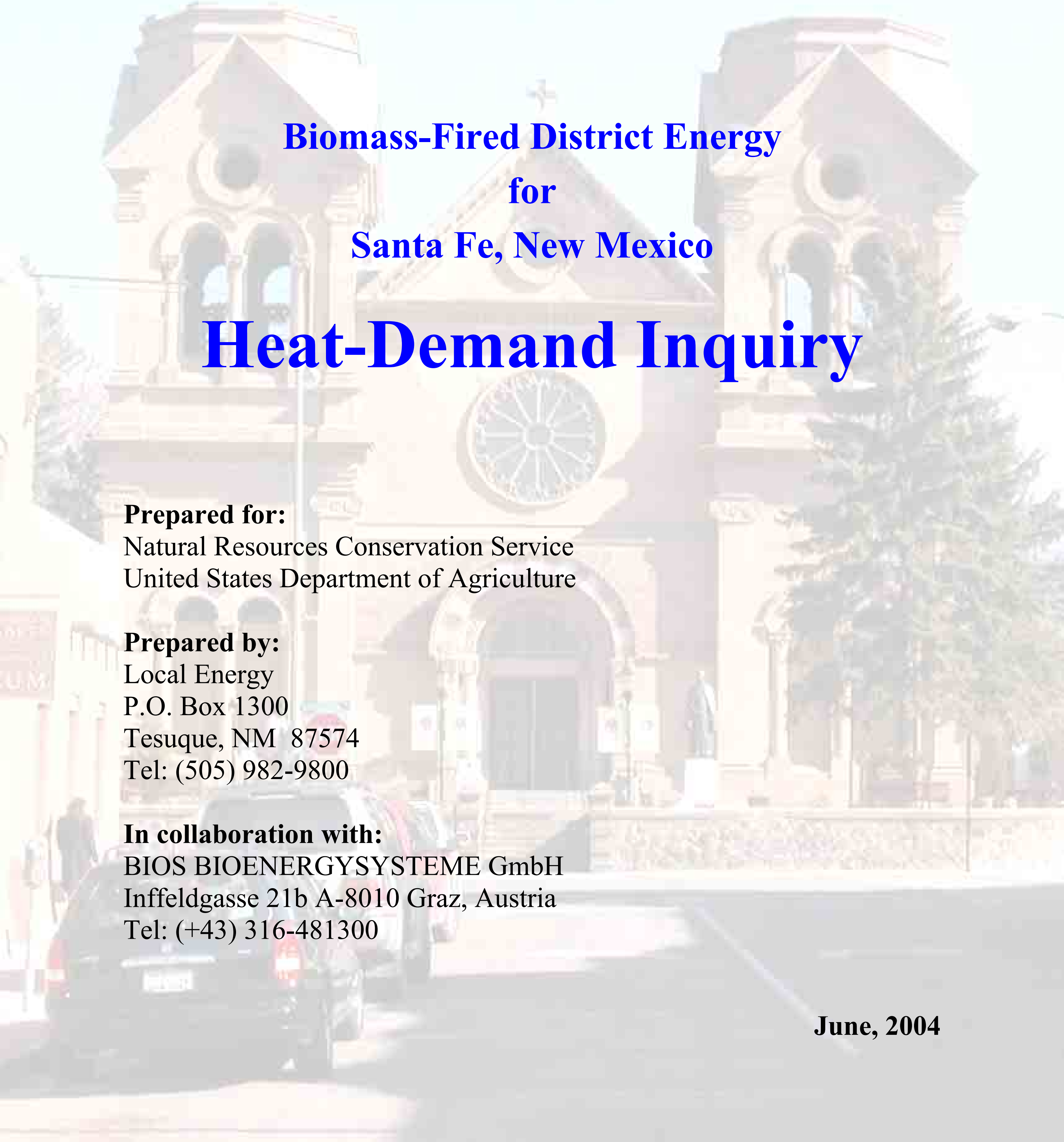

Biomass-Fired District Energy for Santa Fe, New Mexico

Heat-Demand Inquiry

Prepared for:
Natural Resources Conservation Service
United States Department of Agriculture

Prepared by:
Local Energy
P.O. Box 1300
Tesuque, NM 87574
Tel: (505) 982-9800

In collaboration with:
BIOS BIOENERGYSYSTEME GmbH
Inffeldgasse 21b A-8010 Graz, Austria
Tel: (+43) 316-481300

June, 2004

Acknowledgements

This study was made possible by a grant from the United States Department of Agriculture under the Biomass Research and Development Initiative, a program that it co-manages with the United States Department of Energy.

The authors would like to acknowledge a number of people who helped make this study possible. First, for their joint resolution in support of our effort, we would like to thank Santa Fe City Councilors Patti Bushee, Miguel Chavez, David Coss, Karen Heldmeyer, Matthew Ortiz, David Pfeffer, Carol Robertson-Lopez, and Rebecca Wurzburger, and Santa Fe County Commissioners Mike Anaya, Paul Campos, Paul Duran, Harry Montoya, and Jack Sullivan. Additional thanks goes to Bill DeGrande, Richard Fiedler, Craig Fiels, Robert Gallegos, Mike Lujan, and Lawrence Ortiz from the City of Santa Fe; Rudy Garcia, Ish Lovato, Vincent Ojinaga, and Shawn Thornton of Santa Fe County; Jill Holbert and Justin Stockdale from the Santa Fe Solid Waste Management Agency; Bill Belzner from Santa Fe Public Schools; Henry Kavanaugh, Larry Miller, and Manuel Sanchez from the New Mexico General Services Division; and Dave Paul from the U.S. General Services Administration. We furthermore express our gratitude to Lleta Scoggins from the Santa Fe Railyard Community Corporation, and Jim McLaughlin from Santa Fe Community College for their assistance and their enthusiastic support for this project. For help with gathering building data, we are indebted to David Barker from Barker Realty, Jim Cutropia from The Archdiocese of Santa Fe, and the many other building managers and owners who graciously gave us their time and support.

Credits

Program Officer:	Dr. Glenn Carpenter – NRCS
Bioenergy Specialist:	Jerry Payne – USDA Forest Service
Project Director:	Mark Sardella, PE – Local Energy
Technical Specialist:	Prof. Dr. Ingwald Obernberger – BIOS BIOENERGIESYSTEME GmbH
Project Manager:	Boaz Soifer – Local Energy
Senior Engineer:	Alfred Hammerschmid M.S. – BIOS BIOENERGIESYSTEME GmbH
Senior Engineer:	Klaus Supancic M.S. – BIOS BIOENERGIESYSTEME GmbH
Junior Engineer:	Thomas Baernthaler M.S. – BIOS BIOENERGIESYSTEME GmbH
Junior Engineer:	Heath Blount – Local Energy
Report Authors:	Klaus Supancic, Mark Sardella, Thomas Baernthaler, Boaz Soifer, Ingwald Obernberger

Copyright © 2004 by Local Energy - All Rights Reserved

Disclaimer

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

Cover Photo

Saint Francis Cathedral, as seen from the Plaza in Santa Fe, New Mexico. Photo by Klaus Supancic.

Table of Contents

List of Figures

List of Tables

Abbreviations and Notation

(in alphabetical order)

BTU	British thermal unit
DHW	domestic hot water
ΔT	temperature differential
kW	Kilowatt
kWh	Kilowatt-hour
MMBTU	1 Million British thermal units (=293.07 kWh)
w.b.	wet base

Abstract

This report documents the methodology, results, and conclusions for a heat-demand inquiry in the target area of a proposed biomass-fired district energy system in downtown Santa Fe, New Mexico. Similar heat-demand inquiries were also carried out at four nearby prospective sites for decentralized biomass micro-grids. In each case, the target area containing the heating plant and potential customers were identified, and detailed information regarding the size, type, and condition of many of the existing heating systems within the target areas was recorded. These data were then correlated with heating fuel consumption data for each assessed site, as well as with historical weather and heating season data. After adjusting for altitude, all of the data are then checked for plausibility using specific classification numbers and the broad knowledge base accumulated from experience in more than 500 installed biomass district heating systems in Austria. Implausible data were corrected to ensure the accuracy of the results.

Based on the data collected and calculations performed, and with additional consideration of the existing heating control systems and the condition of each building's envelope, the total substitutable annual heat demand and connected heat-load potential of assessed buildings within the target areas were determined. The heat demand and heat-load potential of buildings within the target area that were not assessed were then estimated by extrapolation of the data from similar (assessed) buildings, allowing estimation of the total demand and potential within the target area.

The results show great potential for installing a biomass-fired district heating system to serve downtown Santa Fe. The four micro-grid sites also show very good potential for biomass heating projects. The high heat demand within a relatively small area in downtown Santa Fe should result in a high network utilization ratio, and the predominant use of hydronic heating systems that can be easily retrofitted to use district heating ensures that a high percentage of the heat load is substitutable.

The study further concludes that many heating systems in Santa Fe are oversized, resulting in lower than normal full-load operating hours and thereby increasing both the difficulty and the importance of correctly designing the biomass heating system. The heat-demand characteristic curve suggests that the correct design will include, at a minimum, a biomass boiler to serve the base load and a gas-fired boiler for the peak and backup loads. Two measures for improving system performance are furthermore identified: the integration of heat storage tanks within the district heating networks, and the addition of process-heat consumers needing year-round heat. These measures will be fully investigated in the upcoming design phase of the project.

Kurzfassung

Der vorliegende Bericht beschreibt die Methodik, Ergebnisse und Schlussfolgerungen der Wärmebedarfserhebung im Versorgungsgebiet des geplanten Biomassefernheizwerks für den Stadtkern von Santa Fe, New Mexiko, sowie für mehrere potenzielle Standorte für dezentrale Mikronetze außerhalb des Versorgungsgebietes. Für jede Variante werden das Versorgungsgebiet festgelegt und detaillierte Informationen hinsichtlich Größe, Art, Zustand und Brennstoffverbrauch der bestehenden Heizungssysteme innerhalb des Versorgungsgebietes sowie Klimadaten für Santa Fe erhoben. Die erhobenen Daten werden an die Höhenlage von Santa Fe angepasst und unter Verwendung von spezifischen Kennzahlen und der Erfahrung aus 500 errichteten Biomasseheizwerken in Österreich auf Plausibilität geprüft. Unplausible Daten werden entsprechend korrigiert, um die Korrektheit der erhaltenen Ergebnisse zu gewährleisten.

Anhand der erhobenen Daten und durchgeführten Berechnungen sowie unter Berücksichtigung der bestehenden Heizungsregelungssysteme und der Gebäudehülle jedes Gebäudes werden der ersetzbare Wärmebedarf und die Anschlussleistung für alle erhobenen Gebäude innerhalb des Versorgungsgebietes ermittelt. Der ersetzbare Wärmebedarf und die Anschlussleistung von nicht erhobenen Gebäuden werden mittels der im Rahmen der Wärmebedarfserhebung ermittelten spezifischen Kennzahlen und der beheizten Fläche der Gebäude abgeschätzt, um das Wärmebedarfspotenzial für das gesamte Versorgungsgebiet ermitteln zu können.

Die Ergebnisse der Wärmebedarfserhebung zeigen gute Voraussetzungen für die Errichtung eines Biomassefernwärmenetzes für die Innenstadt von Santa Fe sowie für die betrachteten dezentralen Mikronetze. Der hohe Wärmebedarf innerhalb eines relativ kleinen Einzugsgebietes in der Innenstadt von Santa Fe lässt eine hohe Wärmebelegung des Fernwärmenetzes erwarten. Aufgrund der weiten Verbreitung von Zentralheizungssystemen mit Heißwasser als Wärmeträger ist ein Großteil des Wärmebedarfs leicht durch Fernwärme ersetzbar.

Die Untersuchungen im Rahmen der Wärmebedarfserhebung zeigen, dass viele der bestehenden Heizungssysteme in Santa Fe überdimensioniert sind. Dies führt zu niedrigeren Volllaststunden und unterstreicht die Wichtigkeit einer korrekten Auslegung der Fernwärmesystems, um eine hohe Auslastung der Biomassekessel zu erreichen. Die Charakteristik des Wärmbedarfs innerhalb des Versorgungsgebietes mit hohen Wärmebedarfsspitzen im Winter und geringem Wärmebedarf im Sommer macht eine Lastverteilung zwischen Biomassekessel und Gaskessel notwendig. Der oder die Biomassekessel dienen zur Grundlast- und Mittellastabdeckung, während der Gaskessel als Spitzenlastkessel und Ausfallsreserve dient. Zwei wichtige Maßnahmen zur Effizienzsteigerung des Fernwärmesystems werden ermittelt: zum einen die Installation von Wärmepufferspeichern in den Fernwärmesystemen sowie der Anschluss von Prozesswärmeabnehmern, die einen über das Jahr konstanten Wärmebedarf aufweisen. Diese Maßnahmen werden in der folgenden Auslegungs- und Optimierungsphase dieses Projekts genauer untersucht.

1 Introduction

New Mexico's forests are dangerously overgrown with biomass fuel. While a 1993 USDA Forest Resource Assessment estimated the state's annual forest and woodland growth at a volume that could provide over 70 trillion BTU per year, the overgrowth in forests throughout the state offers a fuel resource many times that size. The removal of this overgrowth is a high priority for New Mexico due to the widely publicized fire danger that it presents.

Unfortunately, the urgent need to thin New Mexico's forests is complicated by a difficult economic situation. Thinning projects in the forests can cost upwards of $1,400 per acre according to the State Land Office, and this expense prevents thinning efforts from being carried out at the pace needed to effectively restore forest safety and health. New Mexico's difficult economic situation is exacerbated by the recent increases in energy costs. Wholesale natural gas prices have more than doubled over the last several years, and continue to climb on news of poor drilling results and high depletion rates. Everyone suffers from higher energy costs, but New Mexicans are far more vulnerable to energy price hikes because as a percentage of disposable income, New Mexicans already spend more than twice the national average to meet their energy needs [1].

From the intersection of these two crises – dangerously overgrown forests too expensive to thin, and rising energy costs damaging New Mexico's economy – comes the impetus for this project. By structuring biomass projects in New Mexico as powerful tools of economic development, the safety and health of the New Mexican forests can be quickly improved while fostering rapid growth of a stable, secure, and sustainable energy industry. This project seeks to further the state-of-knowledge of that process, and to put it into practice in New Mexico.

This report summarizes the first important stage of the project: the heat-demand inquiry for the target area of a proposed biomass-fired district heating grid in downtown Santa Fe. Several potential sites for decentralized biomass micro-grids were also investigated at this stage, allowing us to identify the best possible options for introducing biomass-based energy in Santa Fe.

