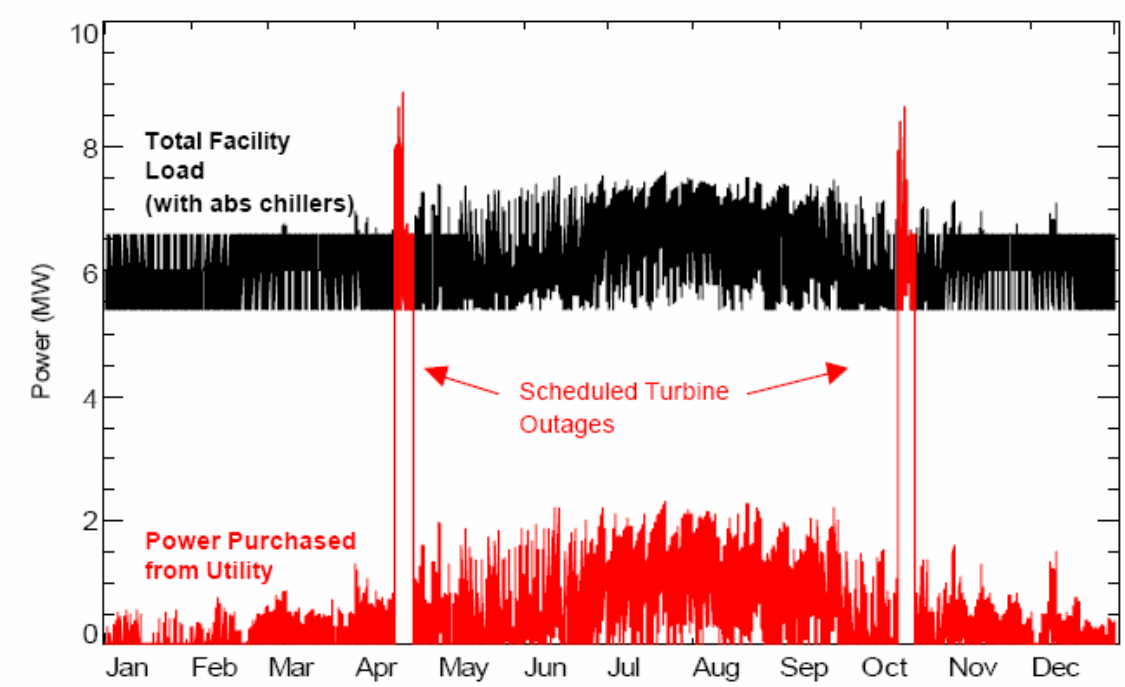
Figure 14 shows the comparison of the post expansion facility load with the load after a 5.5 MW CHP system with absorption cooling was installed. Without CHP, the facility electric loads would have been a minimum of 5.5 MW with summer peaks of over 11 MW. With the BCHP system (building cooling heating and power) the facility generates its own power year-round and peak loads are reduced by 2.9 MW due to the addition of gas cooling using double effect absorption chillers fired by the steam produced by the HRSG. The spikes in April and October represent scheduled outage periods for the gas turbine during which time the facility relies on the electric chillers to meet the cooling load. As designed at full build-out, the CHP system meets 90% of the electric energy for the facility (84% from the turbine generator and 6% from the displaced electric cooling). The CHP system as analyzed in the feasibility study was projected to meet 79% of the peak load – 52% from the generator output and 27% from the displaced electric cooling load. **Figure 15** shows the projected facility load with absorption cooling and the utility purchases with BCHP.

The CHP system is designed to assume 69% of the facility thermal loads in addition to providing the steam energy for the absorption chillers.



Source: CDH Energy Corporation

Figure 14 Load Comparison for the Facility with and without CHP



Source: CDH Corporation

Figure 15 Facility Loads and Utility Purchase Requirements for CHP System

The CHP system was completed and went into operation in 2004. Gas prices are much higher now than during the planning period resulting in recent operating losses. The Oneida Indian Nation is planning to connect some of their own gas wells to the facility, which will provide a captive source of fuel for the system. The heat recovery hasn't reached full potential yet as all of the new space has not yet been completed, so the total CHP efficiency is currently approximately 50% -- below the projected 70-75%.

The resort had to change out the casino air handlers and revise designs in an effort to control the indoor air quality of the casino. The casino is exempt from New York State's smoking ban in public buildings and there was a significant problem in both air quality and equipment performance due to the smoke that needed to be removed from the casino floor. The resort facility management questioned the understanding of A&E firms and CHP developers concerning the complexities of a casino compared with more standard hotel designs. There was also considerable discontent concerning the utility standby rate structure and the electric industry restructuring rules concerning wholesale power markets that have perpetuated high power costs in New York State.

The Borgata Casino Hotel and Spa and the Marina Thermal Facility

The Borgata Casino Hotel and Spa located in the Renaissance Pointe area of Atlantic City's Marina District, completed in 2003, is touted as the first "Las Vegas style" resort in Atlantic City. The 3 million square foot facility is served by an energy plant called the Marina Thermal Facility that provides hot water and chilled water and emergency back-up electricity for the complex.[15]

[15] Energy consumption data in this section was provided by the Marina Thermal Facility developer, DCO Energy, LLC.

The resort is an extensive and complex facility that does share the typical features of a Las Vegas strip casino hotel, such as:

- 2002 guest rooms and suites
- 7 story parking garage
- 70,000 ft² Event Center
- 125,000 ft² Casino
- 11 Restaurants
- 2 night clubs and 3 bars
- 50,000 ft² European Health Spa & Pool
- 11 Retail Boutiques
- 1.5 million ft² (140,000 m²) tower
- 1.5 million ft² (140,000 m²) low rise building.

Thermal energy and back-up power is provided by the brand new Marina Thermal Facility (MTF), a 26,000-square-foot plant, to provide the hot and chilled water needed to heat and cool The Borgata Casino Hotel. The $54 million plant is capable of providing nearly 15,000 gallons of chilled water and 2,600 gallons of heated water per minute, delivering enough hot and chilled water to meet all of The Borgata's heating, cooling and domestic hot water needs.

Electric Use

The Borgata consumes about 86 million kWh/year. **Figure 16** compares the peak summer week with a cold winter week. Loads are lowest on Mondays and Tuesdays increasing throughout the week to a peak on the weekends. Peak summer load for 2004 was 16.1 MW; peak winter loads are between 9 and 10 MW per day. Minimum electric loads of 7 MW/day occur during the winter with minimum daily summer loads above the peak winter loads of 10 MW/day.

