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**Environmental Energy
Technologies Division**

January 2002

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Acronyms and Abbreviations

CHP	combined heat and power
COE	cost of electricity
dB	decibel (sound level)
DER	distributed energy resources
DER-CAM	Distributed Energy Resource Customer Adoption Model
DG	distributed generation
GAMS	General Algebraic Modeling System
GIS	Geographic Information System(s)
GJ	gigajoule (energy)
kW	kilowatt (power)
kWh	kilowatt hour (energy)
O&M	operation and maintenance
SANDAG	San Diego Association of Governments
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
μGrid	microgrid

Executive Summary

This report outlines a method to assess the local potential for deployment of distributed energy resources (DER), small power-generation installations located close to the point where the energy they produce will be consumed. This methodology combines established economic optimization techniques with a geographic information system (GIS) analysis of local land-use constraints that limit the use of distributed generation (DG) systems. This methodology was developed using an example case in the San Diego area. Our work approaches DER adoption from a customer perspective, based on the premise that future development of DER may take the form of microgrids (μGrids), where multiple neighboring end users are aggregated, and energy loads and generation are jointly managed using standardized "plug and play" power electronics. Previous work in the field of power system planning has focused on the electrical requirements and economic feasibility of incorporating μGrids into the current power-supply infrastructure. However, although local restraints such as zoning codes and on-site physical barriers are well-known frustrations in the field of DER, no analysis method has been developed to address them. The need for such a method is the inspiration for this work. By incorporating established DER analysis techniques with a GIS, local spatial constraints on DER can be readily addressed and analyzed. GIS currently plays an essential role in transportation and city infrastructure planning; we propose that it can play a similarly important role in future DER deployment.

The method developed in this project builds on previous work at Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) that produced the Distributed Energy Resource Customer Adoption Model (DER-CAM). DER-CAM is an economic model that compares distributed technology installation and operation costs to utility rate structures; it determines the optimal, cost-minimizing combinations of generation and CHP technologies for any test customer. DER-CAM provides an economic basis for assessing DG technology adoption patterns within a μGrid, and a GIS is used to enhance this basic approach in two primary ways. First, GIS data for existing building patterns in the San Diego area are used to identify neighboring customers that could hypothetically join together to form a μGrid. Using GIS data to restrict the customer combinations analyzed in this project to those that are located near each other in an existing city plan ensures that the hypothetical μGrid has a realistic basis. Second, a GIS is used to identify local land-use restrictions that may inhibit or prevent installation of economically attractive DER technologies. These land-use restrictions include noise and air quality limits, restrictions on crossing public rights-of-way, the density of buildings and availability of open space to install a generator, physical limitations on the transfer of generator waste heat, and access to high-pressure natural gas lines. By using a combination of DER-CAM and GIS to assess the economic feasibility and land-use compatibility of commercial DG technologies, suitable DER adoption patterns can be identified. Figure ES-1 outlines the methodology developed in this report.
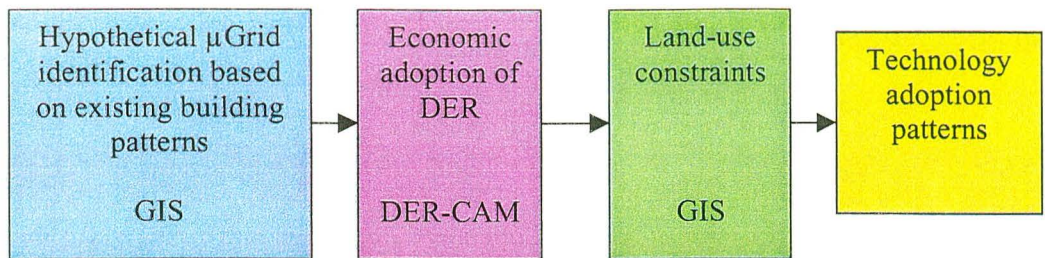
Figure ES-1. Methodology to assess suitable DER technology adoption patterns using DER-CAM and GIS

This analysis methodology was used to answer three fundamental questions about μGrid development:

- Where are adjacent customers with complementary energy loads found, providing an existing basis for μGrid development?
- Do individual customers benefit from joining a μGrid, or are they better off installing DG independently?
- What types of DER are the best for a specific site? This question has two components: First, which generation technologies are the most economical once CHP benefits have been accounted for, and second, will those technologies be suitable in view of local land-use restrictions?

The first analysis step is to identify potential μGrid sites based on the existing distribution of customers with complementary energy loads. Complementary energy loads are used here to describe end users that realize greater economic benefits through the shared use of on-site technology than through independent installations. We assume that these conditions may result in two ways. First, when customers with large electricity demands and small thermal demands can share waste heat from on-site generation with other end users. Second, when two or more customers have peak electricity demands at different times of the day so that an aggregation of their electricity loads results in a higher capacity factor for the installed generation technology. The aggregation of these loads will result in a greater number of kWh over which to spread the levelized generator cost without requiring that an additional generator be purchased to meet a larger peak.

Beginning with the above assumptions about which customer combinations have complementary energy loads, a GIS was used to locate specific neighborhoods in the San Diego area where these customer combinations exist. Three areas were identified: a small commercial/residential neighborhood with retail shops, residences, and a small hospital; an industrial area with manufacturing facilities, warehouses, and some bars and restaurants; and an area in the downtown financial district with office buildings, retail stores, and fast food restaurants. These three neighborhoods have different zoning classifications, and zoning laws determine the land-use restrictions to which customers in the area are subject. In addition, the zoning designation for an area gives some indication of the energy requirements of a typical customer located in that area. For example, an industrial-zoned customer and a commercial-zoned customer are likely to have different energy end-use needs.

A detailed energy analysis was conducted for the commercial/residential area. This required the construction of a database of energy loads that could be applied to customers at that site, divided into five energy end uses for input into DER-CAM. These five end-use loads are: electricity-only loads such as lighting, computers, and most appliances; hot-water and space-heat loads that can be met with either generator waste heat or direct combustion of natural gas; cooling loads that can be met with either standard compressor chillers or absorption cooling technologies using waste heat; and natural-gas-only loads, such as cooking, that cannot be met with CHP technologies. This database was created primarily using electricity end-use data collected by Southern California Edison (SCE) and natural gas loads simulated by DOE-2 (a building-energy program created at Berkeley Lab), though several additional sources and extrapolations were required. These load shapes are input into DER-CAM along with cost and operating characteristics of commercially available DER technologies, fuel costs, and utility electricity tariff rates. DER-CAM then outputs the optimal generator supply schedule for a given customer.

The DER-CAM results for five μGrid customer combinations within the small commercial/residential neighborhood were analyzed to determine the advantages of complementary energy loads. First, the entire μGrid was compiled to establish a base-case scenario and to reflect the existing land-use patterns at the site. Two variations on this base case were constructed: doubling the energy loads of all the customers in the μGrid to reveal potential economies of scale, and disconnecting the residential customers. Next, two customers, the hospital and a laundromat, were analyzed individually to address the question of whether or not it would be beneficial for certain customers to install DG independently. DER-CAM results for these five cases show the DER technologies chosen on an economic basis to supply power and heat to the μGrid and the hours at which these technologies operate. In all five scenarios, different combinations of natural gas reciprocating engines were chosen by DER-CAM, ranging in size from 25 kW to 500 kW. These generators operate throughout the day and are supplemented by purchased electricity during late-night and early-morning hours when utility time-of-use (TOU) tariff rates are lowest. All three μGrid scenarios displaced 81 percent of their annual gas load through CHP. The laundromat and the hospital supplied 36 percent and 84 percent of their annual gas load with CHP, respectively. Figures ES-2 and ES-3 below show how the base-case μGrid energy loads are met with purchased and on-site generation and CHP.
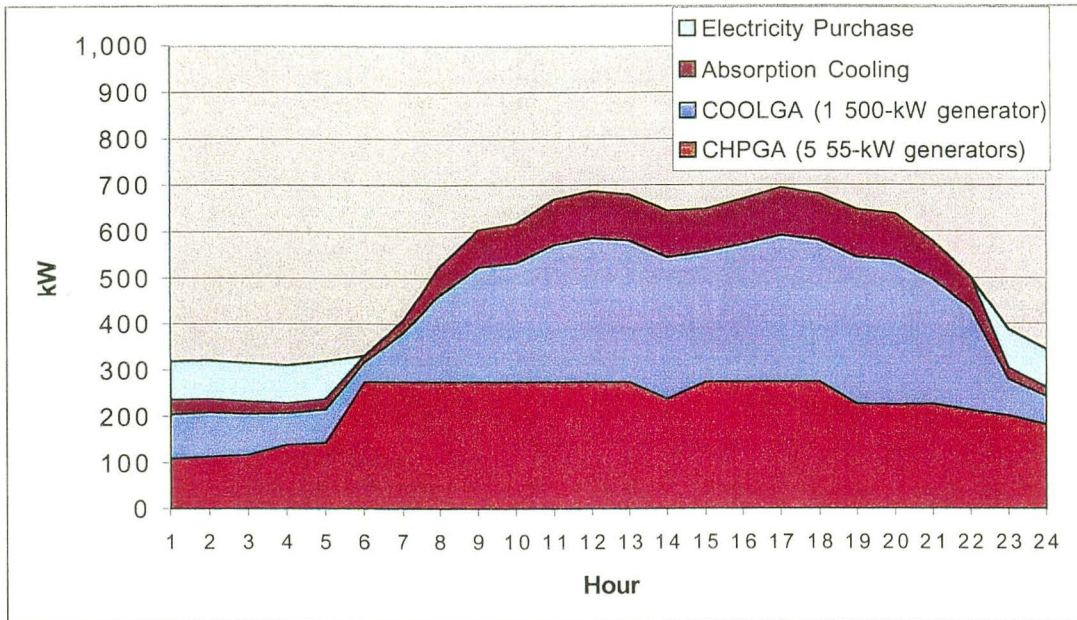
Figure ES-2. How electricity loads are met in the base-case μGrid. The absorption cooling band represents an electricity demand reduction as air-conditioning loads are displaced by on-site CHP cooling technologies.
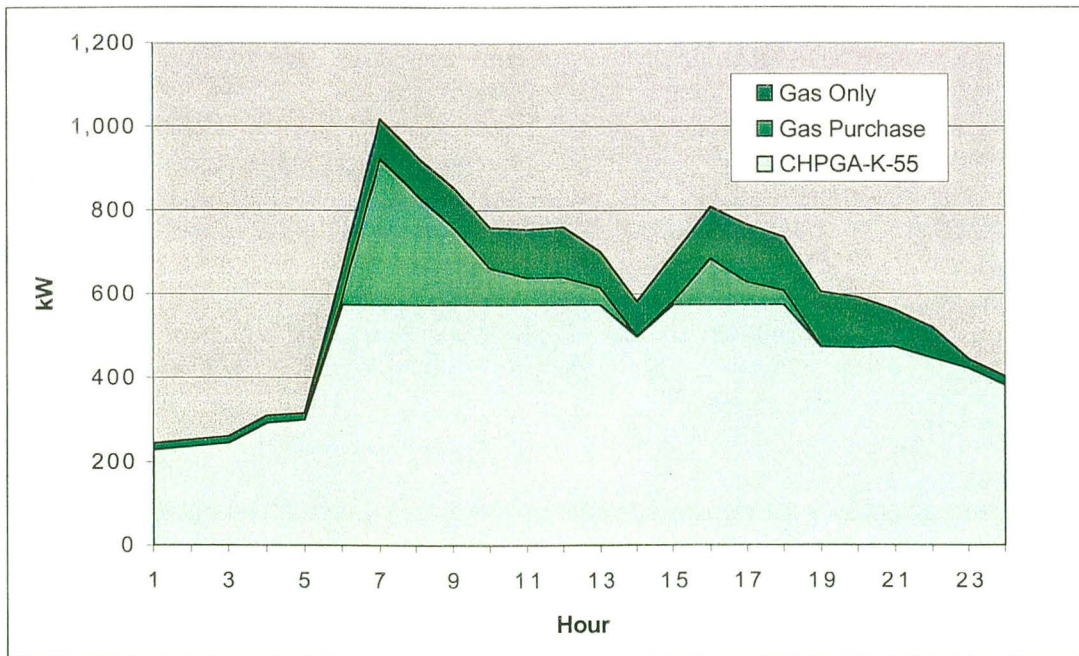
Figure ES-3. How gas loads are met in the base-case μGrid. The CHP output shown in the lowest band is supplied by five 55-kW generators.

A cost comparison of the three μGrid cases showed no variation between the base-case μGrid and the double-size μGrid, both of which had an average cost of electricity (COE) of 6.8¢/kWh. The COE for the no-residence case was slightly higher at 8¢/kWh, because the technology investment is the same as for the base-case μGrid, but there are fewer kWh over which to spread the levelized generator costs. This demonstrates the benefits of complementary electricity loads, because residential electricity use is highest in the early evening, and the peak use of commercial and office customers is in the afternoon. The laundromat saves an average of 0.7¢/kWh by purchasing electricity through the μGrid. The laundromat is an interesting case because of its high ratio of heat to electricity demand. The high heat demand suggests a large economic benefit would result from the use of CHP. On an individual basis, however, the low electricity load prevents the customer from benefiting from CHP because the generator electrical output is not large enough to produce adequate waste heat. This result demonstrates another benefit of complementary energy loads, as the laundromat realizes greater economic benefits by sharing electricity and waste heat from larger generators with other customers in a μGrid. Results show that the average COE is lowest for the hospital case at 4.9¢/kWh, in part because the hospital has the highest annual load factor of 69 percent. This low cost does not provide an immediate economic incentive for the hospital to connect to the μGrid. These two individual customer cases demonstrate the large variability in the economics of DER adoption, which depends on the size of the customer and the ratio and overlap of electricity and heat loads as a determinant of potential CHP benefits.

Once the hypothetical μGrid technology choices and operating schedules were identified by DER-CAM, a GIS was used to assess three local land-use constraints. First, the availability of open space for a generator site was determined by calculating the generator footprint and identifying the building sites large enough to accommodate the generator. Five possible sites were identified at this stage: the hospital, three large retail sites, and a medical office building. Second, physical constraints on CHP heat transfer were examined by measuring the distance between these five identified sites and the hospital, the largest heat sink in the μGrid. The heat-transfer distances were shown to be relatively large, ranging from 220m to 280m, suggesting that insulation upgrades may be an important economic consideration for this μGrid. The third constraint analyzed was the effect of generator noise on local buildings. The distance at which the noise output of the largest generator is reduced to the level allowed by local zoning codes was calculated to be 60m, and a buffer zone was placed at this distance from each of the possible generator sites. Local buildings that would be negatively affected by noise can be identified from their overlap with this buffer zone. The results of this analysis show that six or seven residences would be affected by noise at each possible generator site.