The work summarized in this report provides a basis for all further development and engineering activities within this project. The results of this inquiry will be used to determine the technical, economic, and environmental feasibility of both centralized and decentralized (micro-grid) biomass applications in Santa Fe.

2 Objectives

The purpose of this study is to gather and analyze the information and data needed to accurately design a biomass-fired district energy system for downtown Santa Fe, New Mexico. The results of the heat-demand inquiry, including the connected heat load, substitutable heat demand, and the trend of the annual heat demand within the target area for the district energy system are important input parameters for all subsequent design calculations.

The heat-demand inquiry addressed the following specific objectives:

- ***Determination of system target areas:*** The study sought to identify the likely boundaries for the target area of a central district heating system, as well as for potential sites of decentralized heating systems (micro-grids).
- ***Investigation of the local parameters affecting heating:*** The study sought to gather and analyze local weather and altitude data, and to correlate this data with observed behavior regarding the sizing and seasonal operation of heating systems.
- ***Creation of a heating systems database:*** The study sought to assess the type and condition of existing heating systems at buildings that could potentially be connected to the district energy system, and to record and tabulate the heat consumption behavior of these customers. The information was gathered through site assessments that included detailed, standardized questionnaires.
- ***Determination of the substitutable heat demand:*** The study sought to evaluate the substitutability of each assessed piece of heating equipment within the target area, and to use this information to estimate the total substitutable heat demand within the target area.
- ***Determination of the connected heat load and full-load operating hours of each customer:*** The study sought to calculate the connected heat load and full-load operating hours of each potential customer, based on data that had undergone systematic plausibility checks to ensure accurate conclusions.
- ***Development of the heat-demand characteristic curve:*** The study sought to develop the heat-demand characteristic curve within the target area based on the results mentioned above.
- ***Furtherance of public awareness:*** The study sought to recognize and address opportunities to inform potential customers and the public about the advantages of a future heat supply based on bioenergy.

3 Methodology

3.1 Evaluation of Weather Data

3.1.1 Daily Mean, Minimum, and Maximum Temperatures

The daily average minimum, maximum, and mean temperatures for the Santa Fe area were calculated based on recorded weather data from local National Weather Service reporting stations. The data set used contains recorded weather information dating back to 1948. The results were graphed to show the annual line of mean, minimum and maximum temperatures.

The same data set was also used to calculate the daily heating degrees (Section 3.1.2), and will further be used to calculate the annual heat-demand line and to design the network of pipes.

3.1.2 Daily Heating Degrees

The daily heating degrees for every day of the year were calculated based on the daily mean temperatures. One daily heating degree represents one day with a mean outdoor temperature one degree below 65°F (18°C). A day with a mean outdoor temperature of 55°F therefore has 10 daily heating degrees.

The number of daily heating degrees for a particular day gives an indication of the amount of space heat needed to maintain a comfortable room temperature on that day. The trend of daily heating degrees over a full year thus gives a good indication of the expected trend of the annual heat demand for space heating. (The heat demand for domestic hot water is generally independent from the ambient temperature.) The trend of the daily heating degrees can therefore be used to check the plausibility of the annual heat-demand calculations. (See Section 3.4, step 6.)

3.2 Heat-Demand Inquiry

3.2.1 Determination of the Area to be Investigated

The heat-demand inquiry focused on areas that have a high density of large heat consumers such as hotels, office buildings, shopping centers, and apartment complexes. These areas are the most promising for the installation of a district heating grid. Furthermore, assessing the large heat consumers first allowed the majority of the total heat load in the target area to be assessed within a relatively short period of time.

In addition to the consideration of a main district heating system for downtown Santa Fe, the potential for micro-grids outside the supply area of the main grid were also considered in this project. The heat-demand inquiry thus focused not only on the downtown area of Santa Fe, but also on potential sites for the installation of micro-grids. This approach was used to identify the best options for introducing biomass-based energy in Santa Fe.

3.2.1.1 Main District Heating System

Many large hotels, some of the largest commercial buildings, and most of the federal, state, county, and city buildings in Santa Fe are located in the downtown area. Paseo de Peralta forms a loop defining the northern, eastern, and southern borders of downtown, while Guadalupe Street defines the western border. These borders define the main target area of the heat-demand inquiry, as shown in Figure 1.

Another area with a high density of heat demand is situated just southwest of downtown at the junction of St. Francis Drive and Cerrillos Road. Some of the larger heat consumers in this area include the campus of the School for the Deaf and the New Mexico Department of Transportation.

If the project proves feasible, these two areas would represent the primary target area of the main district heating system for downtown Santa Fe, and the heat-demand inquiry therefore focused on these areas. Large buildings along the proposed path of the main supply line for the network of pipes were also assessed, including buildings along a path leading to the Santa Fe Waste Transfer Station, which is one of the proposed locations for the heating plant. Figure 1 shows the proposed path of the network of pipes and the target area for the heat-demand inquiry.

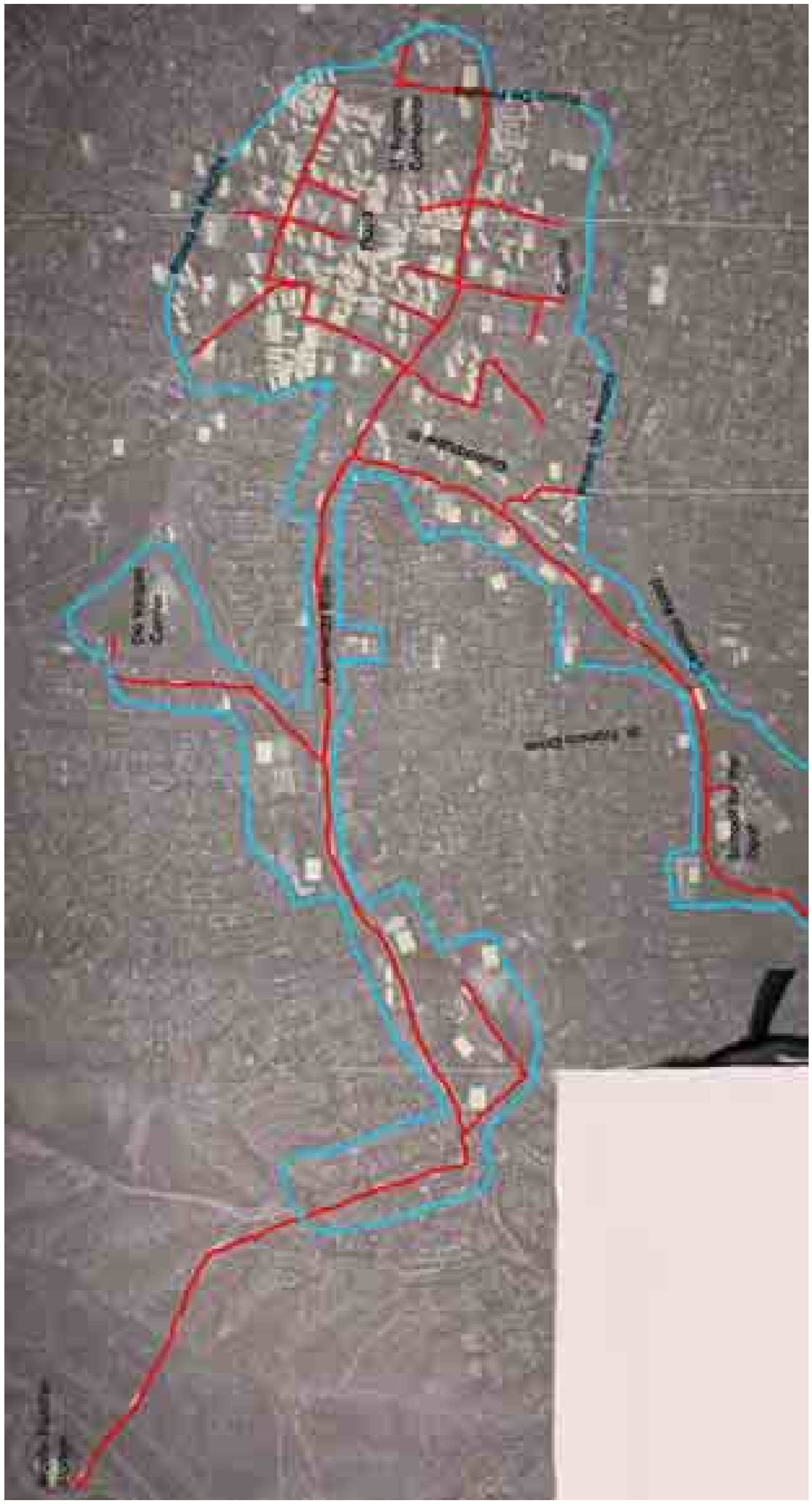

Figure 1: Target Area and Proposed Path of the Network of Pipes

Notes: The red line indicates the proposed path for the network of pipes with the heating plant located at the proposed Santa Fe Waste Transfer Station location. The blue line shows the target area for the heat-demand inquiry.

3.2.1.2 Potential Micro-Grid Sites

Several areas were identified as promising sites for biomass-fired micro-grids that could operate separately from the main system. Micro grids may be a viable alternative for areas that have a high heat demand but are too far from the main district heating system to be connected.

Four of these sites were assessed during the heat-demand inquiry, as shown in Table 1. Other potential sites that have not yet been assessed are the Indian School, the campus of the Institute of American Indian Arts, and several apartment complexes along St. Francis Drive south of downtown and in other areas. All of these sites consist of several buildings grouped within a relatively small area and are either owned or operated by a single entity. This configuration facilitates connection of several buildings to the micro-grid, which is important for achieving the highest possible utilization rate of the heating system.

Table 1: Assessed Sites for Biomass-Fired Micro Grids

Name	Location
Los Arroyos Home Owners Assocation	South of St. Michaels Drive, west of the hospital
South Capital Complex	St. Francis Drive, south of Cerrillos Road
Santa Fe Community College	10 miles south of downtown
College of Santa Fe	4 miles south of downtown

The Santa Fe Rail Yard could also operate as a stand-alone micro-grid even though it is in the target area of the downtown district heating grid. As a stand-alone micro-grid, the rail yard could be a strategic location from which to move towards realization of the downtown system. To avoid confusion, in this report the rail-yard area is included in the main target area rather than considered a separate micro-grid. A detailed investigation of the micro-grid opportunity for the rail yard will take place in the next phase of this project, which will be the preliminary design of the network of pipes and the heating plant.

3.2.2 Heat-Demand Inquiry Questionnaire

Surveys using standardized questionnaires were conducted with all potential future customers of the system. These questionnaires solicited detailed information on all relevant aspects of the inquiry, including annual heat consumption, fuels used, condition of the existing heating system, insulation quality of the buildings, heated area and volume, necessary supply and return temperatures, and customer-specific information concerning the heat-consumption behavior.

Surveys were generally carried out either by an engineer from BIOS BIOENERGIESYSTEME GmbH or by a staff member of Local Energy. During the first two weeks, however, two or three persons carried out surveys together for training purposes and to ensure uniformity of the method.

Three different questionnaires were used, each addressing the unique characteristics of residential buildings, hotel and service buildings, and commercial/municipal buildings. A fourth questionnaire for process-heat facilities was developed but not used because no process-heat consumers were identified in the target areas.

3.2.2.1 Residential Buildings

The questionnaire for residential buildings served as the template for all questionnaires. It included questions about the customer (name, address, etc.), the annual fuel consumption over the last three years, the building (year of construction, insulation levels, heated area, number of persons living in the building, location of the boiler room), the domestic hot-water system (fuel type and consumption), and the heating system (type, fuel input rate, heat output, supply and return temperatures, control system).

3.2.2.2 Commercial/Municipal Buildings (Offices, Shops, Schools)

The questionnaire for commercial and municipal buildings included additional questions pertaining to the number of persons employed and the typical occupancy schedule.

3.2.2.3 Hotels and Service Buildings

The questionnaire for hotel and service buildings included additional questions specific to these building types, such as detailed questions about the heat-consumption behavior (peak hours, off-peak hours), heat-intensive items such as swimming pools, spas, dishwashers, washing machines, etc., as well as questions regarding the number of guest rooms and typical occupancy rates throughout the year.

3.3 Calculation of Specific Classification Numbers, Plausibility Check, and Identification of Oversized Heating Systems

Specific classification numbers were used to evaluate the heating systems in each building. Classification numbers were calculated for every building, and then averaged for buildings with similar characteristics. The specific classification numbers for particular buildings were then compared to the averages to check the plausibility of the data for that building and to identify oversized heating systems. Although identifying a single classification number that is out of range is a possible indicator of a problem with the data, the plausibility determination was made by considering all of the specific classification numbers for the building in question, and also by considering any unique characteristics of the building.

After applying any needed correction factors to account for oversized heating systems, the classification numbers for all buildings within a category were averaged, and these averages were then used to estimate the heat demand and nominal heating capacity of buildings that were not assessed during the heat-demand inquiry. The averaged classification numbers also made possible a more generalized characterization of the buildings in each category (e.g. hotels, offices, homes.)

3.3.1 Specific Nominal Heating Capacity

The specific nominal heating capacity is the installed nominal heating capacity (less any back-up capacity) per unit of heated area.

The specific nominal heating capacity of each building was calculated and compared with the average for similar buildings (e.g. hotels, residences, offices) to evaluate the design of the heating system. Hotels, for instance, usually have a higher specific nominal heating capacity than residential or office buildings, since they often have service or recreational facilities such as kitchens and swimming pools that necessitate additional heating capacity.

A higher-than-average specific nominal heating capacity generally indicates either an oversized heating system or poor thermal insulation of the building's exterior walls. It may also be an indication that the heated area is larger than specified, or a combination of these factors.

A lower-than-average specific nominal heating capacity could indicate either an undersized heating system (not likely) or better-than-average insulation. It may also be an indication that the heated area is actually smaller than specified, or a combination of these factors.

Accurately determining the cause of an out-of-range specific nominal heating capacity requires simultaneous consideration of the specific heat demand and boiler full-load operating hours for the building in question.

3.3.2 Specific Heat Demand

The specific heat demand is the annual heat demand (as calculated in Section 3.4, Step 6) per unit of heated area.

The specific heat demand of each building was compared to averages calculated for similar buildings (e.g. hotels, residences, offices) to evaluate the heating behavior of the building. Buildings with kitchens, swimming pools, or similar facilities requiring additional heat generally have a higher specific heat demand than residential or office buildings.

A higher-than-average specific heat demand could indicate either poor insulation or additional heat-consuming items that are not common in buildings of the same category. Other possibilities include underestimation of the heated area of the building, or overestimation of the annual heating-fuel consumption as a result of improperly accounting for the consumption of heating fuels by non-heating equipment. Higher-than-average specific heat demand can also result from a combination of several of these factors.