Thermal Energy Use

The thermal energy delivered to the casino was evaluated in terms of the energy content. **Figure 17** compares the thermal delivery for January, April, August, and October. These months show winter, summer, and Spring/Fall thermal loads. The graphs show that thermal loads are high in both the summer and winter with cooling and heating loads swapping the primary roles. In the spring and fall months, thermal loads are about 60% of winter/summer values. **Figure 18** shows the loads on an annual basis. These loads reflect thermal energy delivered to the facility. The estimated gas consumption to deliver this energy, assuming 80% efficient boilers, is 498 billion Btu/year.

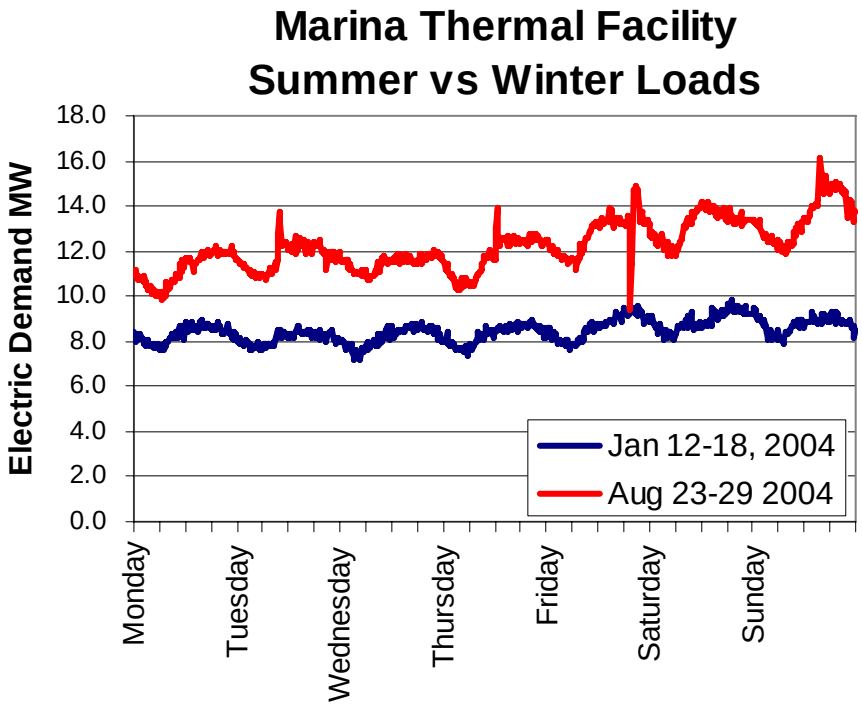


Figure 16 Summer and Winter Electric Consumption – Marina Thermal Facility

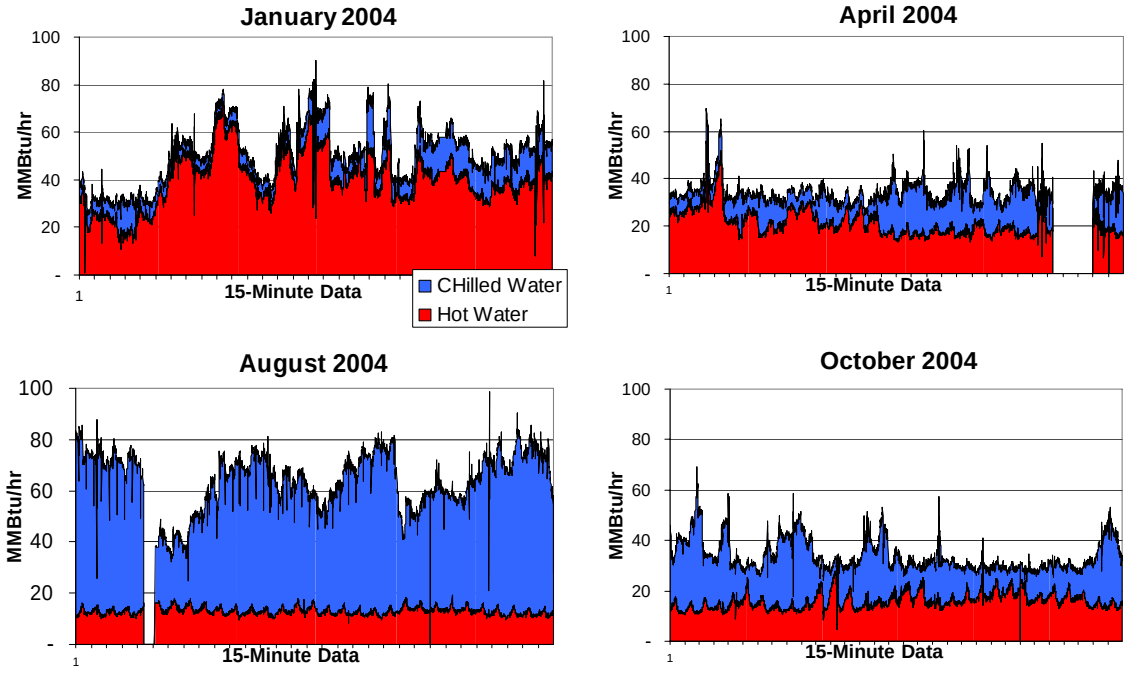


Figure 17 Seasonal Thermal Loads – Marina Thermal Facility

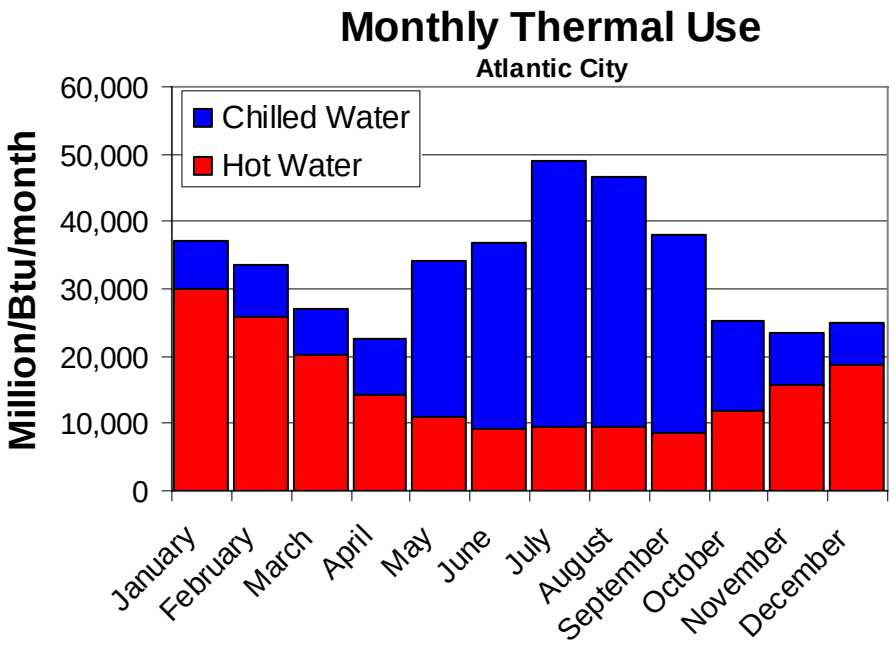


Figure 18 Annual Thermal Loads by Month – Marina Thermal Facility

Effect of Climate and Cooling Equipment Changes on Energy Use

The use of absorption chillers is a feature of the Borgata that is not as common as the use of electric chillers. In an electrically cooled facility, the thermal energy use would be represented by the hot water delivery components of the previous two figures. In this type of facility, gas consumption would be reduced by more than half to 229 billion Btu/year.

