Identifying High Value CHP Candidates Using a Low-Cost Methodology

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ABSTRACT

In an effort to achieve greater greenhouse gas reductions and energy efficiency, program planners are turning to combined heat and power (CHP) technologies. A properly sized, thermal-following CHP system can exceed the combined efficiency of a standard boiler and electrical grid in meeting a customer's heat and power requirements. This paper addresses a relatively straightforward and inexpensive methodology for robust identification of statewide and sector-level markets as well as a specific customer "lead list."

The estimation methodology utilizes individual commercial and industrial (CI) gas-customer billing-usage data as a proxy for thermal loading. Customer-by-customer monthly gas usage is analyzed to estimate base and weather-sensitive loading. Hourly weather data is analyzed to determine the operating profile of the weather-sensitive load; typical base-load profiles, mapped by SIC code, are used to characterize the base load. An optimization algorithm selects a CHP installed capacity that meets a payback threshold and is also of a size that is commercially available.

The end product is a rich, "bottoms-up" estimate of CHP lead sites, which can be grouped by capacity range, sector, community, and energy efficiency provider. It can also be further filtered to account for factors such as zones of restrictive interconnections and existing generation.

Introduction

The Massachusetts energy efficiency program administrators (PA) sought a detailed understanding of the CHP market since it is projected to constitute as much as 20% of the kWh reductions achieved in 2012. CHP is a new product for the electric PAs and their marketing strategies are not mature. Identification of promising markets with detailed characteristics - number of customers, business type, CHP equipment type, and specific customer leads - can lead to more effective marketing. The specific goals of the project were to:

- Identify promising markets reflecting the current state of CHP technology and barriers, such as existing equipment size, efficiency, and cost, as well as other factors such as zones of restrictive interconnects, electric distribution rates, and existing generation.
- Provide market estimates at the individual PA level (there are five providers in Massachusetts).
- Characterize markets by number of customers, type of customer, estimated installed capacity, and CHP technology.
- Provide customer level results (lead lists), including service address, customer type, and estimated installed capacity.

This is not a traditional technical potential or economic potential study. The focus of the study is in the near term, considering pricing, technologies, and market barriers that exist today. Also, financial viability of systems is determined from a customer perspective using payback as the screening criteria and does not include all cost-effective units from a societal benefits perspective. This market view is a subset of all the societal cost-effective statewide CHP.

Methodology

The power of the model is in the quality of the thermal characterization provided by the customer's billed gas usage. The Massachusetts gas distribution companies provided individual monthly gas billing account information for all of their commercial accounts (about 115,000 accounts with a full year's billing). The data included an account number and 12 months of billed gas usage. This usage data characterizes the customer's thermal load with a high level of certainty, providing an upper bound estimate of the CHP opportunity for that location, at that point in time. In addition customer name, service address, and SIC codes were used to further characterize the customer's thermal profile and improve the estimate of CHP opportunity.

The model takes advantage of the fact that high efficiency CHP systems are usually limited by the thermal load profile of the host site. The underlying assumption of the model is that a customer's gas usage is a good proxy for the facility thermal loading and that some portion of that thermal loading can be displaced by CHP. Using gas bills is a similar methodology that CHP developers use to prospect for potential sites.

A cost-effective and energy efficient CHP system requires the confluence of a number of factors. The model estimates opportunity, assuming a system purchased, installed, and operating will meet these requirements:

- The magnitude of the thermal usage will be large enough to support the installation of a commercially viable CHP unit. The model used 60 kW as the minimum size of a viable CHP unit. Supplementary estimates of the potential for 30-60 kW systems were calculated as well.
- The unit operates thermal following. The model assumes that units are sized to meet the thermal load and operated to match the thermal requirements of the facility. This maximizes the system efficiency. The model also assumes that all the electricity generated is consumed by the facility and that, depending upon the building type, some portion of the base usage may not be displaced by CHP (for example, restaurants assume a portion of base usage is for cooking, which is not generally displaced by CHP).
- Typically, the full-load operating hours of the unit must meet or exceed about 6,000 hours per year to be cost-effective. Typically, in order to meet the operating-hours' threshold, a portion of the thermal load must come from a year-round base load that is required for extended periods each day. Downsizing a CHP unit will increase the unit load factor and improve cost-effectiveness.