A lower-than-average specific heat demand could indicate better-than-average insulation, overestimation of the building's heated area, underestimation of the annual fuel consumption due to incomplete or inaccurate heating records, or a combination of several of these factors.

Accurately determining the cause of an out-of-range specific heat demand requires simultaneous consideration of the specific nominal heating capacity and boiler full-load operating hours for the building in question.

3.3.3 Boiler Full-Load Operating Hours

The boiler full-load operating-hours parameter is the annual heat production of the boiler divided by the nominal heating capacity of the boiler. The value of the boiler full-load operating hours represents the annual boiler utilization. The longer the heating system operates per year, the higher the full-load operating hours. Full-load operating hours can thus also be an indicator of the length of the heating season.

The full-load operating hours for each building was compared with averages for similar buildings (e.g. hotels, residential buildings, offices) to evaluate the design of the heating system as well as the heat demand.

Higher-than-average full-load operating hours could indicate either an undersized heating system or the presence of additional heat-consuming devices that are not common to buildings of the same category. The latter only presents a problem when the additional heat-consuming devices themselves have high full-load operating hours. Other factors could include poor insulation or lower-than-estimated annual heating fuel consumption (e.g. from failure to properly account for non-heating equipment that consumes heating fuel), or several of these factors combined. Lower-than-average full-load operating hours could indicate an oversized boiler, infrequent use of the building, or a temporary shutdown of some or all of the building. It can also be the result of the actual heat demand being higher than calculated (e.g. because of incomplete heating records), or several of these factors combined.

Accurately determining the cause of out-of-range boiler full-load operating hours requires simultaneous consideration of the specific nominal heating capacity and specific heat demand for the building in question.

3.3.4 Identification and Adjustment of Oversized Heating Systems

The identification and adjustment of oversized heating systems were carried out with a combined evaluation of all calculated specific classification numbers. In addition to comparing specific classification numbers, any unique characteristics of the building were also taken into account.

The approach for identifying an oversized heating system varies significantly from building to building. Regardless, the single most likely indicator of an oversized heating system is that the full-load operating hours are significantly less than the average for similar buildings. Further indicators are a significantly higher-than-average specific nominal heating capacity, or a significantly higher-than-average specific heat demand in a building with average full-load operating hours and good insulation.

If an oversized system was identified and an adjustment was necessary, the nominal heating capacity was changed until the specific classification numbers (specific nominal heating capacity and full-load operating hours) reached a plausible level for that building category. To prevent underestimation of the heating capacity requirement for a building, the maximum correction factor used was 40 percent even if this was insufficient to bring the specific classification numbers into the target range.

The 40 percent maximum correction factor was chosen because a number of buildings are outfitted with two boilers of the same size, with simultaneous operation only needed during the coldest winter periods. (This configuration is especially prevalent in larger buildings, and the second boiler is typically called a “backup”.) So although the sum of the nominal heating capacities of the two boilers seems too large for the building, the maximum required nominal heating capacity still exceeds 50 percent of the total capacity.

For buildings with several heating systems, the correction factor (if needed) was applied uniformly across all of the heating systems. This was necessary because it was usually not possible to evaluate the systems individually, since the area heated by each device could not be accurately determined.

After all heating systems were checked and correction factors applied as needed, the average of each classification number in every building category was re-calculated to allow accurate estimation of the heat demand and nominal heating capacity of buildings that were not assessed during the heat-demand inquiry.

3.4 Calculation of Substitutable Heat Demand and Connected Heat Load

Not all heating devices can be easily replaced by a district energy system. On the contrary, the type and location of heating devices can be limiting factors. Devices that do not use water as the heat carrier (non-hydronic devices) cannot easily be replaced by a district energy system, although some can be retrofitted to allow utilization of district heat. Other heating systems, such as low-pressure steam systems, can sometimes be reconfigured to function as hydronic systems fairly inexpensively, especially when the existing pipes can be used. But buildings with individual forced-air "package" units, forced-air distribution systems, gas-fired radiators, or electric heaters cannot generally utilize district heat without replacing the entire heating system. Buildings with such systems were therefore designated as non-substitutable, whereas all hydronic and steam systems were considered substitutable. The location of a heating device within a building may also determine whether it is substitutable. Domestic water heaters that are installed remotely from the space heating system, boosters for dishwashers, and boilers installed at swimming pools or other locations that are not easily accessible are often non-substitutable. (Lack of accessibility is another reason that rooftop units are usually not suitable for substitution.)

Table 2 presents an overview of non-substitutable heating devices. These devices may in some instances be substitutable, however, depending on their capacity, annual heat demand, and cost of fuel. Installing a new heating system may be beneficial, for instance, if expensive fuels such as propane or electricity are used to heat the building. Such factors are identified in the Detailed Building Description Section in APPENDIX II.

Based on the data taken during the heat-demand inquiry, the portion of the annual heat demand for which district energy could be substituted was calculated. The following ten-step process was used:

1. **Identification of non-heating devices that consume heating fuel.** Examples include dryers and flat-ironer machines used in laundries.
2. **Calculation of annual fuel consumption by non-heating devices.** The calculation is based on the specified fuel input rate and any available information on the annual full-load operating hours. (Annual fuel consumption of non-heating devices is the product of the specified fuel input rate and the full-load operating hours.) This value is labeled "Annual Gas Consumption for Other Purposes" in the tables of APPENDIX II.
3. **Calculation of annual fuel consumption by heating devices**. The annual fuel consumption by heating devices is the total annual fuel consumption less the annual fuel

consumption by non-heating devices. This value is shown as "Annual Gas Consumption for Heating Purposes" in the tables of APPENDIX II.

4. **Calculation of heating-system efficiency at nominal load**. The efficiency of each heating device was calculated based on information given on the specification plate, specifically the fuel input rate and the heat output. (Efficiency = heat output/fuel input). If only the fuel input rate was specified, the heat output was calculated based on the average efficiency of similar heating systems.

5. **Determination of annual utilization rate of the heating system**. The annual utilization rate of a heating system is the ratio of the annual heat demand to the annual fuel consumption. This ratio is generally lower than the specified efficiency of a heating device at nominal load. This is due to the fact that space-heating systems do not operate constantly throughout the year, but are instead switched off and on many times over the course of a heating season. Moreover, space-heating systems generally operate at partial load conditions, and only occasionally at full load. Every time a heating device is switched on, some of the energy input is used to heat up the device, resulting in a loss of efficiency. Further energy losses occur during shutdown as the unit cools. At partial load, the efficiency of a heating system is generally lower than at full load. All of these factors contribute to a lower annual utilization rate compared to the specified efficiency at full load. Based on a study carried out in Austria [2], reducing the specified efficiency by about five percentage points to account for these factors gives a more accurate estimate of the annual utilization rate. A boiler with an efficiency of 80 percent will thus have an estimated annual utilization rate of approximately 75 percent.

6. **Calculation of annual heat demand.** The annual heat demand of a building was calculated from the annual fuel consumption of all heating device(s) multiplied by the annual utilization rate of the heating device(s). (Annual heat demand = annual fuel consumption of heating device(s) * annual utilization rate of the heating device(s))

7. **Identification of non-substitutable heating devices.** Heating devices deemed non-substitutable based on their type, location, or other factors were identified, and their capacities were totaled.

8. **Calculation of substitutable nominal heating capacity.** The substitutable nominal heating capacity of a building is the total heating capacity of all devices in the building less the capacity of devices deemed non-substitutable in step 7 above.

9. **Calculation of connected heat load potential.** The connected heat load represents the nominal heating capacity that can be replaced by the district heating system, and is equivalent to the output of the heat-transfer station to be installed at the customer's facility. It is calculated from the nominal heating capacity of the substitutable heating devices multiplied by the correction factor, if needed, to account for oversized heating systems.

10. **Calculation of the substitutable heat demand**. The substitutable heat demand is the total annual heat demand less the heat demand of non-substitutable heating devices. In buildings for which the full-load operating hours of all heating devices are deemed to be

roughly equivalent, the substitutable heat demand is calculated based on the percentage of the total installed capacity that is substitutable. For example, in a building with 1,000,000 BTU/hr of total installed heating capacity, of which 900,000 BTU/hr is considered substitutable, 90 percent of the total annual heat demand is also considered substitutable. If the full-load operating hours are calculated separately for individual heating devices (e.g. one boiler for space heating and one boiler for year-round pool heating), the annual heat demand was calculated according to the full-load operating hours of the substitutable devices.

Table 2: Determination of Non-Substitutable Heating Devices

Non-substitutable Because of Type of Heating System
Forced-air single unit heaters
Rooftop units (forced-air ducted systems)
Gas-fired radiators
Electrically heated systems
Non-substitutable Because of Location
DHW boilers and DHW boosters outside the boiler room
Rooftop units and other heating devices on the roof
Pool boilers (if not easily accessible)

Note: Depending on the capacity, annual heat demand, cost of fuel used, and the location of the building, replacement of these devices to allow utilization of a district heating system may sometimes be beneficial.

3.5 Estimation of Substitutable Heat Demand and Connected Heat Load in Buildings Not Assessed

Estimations of the substitutable heat demand and the connected heat load for buildings within the target area that could not be assessed during the heat-demand inquiry were estimated using data and information gathered from similar buildings.

The average specific classification numbers were calculated (after application of any needed correction factors) for each building type. Based on these averages, the annual heat demand and the nominal heating capacity of buildings not assessed were estimated based on their size and type. In some cases the actual heated square footage was not available, and estimations were used.

3.6 Determination of the Achievable ΔT at the Heat Transfer Station

3.6.1 Evaluation of Existing Heating Systems for their Temperature Level and Differential, and Determination of Achievable Return Temperature

Based on the readings of thermometers installed in the heating systems (or our own measurements with a portable surface thermocouple), the operating temperatures of the heating systems and the temperature differential (ΔT) between the supply and return lines of hydronic systems were determined.

The degree to which the existing ΔT could be increased is then estimated by considering:

- the manufacturer's specifications for the performance of installed heat delivery devices (fancoil units, baseboard heaters, radiant floor systems) as a function of the entering and exiting water temperatures
- the flow rates of the pumps
- the existing supply temperature
- the condition of the system
- the relative ease and cost of installing one or more mixing valves or other devices to improve the ΔT

Using the existing supply temperature and the estimation of achievable ΔT, the achievable return temperature of each heating system was then determined.

3.6.2 Determination of Achievable ΔT at the Primary Side of Customer-Sited Heat Transfer Stations (Heat Exchangers)

The achievable ΔT at the primary side of each of the customer-sited heat-transfer stations is the primary determinant of the achievable ΔT within the district network of pipes. A higher ΔT in the network means that a higher rate of energy transfer (to the customers) can be achieved per gallon of hot water pumped. Thus, a higher ΔT in the network results in reduced pumping costs, since a lower volume of pumped water is needed to deliver the same amount of heat to the customers. The reduction in flow rate also allows reductions in the network pipe diameters, resulting in investment-cost savings.

The ΔT at the primary side of a heat-transfer station is a function of the entering water temperature on the primary side (from the heating plant supply), the temperature difference between the primary and secondary side for which the heat exchanger was designed, and the return temperature from the customer's heat delivery device system (to the secondary side of the heat exchanger.)

Specifications from heat-transfer stations used in central Europe typically have a design temperature difference between the return on the primary side and the return on the secondary side of 5.4°F (3°C). Thus, if the minimum return temperature at the secondary side of the heat exchanger (returning from the customer's heat delivery device) is 140°F (60°C), the minimum return temperature on the primary side of the heat exchanger (to the network of pipes) would be 145.4°F (63°C).

The achievable ΔT at the primary side of the heat-transfer station is calculated according to the following equation:

Achievable ΔT primary side = supply T primary side – (achievable return T secondary side + temperature difference between returns on primary and secondary side)

3.7 Evaluation of the Heat-Demand Characteristic Curve

The heat-demand characteristic curve gives a first indication of what the annual heat-demand line will look like. The curve is constructed by first summing the average substitutable heat demand for each month for every building in the target area, and then plotting these values in order from highest to lowest. The resultant curve gives a first-order approximation of the expected load duration behavior of the system. The curve yields insight into the heating season in addition to being the first step towards creating the annual heat-demand line, as discussed below.

3.7.1 Heating Season

Determining the duration of the period of high heat demand (the heating season) and the period of very low heat demand (when domestic water heating is perhaps the only load) is important for the future calculation of the annual heat-demand line. The heat-demand characteristic curve sorts the months from highest to lowest heat demand, which enables an easy visual determination of the duration of the heating season, swing season, and off-season.

3.7.2 Annual Heat-Demand Line

The annual heat-demand line gives an indication of the expected hourly heat demand at the heating plant, including heat losses of the network of pipes, over a full year. The annual heat-demand line is the result of the performance calculations of the network of pipes over a full year. It is the basis for the determination of the size of the biomass-fired boilers and the peak load boiler at the heating plant.

Calculation of the annual heat-demand line of the heating plant requires consideration of the simultaneity factor as well as the heat losses in the network of pipes. Both parameters will be determined in the next phase of the project as we complete the preliminary design of the network of pipes and the heating plant.

4 Results

4.1 Meteorological Conditions

Santa Fe (35.7° N 106.0° W) is located in the Rocky Mountains of northern New Mexico, at an elevation of 7,000 ft (2,170 m) above sea level. The air is thin and dry. Santa Fe is surrounded by several mountain ranges. The most proximal are the Jemez Mountains and the Sangre de Cristo Mountains. This high-desert climate has four distinct seasons, usually with prolonged windy periods in the spring and fall, both of which tend to be fairly warm. Summers are hot, with temperatures reaching into the 90s °F (30s °C) and winters cold, with temperatures occasionally (but rarely) dropping below 0°F (-18°C). In general, due to the thin air, temperatures fall quite far during nights throughout the year.

There is relatively little precipitation in Santa Fe, consisting largely of a rainy period during summer, usually in late July or early August. During this period, usually lasting one to three weeks, the city is consistently hit with thunderstorms, also called monsoons. There are usually several snow events during the winter as well. The snow typically melts off within a day or two in the city, while in the surrounding mountains snow often is present throughout the winter months.

4.1.1 Daily Maximum, Minimum, and Mean Temperatures

Several sources of weather data were examined during the heat-demand inquiry. Many of them contained only wet bulb temperature data, which could not be used for the calculation of the daily heating degrees because humidity data were not available. The source that was used was found at www.weather.com, which shows the average maximum, minimum, and mean temperature in Santa Fe for every day of the year, based on data recorded by local National Weather Service reporting stations since 1948 [3]. The graphs in Figure 2, Figure 3 and Figure 4 are based on this data.