Electric use would be correspondingly increased as shown in **Figure 19**. Peak load would be increased by about 4.5 MW and annual consumption increased by 13 million kWh. Peak cooling load is actually 5.4 MW but this cooling peak doesn't correspond to the peak facility load which occurred at 3:15pm August 29th. Peak loads for cooling in the hot desert climate of Las Vegas are not increased compared to corresponding peak loads in Atlantic City due to the greater contribution of the cooling tower to overall cooling loads.

Most hotels with characteristics similar to the Borgata are in Las Vegas. Therefore, heating and cooling loads were re-estimated for the facility based on remodeling the temperature sensitive loads. In Las Vegas, heating loads are much lower and cooling loads are much higher. **Figure 20** shows the monthly thermal loads estimated for the facility in the Las Vegas climate. On an annual basis, hot water loads (including space heating) are 70% of what they are in Atlantic City, chilled water loads are 140% of what they are in Atlantic City.

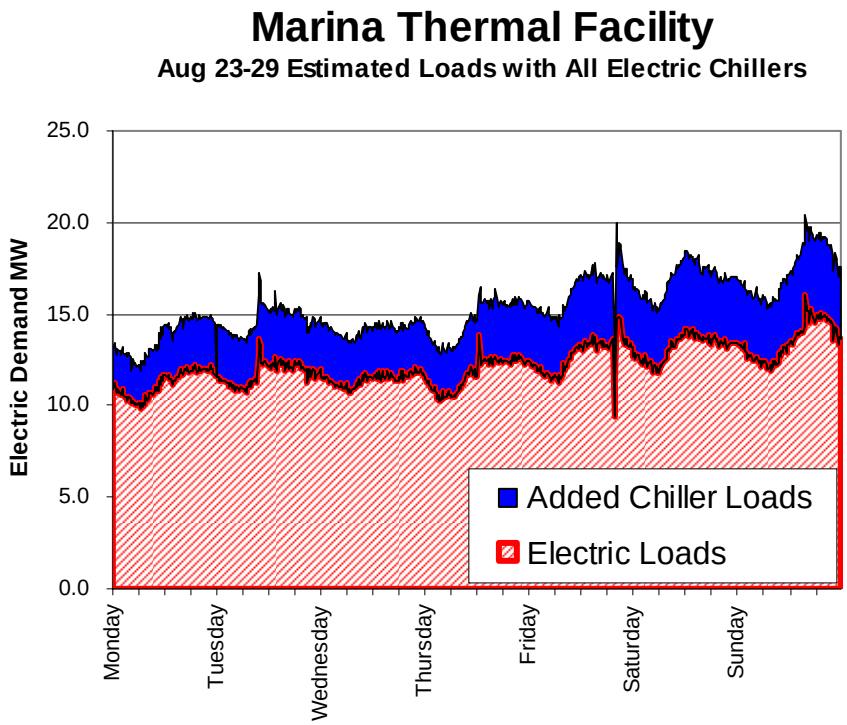


Figure 19 Effect of Converting Absorption Chiller Loads to Electricity

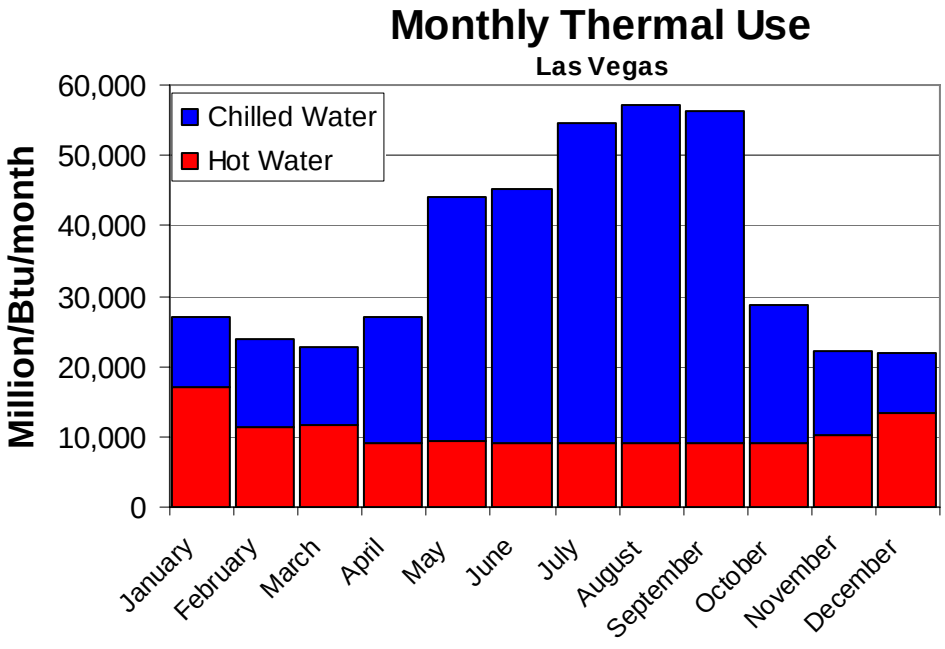


Figure 20 Monthly Total Thermal Loads – Las Vegas Climate

Table 20 summarizes energy consumption measures for the Borgata and for 3 alternative configurations of climate and cooling energy source.