Figure 1 presents an overview of the inputs, results, and the methodology for calculating the optimum CHP system sized in kW along with the generation, net therms, installed cost, and payback. Other inputs and assumptions of the model include electrical distribution costs by electrical provider, commodity gas and electric pricing, O&M cost per kWh generated, average CHP installed cost per kW by CHP equipment size, PA incentives, and payback criteria.

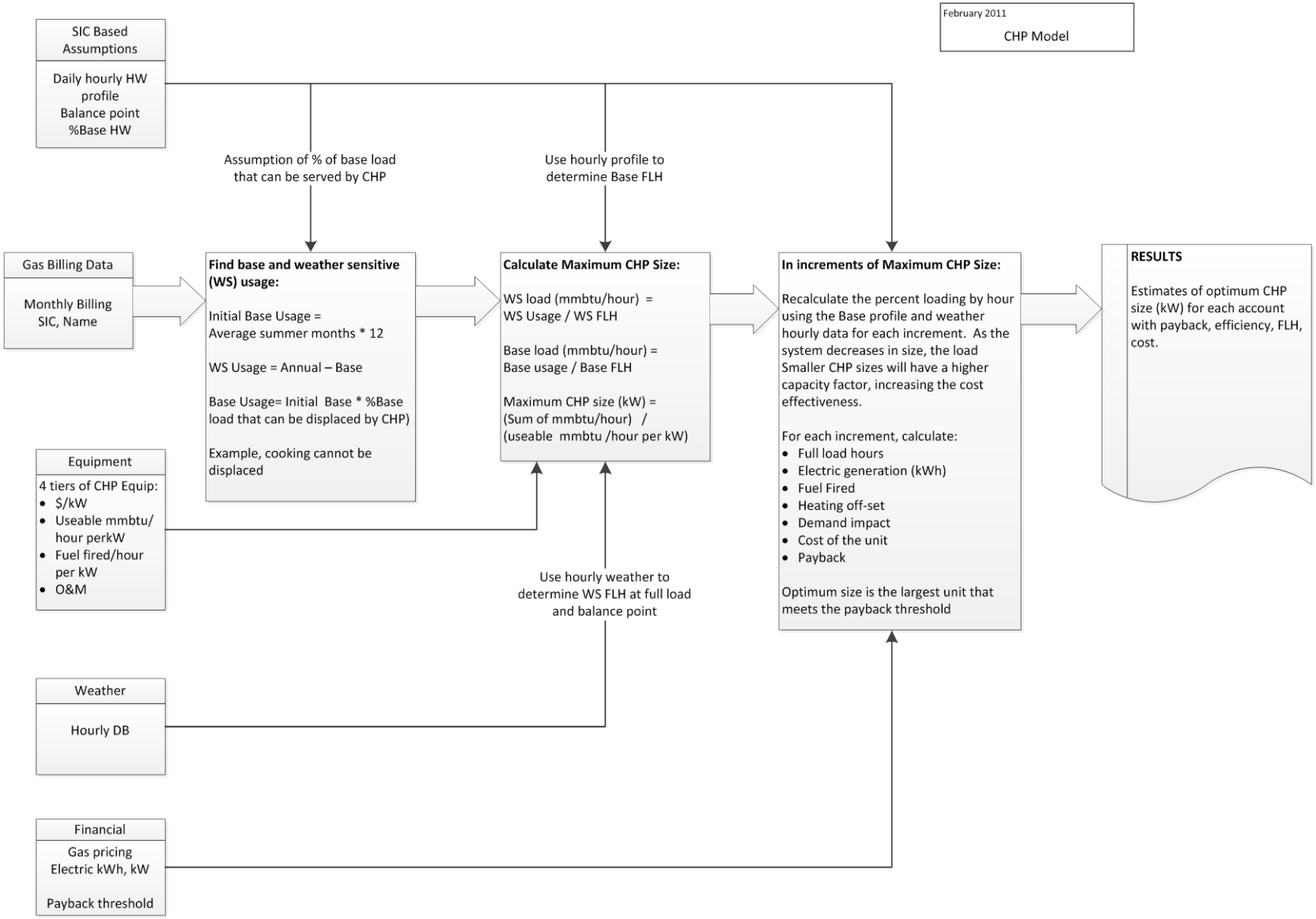

Figure 1. Schematic of Methodology to Calculate Account-Specific CHP Optimum Installed Capacity

Algorithms

The methodology utilizes an 8,760 hourly model using hourly weather data matching the period of the billing data and hourly base load profiles and then distributes the thermal load through all hours of the year. The account-specific, weather-sensitive load is distributed using a weather-driven hourly profile, and the account-specific base thermal usage is distributed using a building-type hourly profile. While the shape of the profile is not wholly unique to a customer (profiles are weather- and building-type determined), the sum of the hourly usage must equal that particular customer's billed usage, which provides very specific results for each account.