Figure 2 shows that the average daily mean temperature reaches the high 60s°F (10s°C) in summer and drop to the freeze point in winter. The graphs of the average daily maximum and minimum temperatures show that the days can be quite hot in summer, reaching around 85°F (30°C), although it cools down during the night to around 50°F (10°C). Winter days reach a high of around 50°F (10°C), whereas the nighttime lows average 15 to 20°F (-10 to -6°C).

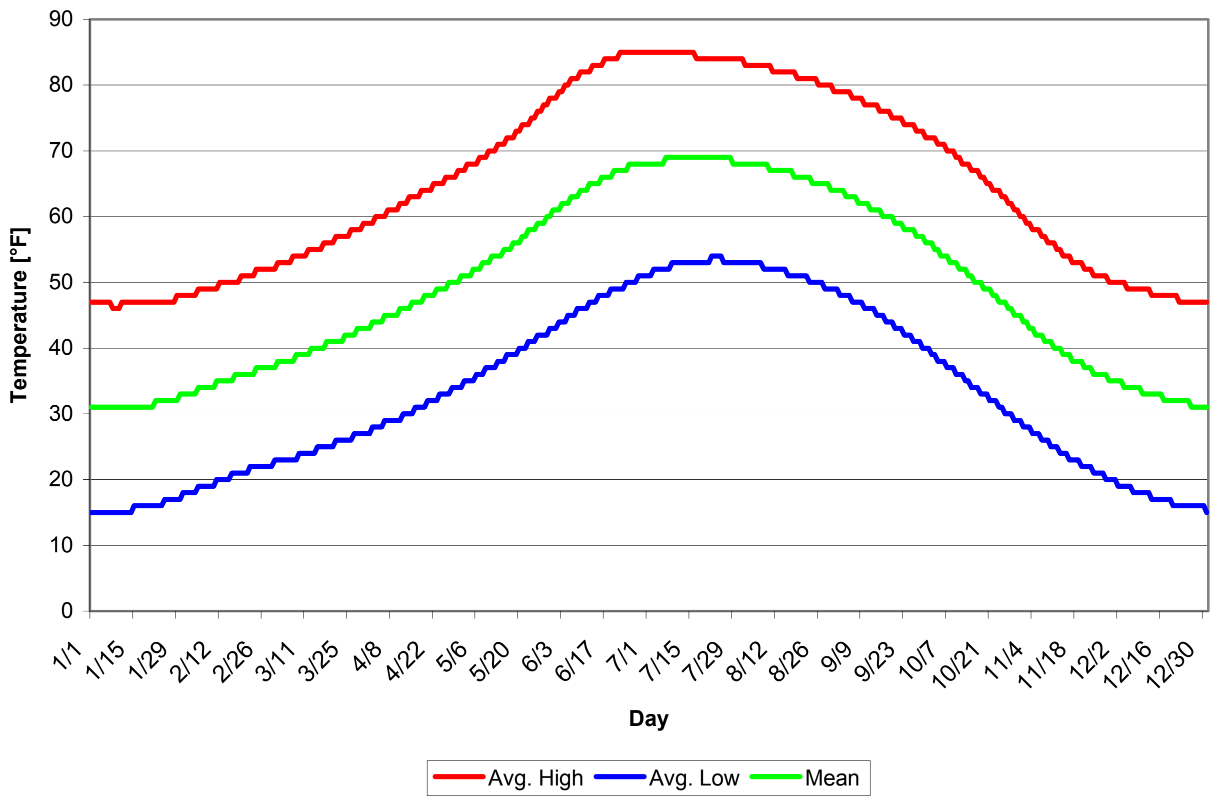

Figure 2: Average Maximum, Minimum, and Mean Temperatures for Santa Fe

Note: Based on historical data from National Weather Service reporting stations. See Reference [3].

4.1.2 Daily Heating Degrees

The average mean temperature of each day was used to calculate the average heating degrees for every day of the year, and the results are shown in Figure 3. From mid June until the end of August there are no heating degrees, meaning that no heating is required during that period.

Actually, the need for heat usually ends a bit earlier and starts a bit later than daily heating degrees indicate, because other heat sources within the building, especially in office buildings with many computers and significant lighting loads, may generate enough waste heat to keep the buildings comfortable during the warmer months of spring and autumn. In summer the outside nighttime temperature often drops well below the building indoor temperature, but the thermal energy stored in the building during the day is generally sufficient to keep the building comfortable without supplemental heat.

To enable correlation of the heating-degree data with the heat demand of buildings, the daily heating-degree data were totaled by month. (See Figure 4.) These data were then used to check the plausibility of each building's calculated heat demand, as given by monthly utility-bill data.

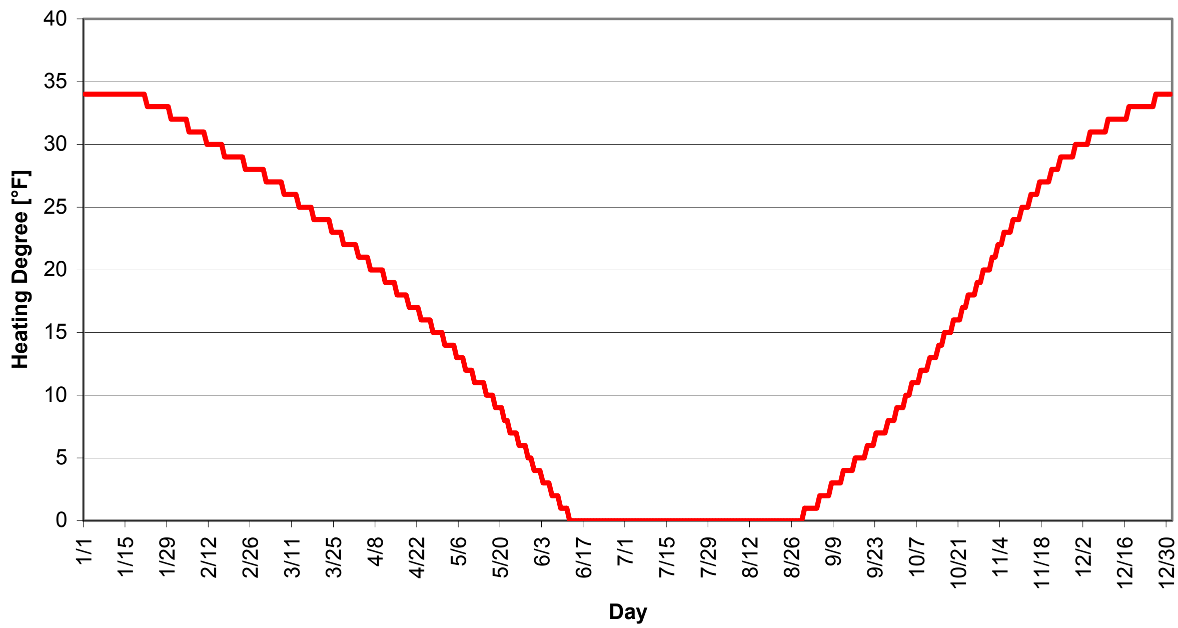

Figure 3: Daily Average Heating Degrees for Santa Fe

Note: Heating degrees are calculated according to Section 3.1.2, Source [3]

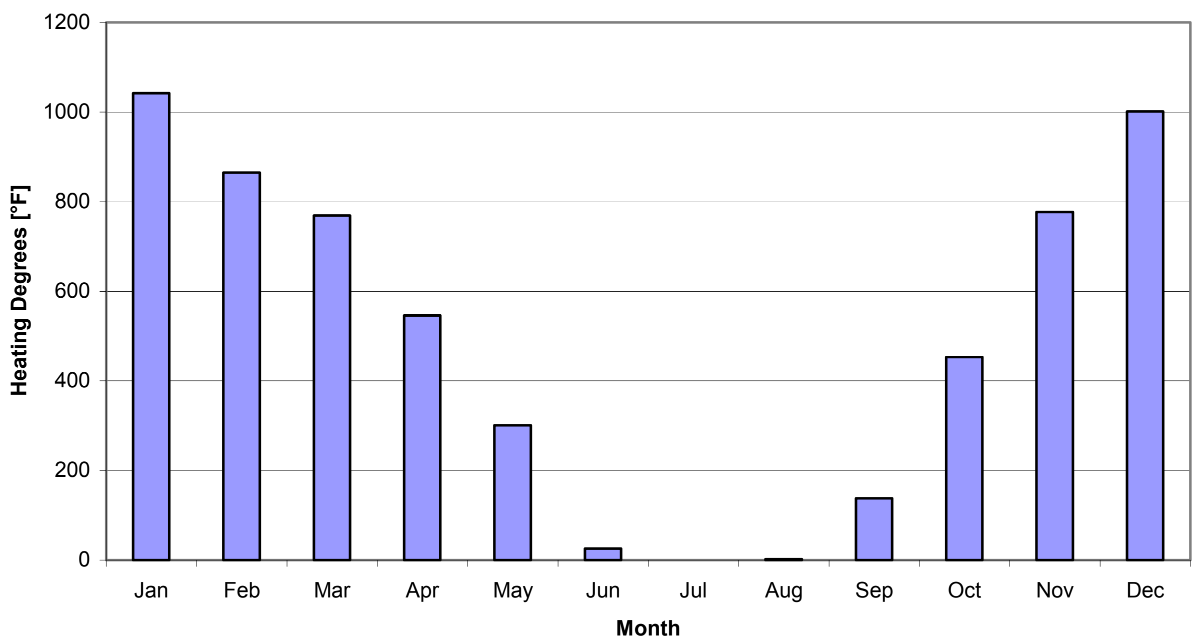

Figure 4: Monthly Average Heating Degrees for Santa Fe

Note: Heating degrees are calculated according to Section 3.1.2, Source [3]

4.2 Heat-Demand Inquiry

4.2.1 Assessed Buildings

The heat-demand inquiry began in the second week of February, 2004, and was completed in the second week of April. During that period approximately 160 potential customers were contacted, mostly in the downtown area but also at the four micro-grid sites. Of the 160 contacts, approximately 120 accepted appointments. These 120 sites represent most of the largest heat consumers in Santa Fe, as well as a sampling of smaller consumers including residences, shops, and restaurants.

Most organizations were very helpful in accommodating appointments at their buildings. The State General Services Department, Santa Fe County, the City of Santa Fe, and the Santa Fe Railyard Community Corporation all welcomed assessments of their heating infrastructure. Only a few large buildings could not be assessed, mainly because the owners or managers rejected the appointment requests or the appointments could not be accommodated within the two-month time frame during which the inquiry took place. The El Castillo Retirement Residence and the State PERA Building are the two largest facilities not assessed.

The tables and graphs in the following two sections show an overview of the buildings assessed during the heat-demand inquiry.

4.2.1.1 Main District Heating System

In total, 106 buildings within the target area of the main district heating system (as defined in Figure 1) were assessed during the heat-demand inquiry. Among the assessed buildings were single-family homes, apartment buildings, museums, office buildings (including private, federal, state, county and city buildings), schools, recreation buildings, commercial buildings (including shopping centers, plazas, and shops), churches, theaters, and hotels of all sizes. An overview of the buildings that were assessed during the inquiry is given in Table 3, Figure 5, and Figure 6.

Office buildings make up the largest portion of the assessed buildings, comprising 25.5 percent of the number of assessed buildings and representing 32.5 percent of the total heated area assessed. The office buildings are followed by hotels (all sizes) at 20.8 percent (representing 27.9 percent of the total heated area) and commercial buildings at 17.0 percent (representing 10.3 percent of the total heated area.) The remaining 29.3 percent consist of 10 residential homes (0.4 percent of the heated area), eight schools (11.2 percent), seven museums (3.5 percent), three shopping centers (9.5 percent), three municipal buildings (0.7 percent), two churches (0.8 percent), and two theaters (1.7 percent), as well as one apartment complex, one healthcare center, one restaurant, and one public outdoor swimming pool.

Of the 106 buildings assessed, 87 are located within (or near) the primary target area bounded by Paseo de Peralta and Guadalupe Street or near the junction of Cerrillos Road and St. Francis Drive. The remaining 19 buildings are located along the proposed path of the network of pipes leading to the Santa Fe Waste Transfer Station, which is one of the proposed locations for the heating plant.

Table 3: Quantity and Heated Area of Buildings Assessed During the Heat-Demand Inquiry

TYPE OF BUILDING	QUANTITY	% of the TOTAL QUANTITY	HEATED AREA		PERCENTAGE of the TOTAL AREA
			[ft²]	[m²]	
Apartments	1	0.9%	46,831	4,351	1.0%
Church	2	1.9%	37,410	3,476	0.8%
Commercial	18	17.0%	467,605	43,442	10.3%
Healthcare	1	0.9%	18,000	1,672	0.4%
Large_Hotel	12	11.3%	1,046,388	97,213	23.1%
Medium_Size_Hotel	3	2.8%	142,321	13,222	3.1%
Municipal	3	2.8%	33,200	3,084	0.7%
Museum	7	6.6%	159,811	14,847	3.5%
Offices	27	25.5%	1,470,900	136,651	32.5%
Residential	10	9.4%	16,252	1,510	0.4%
Restaurant	1	0.9%	4,500	418	0.1%
School	8	7.5%	504,087	46,831	11.2%
Shopping_Center	3	2.8%	427,036	39,673	9.4%
Small_Hotel	7	6.6%	71,568	6,649	1.6%
Swimming_Pool	1	0.9%	0	0	0.0%
Theater	2	1.9%	75,000	6,968	1.7%
TOTAL	**106**	**100.0%**	**4,520,910**	**420,006**	**100.0%**

Note: Heated-area data were not available for all buildings, and when necessary estimates were based on the footprint of the buildings and the number of floors. Swimming pools are not considered to have a heated area.

At this early stage of the project, the future site of the heating plant has not yet been determined. Two sites with good potential are the Santa Fe Waste Transfer Station to the northwest of the city (shown in Figure 7), and the site of Santa Fe's original coal-fired power plant, located southwest of the New Mexico School for the Deaf. A more detailed study of these and other potential sites will appear in a future report on the preliminary design of the network of pipes and heating plant.

Figure 7 shows the location of all assessed buildings in the target area of the main district heating system. The numbers on the map are identification numbers corresponding to the list of assessed buildings that appears in APPENDIX I.