Table 20 Load Analysis for Mega-Hotel in Alternative Locations and Configurations

Energy Measure	Units	Actual	Estimate 1	Estimate 2	Estimate 3
Climate		Atlantic City	Atlantic City	Las Vegas	Las Vegas
Cooling		Absorption	Electric	Absorption	Electric
Annual Electric Consumption	Million kWh/year	86.1	99.4	86.1	104.9
Annual Gas Consumption	MMBtu/year	498,441	229,364	538,220	159,748
Electric Load Factor	Percent	61%	53%	61%	56%
Electric EUI	kWh/year/s.f.	28.7	33.1	28.7	35.0
Gas EUI	KBtu/year/s.f.	166.1	76.5	179.4	53.2
Peak Load	MW	16.1	21.3	16.1	21.3
Average Load	MW	9.8	11.3	9.8	12.0
Minimum Load	MW	7.0	7.4	7.0	7.4
Base Thermal Load	MMBtu/hour	30	12	29	12
Base Thermal Share of Total	Percent	53%	46%	47%	66%

For these large facilities, the inclusion of thermally activated cooling systems allows a significant economic expansion of the CHP system. These size relationships are used in the next section for the market screening analysis.

5. CHP TECHNICAL AND ECONOMIC MARKET POTENTIAL

This section describes the results of an analysis of the technical and economic market potential for CHP in hotels and casinos. **Figure 21** shows the basic approach that consists of the following steps:

- Evaluation of the number of hotels by size and by state based on the breakdown shown in *Section 2* – Table 8.
- Removal of the existing CHP, described in *Section 3*, from the database of remaining hotels.
- Characterization of the appropriate CHP sizing for hotels by size class based on the load analysis presented in *Section 4*.
- Calculation of the technical market potential in megawatts which is the sum-product of the CHP sizing times the number of hotels by size and state after the hotels that already have CHP are subtracted.
- Characterization of average gas and electric prices by state using EIA data.
- Characterization of the cost and performance of typical CHP systems in the size classes selected for each of the hotel size categories based on prior EEA analyses.

- Calculation of paybacks for each size and state category based on the CHP system performance and the average energy prices.

- Calculation of the economic market potential as all CHP capacity that shows an economic payback of less than 10 years.

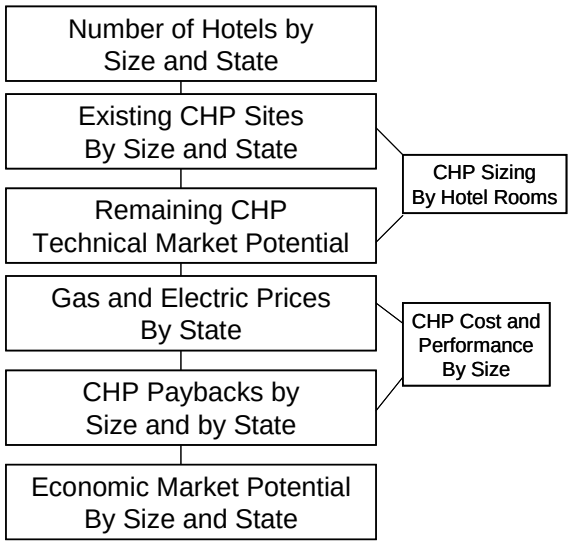


Figure 21 Hotel Market CHP Screening Approach

Table 21 summarizes the results of this market screening approach. There are 9,464 hotels in the target market of hotels with more than 100 rooms. The hotels are separated into five size categories. Nearly two thirds of the hotels fall into the 100-199 room size, and 94% of the hotels are less than 500 rooms. There are 148 mega-hotels in the U.S. with more than 1,000 rooms. There are 98 hotels with existing CHP but 19 of these are in hotels with fewer than 100 rooms; therefore only 79 hotels with CHP are subtracted from the target market[16].

Appropriate CHP sizing for each category is shown in the Table. For the 100-199 room size, it was assumed that CHP would be sized to the addressable thermal load which is less than the minimum electric load. This value was based on the estimated sizing described in *Section 4.3.1* for a 230 room full service hotel. This value was reduced proportionally to an assumed average size of 150 rooms. For the 200-499 room category it was assumed that sizing would be at the minimum electric load and include absorption chillers for air conditioning. The CHP system for the 500-999 room size category was set at 1 MW based on evaluation of existing CHP systems. CHP for the 1000-1999 room size category was sized based on the Turning Stone Casino system. The sizing for the 2000+ rooms category was based on a sizing that was 40% larger than the energy requirements of the Borgata/Marina Thermal Facility.

The total remaining technical market potential for CHP in this target market is 2,773 MW. After screening each state and size category for paybacks, the economic market potential is 1,456 MW based on current energy pricing and near-term technology cost and performance. Only 23% of the market below 200 rooms is economic. However, as the hotel and CHP system sizes get larger, the share of the technical market that is economic increases. In addition, the largest hotels are more and more concentrated in the states that have favorable economics so that 90% of the 1000-1999 room hotels are economic and 97% of the 2000+ room hotels are economic.

[16] The nineteen existing CHP systems installed in hotels with 100 rooms or less were also installed prior to 1990. This size of hotel is not normally considered a candidate for CHP in today's environment.

Table 21 Summary of Hotel CHP Market Screening Results

Screening Approach	Number of Rooms					Total
	100-199	200-499	500-999	1000-1999	2000+	
Hotels in U.S.	6,323	2,614	379	116	32	9,464
Hotels with CHP	33	30	9	5	2	79
Remaining Market (sites)	6,290	2,584	370	111	30	9,385
Appropriate CHP Size (kW)	90	380	1,000	5,000	10,000	
Technical Market Potential (MW)	566	982	370	555	300	2,773
Economic Market Potential (MW)	130	371	170	495	290	1,456
% of Market Economic	22.9%	37.8%	45.9%	89.2%	96.7%	52.5%

Additional detail is presented in the following sections and detailed state-by-state results are presented in **Appendix A.**

Energy Prices

To compute economics for a CHP system, it is necessary to understand the applicable electric and gas rates that hotels must pay for their energy. In analyzing CHP competitiveness for a real project, it is important to understand the specific tariffs that are used and other factors such as standby charges. For this simple screening, the purpose is simply to indicate areas of the country that appear to have favorable conditions based on a comparison of average prices. Average retail price information was taken from the Energy Information Administration (EIA).