An important refinement of the algorithm is its "right sizing" feature. An initial CHP system size is selected that has sufficient thermal capacity to meet the peak thermal load. Its part loading is assumed to vary with the load through all hours of the year. Typically a system sized to meet the maximum thermal load of a facility is not cost-effective, so the model downsizes the unit in increments, testing the performance at a series of fractions of the maximum size. As the unit is downsized, it operates for more hours at higher part loading, increasing the utilization and the annual full-load equivalent hours. The capital costs are lower with the smaller unit and the utilization is higher, increasing the cost-effectiveness. The optimum size is the maximum-sized unit that meets the payback threshold.

Account Screening

Once an optimum installed capacity and payback has been calculated for an account, further screening winnows out the high value accounts. Beginning with the population of 115,000, accounts were screened as illustrated in Figure 2 and further described as follows:

- **Low Usage Accounts.** Those accounts with less than 5,000 therms base usage or 20,000 therms annual usage were screened out without further calculations. Analysis had shown that usage below these levels does not support a 10 kW CHP system cost-effectively under even the most favorable rates and building profiles.
- **Optimum-Sized CHP Systems.** These were estimated for the remaining accounts. Those accounts with an optimum system size of less than 60 kW but with a payback of less than 5 years (with PA incentives of $750 per kW) were screened out because this was identified as the threshold for commercially available systems.
- **Exceed Payback Threshold.** Remaining accounts with paybacks greater than 5 years after incentive were screened out because they exceeded the financial screening criteria. The payback is computed as the total installed costs less incentives divided by the sum of the electrical commodity and demand savings, the net gas increase cost, and the increase in operation and maintenance costs.
- **Located on a Network.** In this particular state, accounts served on a network designed electrical distribution system cannot be interconnected cost-effectively and therefore are screened out.
- **Existing Generation.** Sites with confirmed existing generation were screened out because it is assumed the CHP opportunity has been largely captured at those sites. Existing generation was confirmed by matching gas accounts with the generator lists provided by some of the electric distribution companies and also using state air emission permitting lists. Since the matches were done manually using customer name and service address, not all existing generators could be matched with a gas account; therefore this screen includes some generator sites.

Figure 2 tabulates the impact of each of the screening steps in terms of number of accounts and related usage affected, the number of accounts remaining after the screening, and the remaining CHP potential.