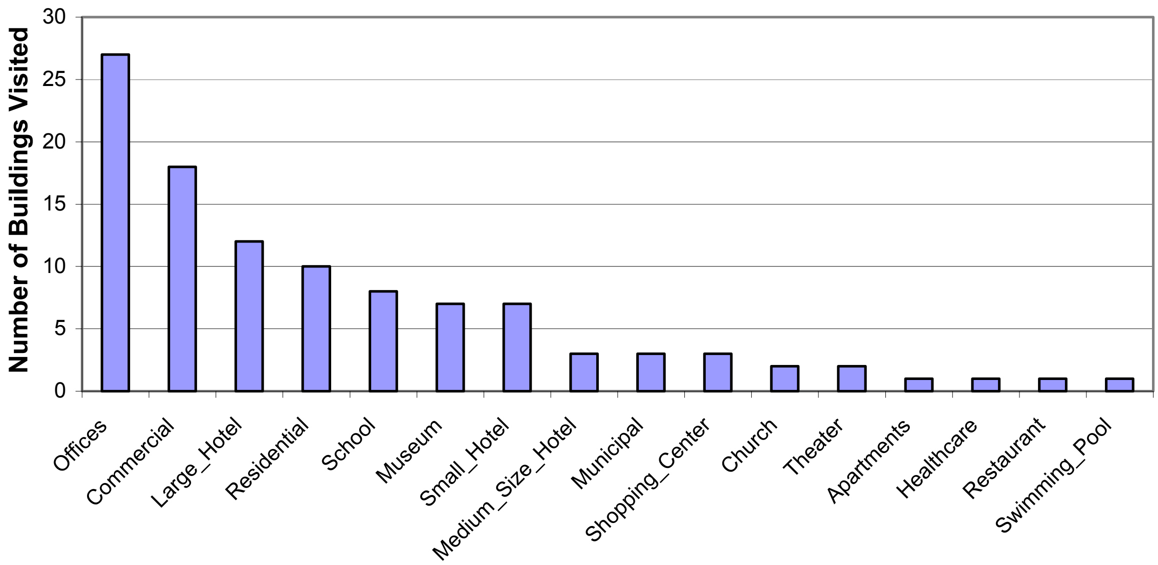

Figure 5: Number of Buildings Assessed During the Heat-Demand Inquiry, by Type

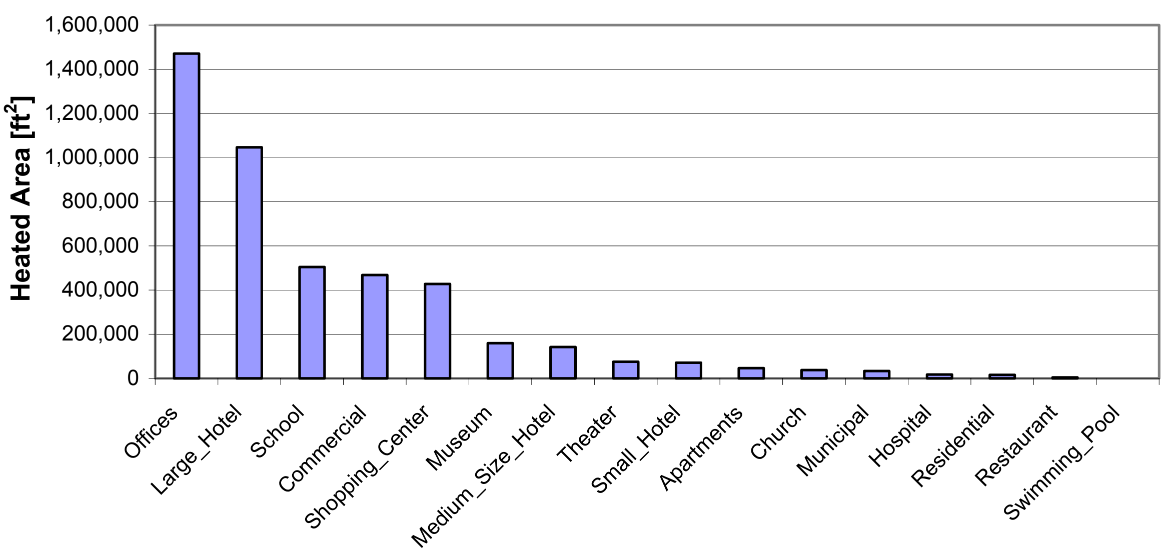

Figure 6: Heated Area of Assessed Buildings, by Type

Notes: Heated-area data were not available for all buildings, and when necessary estimates were based on the footprint of the buildings and the number of floors. Swimming pools are not considered to have a heated area.

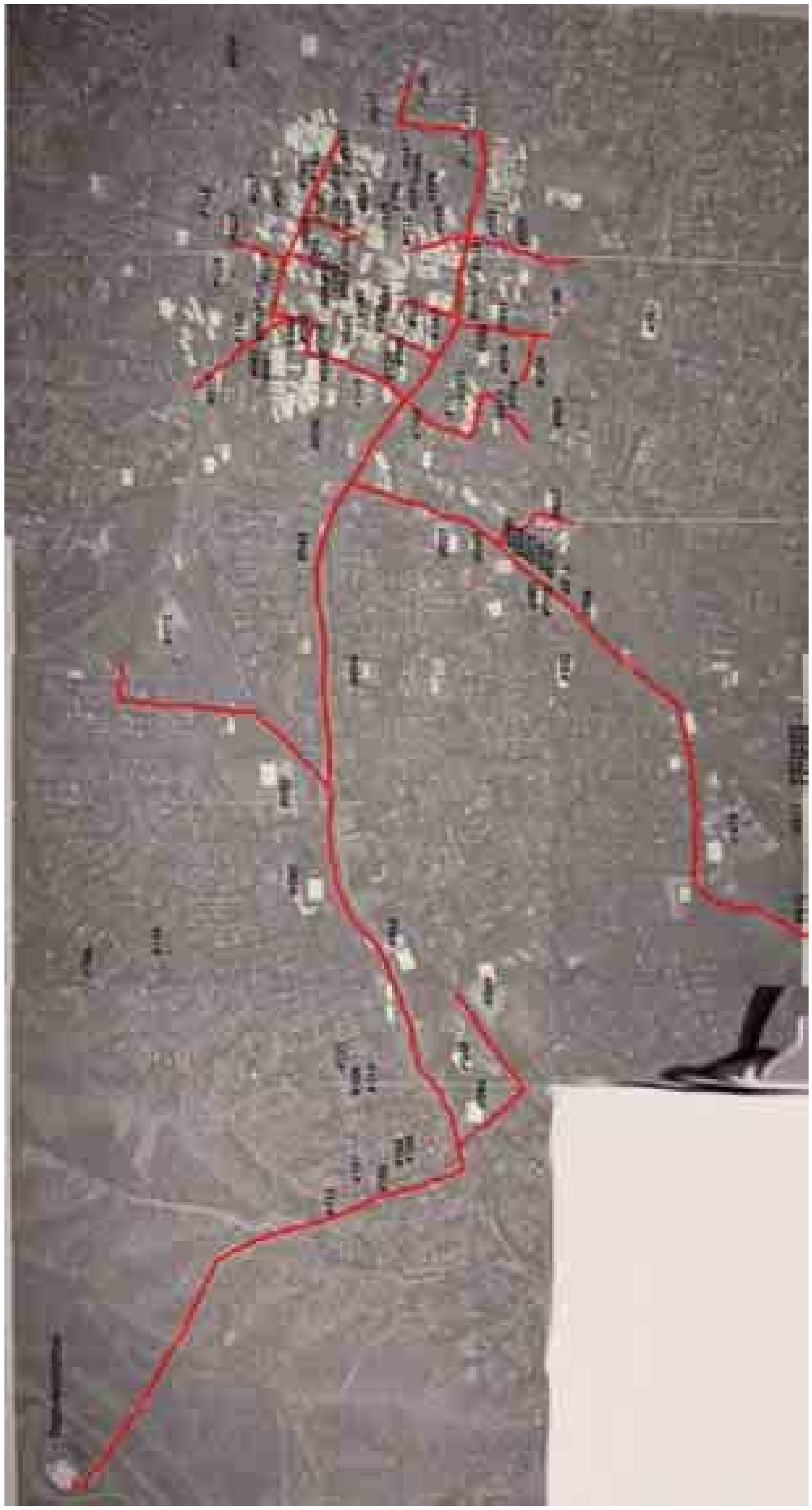

Figure 7: Location of the Buildings Assessed During the Heat-Demand Inquiry

Note: ID numbers of the buildings refer to the list of buildings given in APPENDIX I.

4.2.1.2 Potential Micro-Grid Sites

Los Arroyos Compound

Los Arroyos Compound is an apartment complex located on a hill southwest of St. Vincent's Hospital. It consists of seven residential buildings and one administration building. Four of the residential buildings each consist of 24 residential units, while the other three each consist of 18 residential units. The administration building has an indoor swimming pool.

The total heated area of the complex is approximately 135,000 ft² (12,500 m²), as shown in Table 4. Each of the seven residential buildings has its own boiler and domestic water heater. The administration building has a boiler for the pool, a domestic water heater, and a rooftop unit for space heating.

Table 4: Heated Area for Los Arroyos Compound

TYPE OF BUILDING	NUMBER OF BUILDINGS	TOTAL HEATED AREA [ft²]	[m²]
Apartment Block type 1	4	88,320	8,205
Apartment Block type 2	2	29,440	2,735
Apartment Block type 3	1	14,720	1,368
Administration Building*	1	2,000	186
TOTAL	**8**	**134,480**	**12,494**

Note: The area for administration building was estimated using available drawings.

South Capitol Complex

The South Capitol Complex is located on St. Francis Drive one block south of the junction of Cerrillos Road and St. Francis Drive. It consists of four buildings that serve as offices for several state departments. The buildings were constructed between 1974 and 1986, and are operated and maintained by the state's General Services Division.

The total heated area of the four buildings is approximately 424,000 ft² (39,400 m²), as shown in Table 5. Each building has its own HVAC system and domestic hot-water system. The Montoya building also has solar hot-water collectors on the roof to preheat domestic hot water.

The buildings are connected by a system of underground tunnels. Within the tunnels are pipes interconnecting the four chillers, thus enabling redundancy should any of the four chillers go out of service. The tunnels are large enough to accommodate the supply and return pipes of a thermal micro-grid, which would greatly reduce the cost of installing a stand-alone district heating system at this site.

Table 5: Total Area and Heated Area of the South Capitol Complex

	TOTAL AREA		TOTAL HEATED AREA	
NAME OF BUILDING	**[ft²]**	**[m²]**	**[ft²]**	**[m²]**
Harold Runnels	174,092	16,174	156,683	14,556
John F. Simms	71,425	6,636	71,425	6,636
Joseph Montoya	133,000	12,356	119,700	11,120
Manuel Lujan Sr.	76,262	7,085	76,262	7,085
TOTAL	**454,779**	**42,250**	**424,070**	**39,397**

Note: The heated areas of the Runnels and Montoya buildings were estimated by assuming that the unheated storage rooms and basement areas amount to 10 percent of the total building area.

Santa Fe Community College

The campus of the Santa Fe Community College is located about 10 miles south of downtown Santa Fe. The campus consists of three main buildings and some temporary classroom buildings.

The total heated area of all permanent buildings is approximately 465,000 ft^2 (43,200 m²), as shown in Table 6. Several expansion projects at the existing buildings are planned within the next five years. Heating and cooling for most of the main building and for the Fitness Education Center are provided by a small micro-grid, which is heated by two gas-fired boilers. This micro-grid may be a potential starting point for a first demonstration project to develop and establish the reliability of biomass-fired heating systems in Santa Fe. The remainder of the main building (the Visual Arts Center) has a dedicated heating system, as does the Early Childhood Education Center, which is located in a separate building. The Visual Arts Center has several electrically heated domestic water heaters located throughout the building. The other part of the main building and the two other large buildings on campus each have a single, central domestic hot water boiler.

Table 6: Total Area and Heated Area of the Santa Fe Community College

	TOTAL AREA		TOTAL HEATED AREA	
NAME OF BUILDING	**[sqft]**	**[m²]**	**[sqft]**	**[m²]**
Main Building	300,500	27,917	270,450	25,126
Fitness Education Center	125,000	11,613	112,500	10,452
Visual Arts Center	57,000	5,295	57,000	5,295
Early Childhood Development Center	25,000	2,323	25,000	2,323
TOTAL	**507,500**	**47,148**	**464,950**	**43,195**

Note: The heated area of the Main Building and the Fitness Education Center were considered 10 percent smaller than the total area (unheated storage rooms.)

Across the street from the campus, the Archdiocese of Santa Fe plans to build a new school. The site may be close enough to allow interconnection with the planned biomass-fired micro-grid at the college, making this site even more attractive as a biomass demonstration site.

College of Santa Fe

The campus of the College of Santa Fe is situated about four miles south of downtown Santa Fe, and includes 46 buildings of various sizes, ages, and functions.

The total heated area of all buildings on the campus is approximately 568,000 ft² (52,700 m²), as shown in Table 7.

Table 7: College of Santa Fe Buildings and Heated Areas

NAME OF BUILDING	HEATED AREA [ft²]	HEATED AREA [m²]
Alumni Hall	11,742	1,091
Cafeteria	17,836	1,657
Brothers Residence	19,517	1,813
Onate Hall	6,550	609
11 smaller buildings (T-38-T45, T63-T65)	54,441	5,058
St. Michael's Chapel	2,550	237
St. Michael's Hall	30,319	2,817
King Hall	46,109	4,284
La Salle Hall	24,764	2,301
Alexis Hall	14,844	1,379
Kennedy Hall	25,295	2,350
Benildus Hall	16,280	1,512
Luke Hall	26,177	2,432
Garson Theater	32,628	3,031
Administration Building	8,680	806
Fogelson Complex (micro-grid)	58,457	5,431
Garson Communications Center	49,200	4,571
Driscoll Fitness Center	22,200	2,062
Physical Plant	6,000	557
Bookstore	2,912	271
Center for Academic Excellence	1,693	157
Development Office	3,441	320
Humanities/Education Dept. Offices	1,500	139
Student Apartments (1 & 2)	30,000	2,787
Visual Arts Center Phase 1	54,615	5,074
TOTAL	**567,750**	**52,746**

A gas-fired micro-grid currently supplies heat to three of the buildings, which have a combined heated area of 58,400 ft² (5,400 m²). The replacement of this gas-fired boiler with a new biomass-fired boiler looks promising for a demonstration project. Most of the remaining buildings on the campus have hydronic heating systems, so there is good potential for further expansion of the micro-grid at the site.

4.2.2 Utilized Fuels

4.2.2.1 Main District Heating System

Santa Fe is connected to a natural-gas pipeline system that serves the whole city, and nearly every building assessed uses natural gas for heating. A few buildings use electric heating and domestic hot-water systems. One building we assessed is heated in part by propane-fired forced air heaters.