In this report, natural gas prices reported by the Energy Information Administration (EIA) were used as the basis. EIA reports average prices of natural gas at several points in the supply chain, including:

- Electric Utility Power Generation Station (lower than industrial customer rate)
- Industrial Customer

For commercial and industrial customers, the EIA industrial price point was used as an estimate of the cost of natural gas prior to the installation of the CHP system. Gas utilities frequently offer lower rate tariffs to customers that install CHP systems. To estimate the price of natural gas after the CHP system is installed, the EIA industrial and utility generation prices were averaged. The rationale for this approach is that commercial and industrial CHP customers are likely to pay a reduced gas rate after the CHP system is installed, but the rate will not be as low as the rate paid by electric utilities that consume large volumes of natural gas for central or peaking power stations. For some states, EIA did not report either the utility or the industrial price. In these cases, the estimated cost for natural gas for the CHP system was computed by either adding $1.00 to the utility price or subtracting $1.00 from the industrial price. This approximation was based on reviewing the EIA data, with a focus on California and New York, and concluding that the average difference between utility and industrial rates is near $2.00. The gas rates used in this assessment are shown in **Appendix A**.

Figure 22 shows average industrial electric rates by state. While hotels are not industrial facilities, the size and scope of operations more closely matches the EIA industrial price than the EIA commercial price, which is affected by a large number of very small commercial customers. The figure is ordered from left to right in terms of the rates that produced the lowest paybacks. For example, Louisiana

has lower electric rates than New York, but is ranked ahead of New York because of its lower gas rates. The figure shows that there are 13 states in which all hotel size categories pass the economic screen. In these states, all market sizes are economic. There are an additional 14 states in which only hotels larger than 1000 rooms are economic. Only 7 of these 14 states actually have such large hotels.

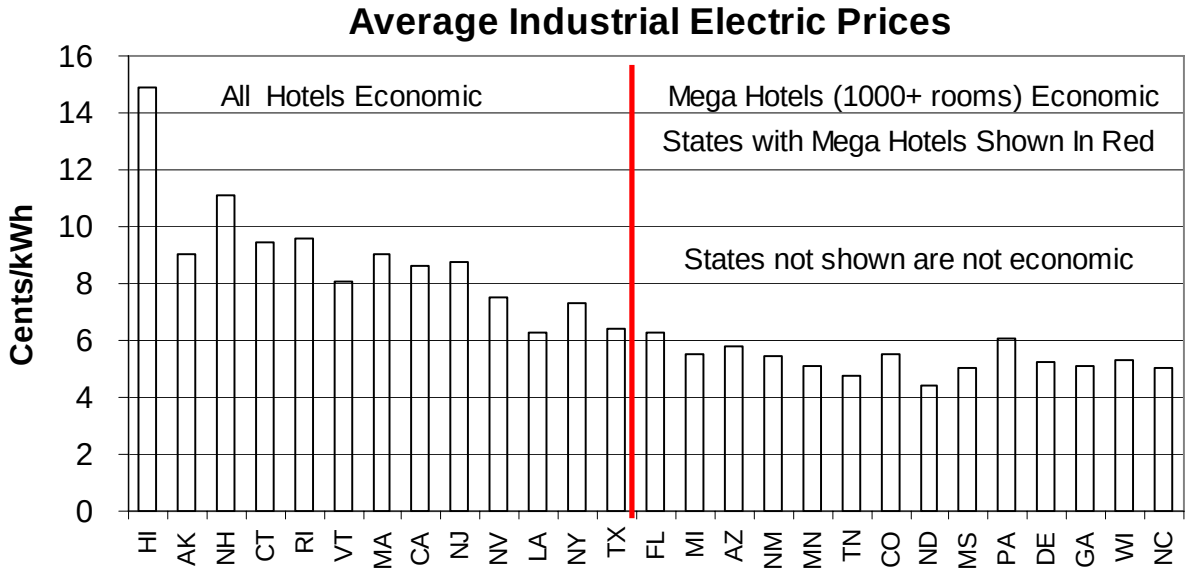


Figure 22 Average Large Customer Electric Prices in Order of Highest to Lowest CHP Competitiveness

CHP System Cost and Performance

For the sizing selected for each category, a typical CHP system was selected based on near-term technology characteristics. These systems are shown in **Table 22**. The table shows installed cost, the cost of adding absorption cooling, heat rate, recoverable waste heat, and non-fuel O&M costs. For small systems, reciprocating engines, microturbines, and fuel cells can be used. Gas engines were selected for the comparison because, based on existing technology, they provide the best economics. Larger systems of 5 to 10 megawatts can utilize gas turbines or multiple engines. Reciprocating engines are more efficient, but gas turbines provide high quality thermal energy (steam) that can be used to drive efficient double-effect absorption chillers. Only a portion of reciprocating engine heat can be used to produce steam.

Table 22 CHP Technology Cost and Performance

	Number of Rooms				
	100-199	200-499	500-999	1000-1999	2000+
Typical CHP System Type	Recip. Engine	Recip. Engine	Recip. Engine	Recip. Engine	Gas Turbine
Approximate CHP Capacity, kW	100	300	1000	5000	10000
Basic Capital Costs ($/kW)	$1,350	$1,150	$1,100	$900	$950
Absorption Chiller Cost Adder ($/kW)	Not Used	$294	$203	$105	$67
Early Market/Site Specific Multiplier	128%	108%	108%	105%	105%
Installed Costs, $/kW	$1,728	$1,559	$1,407	$1,055	$1,068
Heat Rate, Btu/kWh	11,500	11,500	10,350	9,213	11,765
Electric Efficiency, %	29.7%	29.7%	33.0%	37.0%	29.0%
Thermal Output, Btu/kWh	5300	5300	3709	3345	4674
O&M Costs, $/kWh	$0.018	$0.013	$0.012	$0.008	$0.006

Market Screening

Table 23 shows the economic potential by size and state. The states are ordered from lowest payback at the top to highest payback at the bottom. The smaller sized systems are economic in fewer states because the installed costs are higher and the electrical efficiencies are somewhat lower. The highest economic potential states are shown in green. These state/size combinations have screening paybacks of less than 5.5 years which corresponds to a return on investment of 10% or greater. The total high return potential is 908 MW. The state/size combinations shown in yellow have paybacks greater than 5.5 years and less than 10 years. Facilities in this range were also included in the economic potential for a number of reasons. Some facilities may accept a longer payback; certain site specific factors might improve the payback for an individual facility; and there might be other factors such as incentive payments. For example, California 100-199 room hotels are shown in yellow, screening payback of 5.6 years, though this has been and continues to be a very active state for CHP development due to incentive payments on CHP that reduce the initial investment.