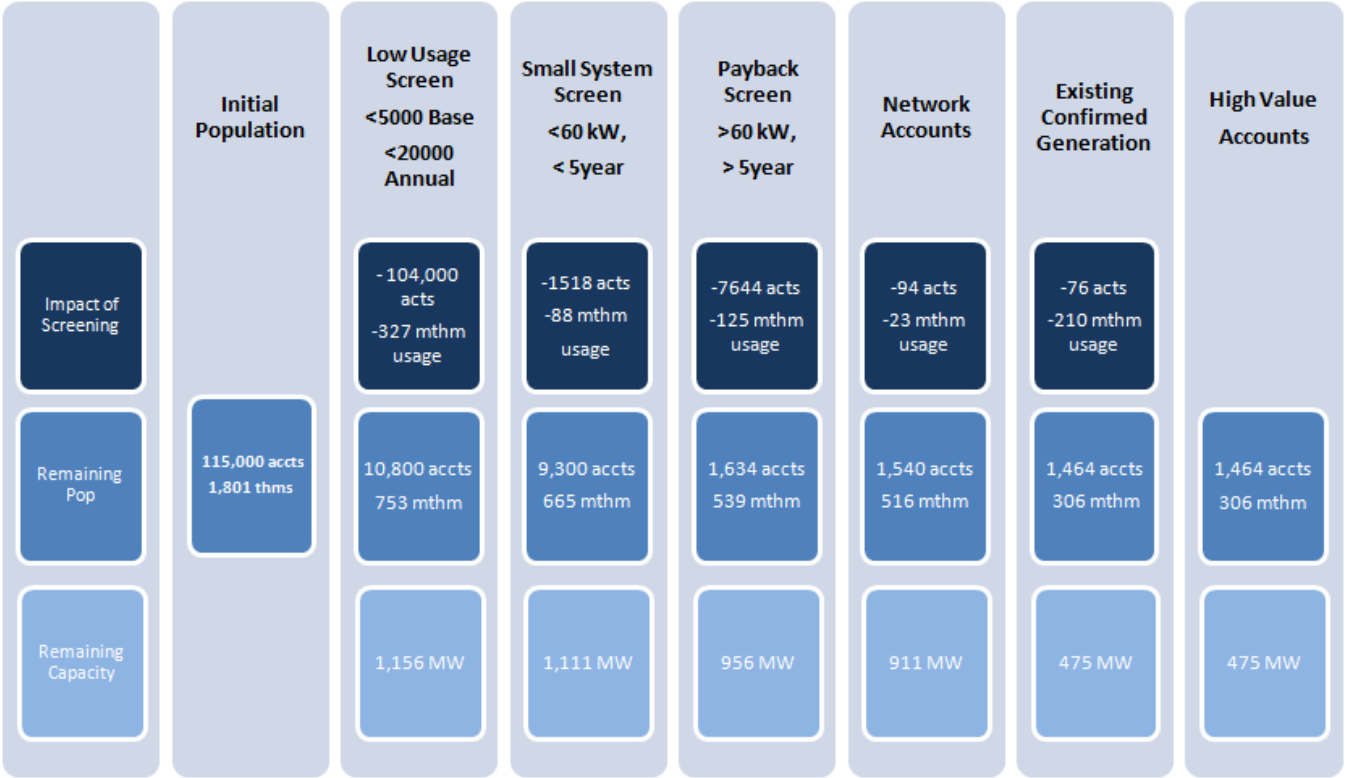

Figure 2. Screening for Viable Accounts

The results of the screening are optimistic from a short-term point of view, in order to include all potential candidates and a number of false-positives. The intent was to cast wide to ensure a good site was not excluded. Some of the factors that optimistically identify leads include:

- Reasonable minimum pricing of installed systems.
- Five-year payback with full incentive level ($750/kW) for all system sizes, which may exceed the payback threshold of many customers.
- About a third of the sites will have HVAC systems that are not conducive to CHP (such as direct-fired rooftop units).
- Standby rates and mismatches between electric load and gas usage will screen out a fraction of candidate.

Results

Two types of results are available from the analysis: individual customer results and aggregate analysis. The focus of this study was to produce specific customer results for a lead list and to better characterize market segments as aggregations of those customers. However, additional analytics examined the impact of variances in some of the model assumptions and was used to identify emerging markets and examine the impacts of different incentive levels and the impact of standby rates.

Aggregation of Site Results

The customer-by-customer results were aggregated by various customer attributes to create useful views of the market. The following groupings are illustrative of these aggregations:

- By CHP equipment size
- By customer type
- By customer gas usage quartile

Other aggregation methods that were developed but are not shown include by community and by electrical and gas provider. Cross tabulations views were created as well (for example, by building type, by equipment size).

CHP Equipment Size. The CHP market consists of different technologies that are supplied by different vendors and distributors that can be roughly categorized by installed capacity size intervals. These vendors and distributors target customers with characteristic thermal loads that support a CHP unit of the size they sell. This analysis characterizes CHP systems within four size intervals representing technology classes and a related vendor community. Figure 3 presents the sum of the project installed capacities sorted by equipment size interval. This view of the market emphasizes the importance of larger systems (over 300 kW), which account for 70% of the opportunity.