The figure below shows the GIS results for the hospital and one of the retail sites in the small commercial/ residential base case μGrid. The buildings in yellow are the sites large enough to accommodate a generator. The gray bands represent the noise buffer for each site at a distance of 60 m. The figure shows the local residences that fall within this buffer and would therefore be exposed to noise levels exceeding those allowed by zoning laws. In addition, the red arrow shows the heat-transfer distance from the retail site to the hospital.
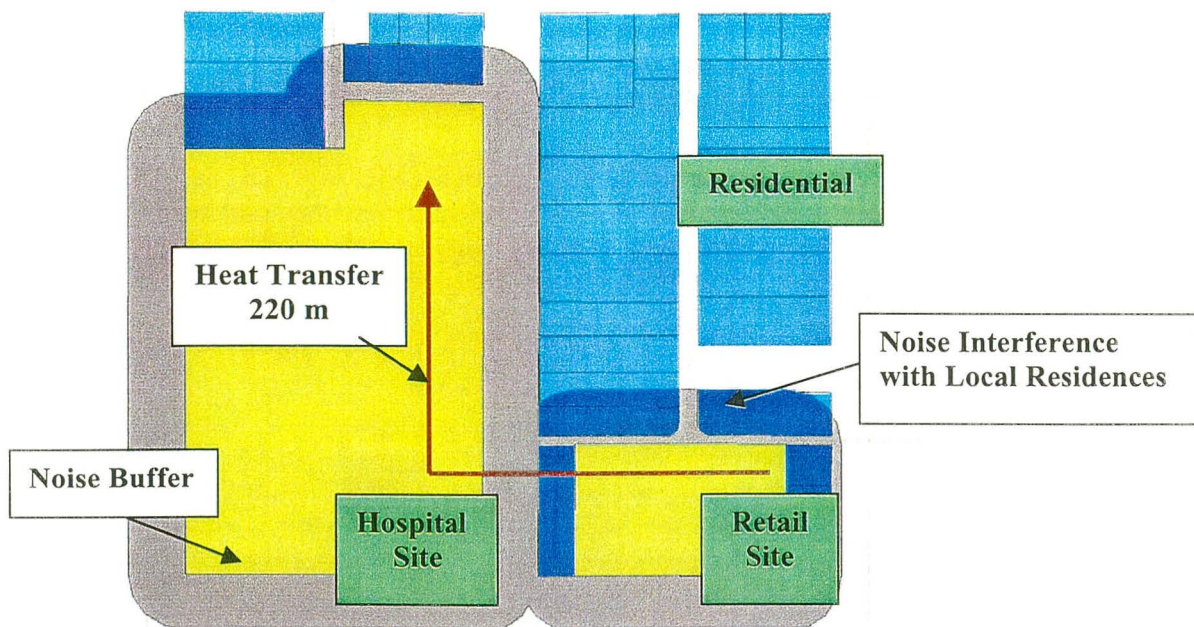
Figure ES-4. Local land-use constraints in the small commercial/ residential μGrid.

The results from the GIS analysis described above show the optimal sites for the technologies chosen on an economic basis by DER-CAM, and reveal some of the inherent difficulties or possible advantages DG might encounter as a result of local land-use patterns. The GIS analysis process reveals that certain technologies might have to be eliminated from consideration based on overall noise restrictions, and that other technologies would be suitable if additional requirements, such as heat-transfer upgrades, were met. The GIS analysis methods used for these three example constraints can easily be extrapolated to include additional local barriers.

This work is intended to be an exploratory first step toward an integration of GIS analysis methods with DER-CAM to produce an automated process of μGrid identification. The focus of this report is on the GIS portion of the analysis although several important economic questions are also addressed. The fundamental future barriers to DER adoption will most likely be economic, but it is worthwhile to take geographic constraints into account at this stage of development, and to evaluate methods of assessing them. With the compilation of more complete databases of small-scale land-use information, GIS may prove to be an important tool in the analysis of DER technology potential.

1. Introduction

This report describes the use of a Geographic Information System (GIS) to identify physical barriers, such as local land-use and zoning constraints, to the deployment of distributed energy resources (DER). A method to simulate and identify potential locations of on-site power generation was developed and applied to some example sites in San Diego, California.

1.1 The μGrid concept

Non-utility distributed generation (DG) development is typically thought of as a single-customer/single-generator problem. DG investment is made by one end user to meet its own specific energy needs, e.g., for back-up generation, high power quality, or use of combined heat and power (CHP). Efforts to create standardized interconnection rules for DER usually start from the premise that DG is added in discreet, single units. However, DG could be made more attractive through the development of microgrids (μGrids), in which multiple neighboring end users are aggregated, and energy loads and generation are jointly managed using standardized "plug and play" control technologies.[1] DG systems that are planned around μGrids have several advantages over systems based on single customer-generators. First, combining the electricity demand of several small end-users is a flexible way of allowing customers to take advantage of economies of scale. Second, certain customer types may have complementary energy needs and can increase efficiency through mutual use of on-site CHP. One example might be a building with large electricity needs but a small heat load located next to a building with a high heat demand, so both customers can take advantage of the electrical and CHP output of the same generator. Identifying and simulating such potentially compatible loads is one important element of this study.[2]

The μGrid concept is based on the belief that power electronics can be developed to allow multiple small generators and loads to function as a unit in both grid-parallel and "islanded" modes. That is, the μGrid could function as a single legitimate entity in relation to the utility grid. From the customer's point of view, the μGrid could deliver minimum-cost energy services to end users because a central μGrid control station could regulate the μGrid's energy purchase, self-generation, and energy sale schedules so that costs are minimized.

1.2 Identifying Potential μGrids

Optimal combinations of building loads can be found through analysis of yearly energy load shapes for different customer types. For the purposes of this project, energy end uses are categorized into five types (as shown in Figure 1): electricity-only loads such as lighting; cooling loads that can be met with either standard compressor chillers or absorption cooling technologies using waste heat; hot-water and space-heat loads that can be met either with

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[1] For more information on μGrids see Marnay et al., 2001.

[2] A third potential benefit of μGrids, that is not addressed in this study, derives from the possibility that electricity reliability and quality might be locally tailored to the requirements of the heterogeneous end uses of on-site facilities. By locally supporting sensitive loads, such as computer or control equipment, the μGrid could function adequately with relatively low levels of grid-supplied power.

generator waste heat or combustion of natural gas directly; and natural-gas-only loads, such as cooking, that cannot be met with CHP technologies.
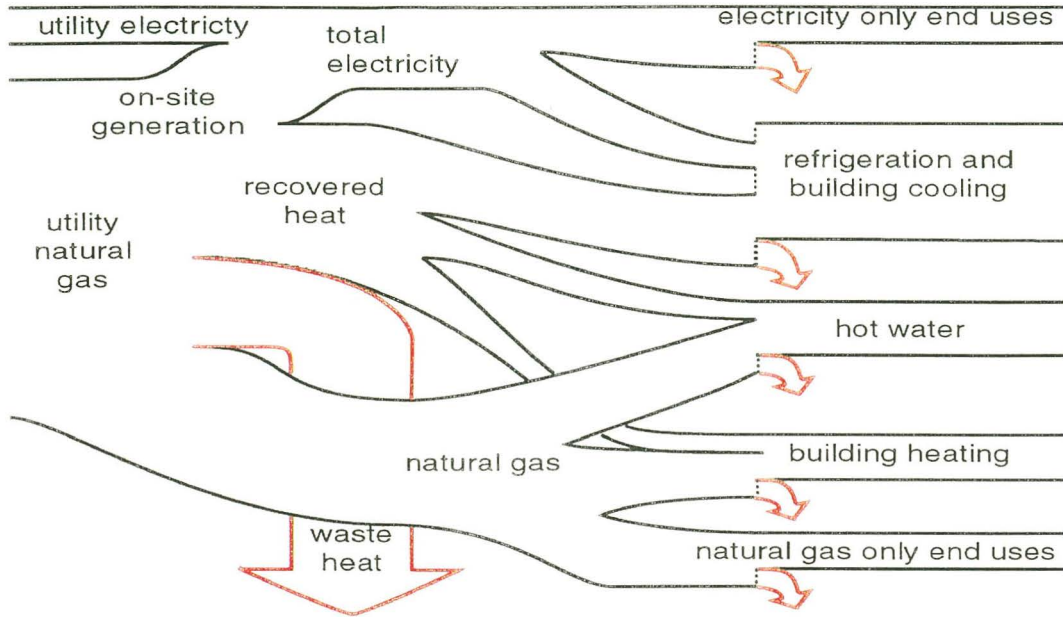
Figure 1. μGrid Building Energy Flows

Finding optimal on-site generating adoption requires hourly load profiles for energy use by the end-use categories. These end-use load shapes can be analyzed using the Distributed Energy Resource Customer Adoption Model (DER-CAM)[3] developed by Ernest Orlando Lawrence Berkeley Lab (Berkeley Lab). DER-CAM is an economic model that compares the installation and operation costs of commercially available DER technologies to utility rate structures; DER-CAM's output is the optimal cost-minimizing supply schedule of generation and CHP technologies for a given customer. Equipment options include natural gas reciprocating engines and microturbines with CHP retrofits, solar panels, wind turbines, and fuel cells. Altering the DER-CAM energy load inputs to correspond to different test μGrids shows which building combinations benefit economically from shared use of on-site energy generation.

1.3   The Role of Geographic Information Systems

Because distributed power generation is by definition located near the end user, the planning and siting of DG units must take into account not only the electrical and economic requirements of the system but also key deployment constraints at the site. These constraints include land-use restrictions, such as local zoning and noise ordinances, that affect the use of certain DG technologies but cannot be analyzed based on economics alone. In addition, although theoretical ideal building combinations may be found by DER-CAM analysis, the buildings that DER-

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[3] For more information see Appendix C and Marnay et al., 2000 and 2001, Rubio et al., 2001, and Siddiqui et al., 2001.

CAM identifies may not be located near each other in typical city plans. These land-use and locational constraints to μGrid planning are inherently spatial and can readily be analyzed using a GIS. By incorporating an analysis of μGrid distributed technology adoption into a GIS, one can identify crucial spatial issues influencing μGrid deployment. Furthermore, by using GIS land-use data that show building layouts in existing neighborhoods as the basis for choosing μGrid customer combinations, the theoretical μGrid concept is applied in a real-world context. Therefore, the role of GIS analysis in simulation of DER adoption by μGrids has two components: first, to use existing city plans as the basis for choosing μGrid customer combinations, and second, to show how spatial constraints that are not revealed through pure economic analysis can influence DER adoption.

1.4   Background Work at Berkeley Lab

The work described in this report has been completed with fiscal year 2001 funding from the Office of Power Technologies (OPT) Analysis Collaborative. The intent of this work is to explore analysis techniques that can take into account localized restrictions on DER deployment that are not readily incorporated into traditional economic analyses, such as the method embodied in the Energy Information Administration's National Energy Modeling System (NEMS). Prior Berkeley Lab work has shown that GIS can be a powerful tool for addressing spatially defined limitations in energy research.[4] In the exploratory work described here, economic analysis tools (primarily DER-CAM) developed prior to this project (with funding from the Transmission Reliability Office of OPT and the California Energy Commission) are supplemented by a GIS as a step toward a fully integrated model of DER adoption that includes localized constraints along with economic considerations.

1.5   Choice of μGrid Location

Although the goal of this work is to develop a general analysis approach for assessment of DER adoption potential, the practical starting point is to study an example case. This project looks specifically at μGrid development potential in San Diego CA. Several factors make San Diego an interesting test case for customer-adopted distributed generation:

- Customers served by San Diego Gas and Electric (SDG&E) received much attention during the summer of 2000 because SDG&E had completed the process of deregulation mandated by the state and was able to pass on that summer's high market electricity rates to customers. This situation motivated customers and policy makers to consider possible alternatives to the current electricity supply structure, such as distributed generation and real-time pricing to allow customer demand to respond directly to market fluctuations.
- San Diego is a transmission-constrained area with rapid load growth where sizeable transmission or generation construction is unlikely, so it is an attractive location for DER.
- San Diego has collected a wealth of publicly available GIS data for land-use patterns, roads, climate variation, environmentally sensitive areas, and other information relevant to a local analysis of distributed generation deployment.

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[4] See Marnay et al., 1997 and Segzen, et al., 1998.

2. Analysis Method

This section describes the general analysis approach used to incorporate a GIS into a simulation of DER adoption for the San Diego example case. Limitations on time, budget, and data mean that we performed only some of the possible analysis steps in this study. The following section on completed tasks describes in detail the actual implementation achieved in this study.

2.1 Complementary Energy Loads

The first step in this analysis is to identify example µGrid customer combinations. These µGrid customer combinations were chosen based on their proximity to each other in an existing city plan and their potential to have complementary energy loads with neighboring customers. Complementary energy loads refer to customers that realize greater economic benefits through the shared use of on-site generation than through individual installations.

GIS data for existing land-use patterns and building locations were used to identify customers located near each other. One database containing this information has been compiled through SanGIS, a Joint Powers Agreement between the city and county of San Diego whose purpose is "to maintain and promote the use of a regional geographic data warehouse for the San Diego area."[5] Data from SanGIS show individual land parcels classified by building type, e.g., single-family residence, community shopping center, or medical office. Figure 2 shows an example of these data for one of the areas identified in this study.

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[5] For more information see http://www.sangis.org.
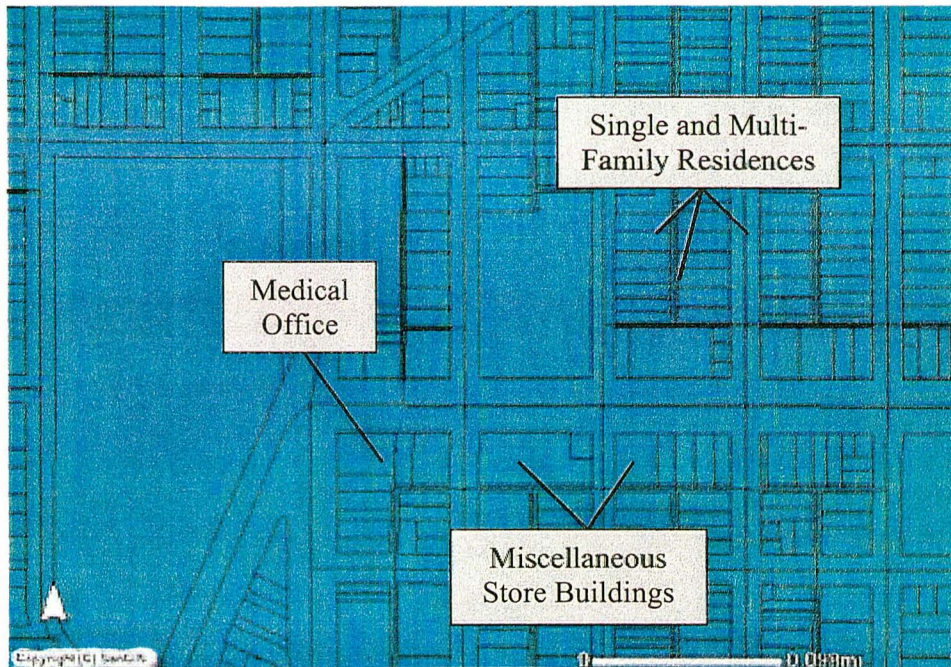
Figure 2. GIS data for individual buildings within the small commercial/residential neighborhood.