Table 24 shows the top 10 states in terms of total MW economic market potential. Nevada has the highest potential due to the extremely high concentration of mega-hotel/casinos in Las Vegas. California is second followed by Florida, Texas, and New York. Of the 11 states in the top 10 (Mississippi and Georgia are tied at number 10) four of them have commercial casinos and seven have tribal casinos. Only three of the states have no casinos – Hawaii, Georgia, and Massachusetts.

Table 23 Hotel Market CHP Economic Screening Results

States Econ. Potential Highest to Lowest	MW of Economic CHP Potential					Total (MW)
	100-199	200-499	500-999	1000-1999	2000 +	
Hawaii	1	16	19	25	10	71
Alaska	2	4	2			8
New Hampshire	3	5				8
Connecticut	8	8	1	5		21
Rhode Island	2	5				6
Vermont	3	2		5		10
Massachusetts	12	27	5	5		49
California	50	121	49	55		276
New Jersey	13	22	9	25	10	80
Nevada	5	23	29	100	230	387
Louisiana	11	21	9	20		61
New York	20	38	27	40		125
Texas		79	20	30		129
Florida				110	40	150
Michigan				5		5
Arizona						
New Mexico						
Minnesota						
Tennessee						
Colorado		Not Economic		10		10
North Dakota						
Mississippi				25		25
Pennsylvania				5		5
Delaware						
Georgia				25		25
Wisconsin						
North Carolina				5		5
All other states						
U.S. Total	130	371	170	495	290	1,456
High Return Total	30	233	85	310	250	908

Table 24 Top State CHP Targets for the Hotel Industry in Terms of MW of Economic Potential

Top 10 States (and ties)	MW
Nevada	387
California	276
Florida	150
Texas	129
New York	125
New Jersey	80
Hawaii	71
Louisiana	61
Massachusetts	49
Mississippi	25
Georgia	25
All other states	78

6. CONCLUSIONS

This analysis has shown that there is significant market potential for CHP in the hotel and casino market. This market potential is concentrated in the larger, full-service facilities. While there are nearly 48,000 hotels in the U.S., less than 10,000 of them have the usage and energy characteristics suitable for CHP using current technology. The economic cut-off for this analysis was set at 100-rooms or greater, though it is possible that CHP can be effectively placed in hotels below this size threshold. Of the 98 existing CHP systems in hotels, 20% of them are in hotels with fewer than 100 rooms.

The large mega-resort hotels of 1,000 rooms or greater represent a distinct and very important market segment. These huge facilities have more in common from an energy standpoint with a small university than with a small business hotel or roadside motel. These facilities are typically, though not exclusively, associated with casino gaming. There are multiple restaurants, nightclubs and other entertainment venues, spas, casinos, health clubs, movie theaters, shops, and often large attractions – zoos, aquaria, fountains, even an "active" volcano. The facilities occupy millions of square feet of building space and the energy usage intensity per square foot is much higher than for the typical business hotel.

There are 148 hotels in the U.S. with more than 1,000 rooms. The economic market potential for CHP in these mega-sites represents 54% of the total economic potential for CHP in the hotel industry. There are 32 hotels with more than 2,000 rooms and 75% of them are on the Las Vegas strip. These facilities could support CHP systems with an average size of 10 MW each representing 20% of the economic potential.

One of the big drivers for CHP in these large facilities is to provide the thousands of tons of air conditioning needed using the waste heat from the on-site electric generation. Industrial gas turbine generators can produce power for the facility baseload needs and the high temperature exhaust can be converted to steam in heat recovery steam generators that can be used to drive a central heating and cooling plant.

The remaining identified market is in hotels with 100 to 999 rooms. These facilities are less energy intensive than the large casino and resort hotels, but they still have round-the-clock electric and thermal loads that can effectively support CHP. As the hotel sizes get smaller, the cost of absorption chillers goes up, and their effectiveness goes down. It is not considered cost-effective with current technology to try to include absorption cooling in a hotel system until the generator size reaches about 300 kW. This size can support about a 100-ton absorption system. Hotels need to have more than 200 rooms before such a system would be warranted.

In smaller hotel sizes, without adding cooling, it is very important to size the system to the available thermal load. As shown in Section 4, a system with 70-80% seasonal utilization of the available thermal load is going to be utilizing only about 60% the capacity of a system that is sized to the minimum facility electric load. The problem is that there are fairly wide swings in thermal energy consumption during the day, with nighttime values dropping considerably. The key thermal load is the hot water for the guest rooms, though it may be possible to augment these loads with hot water needs for the kitchen, laundry, pools, and even space heating seasonally.

While there is an economic opportunity to expand the use of CHP in the hotel industry, the current market penetration is just under 1% of available sites. When only sites within the economic states

and sizes are considered, the market penetration increases to 2% for the 100-199 room hotel category up to 7% for the largest size category of more than 2,000 rooms. Hotel management is focused on hotel business and investment is geared to adding to guest amenities. However, hotels are comfortable with contracted facilities management and arrangements with energy service companies. General awareness of CHP advantages needs to be increased in the hotel industry, and detailed options and approaches need to be circulated among engineering firms, potential developers, and energy service companies that serve the industry.

APPENDIX A: TECHNICAL AND ECONOMIC MARKET SCREENING TABLES

Table A1 Target Market for CHP in the Hotel Industry

State	Number of Rooms					Total
	100-199	200-499	500-999	1000-1999	2000+	
Alabama	110	24	1			135
Alaska	22	11	2			35
Arizona	198	57	12			267
Arkansas	46	18				64
California	581	337	51	12		981
Colorado	155	66	9	2		232
Connecticut	87	21	1	2		111
DC	32	35	8	2		77
Delaware	18	6				24
Florida	606	285	57	22	4	974
Georgia	229	79	7	5		320
Hawaii	9	43	21	5	1	79
Idaho	31	5	1			37
Illinois	220	115	16	5	1	357
Indiana	102	33	5			140
Iowa	64	17				81
Kansas	58	14				72
Kentucky	69	29	2	1		101
Louisiana	122	54	9	4		189
Maine	40	8				48
Maryland	135	47	4	1		187
Massachusetts	139	73	5	2		219
Michigan	187	56	5	1		249
Minnesota	103	53	6			162
Mississippi	51	17	7	5		80
Missouri	139	60	11			210
Montana	26	7	1			34
Nebraska	33	10				43
Nevada	53	61	29	20	24	187
New Hampshire	36	13				49
New Jersey	153	63	9	5	1	231
New Mexico	68	18				86
New York	225	101	29	10		365
North Carolina	232	40	4	1		277
North Dakota	18	4				22
Ohio	198	77	4			279
Oklahoma	41	21	1			63
Oregon	91	26	2			119
Pennsylvania	230	76	8	1		315
Rhode Island	17	12				29
South Carolina	113	41	12	1		167
South Dakota	19	7				26
Tennessee	170	57	2		1	230
Texas	411	209	20	6		646
Utah	71	17	4	1		93
Vermont	28	6		1		35
Virginia	241	95	6			342
Washington	131	39	4			174
West Virginia	43	7	1	1		52
Wisconsin	100	35	3			138
Wyoming	22	9				31
U.S. Total	6,323	2,614	379	116	32	9,464