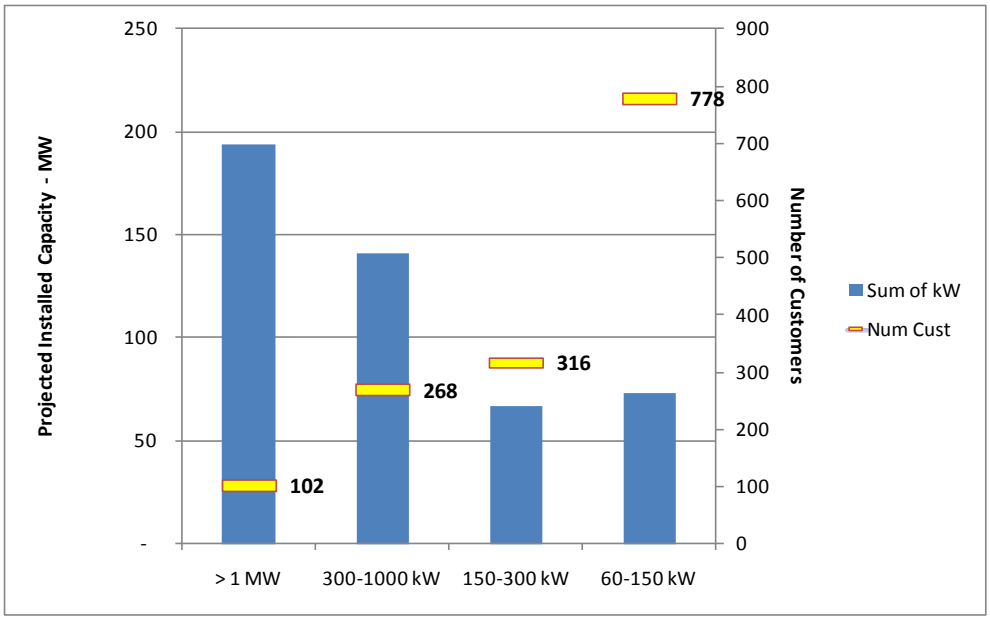

Figure 3. Projected Installed Capacity Opportunity by Equipment Size

Customer Type. The high value accounts can be grouped by customer type for another view of the market. Customer type was determined by SIC code supplemented with manual classification of larger accounts by name. Unfortunately a significant number of business types did not have an SIC code, as shown in Figure 4. One of the interesting findings was the size of the CHP market in office buildings. Office space is the predominant space type in this market, which partially explains the market size. It is also suspected that summer HVAC reheat systems and domestic hot-water loads, combined with winter heating provided enough load to support an appropriately sized unit for office spaces. The algorithm does not include estimates of absorption cooling potential.