The next step in identifying potential µGrid customer combinations is to ascertain the end-use energy loads of each individual customer type as a determinant of their potential role in a µGrid. By assigning energy end-use load data to a map of individual customers, the energy intensity and hours of use appropriate to a specific customer type can be spatially analyzed, and customer combinations with complementary energy loads can be identified based on their proximity to each other.

A key consideration in identifying complementary energy loads is related to a finding from previous work with DER-CAM, which showed that the economics of distributed generation correspond closely to a customer's electricity load factor.[6] The load factor is a measure of the total electricity consumed relative to the electricity that would have been consumed if the peak load were sustained throughout a given time period. A high load factor implies that electricity load varies little over time, and a load factor of 100 percent represents a constant load throughout the time period. A high load factor would correspond to a high capacity factor for installed generation technology, providing a large economic incentive for on-site generation. Therefore, complementary electrical loads within a µGrid are buildings whose hours of peak usage vary from each other throughout the day. For example, an office building and a sit-down restaurant have complementary electrical loads because the office tends to have peak usage in the afternoon, and the restaurant has peak usage during evenings and weekends.

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[6] See Marnay et al., 2001

A second type of complementary building load allows customers with high electricity usage but low heat loads to share waste heat with neighboring customers that have high thermal demands. One example would be a neighborhood with retail stores or office buildings that have high daytime electrical usage rates located near a building with a high daytime heat sink, such as a hospital. A GIS analysis of the proximity of buildings with complementary heat and power loads is especially important, because of the relatively high losses associated with heat distribution.

Although the work conducted for this project focuses on the energy benefits of certain customer combinations, it is also important to consider the role of individual customers with exceptional power quality or reliability needs. Siting generation or storage close to these sensitive loads is likely to provide considerable benefits to the μGrid. A spatial analysis that identifies sensitive loads could be incorporated into the identification of complementary energy loads, to address two potential benefits of the μGrid simultaneously.

2.2 Local Land-Use Issues

Once energy loads have been quantified and the economically attractive distributed technology combinations chosen by DER-CAM, other obstacles or advantages to siting the chosen technologies in a specific location can be identified. This second analysis step is based on zoning classifications of the specific μGrid site in question. GIS data from the San Diego Association of Governments (SanDAG) classify regions of the county based on general land-use patterns, such as commercial, industrial, or single- or multi-family residential districts. These data complement the individual building data from SanGIS and contain the zoning patterns of the county, indicating regions of distinct building or noise ordinances.[7] Figure 3 shows an example of these zoning data from SanDAG for the same neighborhood represented in Figure 2 above.

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[7] For an example of San Diego zoning ordinances, see Appendix F.
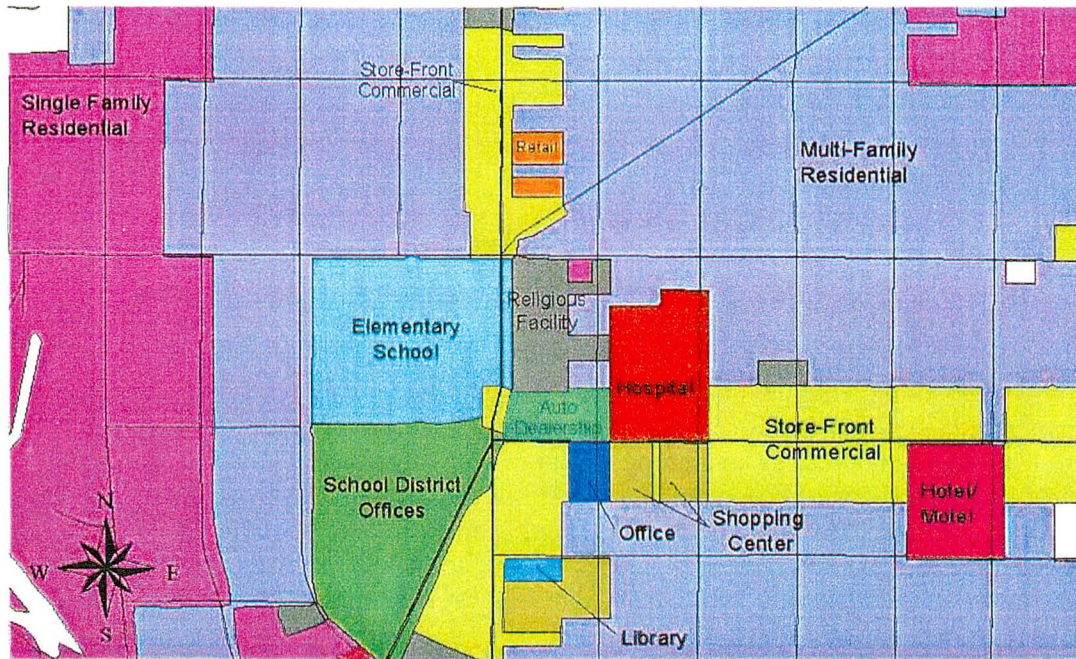
Figure 3. Land-use variation within the small commercial/residential neighborhood. Zoning boundaries as well as large individual buildings are shown.

Once zoning patterns for a particular neighborhood are known, land-use restrictions applicable to distributed generation can be referenced in city or county zoning ordinances. These include noise or air quality limits, useable open space requirements, and restrictions on crossing public rights-of-way. Other equally important siting constraints that are not related directly to zoning ordinances are the density of buildings and the availability of open space to install a generator, the physical limitations on the transfer of generator waste heat, the shading of photovoltaic systems by tall buildings, access to high-pressure gas lines, and weaknesses of the utility distribution system that may provide added incentive for installing DG. All of the above constraints can be identified and quantified, if applicable, using a GIS.

3. Project Implementation

This section describes the specific steps in the analysis of μGrid potential in San Diego. This research was conducted from February through December 2001.

3.1 Summary of Completed Tasks

The following tasks were completed:

- An initial analysis of San Diego County was conducted using GIS zoning and land-use data from SANDAG (as shown in Figure 3 above) to find three example areas with different building combinations and land-use characteristics in which to place a hypothetical μGrid. At this stage of the analysis, the emphasis was on finding the following: neighborhoods containing buildings with large thermal needs such as hospitals or laundromats, customers with late-night or 24 hour loads such as bakeries or certain industries, regions of industrial zoning, and customers with sensitive loads requiring high reliability. Because of the limits of the SANDAG database, some of these characteristics could not be identified, so best-guess estimates of building type were used. The three areas below were chosen because they represent neighborhoods with different zoning, which determines the land-use restrictions that customers in the area are subject to. In addition, the zoning designation for an area gives an indication of the energy requirements of a customer located there.
  - Small Commercial/Residential: This neighborhood contains a mix of single-family and multiple-family housing units, small retail sites, a small hospital, and some office sites including a medical office building.
  - Industrial: This area has no residences and contains industrial-zoned businesses such as auto repair shops, a bottling plant, a construction supply firm, and warehouses. In addition there are small office buildings, some bars and restaurants, and a telephone exchange that is classified as a sensitive load.
  - Downtown Office/Retail: This area contains large office buildings and several retail stores, a large hotel, and several sit-down and fast food restaurants.

- Once three regions with varying characteristics were identified, GIS data for individual land parcels in each neighborhood were purchased from the SanGIS database (see Figure 2 and Appendix E).

- In some instances, parcel metadata from SanGIS (which describe site characteristics other than a parcel's geographic location) were not sufficient to determine the specific customer type at each location, which is the key determinant of energy end-use loads in this project. For example, a copy store and a 24-hour mini-mart are both classified as miscellaneous store buildings, but they have very different energy-use patterns. Therefore, the SanGIS database was supplemented by in-person surveys of the San Diego sites. Information was collected on the specific commercial and industrial uses of each site as well as individual customer locations within strip malls that are classified as single parcels.

- A detailed energy-use analysis was conducted for the small commercial/residential example μGrid. The area contained approximately 25 commercial customers and 40 residences. These customers were divided into 10 building types based on distinct energy needs. Energy load-shape data representative of these 10 building types were collected from a variety of sources and compiled in an Excel database. In general, energy-load data are proprietary and difficult to obtain. Additional difficulties were encountered because distinct end-use metered load data were needed for electricity and natural gas, but natural gas is rarely metered on an hourly use basis. The primary source of electricity load data is a database collected by Southern California Edison (SCE) of 53 commercial customers in the SCE service territory. Daily load shapes were combined into monthly week- and weekend-day averages, and electricity use attributable to cooling was extracted as a distinct load profile. Some estimations and manipulations to measured data were required where there were missing data or where customer types did not correspond to any available measured data. In the latter instances, load shapes were constructed from measured data of applicable end uses (such as lighting) and estimated additional energy use by appliances characteristic of that customer type (such as washers and dryers for the laundromat). For building types with unusual hours of operation (such as 24-hour markets or late-night stores), the early evening loads of measured businesses were extrapolated to include late evening hours. Natural gas load data were created using DOE-2, a building energy simulation program developed at Berkeley Lab. The correct floor area for each building was input to DOE-2, end-use loads appropriate to each customer type were selected, and the program was run. The output data were then averaged into the same monthly format as the electrical loads. It should be emphasized that the energy data used do not represent actual usage by any of the customers in this analysis; these data were obtained from commercial databases and other metered customers in the southern California area. For more information on preparation of building load shapes, see Appendix B.

- Five energy end-use loads are of importance to this study, as mentioned above. These are cooling loads, electricity-only loads, hot-water loads, space-heat loads, and gas-only loads. These five end-use load sets were collected for each of the 10 building types for a total of 50 energy load sets.[8] The Excel database contains energy end-use data in units of W/m^2. Final energy loads were obtained by inputting the total area for a given building type as calculated by a GIS, using the approximation that each building takes up 75 percent of the total property area. This is a straightforward and flexible method of calculating energy loads for different building combinations within the μGrid.

- Energy load data were compiled for five different cases of the small commercial/residential μGrid and run through the DER-CAM model. These five cases are:
  - Base-case μGrid: The entire μGrid was compiled with all 10 building types and their actual floor area to reflect the existing land use at the site.
  - Double-size μGrid: This case entailed doubling the size of all the buildings in the μGrid to reveal potential economies of scale.

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[8] A single load set contains two representative day types (weekday and weekend) for each month of the year.

- No-residences μGrid: This case eliminated the residential buildings from the μGrid because of the different rate structures of residential customers and the potential complication of aggregating and retrofitting a large number of small residences.
- Hospital and laundromat cases: These two customers were analyzed individually to address the question of whether or not it would be beneficial for certain customers, especially those with high heat loads, to install DG independently.

- DER-CAM analysis was done for each of these cases under two different energy-purchase scenarios: the SDG&E time-of-use (TOU) tariff rate[9] and a do-nothing scenario where no DG is installed. These results are discussed below in Section 4.1.

- Next, a limited GIS analysis of local land-use constraints was conducted. DER-CAM results showing the distributed technologies that are economically appropriate for the μGrid example were incorporated into a GIS and overlaid with a zoning map of the neighborhood. The resulting map reveals areas of conflict between the DG technology chosen by DER-CAM and local zoning requirements. Three land-use constraints were considered: available space for generator siting, physical constraints on CHP heat transfer, and the effect of generator noise on local noise-sensitive buildings. First, the footprint of the DG technologies chosen by DER-CAM was calculated and compared with a GIS map of individual buildings. A building was assumed to be large enough to house a generator if the generator footprint was less than 1 percent of total building space. From these available sites, distance measurements were made to the farthest buildings and to the buildings with the highest heat sinks, and approximate heat-transfer losses were calculated. Then, generator noise levels at equal distance intervals were calculated based on generator specifications (which give noise level at a single distance) and the assumption that generator noise would dissipate as it does for a single point source.[10] Buffer zones were placed around the potential generator sites at these distance intervals to determine whether noise interference would be a deterring factor for sensitive buildings such as the hospital and local residences. The purpose of this portion of the analysis is not to quantify these issues from a technical or engineering standpoint but to determine what the general magnitude and effect of land-use constraints would be on neighborhoods with similar development patterns and to exemplify the use of a GIS to solve such problems. Results for the GIS portion of this analysis are discussed below in section 4.2.

3.2   Additional Data and Assumptions

The following cost assumptions and data sources were used in addition to those described above:

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[9] See Appendix G for SDG&E tariff rates.

[10] Starting from the definition of decibel level, $dB = 10\log(I/I_0)$ where $I = P/4\pi r^2$, P is the power in the sound wave, and I_0 is a constant reference intensity of $10^{-12} W/m^2$, the difference in decibel level between two points located at different distances from a point noise source is derived to be $dB_1 - dB_2 = 10 \log (r_2/r_1)^2$ where r is the distance from the point source.

- Cost and technology data for several commercially available distributed generation technologies were used for input to DER-CAM. These data were collected primarily from manufacturers or retailers and include technology lifetime, variable and fixed operating costs, generator heat rates, and emission output rates of NO_X and PM. Most of these are year 2000 values, which is when the data were collected. A table summarizing these technology data is included in Appendix D.

- The cost of purchasing electricity from the utility is calculated from SDG&E year 2000 tariff rates. A table of these tariff rates is included in Appendix G. In addition to these standard tariff rates, customers are assumed to pay a distribution service charge of $0.036/kWh on electricity purchased from the utility.

- The cost of natural gas is assumed to be $8.66/GJ.

- The interest rate on technology investments is assumed to be 7.5 percent.

4. Results

4.1 DER-CAM Results

In the small commercial/residential example neighborhood, five building combinations were analyzed as discussed above in section 3.1. These five cases are meant to illustrate the potential advantages of complementary energy loads in μGrid planning.