Table A2 Existing CHP by State and Hotel Size (as of September 2005)

State	Number of Rooms						Grand Total
	<100	100-199	200-499	500-999	1000-1999	2000+	
Alabama							
Alaska		1	1				2
Arizona				1			1
Arkansas							
California	16	20	18	2	1		57
Colorado							
Connecticut			1		1		2
DC							
Delaware							
Florida			1				1
Georgia							
Hawaii		1		2			3
Idaho							
Illinois							
Indiana	1						1
Iowa							
Kansas							
Kentucky							
Louisiana							
Maine							
Maryland							
Massachusetts	1	1	2		1		5
Michigan		1					1
Minnesota							
Mississippi							
Missouri	1						1
Montana							
Nebraska			1				1
Nevada						1	1
New Hampshire							
New Jersey		4	4				8
New Mexico		1					1
New York		2		2	2		6
North Carolina							
North Dakota			1				1
Ohio		1					1
Oklahoma							
Oregon							
Pennsylvania							
Rhode Island							
South Carolina							
South Dakota							
Tennessee						1	1
Texas		1	1				2
Utah				1			1
Vermont							
Virginia							
Washington							
West Virginia				1			1
Wisconsin							
Wyoming							
U.S. Total	19	33	30	9	5	2	98

Table A3 Remaining Hotel Technical Market Potential (Sites))

State	Hotels by Number of Rooms					Total
	100-199	200-499	500-999	1000-1999	2000+	
Alabama	110	24	1			135
Alaska	21	10	2			33
Arizona	198	57	11			266
Arkansas	46	18				64
California	561	319	49	11		940
Colorado	155	66	9	2		232
Connecticut	87	20	1	1		109
DC	32	35	8	2		77
Delaware	18	6				24
Florida	606	284	57	22	4	973
Georgia	229	79	7	5		320
Hawaii	8	43	19	5	1	76
Idaho	31	5	1			37
Illinois	220	115	16	5	1	357
Indiana	102	33	5			140
Iowa	64	17				81
Kansas	58	14				72
Kentucky	69	29	2	1		101
Louisiana	122	54	9	4		189
Maine	40	8				48
Maryland	135	47	4	1		187
Massachusetts	138	71	5	1		215
Michigan	186	56	5	1		248
Minnesota	103	53	6			162
Mississippi	51	17	7	5		80
Missouri	139	60	11			210
Montana	26	7	1			34
Nebraska	33	9				42
Nevada	53	61	29	20	23	186
New Hampshire	36	13				49
New Jersey	149	59	9	5	1	223
New Mexico	67	18				85
New York	223	101	27	8		359
North Carolina	232	40	4	1		277
North Dakota	18	3				21
Ohio	197	77	4			278
Oklahoma	41	21	1			63
Oregon	91	26	2			119
Pennsylvania	230	76	8	1		315
Rhode Island	17	12				29
South Carolina	113	41	12	1		167
South Dakota	19	7				26
Tennessee	170	57	2			229
Texas	410	208	20	6		644
Utah	71	17	3	1		92
Vermont	28	6		1		35
Virginia	241	95	6			342
Washington	131	39	4			174
West Virginia	43	7		1		51
Wisconsin	100	35	3			138
Wyoming	22	9				31
U.S. Total	6290	2584	370	111	30	9385

Table A4 Remaining Hotel Technical Market Potential (MW))

State	MW CHP Technical Potential by Number of Rooms					Total MW
	100-199	200-499	500-999	1000-1999	2000+	
Alabama	10	9	1			20
Alaska	2	4	2			8
Arizona	18	22	11			50
Arkansas	4	7				11
California	50	121	49	55		276
Colorado	14	25	9	10		58
Connecticut	8	8	1	5		21
DC	3	13	8	10		34
Delaware	2	2				4
Florida	55	108	57	110	40	369
Georgia	21	30	7	25		83
Hawaii	1	16	19	25	10	71
Idaho	3	2	1			6
Illinois	20	44	16	25	10	115
Indiana	9	13	5			27
Iowa	6	6				12
Kansas	5	5				11
Kentucky	6	11	2	5		24
Louisiana	11	21	9	20		61
Maine	4	3				7
Maryland	12	18	4	5		39
Massachusetts	12	27	5	5		49
Michigan	17	21	5	5		48
Minnesota	9	20	6			35
Mississippi	5	6	7	25		43
Missouri	13	23	11			46
Montana	2	3	1			6
Nebraska	3	3				6
Nevada	5	23	29	100	230	387
New Hampshire	3	5				8
New Jersey	13	22	9	25	10	80
New Mexico	6	7				13
New York	20	38	27	40		125
North Carolina	21	15	4	5		45
North Dakota	2	1				3
Ohio	18	29	4			51
Oklahoma	4	8	1			13
Oregon	8	10	2			20
Pennsylvania	21	29	8	5		63
Rhode Island	2	5				6
South Carolina	10	16	12	5		43
South Dakota	2	3				4
Tennessee	15	22	2			39
Texas	37	79	20	30		166
Utah	6	6	3	5		21
Vermont	3	2		5		10
Virginia	22	36	6			64
Washington	12	15	4			31
West Virginia	4	3		5		12
Wisconsin	9	13	3			25
Wyoming	2	3				5
U.S. Total	566	982	370	555	300	2,773