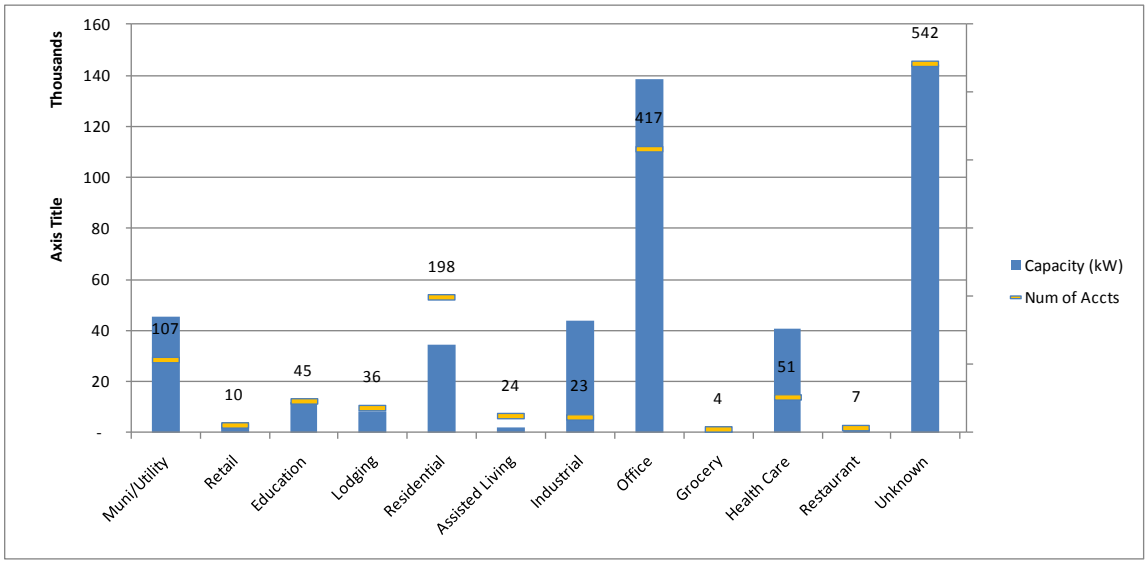

Figure 4. Projected CHP Opportunity by Customer Type

Customer Gas Usage Quartile. Another way to examine the market is by gas sales. Implementers can find it useful to classify customers by their gas usage. Generally, larger users will have a greater opportunity for CHP. Large accounts may also have key account managers that can be enlisted in a marketing effort. Accounts are sorted by ascending annual gas usage and then grouped such that the sum of the usage of each group, or quartile, represents close to a quarter of the total gas sales. In this particular population there are only 96 customers in Q1, while there are 105,000 customers in Q4. Figure 5 identifies the CHP opportunity by each gas usage quartile. The largest opportunity exists in Q2 where gas usage, particularly a base usage, is substantial enough to support a CHP system, yet the penetration rate of existing generation is low. Q1 has significant confirmed generations, which reduces the opportunity for new CHP.

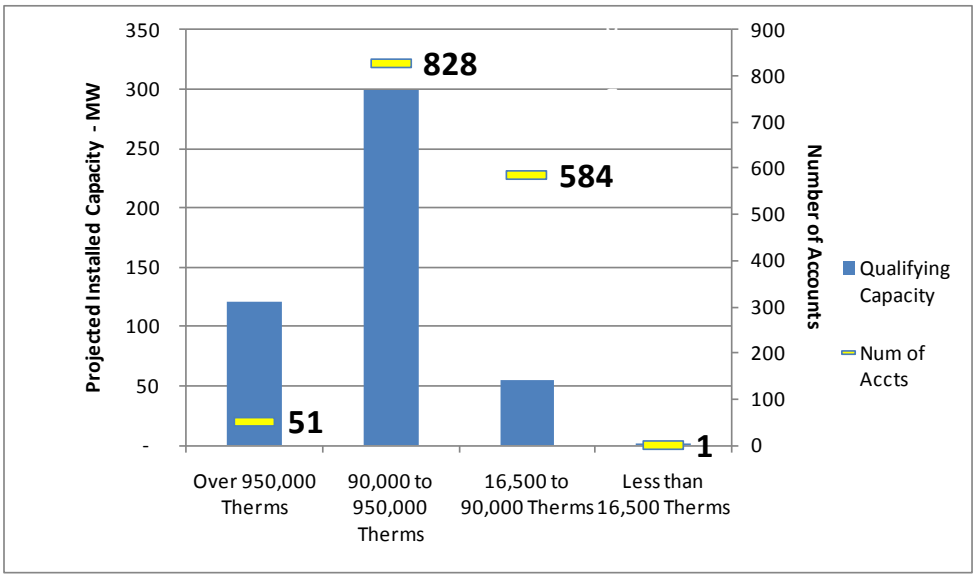

Figure 5. Opportunity by Usage Quartile

Analytics

While the focus of this study was on identifying specific customers and markets, the model can be used to consider alternate scenarios related to pricing, financial screening, and the like. Some of the possibilities are illustrated in the three following examples.

Incentive Levels. The PAs can impact the market by varying the incentive level offered. A higher incentive level will increase the number of customers where CHP is cost-effective and also increase the cost-effective size of the installed CHP capacity at a site, due to the sizing algorithm. Note in Table 1 that as the incentive increases both the number of accounts and the average unit size increases, generally.

Table 1. CHP Incentive Impact on Market

Incentive per kW Installed	Num Accts	Pct Change from Baseline	Capacity (kW)	Pct Change from Baseline	Average System Size kW
$250 / kW	1,051	-28%	306,780	-35%	292
$500 / kW	1,239	-15%	389,941	-18%	315
Baseline $750 / kW	1,464	0%	475,167	0%	325
$1000 / kW	1,829	25%	587,492	24%	321
$1250 / kW	2,268	55%	738,721	55%	326

Emerging Market Potential. Very small CHP units in the 30-60 kW range are beginning to emerge on the market. The market for cost-effective units (less than 5-year payback with incentives) represented a market for an additional 800 participants with an installed capacity of 33 MW. A cost of $2600 /installed kW was used in this analysis, which may be on the low side for this market.

Standby Rates. Table 2 presents an analysis of the impact of one of the electric distribution company standby rates. About 25% of the locations accounting for 70% of the installed capacity opportunity would be subject to the tariff in this population. The standby charge does potentially have a substantial impact on customer economics.