Figure **4** below shows the five January weekday energy-load inputs for the base-case small commercial/residential μGrid, which represents all 10 building types at the site and their existing floor area as measured by a GIS. The space-heat, hot-water, and cooling loads are met through the use of waste heat when it is available, but the electricity-only load must be met with on-site or purchased electricity, and the gas-only load must be met by purchased natural gas. Figure 4 shows an electricity load factor of 75 percent for this January day; the highest peak electricity use for this μGrid is 886 kW on a July weekday.
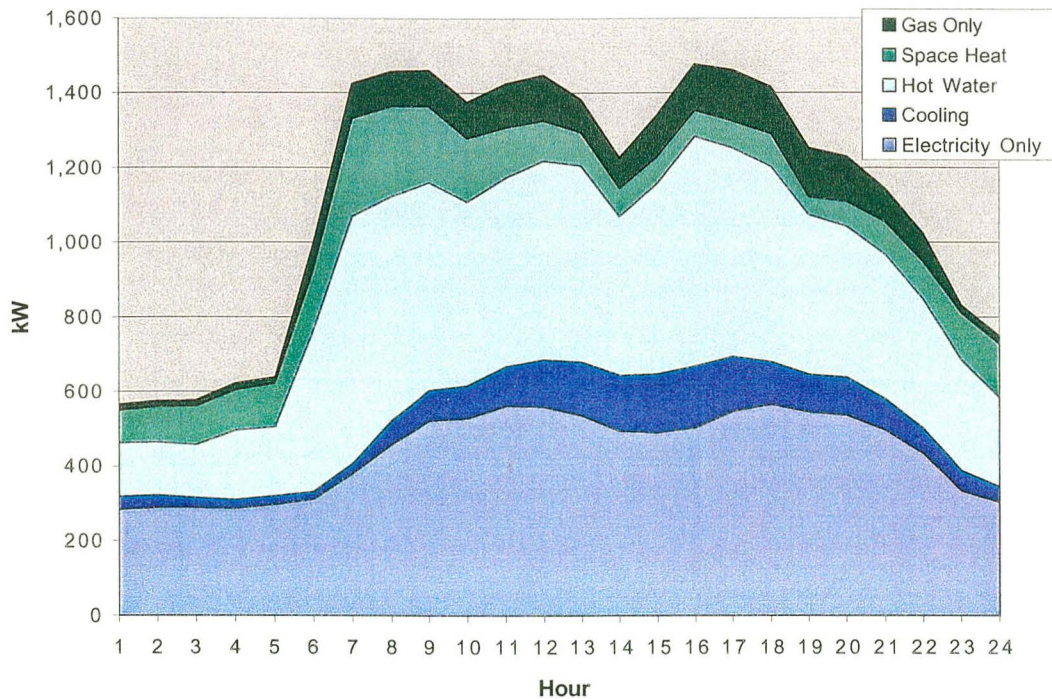
Figure 4. January weekday energy load inputs for the base-case small commercial/ residential μGrid.

The load inputs for the base-case μGrid are compared with the energy inputs for the laundromat, one of the two buildings that were analyzed independently (see
Figure **5** below). Figure 5 shows a low electricity load factor of 50 percent for the laundromat, and a comparatively high ratio of gas use to electricity use, including a large gas-only load for dryer heat. The peak electricity load for the laundromat never exceeds 17 kW.
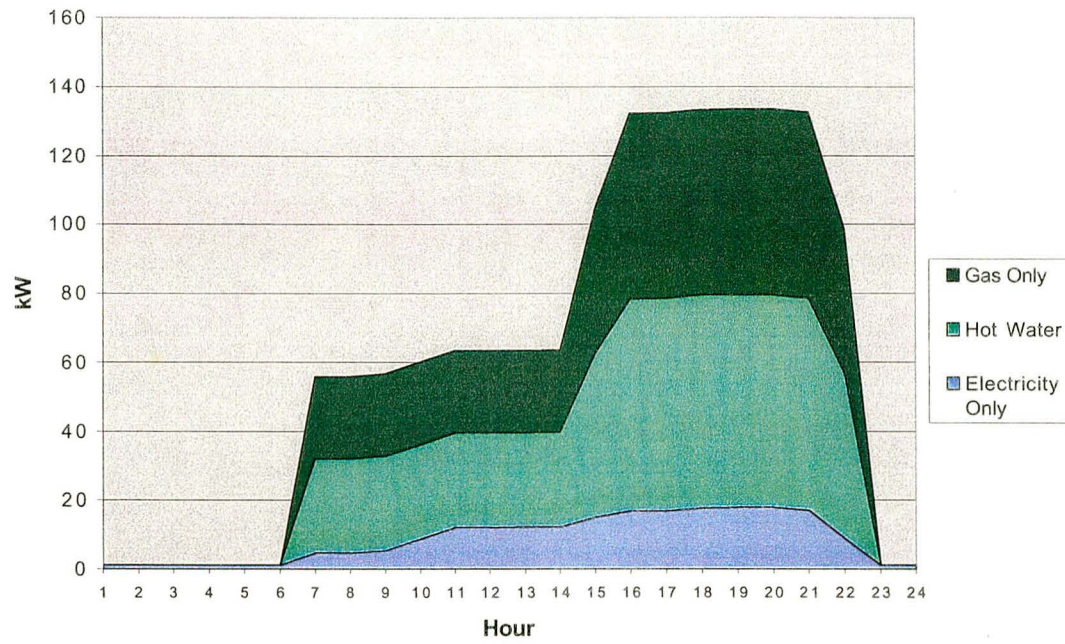
Figure 5. January weekday energy load inputs for the laundromat. Inputs are simplified, assuming no central HVAC.

Table 1 below shows the results from the five DER-CAM runs of different building combinations within the small commercial/ residential μGrid. Three cases represent variations on the base-case μGrid, and two cases analyze individual buildings within the μGrid.

Table 1. Results for the five cases of the small commercial/ residential μGrid

	μGrid (Base-Case)	μGrid (Double Size)	μGrid (No Residences)	Hospital Only	Laundromat Only
Installed Capacity (kW)	775 kW	1,555 kW	775 kW	330 kW	25 kW
Peak Electric (No Demand Reduction)	886 kW *July weekday*	1,772 kW *July weekday*	854 kW *July weekday*	406 kW *Jan weekend*	17 kW
Peak Electric (Cooling Demand Reduction)	730 kW *July weekday*	1,463 kW *July weekday*	706 kW *July weekday*	395 kW *Jan weekend*	*No cooling technologies*
Percent of Peak met by DG[a]	All	All	All	84%	All
Electricity Load Factor[b]	75%	75%	75%	79%	50%
Installed Technologies[c] (Number of Generators)	CHPGA-K-55 (5) COOLGA-K-500 (1)	CHPGA-K-500 (1) CHPGA-K-55 (1) COOLGA-K-500 (2)	CHPGA-K-55 (5) COOLGA-K-500 (1)	CHPGA-K-55 (4) COOLGA-K-55 (2)	CHPGA-K-25 (1)
Average COE[d] ($/kWh)	0.068	0.069	0.080	0.049	0.075
Percent of Total Gas Load met by CHP[e]	81%	81%	81%[f]	84%	36%
Percent of Potential CHP Load met by CHP[g]	95%	95%	95%	94%	67%
Cogeneration Savings ($/GJ)[h]	7.04	7.01	7.04	7.35	3.09

[a] After cooling demand reduction

[b] Calculated for January weekday, prior to cooling demand reduction

[c] See Appendix D for the database of DER-CAM technologies. A CHP prefix means the generator waste heat can be used for heat loads; a COOL prefix means the waste heat can be used for absorption cooling.

[d] The average cost of electricity is the total annual electricity bill divided by the total annual electricity load. Total bill includes fuel costs, levelized investment costs, variable and fixed O&M, and electricity purchased from the utility.

[e] This is the percent of gas-only, hot-water, and space-heat loads met by CHP on an annual basis

[f] Assumed that residences do not have retrofits for CHP; therefore, electricity demand and not heat demand account for any difference with the basic μGrid.

[g] This is the percent of hot-water and space-heat loads met by CHP on an annual basis.

[h] Savings calculated based on a natural gas price of $8.66/GJ.

Cogeneration Savings = (Total annual heat load met by CHP/Total annual heat load)*$8.66/GJ = $/GJ saved

The following figures show the distributed technologies adopted in the base-case and the loads that are met by each technology. The generators that are commonly installed are the 55- and 500-kW natural gas reciprocating generators (GA-K-55 or 500),[11] retrofitted with cooling or CHP technologies.
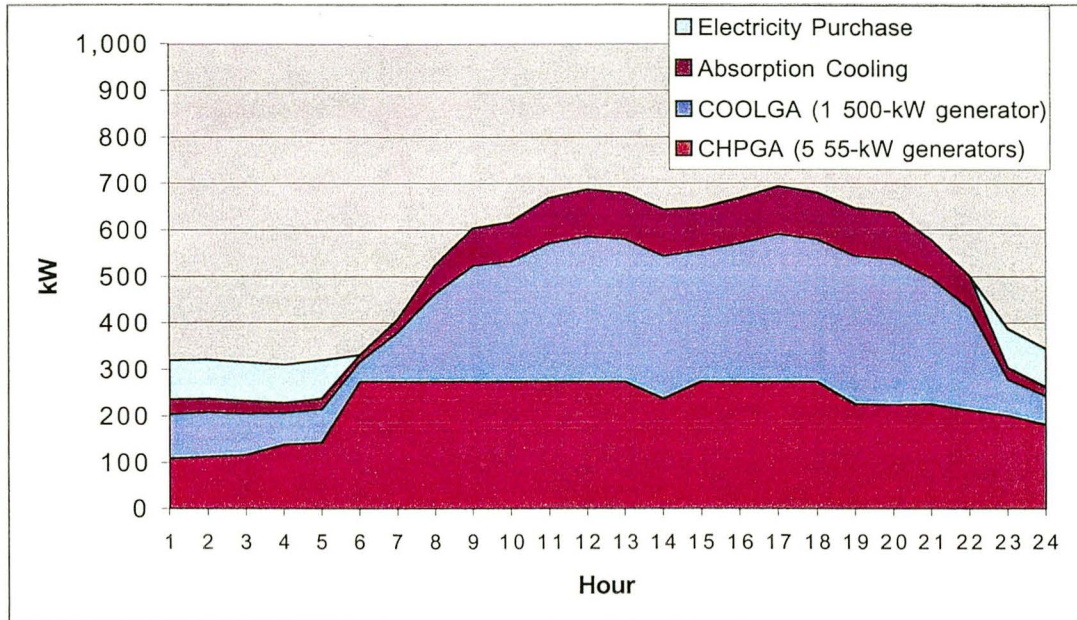
Figure 6. How January weekday electricity loads are met in the base-case μGrid.

The absorption cooling band represents a demand reduction as electricity cooling loads are displaced by absorption chillers. Though not shown in any of the examples here, this absorption cooling demand reduction also has the potential to transfer the peak electricity days from summer to winter, because summer electricity peaks are attributable primarily to cooling loads while other electric loads, such as lighting, are lower. Figure 6 shows that, on this day, 95 percent of the electricity loads are met with on-site generation or demand reduction, although the μGrid continues to purchase electricity from SDG&E during the cheapest times of the day (i.e., hours between 22:00 and 5:00 when TOU tariff rates are lowest).

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[11] For a complete listing of all technologies in the DER-CAM database, see Appendix D
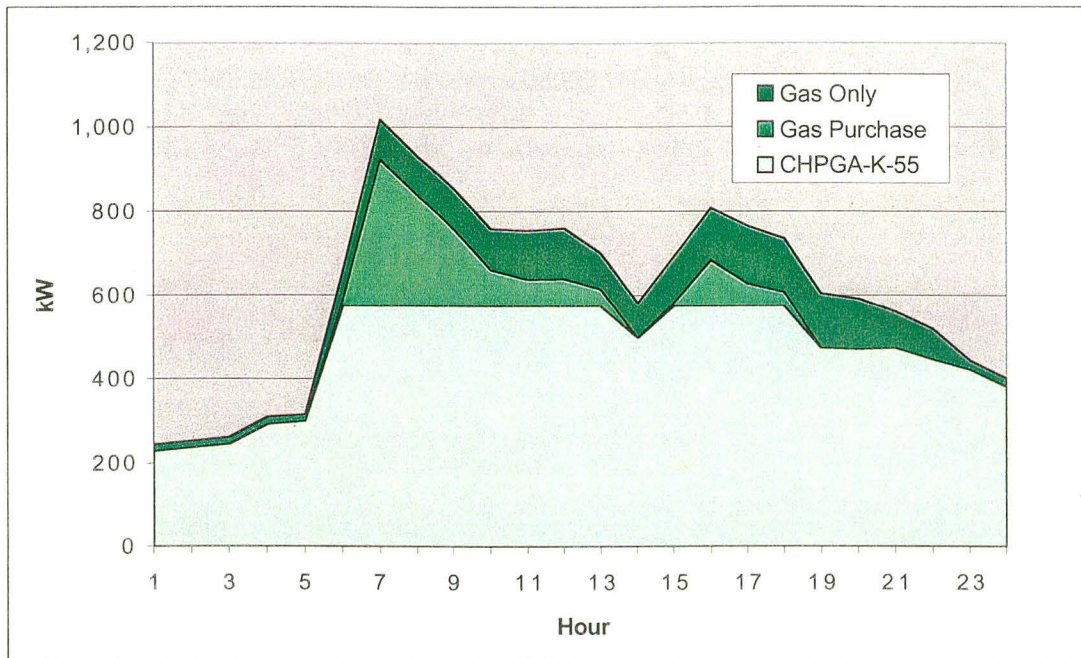
Figure 7. How January weekday natural gas loads are met in the base-case μGrid. The CHP output shown in the lowest band is supplied by five 55-kW generators.

Figure 7 shows how natural gas loads are met in the base-case μGrid. On an annual basis, CHP accounts for 81 percent of all gas loads and 95 percent of the hot-water and space-heat loads that can potentially be met by CHP. The μGrid is required to purchase additional gas, especially in the early morning hours when hot-water and space-heat loads are large but electricity demand has not reached its peak.