Unfortunately, it was not possible to obtain utility-bill data from which to determine the gas consumption in all of the buildings we assessed. At the time of this writing, gas bills had been obtained for 58 of the 106 assessed buildings in the target area of the main district heating system. The annual gas consumption of these 58 buildings totaled 163,180 MMBTU (47,821 MWh) in 2003. Although gas bills were requested for the years 2001, 2002 and 2003, only gas bills from 2003 were obtained for most of the buildings.

The gas consumption for each of the remaining 48 buildings within the target area was estimated based on the size and type of each building. The results of these estimates are presented in Section 4.4.1. Adding these estimates to the calculated values above, the total gas consumption of all buildings within the target area is estimated to be 419,275 MMBTU (122,877 MWh) per year. It is not anticipated, however, that the heating systems in all buildings within the target area can be replaced by district heating. See Section 4.5.1.2 for more details.

There are large residential housing complexes south of downtown that were built with electric heat during the era of “Gold Medallion All-Electric Homes.” The significantly higher cost of electric heat in Santa Fe, coupled with the increasingly limited ability of Santa Fe’s electrical infrastructure to serve the growing electrical demand, suggest that there may be some significant advantages in replacing existing heating systems with biomass-fired systems. A thorough assessment of these homes was outside the scope of this heat-demand inquiry, but this opportunity will be kept under consideration as the project moves forward.

4.2.2.2 Potential Micro-Grid Sites

Los Arroyos Compound

All heating devices at the Los Arroyos Compound apartment complex are natural-gas fired. With the exception of 1997, 1998, and 2003, gas bills from the four gas meters serving the complex were made available dating back to 1990. See Figure 8.

The reason for the 20 percent drop in annual gas consumption that began in 1996 could not be determined. The most likely reason is replacement of the old gas meters with new ones, but the exact date of the replacement was not known, and this assumption could not be verified.

Using the utility data from 1999 through 2002, the average annual gas consumption for the entire complex was 8,217 MMBTU (2,408 MWh) per year.

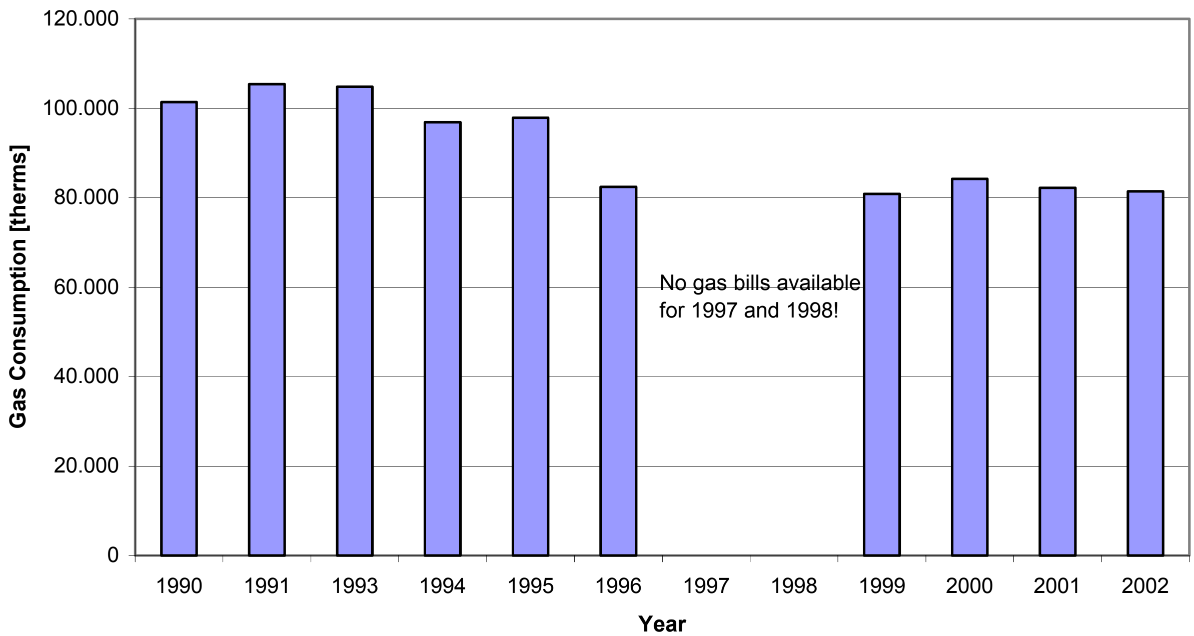

Figure 8: Annual Gas Consumption at the Los Arroyos Compound Apartment Complex

Note: Total gas consumption was calculated based on readings from four different meters.

South Capitol Complex

All heating devices at the South Capitol Complex are natural gas-fired with the exception of the solar-heated domestic hot water storage tank at the Montoya building. Gas bills from February 2001 through September 2003 were obtained, but the data from 2001 were inconsistent with the data from 2002 and 2003, and so only the last two years were used. The last three months of 2003 were estimated using data from the prior year.

Based on the 2002 and 2003 data, the average annual gas consumption of the complex was 13,293 MMBTU (3,896 MWh) per year. Figure 9 shows the annual gas consumption for the four individual buildings at the site.

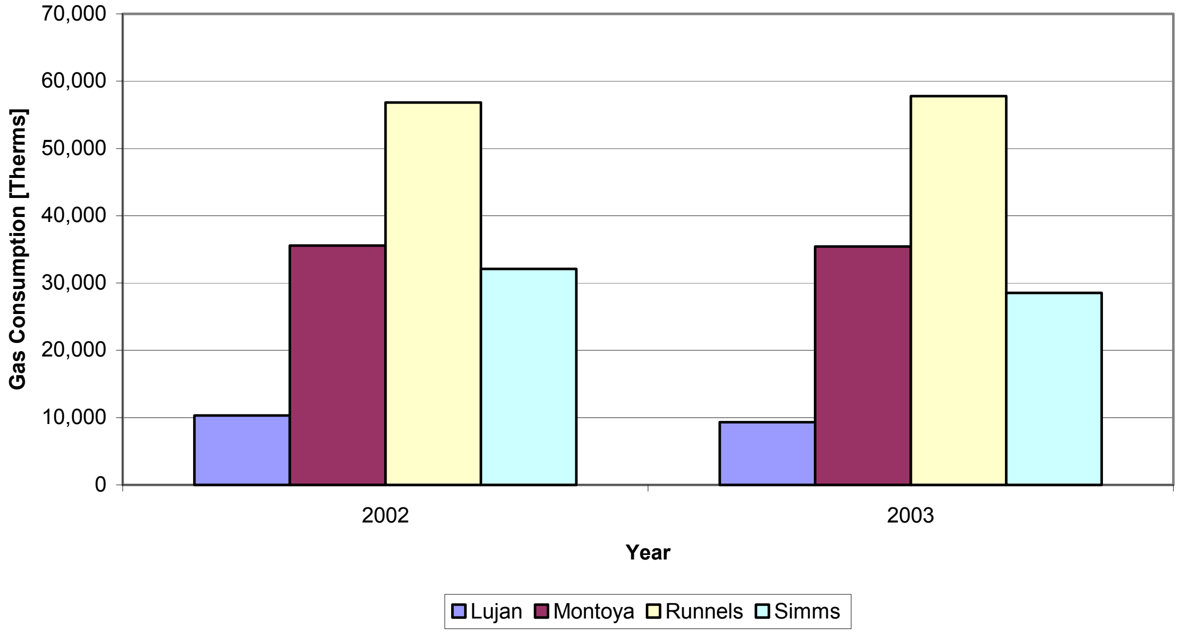

Figure 9: Annual Gas Consumption of the South Capitol Complex

Note: The gas consumption for the last three months of 2003 was estimated using gas consumption data from the same period in 2002.

Santa Fe Community College

All space-heating systems on the campus are natural gas-fired, and all domestic water heaters are gas-fired except in the Visual Arts center. Gas bills dating from September 2000 through September 2001 were obtained. The energy consumption of the electrically heated domestic water heaters could not be determined since they are not separately metered.

Based on the data obtained from September 2000 – September 2001, the annual gas consumption of the entire campus was 37,091 MMBTU (10,870 MWh). Figure 10 shows estimates of how this consumption is distributed among the four main buildings.

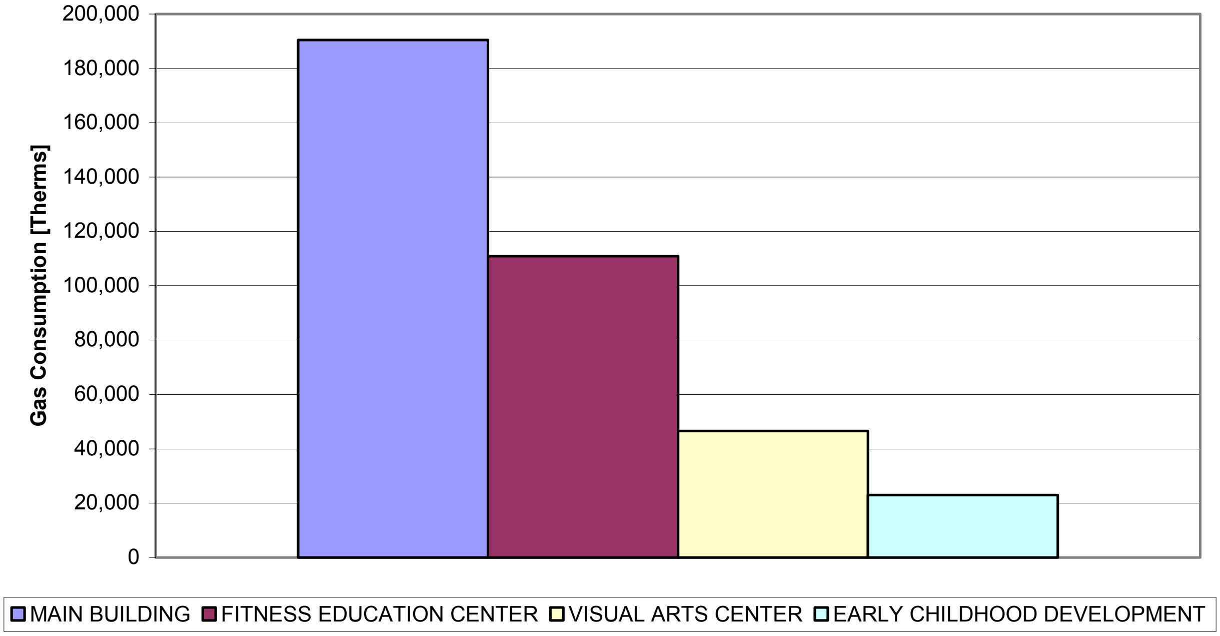

Figure 10: Estimated Distribution of the Annual Gas Consumption at SFCC, by Building

Note: The gas consumption of the Main Building and the Fitness Education Center were estimated based on their heated area. These buildings are connected to a micro-grid, and therefore they share a gas meter. All gas consumption estimates were based on gas bills dating from September 2000 through September 2001.

College of Santa Fe

All buildings on the campus have gas-fired heating devices. Since there are no sub-meters, only the annual gas consumption of the entire campus could be determined. Based on utility-bill data from 2001, gas consumption was approximately 45,400 MMBTU (13,305 MWh).

4.2.3 Installed Heating Systems

The detailed assessment of installed heating systems was needed to determine the substitutable heat demand and the connected heat load in the target area, and to calculate the achievable temperature differential between the supply and return line of the district heating grid.

4.2.3.1 Main District Heating System

Types of Heating Systems

During the heat-demand inquiry, heating systems of various age, size and complexity were identified. Table 8 gives an overview of the installed heating systems in assessed buildings. Table 9 shows the total installed nominal heating capacity in assessed buildings in the target area for each of the system types. This same information is shown graphically in Figure 11.

Table 8: Installed Heating Systems, by Type, in Assessed Buildings in the Target Area

TYPE OF HEATING SYSTEM	HEAT GENERATION TECHNOLOGY	HEAT DISTRIBUTION TECHNOLOGY
Hydronic Space Heating	gas-fired pressurized hot-water boiler	pressurized water through heating units (radiators, fancoils, hot decks, water source heat pumps etc.)
Forced-Air Ducted Space Heating	gas-fired furnace(s)	forced air through ducts
Forced-Air Unducted Space Heating	gas-fired single unit heaters	local fan only (no distribution)
Steam-Only Space Heating	gas-fired steam boiler	steam through heat delivery units (radiators, fancoils etc.)
Steam-to-Water Space Heating	gas-fired steam boiler	pressurized water from heat exchanger to heat delivery units (radiators, fancoils, hot decks, water source heat pumps etc.)
Gas Radiator Space Heating	gas-fired single radiation heating units	none
Gas-Fired Domestic Hot Water	gas-fired boiler (direct or indirect)	
Gas Hydronic Pool Heating	gas-fired pressurized hot water boiler for pool heating	pressurized water
Electric Space Heating	electric resistance element	baseboard radiators and convection heaters
Electric Domestic Hot Water	electric resistance element	

Table 9: Installed Total Nominal Heating Capacity, by System Type, for Assessed Buildings in the Target Area

TYPE OF HEATING SYSTEM	NOMINAL HEATING CAPACITY [BTU/hr]	[kW]	PERCENTAGE
Hydronic Space Heating	123,740,695	36,265	48.4%
Gas-Fired Domestic Hot Water	42,399,251	12,426	16.6%
Forced-Air Ducted Space Heating	39,571,717	11,597	15.5%
Steam-to-Water Space Heating	29,369,000	8,607	11.5%
Gas Hydronic Pool Heating	5,524,700	1,619	2.2%
Electric Space Heating	5,273,820	1,546	2.1%
Steam-Only Space Heating	4,483,500	1,314	1.8%
Forced-Air Unducted Space Heating	4,186,800	1,227	1.6%
Gas Radiator Space Heating	836,000	245	0.3%
Electric Domestic Hot Water	171,400	50	0.1%
TOTAL	**255,556,883**	**74,896**	**100.0%**

Note: Back-up capacity is not considered; see Table 8 for a description of the different heating systems.