Table 2. Impact of Standby Rates

Standby Rate Analysis		
Tariff charge	$20 per metered monthly peak kW	
Systems >250 and serving 30% or more load are subject to the tariff		
	Number of Accts	Projected Capacity
Total Sites with CHP	742	222,922
Sites > 250 kW	192	159,219
Potential stand-by charge		$20,077,440
Current total annual $ benefit at sites subject to standby		$60,794,696
Current total cost, net of incentives		$274,698,479
Current average payback in years		4.5
Average payback with standby		6.7

Corroboration of the Model

Model estimates of CHP capacity were compared to the actual installed capacity at sites with known generation. While from account to account, there is divergence between the estimated and known installed capacities, overall, the sums match quite well, as shown in Table 3. This provides some level of corroboration of the model's ability to estimate CHP size. The one outlier was a large university's generation system where the usage does not appear in the retail gas dataset and may be purchased wholesale.

In other cases, known generation could be mapped to a gas account, but the installed capacity was not provided and could not be included in the comparison.

Table 3. Comparison of Known CHP and Model Estimates

Dispostion of Generation	Number of Accts	Model Est of CHP - kW	Listed Capacity of Generation - kW
Confirmed match with mapped capacity	32	28,552	27,779
Outlier with mapped capacity	1	57	21,500
Confirmed generation, no mapped capacity	43	407,445	
Confirmed generation total	76	436,054	

Model Limitations

The model has known limitations that tend to overstate or understate market potential as a whole in characteristic ways. Below is a list of known factors in the population of sites that cannot be linked to a particular customer account.

Overstate Opportunity

- About a 30% of the HVAC systems, according to CBECS, will have HVAC systems that are not conducive to CHP systems. CHP is most cost-effective when it is installed in parallel with an existing boiler and provides supplemental heat to the steam or hot water distribution systems. In those HVAC system designs where the facility is heated with direct-fired rooftop units, for example, the heat generated by a CHP cannot be readily distributed to that unit without substantial added cost.
- At some sites, the electricity generated by a thermal following CHP system will exceed the electricity needs of the facility. The excess electricity will be exported to the grid at about half the economic value to customer. Since the electric and gas customer systems in the state do not link accounts, sites cannot be screened in the model for this thermal/electric mismatch.

  The study did examine 140 sites where both electric and gas billed usage was available. These sites were selected because they were building types expected to have a higher likelihood of mismatched gas and electric profiles (lodging, schools, residential buildings, and athletic clubs). The electric and gas accounts had to be manually matched, which limited the size of the sample. This sample showed a particular problem with the residential market (public housing, apartments, and condominiums) where 45% of the accounts did not have enough electric load to support a thermal-following CHP system. The other building types showed less than a 5% potential for exporting.

Understate Opportunity

- The market analysis is based on C&I customer current gas usage. The results do not include sites where oil is the primary fuel or any opportunities that might be available from bio-fuels. In Massachusetts, about 20% of the thermal load is provided by oil.

- The methodology does not identify new construction potential.
- The model does not identify locations where existing electric cooling load could be displaced by absorption cooling potentially expanding the operating hours of a CHP system and improving its cost-effectiveness. However, the economics of installing an absorption chiller to build summer thermal load is not compelling, except in fairly unique circumstances.

Conclusions

The relatively straightforward and inexpensive methodology outlined in this paper can identify site specific estimates of CHP installed capacity and performance without the expense of a site visit. Customer-specific information, including service address, building type, specific weather, specific electric rates, and most importantly, monthly gas usage are used to characterize system size, performance, and cost. These same customer attributes allow for aggregation of the results in a variety of ways providing insights into CHP market segments. The model itself can be used to explore the impacts of incentives, spark spread, installed costs, and other factors that influence the CHP market. One of the products of the analysis is a lead list, which can be used to identify specific customers for further marketing.

The technique outlined in this study could provide a valuable supplement to a traditional technical or economic potential study that relies purely on broader market indicators, such as statewide gas sales. The site-specific approach can provide insights and possible improvements to a potential study. For example, several previous CHP potential studies identified car washes as a good target for CHP, assuming a large and constant hot water demand with a matching electric demand from the blowers and car transport system. It was possible to test that hypothesis with the gas customer datasets using a key word search on customer names and SIC code. One such search resulted in a list of twenty-three confirmed car washes. None of these accounts had significant gas usage. While it is possible that some accounts used electric or oil-fired heating systems for hot water, it is unlikely that all of them did. This search methodology confirmed that car washes are not good CHP candidates, which could be factored into the potential.

Acknowledgments

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