Figure 8 below shows capacity installations for the five example cases. All cases other than the hospital install on-site generation that can meet their highest electrical peak during the year although no example µGrid disconnects completely from the utility grid.
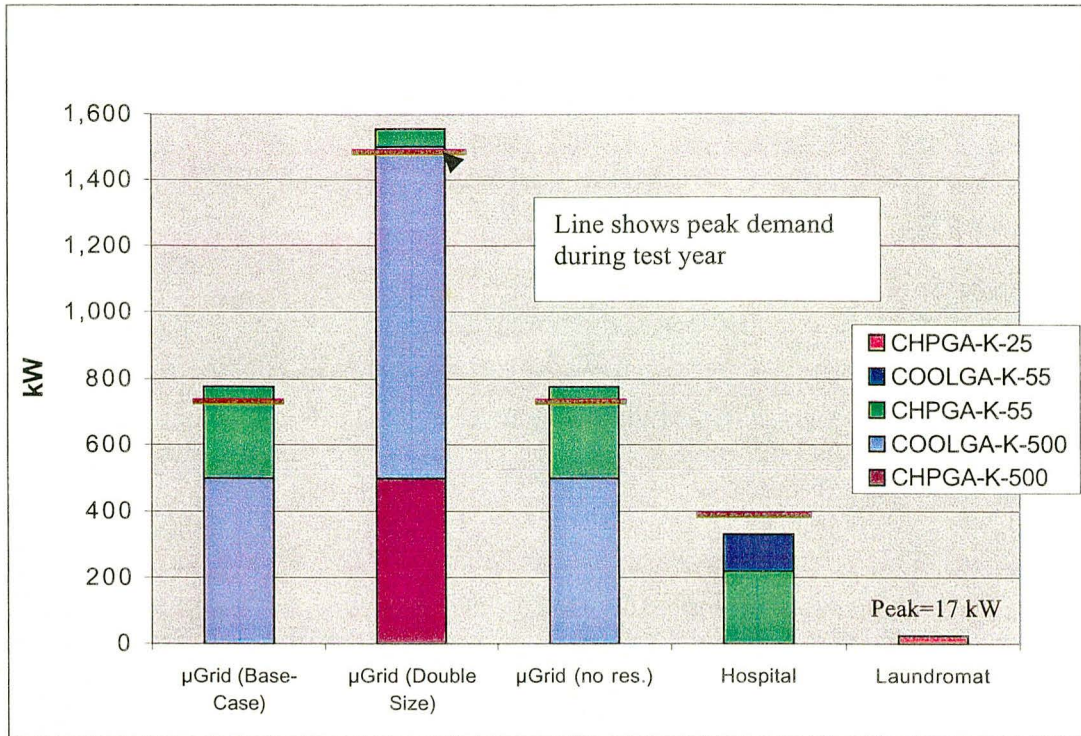
Figure 8. Installed capacity for the five µGrid cases in the small commercial/ residential neighborhood. More than one piece of equipment may be included in a single band (e.g. the light blue column for the double-size µGrid represents two 500-kW generators.)

A comparison of the economics of the five cases can be made by looking at the average cost of electricity (COE) and the cogeneration savings for each customer. The average COE is the total annual electricity bill divided by total annual electricity use where the electricity bill is a function of generator fuel costs, levelized investment and fixed costs, variable O&M, and electricity purchases. The average natural gas cost is equivalently the total gas bill divided by the total gas load where the gas bill is determined by the cost of gas purchases for all uses other than generator fuel (i.e. the gas bill includes purchases for gas-only loads and heat loads not met by CHP). This value assumes a baseline natural gas cost of $8.66/GJ. The average natural gas cost reflects the savings achieved as CHP displaces gas purchases; the potential savings are lower for customer's with large gas-only loads.
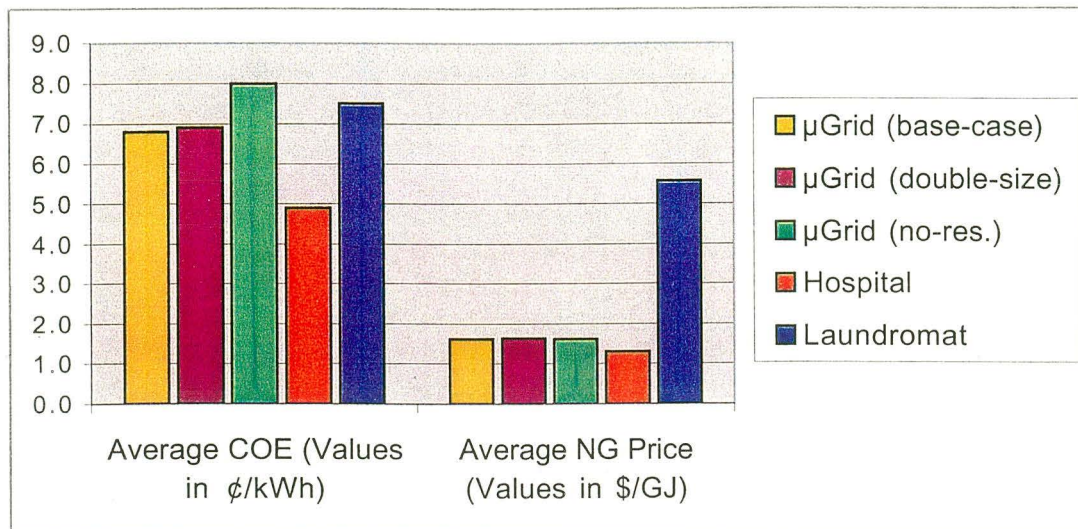
Figure 9. Average cost of electricity and natural gas for the five cases. The average natural gas cost does not include fuel purchases. The baseline natural gas cost is assumed to be $8.66/GJ.

The average COE for the base-case µGrid and double-size µGrid are 6.8 and 6.9 ¢/kWh, respectively. These costs show that, for the double-size µGrid analyzed here, economies of scale do not make a significant difference in the overall COE, although the technologies adopted are different for the double-size µGrid than for the base-case µGrid (500-kW rather than 55-kW generators). The highest COE case is the no-residence µGrid where the technology investment is the same as for the base-case µGrid (see Figure 8) but there are fewer kWh over which to spread the levelized generator costs. This demonstrates the benefits of complementary electricity loads, because residential electricity use is highest in the early evening, and the peak use of commercial and office customers is in the afternoon. Results show that the average COE is lowest for the hospital at 4.9 ¢/kWh, which does not provide a strong incentive for the hospital to connect to the larger µGrid. The laundromat, however, saves an average of 0.7 ¢/kWh by purchasing electricity through the µGrid (base-case).

There is no significant variation in gas costs among the three µGrid cases ($1.62-$1.65 per GJ). The cogeneration savings are again highest for the hospital, which is able to displace 84 percent of its gas load with CHP (see Table 1). The laundromat makes a poor case for installing on-site generation independently from the rest of the µGrid. Though the laundromat has high heat loads and could benefit substantially from the use of CHP, it has the highest relative gas-only load and therefore displaces only 36 percent of its total gas load with CHP. In addition, the low electrical load of the laundromat precludes the benefits of CHP since generator electricity production is never high enough to produce adequate waste heat. This result demonstrates another benefit of complimentary energy loads, since the laundromat realizes greater economic benefits by sharing electricity and waste heat from larger generators with other customers in a µGrid. These two individual customer cases demonstrate the large variability in the economics of DER adoption, which depends on the size of the customer and the ratio and overlap of electricity and heat loads as a determinant of potential CHP benefits.

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4.2 GIS Results

Figure 10 is a map of the small commercial/residential neighborhood showing individual buildings as they were classified for energy end-use purposes. The land parcels show property boundaries, which may include parking spaces, walkways, or other outdoor areas such as lawns and gardens.

Parcels_uc.shp
- Hospital
- Laundromat
- Office 1
- Office 2
- Residential
- Restaurant 1
- Retail 1
- Retail 2
- Retail 3
- Retail 4

Figure 10. GIS map of individual buildings, classified according to their energy needs. For more detail on each of the building classifications, see Appendix B on load-shape preparation.

First, a GIS was used to identify the buildings large enough to accommodate a generator. The largest generator chosen by the DER-CAM model for this neighborhood is a 500-kW natural-gas reciprocating engine. According to manufacturer specifications, the footprint of this generator is 34 m^2. To judge the available siting space, it is assumed that the generator cannot occupy more than 1 percent of the building floor area. Furthermore, it is assumed that the generator would not be sited at a residence. These constraints left five possibilities for generator location: the hospital, three retail sites, and a large medical office building. These sites are shown in Figure 11 highlighted in yellow.

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Figure 11. Possible locations for the 500-kW natural gas generator: the hospital, a large medical office building, and three retail sites.

Next, an approximation of the feasibility of heat transfer from the five possible generator sites was made. The distance was measured between each site and the rear of the hospital, which is the largest heat sink in the μGrid and the most distant building requiring CHP. Heat-transfer loss is a considerable constraint when constructing energy-supply networks on the scale described here. Reasonable transfer distances for this type of CHP are assumed to be on the order of 100 to 200 m.
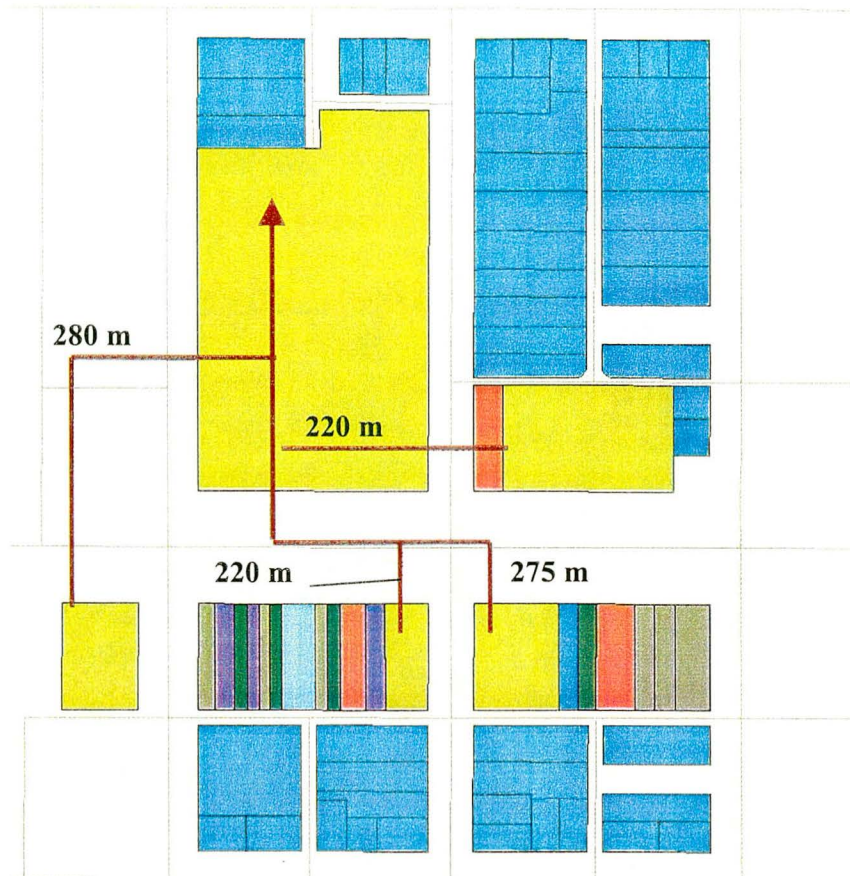
Figure 12. Measured distances between potential generator sites and the hospital.

As shown in Figure 12, the required heat-transfer distances for this particular example are relatively large, and the heat loss may be significant without considerable retrofits and insulation. This suggests that heat-transfer losses should be addressed directly in further studies of the economic feasibility of on-site distributed generation, optimizing the economic tradeoffs between heat-transfer loss and insulation upgrades. The economics of heat transfer can be quantified and included as an optimization parameter in DER-CAM.

In the third step of this analysis a GIS was used to address local noise restrictions. This particular neighborhood has commercial zones located adjacent to residential zones; the latter have more restrictive noise regulations. (A description of San Diego noise ordinances is included in Appendix F.) DER-CAM results show that on-site generation would operate throughout the entire day and must therefore conform to the most restrictive noise level of 50 decibels between the hours of 22:00 and 7:00.[12] Manufacturer specifications give the noise levels of the three generators selected by DER-CAM (25-, 55-, and 500-kW natural gas engines) as 76, 79, and 93 dB at 7 m, respectively. The corresponding dB levels at different distances can then be calculated by making the simplifying assumptions that insulation will quiet the

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[12] San Diego noise ordinances indicate that a noise source located on the border of two zoning districts must conform to the arithmetic mean of the standards for the two districts. Here, that value is 50 dB.

generators by approximately 25 dB and that generator noise emanates from a point source.[13] Distances of 20, 40, and 60 m are chosen as representative examples, and the dB value at each of these points is calculated. The minimum distance at which the 500-kW generator noise will be reduced to the maximum allowable level is 60 m. The magnitude of noise interference with local residences is determined by adding equidistant buffer zones to potential DG sites and approximating the noise level in each region. Figure 14 shows these noise buffers around the hospital and a retail store and the potential overlap with local residences.

	20m	40m	60m
25 kW	42 dB	36 dB	32 dB
55 kW	45 dB	39 dB	35 dB
500 kW	59 dB	53 dB	49 dB

Noise Values in the Three Buffer Areas

Overlap with local residences

Hospital

Retail
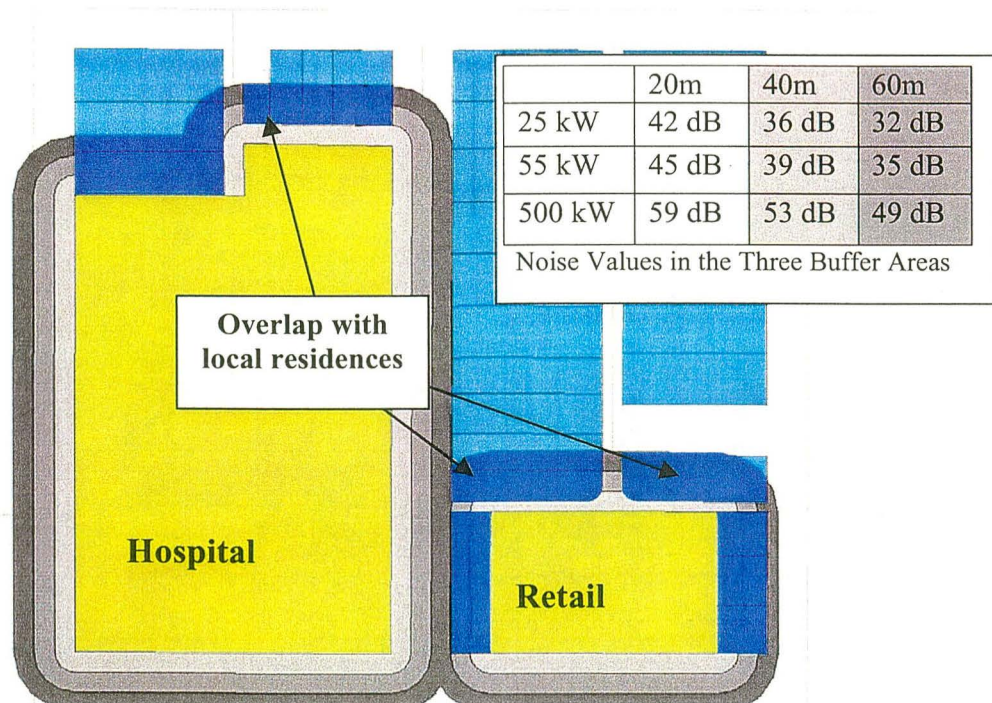
Figure 13. Buffer zones at 20, 40, and 60 m showing noise dissipation over distance and possible interference with local residences.