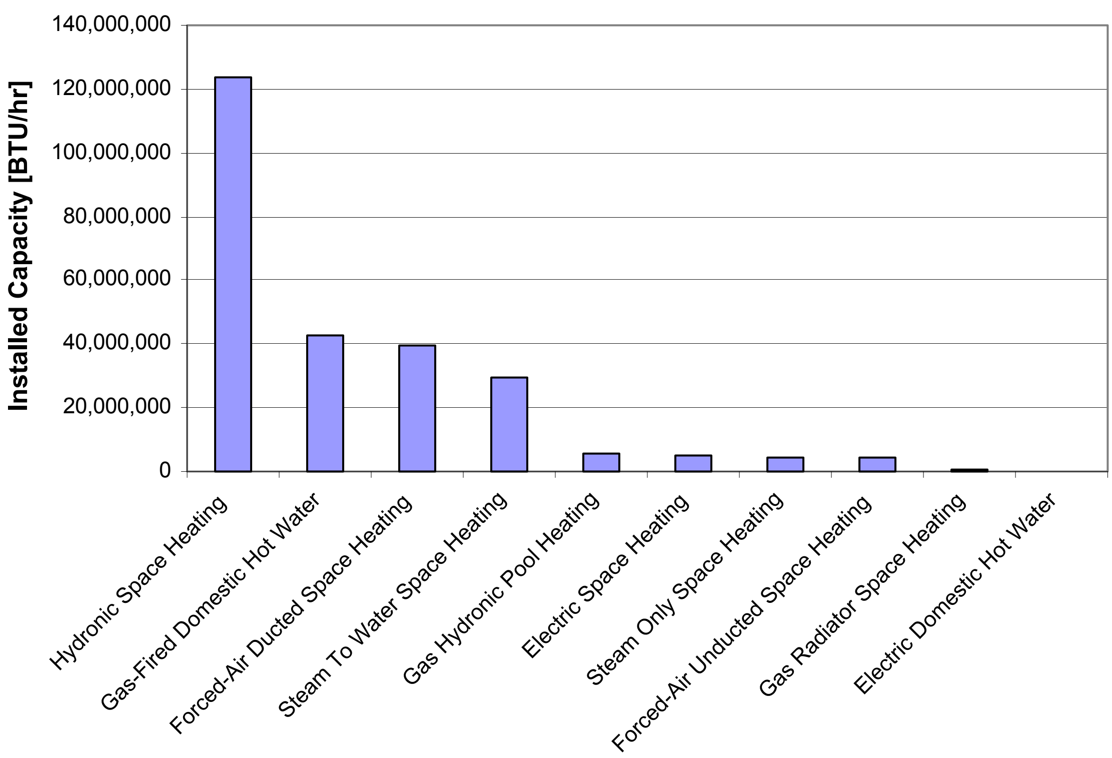

Figure 11: Installed Total Nominal Heating Capacity, by System Type, for Assessed Buildings in the Target Area

Notes: Back-up capacity is not considered. See Table 8 for a description of the different heating systems.

Some of the specified types of heating systems in Table 8 are clearly more prevalent than others. Hydronic space heating systems make up 48.4 percent of the installed nominal heating capacity, followed by gas-fired domestic hot-water systems (16.6 percent) and forced-air ducted space heating systems (15.5 percent). Steam-to-water space-heating systems comprise 11.5 percent of the nominal heating capacity, while the combination of electric space-heating systems, hydronic pool-heating systems, steam-only space-heating systems, forced-air unducted space-heating systems, gas radiator space-heating systems, and electric domestic hot-water systems make up the remaining 8.0 percent.

The heating system type is the primary determinant of whether or not a system or device can be replaced with district heating. After considering the system type, the location of the heating system is the second most important factor in determining whether a heating system is replaceable. Some of the installed hydronic, steam, and domestic hot-water heating systems are not suitable for replacement because they are situated in locations that are difficult to access (e.g. on the roof).

The substitutable nominal heating capacities of assessed buildings were calculated based on system type and location and using the guidelines outlined in Section 3.4, Step 8. The results are shown in Table 10 and Figure 12. The replaceable heating systems amount to more than three quarters (78.2 percent) of the installed nominal heating capacity in assessed buildings. The actual nominal heating capacity of the heat-transfer stations (connected heat load) needed to replace these heating devices will be lower than the capacities calculated here, since some of the installed heating systems are oversized. The results of the calculations of the connected heat load are discussed in Section 4.5.1.

The feasibility of replacing other types of heating systems (forced air, electrical heating) is dependent on the costs for modifying them to make them more suitable for connection to a district system. A more detailed assessment of this will take place, if warranted, after the economic calculations are completed.

Table 10: Replaceable Installed Nominal Heating Capacity of Assessed Heating Systems, by Type, in the Target Area

TYPE OF HEATING SYSTEM	INSTALLED CAP.		SUBSTITUTABLE CAP.		PERCENTAGE
	[BTU/hr]	[kW]	[BTU/hr]	[kW]	
Hydronic Space Heating	123,740,695	36,265	120,746,711	35,387	97.6%
Gas-Fired Domestic Hot Water	42,399,251	12,426	39,045,411	11,443	92.1%
Steam-to-Water Space Heating	29,369,000	8,607	29,369,000	8,607	100.0%
Gas Hydronic Pool Heating	5,524,700	1,619	4,885,500	1,432	88.4%
Steam-Only Space Heating	4,483,500	1,314	4,483,500	1,314	100.0%
Forced-Air Ducted Space Heating	39,571,717	11,597	653,000	191	1.7%
Electric Space Heating	5,273,820	1,546	560,000	164	10.6%
Electric Domestic Hot Water	171,400	50	7,400	2	4.3%
Forced-Air Unducted Space Heating	4,186,800	1,227	0	0	0.0%
Gas Radiator Space Heating	836,000	245	0	0	0.0%
TOTAL	**255,556,883**	**74,896**	**199,750,522**	**58,541**	**78.2%**

Notes: Hydronic, steam and domestic hot-water heating systems that are not easily accessible (e.g. on the roof) were considered non-replaceable. Electric domestic water heaters were considered replaceable if they are installed in buildings with other replaceable heating systems.

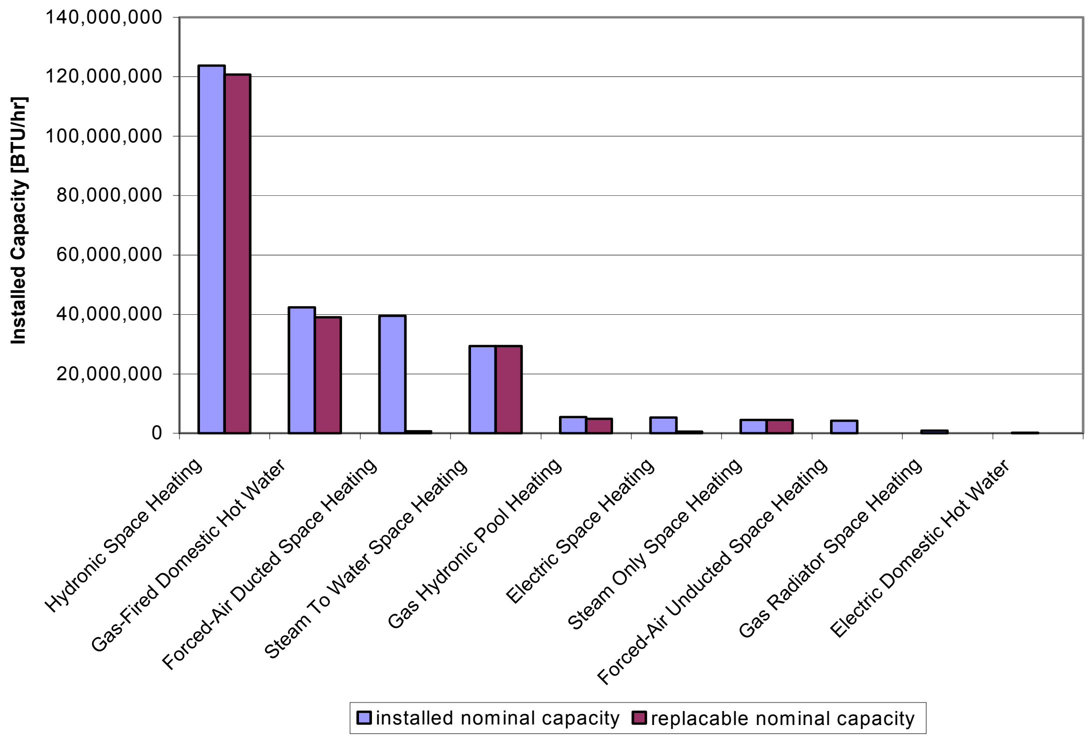

Figure 12: Installed and Replaceable Nominal Heating Capacity, by Type, in Assessed Buildings in the Target Area

Notes: Hydronic, steam, and domestic hot-water heating systems that are not easily accessible (e.g. on the roof) were considered non-replaceable. Electric domestic water heaters were considered replaceable if they are installed in buildings with other replaceable heating systems.

Supply and Return Temperatures

Determination of the existing and achievable supply and return temperatures of hydronic systems, as well as the operating temperatures of other heating systems, was an important component of the heat-demand inquiry. It is beyond the scope of this report to discuss the specific operating temperatures of the heating systems in each assessed building because there are too many of them. Therefore only a general overview of the operating temperatures is given below. See Table 11. For more detailed information about the operating temperatures of the various systems, see APPENDIX II.

1. **Hydronic Space-Heating Systems**

   The supply temperatures of the hydronic heating systems assessed within the target area range from about 130°F (54°C) to 180°F (82°C). Apart from a few radiant floor-heating systems in residential buildings and one heat-pump heating system (at City Hall) that achieve return temperatures below 80°F (27°C), the return temperatures are usually only a few degrees lower than the supply temperatures. The temperature differential between supply and return is usually very low, typically on the order of 5-10°F (3-6°C).

2. **Forced-Air Heating Systems (Ducted and Unducted Systems)**

   Forced-air systems usually use a mixture of inside (return) and outside (fresh) air that is heated and then blown into the heated space or distributed via a duct system. The important parameters for such systems are the air temperature rise across the heating section, and the maximum achievable output air temperature. The air temperature rise ranges from 30-65°F (17-36°C) with maximum output air temperatures of 170-175°F (77-79°C).

3. **Domestic Hot Water Systems**

   The supply temperatures for domestic hot-water systems range from 100-140°F (38-60°C) for personal use (including bathrooms, showers, and sinks) and from 160-190°F (71-88°C) for commercial use (in kitchen, laundry, and other applications). Many domestic hot-water systems are equipped with a circulation pump to save water, which increases heat losses. These findings apply to gas-fired and electric domestic water heaters alike.

4. **Hydronic Pool Heating Systems**

   The supply temperatures for pool heating systems range between 84-104°F (29-40°C) depending on the function of the pool (e.g. whether it is a swimming pool or a spa.)

5. **Other Systems**

   Supply and return temperatures are not applicable for steam-only systems since these systems transfer (latent) heat by condensing low-pressure steam. Steam pressures in such systems range from 5 to 15 psi (0.34 to 1.0 bar).

   Gas-fired radiators primarily transfer heat by radiation, so supply and return temperatures do not apply to these systems.

The average temperature differential between supply and return for the heating systems we assessed in the target area are far too low for optimal operation of a district heating system. Ideally, a temperature differential between the supply and the return of 54°F (30°C) or higher is needed to achieve peak efficiency. However, both the supply and return temperatures of the existing heating systems are relatively low, so a high temperature differential at the primary side of the heat exchanger may be achievable. See Section 4.6.1.

Table 11: Operating Temperature Ranges of Assessed Heating Systems in the Target Area

HYDRONIC SPACE HEATING SYSTEMS	°F	°C
Supply Temperature	130-180	54-82
Return Temperature	125-170	52-76
Temperature Differential	5-10	3-6
FORCED-AIR SYSTEMS (DUCTED & UNDUCTED)	**°F**	**°C**
Temperature Rise	30-65	17-36
Maximum Output Temperature	170-175	77-79
DOMESTIC HOT WATER	**°F**	**°C**
Supply Temperature Personal	100-140	38-60
Supply Temperature Commercial	160-180	71-88
HYDRONIC POOL HEATING	**°F**	**°C**
Supply Temperature	84-104	29-40

Notes: Values represent average numbers. For more detailed values, see APPENDIX II.

Control Systems

Another important task of this inquiry was the assessment of the controls used in heating systems within the target area. An overview of the information obtained regarding control systems appears below. For more detailed information regarding the assessed control systems, see APPENDIX II.

1. **Hydronic Heating Systems**

   The quality and complexity of the installed control systems vary significantly according to the age and size of the buildings in which they are installed. Smaller buildings usually lack any control devices other than thermostats that control room temperatures by switching boilers and pumps on and off. Pumps in smaller buildings are generally single-speed, and are thus not capable of variable flow control.

   In larger buildings, mixing valves for temperature and flow control (either supply or return temperature control) are used in some cases, but thermostats that measure outdoor temperature and adjust the boiler setpoint accordingly are only rarely used. The boilers in the larger buildings we assessed generally maintain a fixed water-temperature setpoint, and the pumps are simply switched “on” when the thermostats call for heat.

   The most advanced control systems identified during the assessment are installed in buildings using hydronic systems combined with large fancoils or other air-handling units. Depending on the outside, inside, and circulating air temperatures, the water entering the heating coils is generally controlled using mixing valves or other flow controls. The air flow rate is controlled using variable-speed circulating fans. Many such systems are connected to a building automation system that controls and monitors the operation.

Only a few assessed buildings have different temperature settings for day and night or for periods when the buildings are unoccupied (e.g. on evenings or weekends in office buildings.)

2. **Forced-Air Systems**

   Single forced-air units are generally controlled by room thermostats, or are manually switched on and off.

   Forced-air distribution systems are usually controlled by inside thermostats. Outside air thermostats are rarely used. Typically these systems have single-speed fans.

   Different temperature settings for day and night or for periods when the buildings are not occupied are very rare.

3. **Domestic Hot Water Systems**

   Domestic water heaters generally maintain a fixed setpoint temperature governed by a thermostat inside the storage tank. The circulation pumps generally do not have a timer, and so they run 24 hours per day.

4. **Pool Heating Systems**

   Pool heating systems usually maintain a fixed temperature. Depending on the use of the pool or spa, the heating system operates either during summer months only or year-round.

5. **Other Systems**

   Steam systems usually maintain a fixed steam pressure. The steam valves simply open and close on demand as the room thermostats call for heat.

   Gas radiators are usually controlled by thermostats, or are manually switched on and off.

Generally speaking, most of the assessed control systems would require upgrading in order to take full advantage of the benefits of a district heating system (including fully automatic operation, different temperature settings for different time periods, etc.) Upgrades would also be necessary to achieve high temperature differentials at the primary cycle (supply side) of each heat-transfer station. The most important upgrade needed is the addition of mixing valves to control the flow rates and temperatures in the secondary cycle (load side) of the heat-transfer stations.

4.2.3.2 Potential Micro-Grid Sites

Los Arroyos Compound

Each building in the Los Arroyos Compound apartment complex has a dedicated, central space heating and domestic hot-water system. All space heating systems are hydronic. The heating capacities installed in the buildings vary depending on the building's size and use (e.g. residential or administrative.) Table 12 gives an overview of the installed systems.