Table A5 Average Energy Prices by State

State	Average Industrial Electric Price ¢/kWh	Average Industrial Gas Price $/MMBtu	Average CHP Gas Price $/MMBtu
Alabama	4.42	$7.15	$6.15
Alaska	9.03	$2.09	$2.41
Arizona	5.79	$7.14	$6.41
Arkansas	4.54	$7.69	$6.69
California	8.60	$7.74	$6.78
Colorado	5.54	$6.36	$5.92
Connecticut	9.47	$8.31	$7.31
DC	3.68	$7.70	$6.70
Delaware	5.25	$7.60	$6.60
Florida	6.29	$8.49	$7.37
Georgia	5.10	$7.42	$6.42
Hawaii	14.89	$12.87	$11.87
Idaho	3.95	$6.80	$5.80
Illinois	4.79	$7.96	$7.21
Indiana	4.38	$7.73	$6.73
Iowa	4.66	$7.16	$6.98
Kansas	4.87	$6.40	$5.95
Kentucky	3.67	$7.24	$6.24
Louisiana	6.28	$6.39	$5.39
Maine	3.46	$10.16	$8.32
Maryland	4.85	$10.07	$9.07
Massachusetts	9.06	$11.41	$8.91
Michigan	5.55	$6.85	$5.85
Minnesota	5.10	$6.47	$5.47
Mississippi	5.04	$6.97	$5.97
Missouri	4.79	$8.67	$7.67
Montana	4.41	$7.94	$6.94
Nebraska	4.33	$6.44	$6.57
Nevada	7.53	$7.20	$6.53
New Hampshire	11.08	$10.60	$9.60
New Jersey	8.79	$8.44	$7.44
New Mexico	5.46	$7.08	$6.08
New York	7.28	$8.45	$7.46
North Carolina	5.06	$7.46	$6.46
North Dakota	4.41	$5.55	$4.55
Ohio	4.91	$9.17	$8.17
Oklahoma	4.92	$8.78	$7.78
Oregon	4.07	$6.13	$5.13
Pennsylvania	6.06	$9.02	$8.02
Rhode Island	9.60	$9.38	$8.14
South Carolina	4.45	$7.53	$6.53
South Dakota	4.94	$6.08	$6.03
Tennessee	4.77	$5.83	$4.83
Texas	6.44	$5.75	$5.76
Utah	4.26	$7.20	$6.53
Vermont	8.04	$5.88	$4.88
Virginia	4.47	$7.70	$6.70
Washington	3.78	$7.16	$6.16
West Virginia	3.87	$7.24	$6.24
Wisconsin	5.30	$7.82	$6.82
Wyoming	3.93	$6.34	$4.90
U.S. Average	5.47	$6.24	$6.09

Table A6 CHP Investment Paybacks by Size and State, Sorted Best to Worst

State	CHP Paybacks by Number of Rooms and State				
	100-199	200-499	500-999	1000-1999	2000+
Hawaii	3.10	2.63	2.29	1.49	1.64
Alaska	4.22	3.51	2.68	1.84	1.88
New Hampshire	4.69	3.86	3.48	2.16	2.39
Connecticut	5.17	4.22	3.71	2.34	2.50
Rhode Island	5.30	4.32	3.91	2.43	2.62
Vermont	5.45	4.43	3.75	2.44	2.50
Massachusetts	5.40	4.39	4.31	2.63	2.77
California	5.97	4.81	4.26	2.65	2.82
New Jersey	6.13	4.92	4.45	2.72	2.94
Nevada	8.25	6.38	5.81	3.41	3.72
Louisiana	9.80	7.38	6.86	3.98	4.18
New York	9.88	7.43	7.44	4.04	4.52
Texas	13.52	9.58	8.71	4.64	5.30
Florida	15.05	10.40	12.10	5.64	6.48
Michigan	15.82	10.81	11.52	5.71	6.21
Arizona	18.26	12.02	13.34	6.12	7.04
New Mexico	18.14	11.97	13.52	6.28	6.96
Minnesota	19.00	12.37	13.63	6.44	6.95
Tennessee	19.31	12.52	13.29	6.48	6.78
Colorado	21.44	13.49	14.51	6.51	7.57
North Dakota	23.39	14.31	15.75	7.29	7.55
Mississippi	24.87	14.92	18.97	7.67	8.63
Pennsylvania	24.31	14.69	22.75	7.71	9.90
Delaware	27.62	15.97	22.85	8.21	9.70
Georgia	29.60	16.69	24.31	8.52	10.01
Wisconsin	29.41	16.62	25.33	8.53	10.30
North Carolina	31.86	17.46	26.70	8.88	10.53
Wyoming	35.37	18.59	28.19	10.00	10.09
Kansas	52.87	23.02	35.35	10.03	12.73
South Dakota	107.97	30.55	53.90	11.29	16.18
Oregon	57.41	23.94	42.27	11.48	12.66
Alabama	86.27	28.31	98.66	13.42	16.80
Arkansas	176.13	34.76	negative	16.04	22.88
South Carolina	188.66	35.28	negative	16.17	22.56
Virginia	377.87	39.36	negative	17.71	26.46
Illinois	negative	46.85	negative	18.72	35.59
Idaho	negative	45.71	negative	19.46	25.60
Oklahoma	negative	45.56	negative	20.39	43.52
Indiana	negative	48.26	negative	20.75	33.98
Missouri	negative	53.57	negative	23.02	54.83
Montana	negative	56.85	negative	23.56	44.78
Utah	negative	101.25	negative	27.94	70.02
Iowa	negative	284.38	negative	29.85	384.95
Ohio	negative	77.12	negative	30.48	236.85
West Virginia	negative	118.12	negative	36.64	82.26
Washington	negative	157.70	negative	42.24	108.84
Nebraska	negative	negative	negative	74.44	negative
Kentucky	negative	negative	negative	86.80	negative
DC	negative	negative	negative	negative	negative
Maine	negative	negative	negative	negative	negative
Maryland	negative	negative	negative	negative	negative

Table A7 Hotel Market CHP Economic Screening Results

States Econ. Potential Highest to Lowest	MW of Economic CHP Potential					Total (MW)
	100-199	200-499	500-999	1000-1999	2000 +	
Hawaii	1	16	19	25	10	71
Alaska	2	4	2			8
New Hampshire	3	5				8
Connecticut	8	8	1	5		21
Rhode Island	2	5				6
Vermont	3	2		5		10
Massachusetts	12	27	5	5		49
California	50	121	49	55		276
New Jersey	13	22	9	25	10	80
Nevada	5	23	29	100	230	387
Louisiana	11	21	9	20		61
New York	20	38	27	40		125
Texas		79	20	30		129
Florida				110	40	150
Michigan				5		5
Arizona						
New Mexico						
Minnesota						
Tennessee						
Colorado		Not Economic		10		10
North Dakota						
Mississippi				25		25
Pennsylvania				5		5
Delaware						
Georgia				25		25
Wisconsin						
North Carolina				5		5
All other states						
U.S. Total	130	371	170	495	290	1,456
High Return Total	30	233	85	310	250	908