Figure 13 shows that there will be some noise interference with residences in the area immediately surrounding the generator sites. Within a radius of 60 m from the retail store, at which point the 500-kW generator noise output would be reduced to 50 dB, three residential buildings and four commercial sites would be affected by a noise level higher than zoning regulations allow. The decibel values used in this example do not account for sound reflection off of buildings or additional sound-proofing retrofits that would almost certainly be used in a scenario like this one. However, the GIS analysis method exemplified here can be applied to any problem involving the dissipation of noise or emissions over distance, no matter what absolute values are used.

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[13] See the above section on completed tasks for a more detailed description of this calculation. For a reference on achievable levels of generator soundproofing see http://www.soundstop.com/soundstop.htm.

5. Summary and Future Work

5.1 Summary of Research

The research presented here shows how the DER-CAM economic optimization model of distributed generation adoption can be used in conjunction with a GIS analysis of local land-use constraints affecting the deployment of DER. Based on the premise that certain customers have complementary energy loads and would mutually benefit from shared on-site generation, a hypothetical μGrid was identified in the San Diego area and energy end-use loads were applied to the selected customers in the μGrid. Using these energy loads as inputs, the DER-CAM model identified various combinations of natural gas reciprocating engines as the lowest-cost options for the five μGrid cases analyzed. A GIS was then used to address three issues affecting the feasibility of deploying these generators at the San Diego site: the amount of available open space to house the generator, the possible energy losses from transporting generator waste heat among customers, and violation of zoning laws restricting noise. The methods described here exemplify the simple, straightforward manner in which a GIS can be used to identify, quantify, and convey spatial issues related to DER deployment.

The hospital proved to be a special case within the μGrid analyzed in this study. With large heat sinks and a relatively flat load, the hospital is a good candidate for installing on-site generation independent from the rest of the μGrid. However, the hospital is especially sensitive to local land-use restrictions. Generation technologies must be close enough to the hospital to minimize heat-transfer losses but also out of earshot of generator noise. A GIS map shows that the distance required for generator noise to dissipate to an allowable level, on the order of 60 m, is smaller than the 100 to 200 m distance at which heat-transfer loss becomes a problem. It might, therefore, be possible to avoid noise interference without serious heat-transfer losses. This may be enough of an incentive for the hospital to join the larger μGrid and use generators located away from its immediate surroundings.

5.2 Limitations of Data and Analysis Method

The primary purpose of this project is to demonstrate the ability of a GIS to model local land-use constraints to the siting of on-site distributed generation. The GIS portion of this project was conducted in conjunction with an economic analysis of DG adoption using DER-CAM. Thus, it was necessary to look at μGrid planning on an individual building scale because individual building energy loads must be quantified in order to address the energy and economic demands of a μGrid. However, in narrowing the geographic area for analysis to a small neighborhood scale, the ability of GIS to accurately analyze land-use constraints was limited. This is primarily because of the limitations on publicly available GIS data, which are collected and shared mainly for the purpose of conducting geographic analyses on a city-wide or larger scale. The GIS data provided by SANDAG were collected mainly to reflect variation among neighborhoods, not within them. Individual building data from SanGIS identify property boundaries by building owner but do not distinguish individual tenants within commercial sites or details such as parking lots or open spaces within a single property. This level of detail is required to study the land-use constraints addressed in this project. Therefore, several assumptions were made about the buildings in the μGrid to fill in these gaps. This analysis is not

intended as a literal suggestion, but as a template to show the potential contribution of a GIS to solve distributed generation siting issues. The real asset of a GIS is its ability to conduct city-, county-, or state-wide assessments of potential DG sites.

5.3   Future Work

It was beyond the scope of this project to analyze in detail the economics of all three example μGrid neighborhoods. Because much of the initial GIS analysis of these neighborhoods has been completed, however, it is a logical next step to further compare the distributed generation adoption potential of the industrial area and the downtown office/retail area. Also, a closer look at building turnover patterns within the neighborhoods would help quantify the economic and land-use impacts of changing end users. It is quite possible that buildings will change within the μGrid over the 15- to 20-year lifetime of the adopted DG technologies, so sensitivity to this type of variation is an important determinant of the economic feasibility of DG investment.

Several land-use constraints with wide impacts on distributed generation potential were not addressed in this study. These include customer access to high-pressure gas lines, existing constraints within the electricity infrastructure, and geographical or meteorological influences on renewable energy systems. These constraints were not analyzed partly because of the sensitivity of the applicable data, but they are nonetheless important factors that should be considered in future work if data become available.

An assessment of μGrid development potential must account for different local constraints depending on whether existing buildings are retrofitted or a μGrid is incorporated into the planning of new development. This is certainly true not only from an electrical engineering standpoint but also for land-use constraints and the energy profiles of local end users. Neighboring buildings within developed cities have different land-use patterns than new development sites, where buildings tend to be larger and grouped together by similar building types, such as tracts of residential homes, strip malls, or large office complexes. For this reason, it would be worthwhile to consider μGrid potential in areas of current development using the tools described here.

As mentioned above, the GIS portion of this analysis depends on detailed building-specific data for individual neighborhoods. GIS also has great potential to address local constraints on a larger scale. Making a large-scale geographic comparison of influences such as areas of new development, access to high-pressure gas, climate variation, distribution constraints, and areas of high electricity cost, one can first identify promising regions for DG adoption and then address the economics of each specific region.

The broad goal of this effort is to develop a tool that can forecast the likely deployment of DER in μGrids. This GIS-driven approach is a counterweight to DER analyses that rely on macro characteristics of the economy and the installed base of host sites. Through detailed analysis of sample areas we hope to develop a more general method, where GIS is applied on a larger scale using automated processing of GIS data for identification of potential μGrids.

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The above reports are available at http://eetd.lbl.gov/ea/EMS/EMS_pubs.html

Appendix A: San Diego μGrid Example Cases

Below are brief descriptions of the three San Diego μGrid example sites analyzed in this study and the customer types included in each. The small commercial/residential site was analyzed in more detail than the other two sites for this report.

A.1   Downtown Office/Retail

This area is dominated by a large office building and retail shopping center and is characterized by a lack of late-night loads. Customer types in the office/retail area include:

- a large office building containing a mixture of businesses;
- a large retail shopping center;
- a hotel encompassing two sites with a total of approximately 500 rooms;
- a movie theater;
- several fast food restaurants characterized by lunchtime peaks;
- a supermarket;
- a bus depot/transit center.
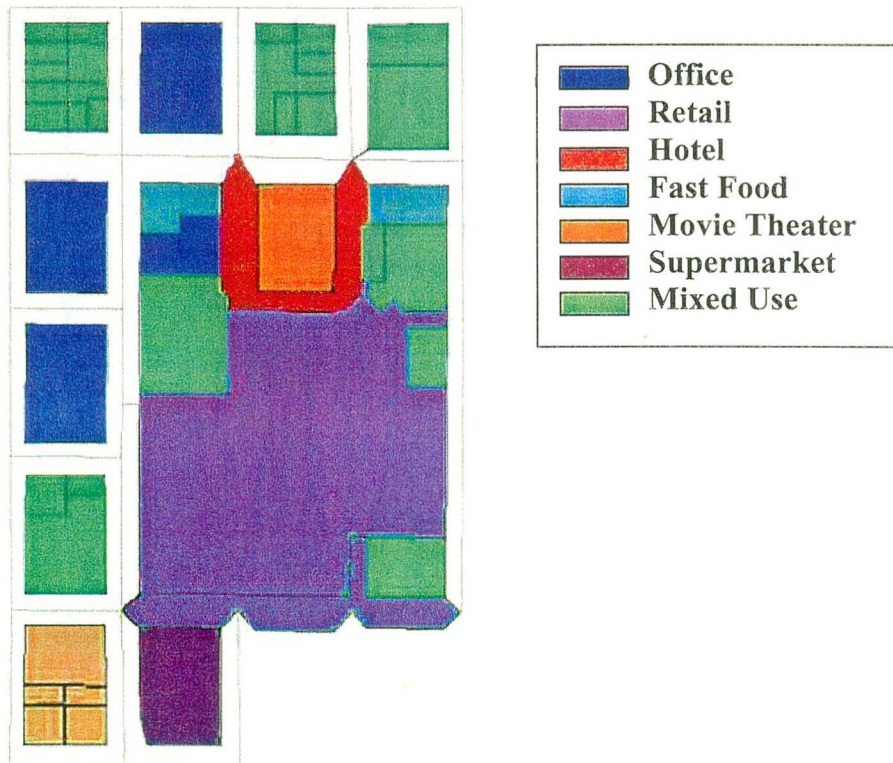
Figure A-1. Map of buildings in the downtown office/retail area.

A.2 Small Commercial/Residential

Customer types in the commercial/residential area include:

- office buildings with typical business hours and loads, including an insurance agent and a property management company;
- a medical office building with typical business hours but higher-than-normal loads because of medical equipment;
- approximately 45 small residences in the surrounding blocks;
- retail stores with typical business hours (10:00-18:00) and non-energy-intensive retail services, e.g., a clothing retail store;
- retail stores with higher-than-normal electricity loads for services such as copying and printing;
- retail businesses that are open late hours, such as a video store;
- retail stores with higher-than-normal heat loads, including a hair salon and a spa;
- restaurants serving lunch and dinner;
- a small hospital with emergency services;
- a laundromat containing 50 clothes washers and 40 dryers.

Figure A-2. Map of buildings in the small commercial/residential area.

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A.3 Industrial

This area contains open lots and warehouse spaces good for DG siting. It also has a higher pre-existing noise level than the other two areas studied Customers in the industrial area include:

- auto dealerships and auto lots;
- repair shops including auto and boat repair;
- a warehouse;
- several small offices;
- a water bottling plant;
- some restaurants;
- a telephone exchange station characterized as a sensitive load.

Legend:
- Office
- Warehouse
- Restaurant
- Bottling Plant
- Telephone
- Auto Dealership
- Other Industry
- Miscellaneous
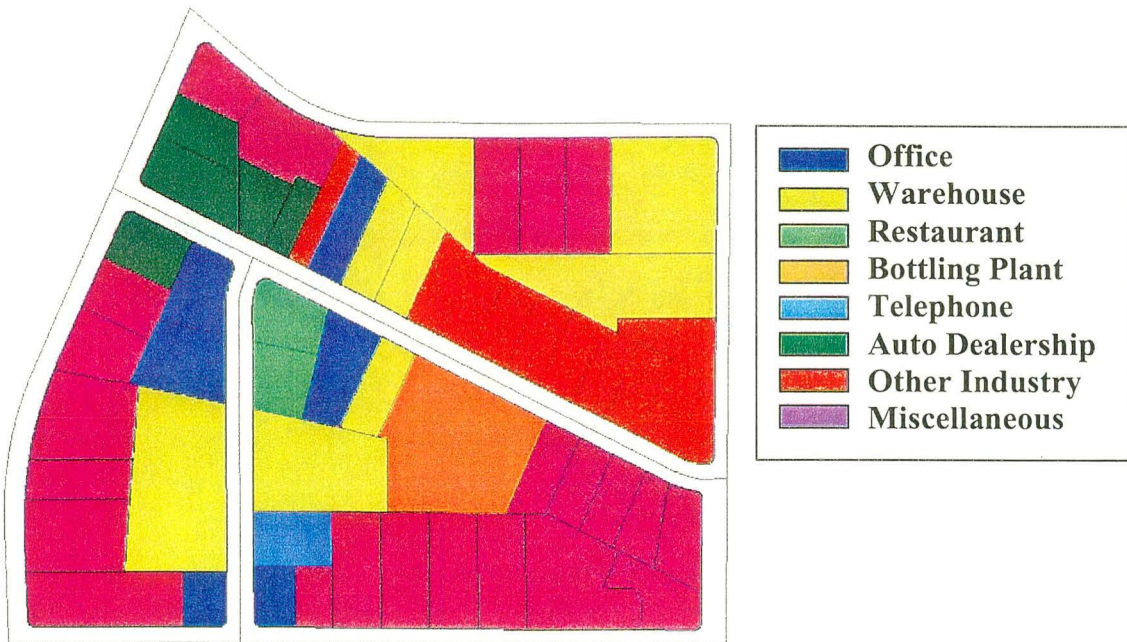
Figure A-3. Map of buildings in the industrial area.

Appendix B: Preparation and Selection of Energy Load Shapes

This analysis uses a combination of metered and simulated end-use load shape data. A set of actual customer load profiles is vital for producing credible results representing the cost-minimizing deployment of DER technology. End-use metered loads for commercial buildings are not widely available, however. Berkeley Lab had an available archived set of commercial hourly load data, collected by Southern California Edison (SCE) in 1988-1989 (SCE 1989; Akbari 1993). Even though these data were collected years ago, they are still valuable for the purposes of this study because end-use loads are unlikely to have changed significantly relative to the other uncertainties in this study. Berkeley Lab recovered these data and recreated load shapes to be used in current modeling efforts.

Unfortunately, the SCE data only include electrical loads, not natural gas loads. Nor could actual gas load data be found by any other means. Because natural gas is the main fuel used to provide building heat and hot water, two major products of CHP technologies, finding plausible data for these loads was critical for this study. DOE-2, which is a building energy simulation program developed at Berkeley Lab, was used to created these heating loads for the same weather year as the SCE data.

It is critical in this study to resolve the electricity and gas loads into end uses because only some end-use loads can be provided by CHP technologies. These include refrigeration and building cooling (HVAC) for electrical loads, and hot water and building heating for gas loads. The DER-CAM model was adjusted to meet these end uses with CHP when possible.

B.1 Data Description and Preparation

The initial version of the SCE electricity load data consisted of a statistical analysis system (SAS) data set containing hourly total load data and some end-use load data for 53 commercial premises in the SCE service territory. For confidentiality reasons, detailed information on the businesses was suppressed, but for most premises, business type, total floor area, conditioned floor area, and a corresponding set of hourly weather data were available.

These data were compiled into a database of total and end-use loads for most premises as follows:
- average weekday by calendar month (1 day type x 12 months)
- average weekend by calendar month (1 day type x 12 months)

Peak day averages, which were used in a previous DER-CAM analysis that examined only total electrical loads were not available for the electrical end-use data. The model was modified to use only week- and weekend day types. For each month of the year two sets of average hourly loads, weekday and weekend, were defined for each end use. For most buildings, electrical end uses, such as refrigeration, cooking, and HVAC, were measured separately. Not every property included data for each end use. Also, in most cases measured end use loads did not add up to the total load given for a specific property. To account for this "missing" electricity, an additional end use was calculated by taking the difference between the sum of the end uses and the total.

This "Residual" load accounts for electrical end uses that were not measured or for errors in data collection or recording. The end uses monitored are not consistent across all customer sites although the major end uses, such as lighting and HVAC, are always identified. The residual load also includes end uses that were measured in general but were not recorded for a given building. For this study, the "Residual" electrical load is considered an electricity-only load, or one that cannot be met by CHP.

Once the 10 building types analyzed in this study were selected, the DOE-2 model was run for each one to produce natural gas loads by end use. This entailed imputing the correct floor area for each building, choosing the appropriate end-use loads, such as cooking, hot water, and space heating (depending on the building type) and running the program. An output file was then produced, from which the appropriate end-use data were extracted, e.g., "Total Heating Watt" for space heating, or "DHW Heat Fuel Watt" for hot water for the Retail Store. DOE-2 is a complex simulation program, so each building type had to be treated separately. Because of the complexity of the model, the appropriate end-use parameters were not the same for each building. These data were then formatted and averaged into the same monthly format as the electrical loads. For the purposes of this analysis, it was assumed that only the hot-water and space-heat loads could be met by CHP. CHP technologies cannot reduce the gas-only load.

B.2 Additional Estimates

Some estimations and manipulations to measured data were required where there were missing data or where building types did not correspond to any available measured data. In the later instances, load shapes were constructed from measured data for applicable end uses (such as lighting) and additional energy use by appliances characteristic of that building type (such as washers and dryers for the laundromat). Additionally, for building types with unusual hours of operation (such as 24-hour markets or late-night stores) the early evening loads of measured businesses were extrapolated to include late evening hours.

B.3 Summary of Energy Data and Sources for Customers in the Small Commercial/ Residential Area

The table below shows the ten customer types in the small commercial/residential area, their energy-use characteristics, building floor area, and data sources for electricity and heat loads.

Table A-1. Energy Load Shape Data Sources

TYPE	CHARACTERISTICS	AREA[a] (m²)	ELECTRIC	HEAT
Residential	Typical	45 Residences	SDG&E[b]	N/A[c]
Office 1	Typical 9-5 hours	1,492	SCE	DOE-2
Office 2	Medical Office (higher load)	1,010	SCE	DOE-2
Retail 1	Typical 10-6 hours	3,398	SCE	DOE-2
Retail 2	Reg. hours, higher loads	418	SCE	DOE-2
Retail 3	Open Late/ 24 hour	1,706	SCE	DOE-2

TYPE	CHARACTERISTICS	AREA^a (m^2)	ELECTRIC	HEAT
Retail 4	Reg. hours, high heat loads	741	SCE	DOE-2^d
Restaurant	Lunch peak, open late	710	SCE	DOE-2
Hospital	24 hr. emergency	20,707	SCE + Est.^{e}	DOE-2
Laundromat	50 washers, 40 dryers	444	SCE + Est.^{f}	Est.^{g}

a. Site area calculated by GIS. This is the total area for all buildings classified as the corresponding customer type. This value includes all area within the property line and therefore does not account for parking or other open space that is contained within building property but does not contribute to building energy use. These values are therefore reduced by 25 percent to correct for the space that does not consume energy.

b. Publicly available data for SDG&E customers averaged over all households. Data are from 1994–1996.

c. It is assumed that the cost of retrofitting individual residences is prohibitive.

d. DOE-2 requires a special input for higher heat loads of the highest hot water usage throughout one day. This value is calculated from the measured annual hot water use of a hair salon as 77.4 MMBtu.

e. Hospital measured data were not available divided into end use. Therefore, the cooling load was calculated from the total load based on the hourly percentage of total load it represented in a simulated run by DOE-2.

f. Electricity use from washers and dryers was added to lighting and plug loads from a similar business type.

g. Hot water use of washers was estimated.

The table below shows the individual energy characteristics of each of the ten customer types in the commercial/residential area. The energy characteristics of the total μGrid shown in the last row are not necessarily a sum of the characteristics of the individual customers. For example, the peak loads of the individual customers do not occur at the same times of the day or year, and will therefore not sum to the total peak load of the μGrid.

Table A-2. Energy Characteristics of Individual Customers

TYPE	# OF SITES	TOTAL ANNUAL ELECTRICITY (MWh)	PEAK LOAD (kW)	PEAK HOUR	LOAD FACTOR
Residential	45	242	50	December Weekend 17:00	56%
Office	6	234	72	July Weekday 13:00	32%
Medical Office	1	242	87	July Weekday 13:00	27%
Retail 1	4	647	172	July Weekend 15:00	43%
Retail 2	2	111	26	July Weekend 15:00	48%
Retail 3	2	256	54	October Weekday 18:00	53%
Retail 4	4	141	37	July Weekend 15:00	43%
Restaurant	3	366	69	July Weekend 19:00	60%

TYPE	# OF SITES	TOTAL ANNUAL ELECTRICITY (MWh)	PEAK LOAD (kW)	PEAK HOUR	LOAD FACTOR
Hospital	1	2449	406	January Weekend 8:00	69%
Laundromat	1	67	18	June Weekday 18:00	42%
Total		2516	886	July Weekday 15:00	60%

Appendix C: DER-CAM Mathematical Model

This appendix describes the most recent version of the Distributed Energy Resources Customer Adoption Model (DER-CAM). This version of the model has been programmed in General Algebraic Modeling System (GAMS).[1] DER-CAM inputs, outputs, objective function, and some key assumptions are described in the following subsection, and the mathematical formulation of the model is presented.

C.1 Model Description

In a previous Berkeley Lab report prepared for the California Energy Commission, the first spreadsheet version of the Customer Adoption Model was described and implemented (Marnay et al., 2000); a subsequent report described programming of the model in GAMS (Marnay et al., 2001). The model's objective function, which has not changed, is "to minimize the cost of supplying electricity to a specific customer by optimizing the installation of distributed generation and the self-generation of part or all of its electricity."[2] In other words, the focus of this work continues to be strictly economic. To achieve this objective, the following issues must be addressed:

- Which is the lowest-cost[3] combination of distributed generation technologies that a specific customer can install?
- What is the appropriate level of installed capacity of these technologies that minimizes cost?
- How should the installed capacity be operated so as to minimize the total customer bill for meeting its electricity load?

It is assumed that the customer desires to install distributed generation to minimize the cost of electricity consumed on site. Consequently, it should be possible to determine the technologies and capacity the customer is likely to install and to predict when the customer will be self-generating and/or transacting with the grid.

Key inputs into the model are:

- the customer's end-use load profiles (space heat, hot water, gas only, cooling, and electricity only)
- the customer's default San Diego Gas and Electric (SDG&E) tariff
- the capital, operating and maintenance (O&M), and fuel costs of the various available technologies, together with the interest rate on customer investment

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[1] GAMS is a proprietary software product used for high-level modeling of mathematical programming problems. It is owned by the GAMS Development Corporation (http://www.gams.com) and is licensed to Berkeley Lab.
[2] Marnay et al., 2000.
[3] Here, costs include turnkey (purchase, delivery, and installation) costs as well as fixed and variable operational costs.

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- the basic physical characteristics of alternative generating technologies, including the thermal-electric ratio that determines how much residual heat is available as a function of generator electric output

Outputs to be determined by the optimization model are:

- the DG technology or combination of technologies to be installed
- the capacity of each technology to be installed
- when and how much of the capacity installed will be running
- the total cost of supplying electricity

The key assumptions are:

- Customer decisions are made based only on direct economic criteria. In other words, the only possible benefit is a reduction in the customer's electricity bill.
- No deterioration in output or efficiency during the lifetime of the equipment is considered. Furthermore, start-up and other ramping constraints are not included.
- Reliability and power quality benefits, as well as economies of scale in O&M costs for multiple units of the same technology are not taken into account.
- Possible reliability or power quality improvements accruing to customers are not considered.

C.2 Mathematical Formulation

This section describes in detail the core mathematical problem solved by DER-CAM. First, the names of all input parameters are listed. Second, the decision variables (i.e. the model outputs) are defined. And third, the mathematical formulation used to solve the optimization problem is presented for two possible tariff options.

C.2.1 Input Parameters

Customer Data

Name	Description
$Cload_{l,m,t,h}$	Customer load in kW during hour h, day type t, and month m for end use l (Hot water, Space heating, Gas only, Cooling, Electricity only).

CHP and Absorption Cooling Technologies Data

Name	Description
$CHPcapcost_i$	Capital cost of CHP technology i
$CHP\ cost\ operating_i$	Operating cost per kWh electric produced ($/kWh) for technology i
$CHPom\ fixed_i$	Fixed operating and maintenance costs of technology i ($/kW)
$TE\ ratio_i$	Thermal output (kWth) per kW electric produced of CHP technology i. This coefficient multiplied by $GenL_i$ (defined below under decision variables) determines how much residual heat is available

Other parameters

Name	Description
IntRate	Interest rate on DER investments (%)
StandbyC	Standby charge in \$/kW/month that SDG&E currently applies to its customers with autonomous generation[4]
$Solar_{m,h}$	Average solar insulation as a percentage of the maximum possible during hour h and month m (%)
$NGprice_{m,t,h}$	Price of natural gas during month m, day type t, hour h (\$/kWh)
ConversionEfficiencyNG	Efficiency of converting purchased natural gas to useable heat (%)
Conversion factor from kW electrical cooling to kW thermal cooling	Efficiency of converting from absorption cooling capacity produced in the form of waste heat (kWth) to a reduction in the use of electric compressor cooling (kWe)

SDG&E Data

Name	Description
$RTPower_{s,p}$	Regulated demand charge under the default tariff for season[5] s and period[6] p (\$/kW)
$RTEnergy_{m,t,h}$	Regulated tariff for energy purchases during hour h, type of day t, and month m (\$/kWh)
RTCCharge	Regulated tariff customer charge (\$)
RTFCharge	Regulated tariff facilities charge (\$/kW)
$RTGPower_{s,p}$	Regulated demand gas charge under the default tariff for season[7] s and period[8] p (\$/kW)
$RTGEnergy_{m,t,h}$	Regulated tariff for gas purchases during hour h, type of day t, and month m (\$/kWh)
RTGCCharge	Regulated tariff customer charge for gas (\$)

Distributed Energy Resource Technologies Information

Name	Description
$DERmaxp_i$	Nameplate power rating of technology i (kW)
$DERlifetime_i$	Expected lifetime of technology i (years)
$DERcapcost_i$	Overnight capital cost of technology i (\$/kW)
$DEROMfix_i$	Fixed annual operation and maintenance costs of technology i (\$/kW)
$DEROMvar_i$	Variable operation and maintenance costs of technology i (\$/kWh)

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[4] Only applicable to customers selling power to the utility, which is not relevant to this report.
[5] There are two seasons: summer and winter.
[6] There are three different time-of-use periods (for tariff purposes only): on-peak, mid-peak, and off-peak.
[7] There are two seasons: summer and winter.
[8] There are three different time-of-use periods (for tariff purposes only): on-peak, mid-peak, and off-peak.

Name	Description
$DERCostkWh_i$	Production cost of technology i ($/kWh)
$DERhours_i$	Maximum number of hours per annum that technology i is allowed to generate. Applicable to diesel generators. (hours)

C.2.2 Decision Variables

Name	Description
$InvGen_i$	Number of units of technology i installed by the customer
$GenL_{l,i,m,t,h}$	Generated power by technology i during hour h, type of day t, and month m to supply the customer's load l (kW)
$Heat_{l,i,m,t,h}$	Residual heat produced by technology i during hour h, type of day t, and month m to supply the customer's load l (kW) when the load is either Hot Water or Space Heating
$Cool_{l,i,m,t,h}$	Residual heat produced by technology i during hour h, type of day t, and month m to supply the customer's load l (kW) when the load is either Refrigeration or HVAC
$Dump_{l,i,m,t,h}$	Dummy variable that allows more residual heat to be produced than is demanded on site.
$GenX_{i,m,t,h}$	Generated power by technology i during hour h, type of day t, and month m to sell in the wholesale market (kW)
$DRLoad_{l,m,t,h}$	Residual customer load l (electricity purchased from the distribution company by the customer) during hour h, type of day t, and month m (kW)
$DRGLoad_{l,m,t,h}$	Residual customer load l (natural gas purchased from the distribution company by the customer) during hour h, type of day t, and month m (kW)

C.2.3 Mathematical Formulation

The equations listed below are the DER-CAM objective function and the constraints to the objective function that ensure realistic operation of generator equipment. A description of each equation is listed at the end of this section.

Objective Function

$$\min_{\substack{InvGen_i,\\ GenL_{l,i,m,t,h},\\ GenX_{i,m,t,h}}} \sum_m RTFCharge \cdot \max\left(DRLoad_{m,t,h}\right) + \sum_m RTCCharge$$

$$+ \sum_m RTGFCharge \cdot \max\left(DRGLoad_{m,t,h}\right) + \sum_m RTGCCharge$$

$$+ \sum_s \sum_{m \in s} \sum_p RTPower_{s,p} \cdot \max\left(DRLoad_{m,(t,h) \in p}\right)$$

$$+ \sum_s \sum_{m \in s} \sum_p RTGPower_{s,p} \cdot \max\left(DRGLoad_{l,m,(t,h) \in p}\right)$$

$$+ \sum_l \sum_i \sum_m \sum_t \sum_h \left(GenL_{l,i,m,t,h} + GenX_{i,m,t,h}\right) DERCostkWh_i$$

$$+ \sum_l \sum_i \sum_m \sum_t \sum_h \left(GenL_{l,i,m,t,h} + GenX_{i,m,t,h}\right) DEROMvar_i$$

$$+ \sum_i InvGen_i \cdot \left(DERcapcost_i + DEROMfix_i\right) AnnuityF$$

$$+ \sum_m \sum_i InvGen_i \cdot DERmaxp_i \cdot StandbyC$$

$$- \sum_l \sum_i \sum_m \sum_t \sum_h \left(GenX_{i,m,t,h} \cdot IEM_{m,t,h}\right)$$

(1)

Constraints to Objective Function

$$Cload_{l,m,t,h} = \sum_i Heat_{l,i,m,t,h} + DRGLoad_{l,m,t,h} \quad \forall_{l,m,t,h} \quad if\ l \in \{Heating\}$$ (2a)

Space and water heating loads

$$Cload_{l,m,t,h} = \sum_i GenL_{l,i,m,t,h} + \sum_i Cool_{l,i,m,t,h} + DRLoad_{l,m,t,h} \quad \forall_{l,m,t,h} \quad if\ l \in \{Cooling\}$$ (2b)

Cooling loads

$$Cload_{l,m,t,h} = DRGLoad_{l,m,t,h} \quad \forall_{l,m,t,h} \quad if\ l \in \{Cooking\}$$ (2c)

Gas only loads

$$Cload_{i,m,t,h} = \sum_i GenL_{l,i,m,t,h} + DRLoad_{l,m,t,h} \quad \forall_{l,m,t,h} \quad if\ l \in \{Electrical\}$$

Electrical loads

(2d)

$$\sum_l GenL_{l,i,m,t,h} + GenX_{i,m,t,h} \le InvGen_i \cdot DER\max p_i \quad \forall_{i,m,t,h}$$ (3)

$$GenX_{i,m,t,h} = 0 \ if \ \sum_t \sum_i GenL_{l,i,m,t,h} < \sum_t Cload_{l,m,t,h} \quad \forall_{i,m,t,h} \ \ if \ l \in \{Electrical\} \tag{4}$$

$$AnnuityF = \frac{IntRate}{\left(1 - \frac{1}{(1 + IntRate)^{DERlifetime_i}}\right)} \tag{5}$$

$$\sum_l GenL_{l,j,m,t,h} + GenX_{j,m,t,h} \le InvGen_j \cdot DER\max p_j \cdot Solar_{m,h} \quad \forall_{m,t,h} \ \ if \ j \in \{PV\} \tag{6}$$

$$\sum_l \sum_j (Heat_{l,j,m,t,h} + Cool_{l,j,m,t,h} + Dump_{l,j,m,t,h}) = \sum_l \sum_j ((GenL_{l,j,m,t,h} + GenX_{j,m,t,h}) \cdot TEratio_j) \ \forall_{m,t,h}$$

$$\tag{7}$$

$$\sum_l \sum_m \sum_t \sum_h (GenL_{l,i,m,t,h} + GenX_{i,m,t,h}) \le InvGen_i \cdot DER\max p_i \cdot DERhours_i \ \forall_i \tag{8}$$

- Equation (1) is the objective function, which says that the customer will try to minimize total cost, consisting of: total facilities and customer charges, total monthly demand charges, total on-site generation fuel and O&M costs, total DER investment cost, total standby charges, and *minus* the revenues generated by any energy sales to the macrogrid.
- Equation (2) enforces energy balance for heating, cooling, gas only, and electrical loads.
- Equation (3) enforces the on-site generating capacity constraint.
- Equation (4) prohibits the customer from buying and selling energy at the same time.
- Equation (5) annualizes the capital cost of owning on-site generating equipment.
- In Equation (6), if the customer is operating any photovoltaic cells, their actual energy output is their rated capacity scaled down by the amount of solar insulation.
- Equation (7) constrains the maximum amount of residual heat available for cooling or heating depending on the operation level of the micro turbine. This ensures that residual heat is produced by on-site electricity generation. In addition, electricity is not produced simply to provide waste heat. In other words, the production of waste heat is limited by the electrical load.
- In Equation (8), the maximum total amount of energy that any given generator *i* can produce throughout the year is effectively restricted by the parameter *DERhours_i*. This constraint is intended mainly to prevent the diesel generators from operating more than the maximum legal allowable number of hours.

Appendix D: DER-CAM Technology Database

	Name	DER Type	Source	Nameplate kW	lifetime (a)	$/kW cost FOB cost	$/kW cost Turnkey cost	OMFix $/kW/a	OMVar $/kWh	Lev Cost c/kWh	Heat Rate kJ/kWh	NOx g/kWh	PM g/kWh
1	MTL-C-30	MT	SCE	30	12.5	1200	1333	119	in Fix O&M	12.14	12,186		
3	MT-HW-75	MT	SCE	75	12.5	700	753	0.5 c/kWh	in Fix O&M	10.56	11,373	0.238	
4	PAFC-O-200	PAFC	TAG	200	12.5	3500	PR	PR	PR	13.68	PR	PR	
5	DE-K-15	Diesel Backup	manufacturer	15	12.5	878	2257	26.5	0.000033	N/A	0		
6	DE-K-30	Diesel Backup	manufacturer	30	12.5	473	1290	26.5	0.000033	5.51	11,887	8.17	0.54
7	DE-K-60	Diesel Backup	manufacturer	60	12.5	290	864	26.5	0.000033	6.30	11,201	11.57	0.54
8	DE-K-105	Diesel Backup	manufacturer	105	12.5	212	690	26.5	0.000033	5.48	10,581	12.25	0.54
9	DE-K-200	Diesel Backup	manufacturer	200	12.5	170	514	26.5	0.000033	5.20	11,041	8.85	0.27
10	DE-K-350	Diesel Backup	manufacturer	350	12.5	156	414	26.5	0.000033	4.61	10,032	8.16	0.68
11	DE-K-500	Diesel Backup	manufacturer	500	12.5	166	386	26.5	0.000033	4.65	10,314	8.57	0.16
12	DE-C-7	Diesel Backup	manufacturer	7.5	12.5	213	627	26.5	0.000033	N/A	10,458		
13	DE-C-20	Diesel Backup	manufacturer	20	12.5	440	1188	26.5	0.000033	7.48	12,783		0.54
14	DE-C-40	Diesel Backup	manufacturer	40	12.5	350	993	26.5	0.000033	7.05	11,658		0.54
15	DE-C-100	Diesel Backup	manufacturer	100	12.5	180	599	26.5	0.000033	5.45	10,287	.	0.54
16	DE-C-200	Diesel Backup	manufacturer	200	12.5	135	416	26.5	0.000033	4.94	9,944		0.27
17	DE-C-300	Diesel Backup	manufacturer	300	12.5	127	357	26.5	0.000033	5.14	10,287		0.41
18	DE-C-500	Diesel Backup	manufacturer	500	12.5	136	318	26.5	0.000033	5.42	9,327		0.16
19	GA-K-25	Gas Backup	manufacturer	25	12.5	522	1730	26.5	0.000033	10.42	15,596		
20	GA-K-55	Gas Backup	manufacturer	55	12.5	290	970	26.5	0.000033	7.55	12,997		
21	GA-K-100	Gas Backup	manufacturer	100	12.5	259	833	26.5	0.000033	9.18	15,200		
22	GA-K-215	Gas Backup	manufacturer	215	12.5	416	1185	26.5	0.000033	7.15	13,157	6.05	
23	GA-K-500	Gas Backup	manufacturer	500	12.5	408	936	26.5	0.000033	7.33	12,003	25.29	
24	WD-1	Wind	Bergey Windpower	1	12.5	3920	8920	3.8	0	39.85			
25	WD-10	Wind	Bergey Windpower	10	12.5	2805	6055	5.7	0	27.05			
26	PV-5	PV	Jeff Oldman, Real Goods	5	20	7150	8650	14.3	0	55.23		0.0	0.0
27	PV-20	PV	Jeff Oldman, Real Goods	20	20	5950	7450	14.3	0	47.56		0.0	0.0
28	PV-50	PV	Jeff Oldman, Real Goods	50	20	5175	6675	5	0	42.62		0.0	0.0
29	PV-100	PV	Jeff Oldman, Real Goods	100	20	5175	6675	2.85	0	42.62		0.0	0.0

Appendix E: San GIS Parcel Layer Metadata

This appendix includes metadata available in SanGIS datasets for the individual building parcels used in this study. These metadata include information such as building address, owner information, assessed land value, and building use at time of survey. It can be seen by the characterizations of building use that the information is often not specific enough to conduct a detailed energy end-use analysis. Additional information regarding SanGIS data is listed at the end of this appendix.

Table A-3. SanGIS parcel metadata

Attribute	Description
Area	Polygon area as calculated by software
Perimeter	Polygon perimeter as calculated by software
Parcel	Software internal ID
Parcel_ID	Software internal ID
Parcelid	SanGIS internal Parcel ID Number
APN	Assessor Parcel Number (10 digit)
APN_8	Assessor Parcel Number (8 digit)
Name1	Owner Name 1
Name2	Owner Name 2
Name3	Owner Name 3
Fractint	Fractional Interest
Addr1	Mailing Address 1
Addr2	Mailing Address 2
Addr3	Mailing Address 3
Addr4	Mailing Address 4
Zipcode	Mailing Zip Code
Sitename	Site Name
Legldesc	Legal Description
Asesland	Assessed Land value
Asesimp	Assessed Improvement value
Asestotal	Total Assessed value

Acreage	Parcel acreage
Taxstat	Tax Status: N = Nontaxable T = Taxable
Ownerocc	Owner Occupied (Y or N)
Tranum	Tax Rate Area Number
Assess_Zone	Assessment Zone Code: 0 = Unzoned 1 = Single family residential (R-1) 2 = Minor multiple (R-2) 3 = Restricted multiple (R-3) 4 = Multiple residential (R-4) 5 = Restricted commercial 6 = Commercial 7 = Industrial (M zone) 8 = Agricultural 9 = Special and/or misc.
Asses_lan	Assessment Land-use Code: 07 = Timeshare 09 = Mobilehome 10 = Vacant residential 11 = Single family residence 12 = Duplex or double 13 = Multiple 2 to 4 units or 2 houses 14 = Multiple 5 to 15 units (res) 15 = Multiple 16 to 60 units (com) 16 = Multiple 61 units and up (com) 17 = Condominium 18 = Co-Op 19 = Miscellaneous 10 = Vacant commercial 21 = 1 to 3 story misc. store bldgs 22 = 4 story & up office/store bldgs 23 = Regional shopping center 24 = Community shopping center 25 = Neighborhood shopping center 26 = Hotel, motel 27 = Service station 28 = Offices/medical,dental,veterinary 29 = Rest home/convalescent hospital 30 = Office condominiums

Asses_lan (continued)	31 =	Garage/parking lot/used car lot
	32 =	Trailer park
	33 =	Theater
	34 =	Bowling alley
	35 =	Restaurant
	36 =	Car wash
	37 =	Grocery/drug store - large chain
	38 =	Auto sales/service agency
	39 =	Radio station/bank/misc.
	40 =	Vacant industrial
	41 =	Factory/light manufacturing
	42 =	Factory/heavy manufacturing
	43 =	Warehouse-processing/storage
	44 =	Storage-built (tanks, etc)
	45 =	Mining & extractive
	46 =	Automotive garages (small)
	47 =	Condominiums - industrial
	49 =	Miscellaneous/special
	50 =	Vacant (water available)
	51 =	Citrus
	52 =	Avocados
	53 =	Vines
	54 =	Trees - Miscellaneous
	56 =	Poultry
	57 =	Irrigated crops misc.
	58 =	Growing houses
	59 =	Miscellaneous/special
	61 =	1-10 acres
	62 =	11-40 acres
	63 =	41-160 acres
	64 =	161-360 acres
	65 =	360 acres and up
	70 =	Vacant institutional
	71 =	Church
	72 =	Church parking & related
	73 =	Cemetery
	74 =	Mausoleum
	75 =	Mortuary
	76 =	Public bldg (school, firehouse, library)
	77 =	Hospital
	79 =	Miscellaneous/special
	80 =	Vacant recreational
	81 =	Meeting hall, gym
	82 =	Golf course
	83 =	Marina, docks
	84 =	Recreational camps

Asses_lan (continued)	86 = Open space easements 88 = Agricultural preserve (under contract) 89 = Miscellaneous/special 90 = Vacant taxable - gov. owned property 91 = Improved taxable - gov owned property
Submap	Subdivision Map Number
Unitqty	Number of dwelling units
Ruisnmbr	Site address number
Ruisfrac	Site address fraction
Ruisunit	Site address unit
Ruispdir	Site address prefix direction
Ruisname	Site address road name
Ruissfx	Site address suffix
Ruisjur	Jurisdiction Code: CB = City of Carlsbad CN = County Unincorporated CO = City of Coronado CV = City of Chula Vista DM = City of Del Mar EC = City of El Cajon EN = City of Encinitas ES = City of Escondido IB = City of Imperial Beach LG = City of Lemon Grove LM = City of La Mesa NC = City of National City OC = City of Oceanside PW = City of Poway SD = City of San Diego SM = City of San Marcos SO = City of Solana Beach ST = City of Santee VS = City of Vista
Ruiszip	Site address zip code
Parjur	Jurisdiction from municipal layer overlay
X_coord	X Coordinate for approximate parcel center
Y_coord	Y Coordinate for approximate parcel center

Additional Characteristics of San GIS data:
Description: Parcel polygons
Extent: San Diego County
Data Type: Shape file
Feature Type: Polygon
Datum: NAD83
Projection: California State Plane
Zone: VI (3401 in ArcInfo)
Units: Feet
Precision: Double
Positional Accuracy: +/- 10 feet
Source: County Assessor/SDG&E
Update Frequency: Daily

Appendix F: San Diego Zoning Noise Ordinance

Section 59.5.0401 of the San Diego zoning code states the following in regards to sound level limits:

A. It shall be unlawful for any person to cause noise by any means to the extent that the one-hour average sound level exceeds the applicable limit given in the following table, at any location in the City of San Diego on or beyond the boundaries of the property on which the noise is produced. The noise subject to these limits is that part of the total noise at the specified location that is due solely to the action of said person.

Table A-4. Applicable Noise Limits

Land-use Zone	Time of Day	One-Hour Average Sound Level (decibels)
1. Residential: All R-1	7 a.m. to 7 p.m.	50
	7 p.m. to 10 p.m.	45
	10 p.m. to 7 a.m.	40
2. All R-2	7 a.m. to 7 p.m.	55
	7 p.m. to 10 p.m.	50
	10 p.m. to 7 a.m.	45
3. R-3, R-4 and all other Residential	7 a.m. to 7 p.m.	60
	7 p.m. to 10 p.m.	55
	10 p.m. to 7 a.m.	50
4. All Commercial	7 a.m. to 7 p.m.	65
	7 p.m. to 10 p.m.	60
	10 p.m. to 7 a.m.	60
5. Manufacturing all other Industrial, including Agricultural and Extractive Industry	Any time	75

B. The sound level limit at a location on a boundary between two zoning districts is the arithmetic mean of the respective limits for the two districts. Permissible construction noise level limits shall be governed by Sections 59.5.0404 of this article.

C. Fixed-location public utility distribution or transmission facilities located on or adjacent to a property line shall be subject to the noise level limits of Part A. of this section, measured at or beyond six feet from the boundary of the easement upon which the equipment is located.

D. This section does not apply to firework displays authorized by permit from the Fire Department.

E. This section does not apply to noise generated by helicopters at heliports or helistops authorized by a conditional use permit, nor to any roller coaster operated on City-owned parkland. (Amended 9-11-89 . by O-17337 NS.)

Appendix G: San Diego Gas & Electric Time-of-Use (TOU) Tariff Rates

The table below shows the commercial time-of-use tariff rates used as a cost input to the DER-CAM mathematical model. The cost of installing and operating on-site generation is compared with the utility electricity price to determine the lowest-cost solution for a representative year.

Table A-5: SDG&E time-of-use tariff rates

MONTHS	HOURS	Demand Charge ($/kW)	Electricity Price ($/kWh)
SUMMER May-September	On peak 10:00-17:59	9.00	.21262
	Mid 5:00-9:59, 18:00-21:59	5.78	.11851
	Off peak 0:00-4:59, 22:00-23:59	5.78	.07442
WINTER January-April October-December	Mid 5:00-21:59	5.78	.11281
	Off Peak 0:00-4:59, 22:00-23:59	5.78	.06995

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