Table 12: Installed Nominal Heating Capacity, by Building, at Los Arroyos Compound

BUILDING	CAPACITY HEATING		CAPACITY DHW		TOTAL	
	[BTU/hr]	[kW]	[BTU/hr]	[kW]	[BTU/hr]	[kW]
Block 1A	840,000	246	318,400	93	1,158,400	339
Block 1B	840,000	246	375,200	110	1,215,200	356
Block 1C	840,000	246	318,400	93	1,158,400	339
Block 1D	840,000	246	315,200	92	1,155,200	339
Block 2A	550,000	161	200,000	59	750,000	220
Block 2B	550,000	161	159,200	47	709,200	208
Block 3A	518,000	152	200,000	59	718,000	210
Community Building	320,000	94	28,400	8	348,400	102
TOTAL	**5,298,000**	**1,553**	**1,914,800**	**561**	**7,212,800**	**2,114**

Notes: The roof-top unit at the administrative building is not included in this figure as it was not possible to obtain information about its capacity. Blocks 1A – 1D house 24 residential units each, while Blocks 2A, 2B, and 3A each house 16 residential units. All residential units are 920 ft² (85m²).

The variation in total installed capacity between apartment buildings of the same size (see Table 12) is likely due to past retrofits of old boilers.

The supply temperature in six of the seven apartment buildings is 130°F (54°C), and in the seventh block the supply temperature is approximately 150°F (66°C). Originally all seven apartment buildings had supply temperatures of 150°F (66°C), but problems with several boilers and the piping system in the blocks led the heating system operator to lower the supply temperature to 130°F (54°C). The temperature differential between the supply and return lines is approximately 15°F (8°C). The supply temperature for all of the domestic hot-water systems is 140°F (60°C). Each domestic hot-water system has a circulation pump that runs 24/7.

During the heating season, the single-speed circulating pumps run 24/7 and the boilers maintain their setpoint temperature. Each residential unit has a single analog thermostat (without nighttime setback capability), which calls for heat by opening a valve to allow the heated water to circulate through the baseboard radiators in the apartment. An outdoor thermostat locks out the heating boiler when the outdoor temperature rises above the setpoint, reducing boiler operation during the swing seasons and preventing it entirely during the summer.

The swimming pool has a dedicated boiler, for which the supply temperature is set to 84°F (29°C) in summer and 88°F (31°C) in winter.

For efficient operation of a micro-grid at this location, mixing valves would need to be installed in the heating systems of each building in order to achieve a high temperature differential in the primary cycle at the heat-transfer stations. The mixing valve would mix the low-temperature return from the baseboards with the high-temperature supply from the heat-transfer station to maintain the existing supply temperature for the baseboards (130-150°F). The mixing valve would be operated by the integral control system of the heat-transfer station.

South Capitol Complex

Each building in the complex has a dedicated heating system and a dedicated domestic hot-water system. All buildings except the Simms Building, which has a steam-only system, have hydronic heating systems. The installed heating capacities vary according to building size. Table 13 gives an overview of the installed systems.

Table 13: Installed Nominal Heating Capacity, by Building, at the South Capitol Complex

BUILDING	CAPACITY HEATING		CAPACITY DHW		TOTAL	
	[BTU/hr]	[kW]	[BTU/hr]	[kW]	[BTU/hr]	[kW]
JOSEPH MONTOYA BUILD.	2,160,000	633	576,000	169	2,736,000	802
HAROLD RUNNELS BUILD.	5,358,400	1,570	315,200	92	5,673,600	1,663
JOHN F SIMMS BUILD.	2,007,200	588	216,000	63	2,223,200	652
MANUEL LUJAN SR BUILD.	1,750,000	513	216,000	63	1,966,000	576
TOTAL	**11,275,600**	**3,305**	**1,323,200**	**388**	**12,598,800**	**3,692**

Notes: All heating systems except for the Simms Building (steam) are hydronic. The capacity of the domestic water heater in the Simms Building was estimated based on the square footage of the building.

The two larger buildings, the Joseph Montoya and the Harold Runnels Building, are each equipped with two Kewanee boilers. The specification plates on the Kewanee boilers are unclear, and show two different values for the nominal heating capacity. Unfortunately, Kewanee is out of business and no further information could be obtained. The values given in Table 13 are the lower of the two values shown on the specification plates, which (according to the maintenance personnel) are believed to represent the actual nominal heating capacity of the boilers. Correction factors were later applied to these capacities using the guidelines discussed in Section 3.4. Also see Section 4.3.2 for more details.

The supply temperature for all of the domestic hot-water systems is 140°F (60°C). Domestic hot water for the Joseph Montoya Building is preheated by six solar panels on the roof of the building. The six panels have a total area of 600 ft² (56°m²). All domestic hot-water systems are equipped with circulation pumps. It was not possible to obtain any information about the domestic hot-water system of the Simms Building, and so the nominal heating capacity of the domestic hot water boiler had to be estimated. This water heater is not located in the boiler room, however, so replacing this load with a heat-transfer station from a district energy system would likely be difficult and costly.

The boilers for the three hydronic heating systems operate between a maximum supply temperature of 160°F (71°C) and a minimum of 120°F (49°C). The steam boiler in the Simms building operates with a maximum steam pressure of 15 psi (1 bar).

There is no outside thermostat that controls the boilers, so the boilers are usually switched off manually when the outside temperature rises too high. The hot water is pumped into air-handling units that maintain a constant hot air temperature of 120°F (49°C). The water flow into the air-handling units is controlled by mixing valves. The set-point of the mixing valves is determined by the outside air temperature, the circulation air temperature and the set temperature for the hot air. The hot air is mixed with cold air at mixing boxes in the offices that are controlled by thermostats (set temperature between 68 and 70°F (20 and 21°C).) The entire heating systems of the Montoya Building as well as the Runnels Building are controlled by their own central computer system that also controls the set temperatures of the thermostats in the building. The heating system of the Lujan Building features the same control units at the air-handling units but does not have an apparent central computer control system.

According to maintenance personnel, the temperature differential between the supply and return on the hydronic heating systems is only around 5°F (3°C). Unfortunately all of the boilers were idle during our assessment, so this information could not be verified. But such a small temperature differential makes it more difficult to implement district heating, because the micro-grid must maintain a high temperature differential in its primary cycle in order to be efficient. To achieve this high temperature differential in the primary cycle, mixing valves would need to be installed in the heating systems of each building to create a greater temperature differential in the secondary cycle. The hydronic flow rate through the heating coils in air-handling units would also need to be reduced in order to generate a higher temperature differential between entering (supply) and exiting (return) water flow. See Section 4.6.2 for more details.

Santa Fe Community College

The main building at the campus was constructed in phases. The first phase, built in 1988, houses classrooms, laboratories, meeting and conference rooms, a bookstore, and a cafeteria. A second phase (1994) added more classrooms, offices, and administrative space, as well as a large lecture hall, planetarium, and an atrium. A single, central hydronic heating system serves all of the building constructed under these two phases, and also heats the Fitness Education Center, which is a stand-alone building but is connected to the main heating system by a small micro-grid. The indoor swimming pool and the domestic hot water at the Fitness Education Center each has an additional, dedicate boiler.

The Visual Arts wing, opened in 1999, contains laboratory/classrooms, exhibition and gallery space, and more administrative areas. This addition has its own dedicated hydronic heating system and (electric) domestic hot-water system. The third main building at the campus, the Early Childhood Development Center, also has dedicated hydronic heating and domestic hot-water systems. Heating system capacities vary according to building size, as shown in Table 14.

Table 14: Installed Nominal Heating Capacity, by Building, Santa Fe Community College

BUILDING	CAPACITY HEATING		CAPACITY DHW		TOTAL	
	[BTU/hr]	[kW]	[BTU/hr]	[kW]	[BTU/hr]	[kW]
MAIN BUILDING	4,824,600	1,414	1,000,000	293	5,824,600	1,707
FITNESS EDUCATION	1,500,000	440	1,000,000	293	2,500,000	733
VISUAL ARTS CENTER	2,788,000	817	450,000	132	3,238,000	949
EARLY CHILDHOOD	2,300,000	674	200,000	59	2,500,000	733
TOTAL	**11,412,600**	**3,345**	**2,650,000**	**777**	**14,062,600**	**4,121**

Notes: The heating capacity shown for the Fitness Education Center is for pool heating only. Capacities shown for domestic water heating in the Visual Arts Center are estimated, as specifications for the electrical water heaters were not available. The back-up heating capacity installed at the Visual Arts center and the Early Childhood Development Center is not considered.

Each heating system consists of two boilers of the same size. In the Main Building both boilers are sometimes in operation at the same time, while the second boilers in the Visual Arts Center and in the Early Childhood Development Center serve exclusively as backup systems. The replacement of one of the two gas-fired boilers in the main building with a biomass-fired boiler may be a promising opportunity to demonstrate the reliability of biomass-fired heating systems.

The measured supply temperature of the heating system at the main building was 135°F (57°C), and the measured differential between the supply and return temperatures was only around 5°F (3°C). The boilers in the other buildings were not in operation during the assessment. The supply temperatures of domestic hot-water systems ranges from 106°F (41°C) to 120°F (49°C). All domestic hot-water systems have circulation pumps. The pool temperature is maintained at 82°F (28°C) throughout the year.

The heating boilers are controlled by outdoor thermostats. In the main building, where both boilers are used, the first boiler starts when the outdoor temperature falls below 63°F (17°C), and the second boiler starts when the outdoor temperature falls below 55°F (13°C). The hot water circulates through coils in the air-handling units, and a variable-speed pump adjusts the flow rate through the coils according to the heat demand. The building automation system turns off the air handlers every night at 10:30 p.m. when the buildings close. The building automation system has ongoing problems, and changes to the system are planned in the near future.

Depending on the outcome of the changes to the building automation system, it may not be necessary to install mechanical upgrades to achieve the higher temperature differential needed for district heat installation. Otherwise, mixing valves may need to be installed at each heating system to achieve a suitable differential temperature. See Section 4.6.2 for more details.

College of Santa Fe

Many heating systems at the College of Santa Fe date back to the original year of building construction. Most of the boilers lack specification plates, so very little information about the installed heating capacity was available. The nominal heating capacity and annual heat demand were therefore estimated based on the average classification numbers calculated during the heat-demand inquiry of the buildings in downtown Santa Fe. The result of these calculations are discussed in Section 4.4.2.

Due to their age, most of the boilers and their accompanying control systems have significant maintenance issues. Several energy assessments have been commissioned over the last few years, but few if any of the recommendations have been implemented and the problems continue. A project to switch the entire campus from gas-fired boilers to biomass-fired boilers, accompanied by an upgrade of all control systems, could therefore offer a unique opportunity to rectify existing heating system problems and implement a promising, environmentally friendly technology at the same time.

4.2.4 Heating Season

4.2.4.1 Downtown Santa Fe

With the exception of a few hotels and office buildings, all heating systems are switched off during the warmer months of the year. Only heat for domestic hot water and swimming pools is needed during that period. Some buildings have two-pipe systems, which require seasonal changeovers between heating and cooling operation, and are incapable of simultaneous heating and cooling.

Generally, the heating season begins between late October and early November and ends between late March and early April. In a few buildings the heating season begins in late September and may end as late as early May. During the assessments in the last weeks of March, most of the heating systems were already out of operation. These results correlate well with the trend of the daily heating degrees shown in Figure 3 and Figure 4.

Compared to central Europe, where heating starts between September and October and ends between April and early May, the heating season in Santa Fe is shorter by about two to four weeks. The boiler full-load operating hours for heating systems in Santa Fe were therefore expected to be generally lower than in central Europe. The results of the data evaluation (Section 4.3) confirm this assumption.

4.2.4.2 Potential Micro-Grid Sites

Los Arroyos Compound

According to maintenance personnel, the outside thermostats that control the boilers are disabled every year on the 1st of May and are re-enabled again at the 1st of September. The actual length of the heating season is of course determined by the outside temperatures during the period for which the boilers are enabled. Heat for domestic water heaters and the swimming pool is needed year-round.

South Capitol Complex

The heating systems at the South Capitol Complex are switched off during the summer months. Depending on the weather, the heating season begins between October and early November and ends between mid March and late April. Outside this period the only heat requirement is for domestic hot water.

Santa Fe Community College

Apart from the swimming pool at the Fitness Education Center, which is heated throughout the year, the heating systems usually operate from mid-September until April.

College of Santa Fe

Because there are 46 buildings with a variety of purposes at the campus, the heating season differs from building to building. According to the annual heat-demand line (Figure 22), the heating season can generally be expected to begin around mid-October and to end between late March and mid-April.

4.3 Specific Classification Numbers, Plausibility Check and Identification of Oversized Heating Systems

4.3.1 Main District Heating System

4.3.1.1 Specific Nominal Heating Capacity

Based on the data obtained during the heat-demand inquiry, the specific nominal heating capacity for all assessed buildings was calculated. Table 15 gives an overview of the results of these calculations. The results presented are prior to application of correction factors for oversized heating systems (done later in Section 4.3.1.3), but they do include any needed corrections to the heated area based on the plausibility checks. Backup heating capacities are not included in the table.

Table 15: Uncorrected Specific Nominal Heating Capacities of Assessed Buildings in the Target Area of the Main District Heating System

TYPE OF BUILDING	SPECIFIC NOMINAL CAPACITY					
	Maximum		Minimum		Average	
	[BTU/hr*sqft]	[kW/m²]	[BTU/hr*sqft]	[kW/m²]	[BTU/hr*sqft]	[kW/m²]
Apartments	75.2	0.237	75.2	0.237	75.2	0.237
Church	71.0	0.224	65.6	0.207	68.0	0.214
Commercial	173.9	0.549	25.5	0.081	54.5	0.172
Healthcare	35.7	0.113	35.7	0.113	35.7	0.113
Large_Hotel	119.4	0.377	42.4	0.134	66.1	0.209
Medium_Size_Hotel	155.9	0.492	47.6	0.150	69.4	0.219
Municipal	86.7	0.273	27.9	0.088	36.8	0.116
Museum	63.0	0.199	30.3	0.096	53.2	0.168
Offices	111.6	0.352	17.0	0.054	47.6	0.150
Residential	92.0	0.290	44.8	0.141	66.4	0.209
Restaurant	71.1	0.224	71.1	0.224	71.1	0.224
School	75.8	0.239	39.2	0.124	53.7	0.169
Shopping_Center	47.3	0.149	40.6	0.128	42.0	0.132
Small_Hotel	92.8	0.293	42.1	0.133	61.3	0.193
Theater	127.7	0.403	37.1	0.117	73.3	0.231

Notes: Back-up boilers are not considered. Values shown are based on boiler nameplate capacities and other information taken during site assessments. Only corrections for implausible estimates of the heated area have been made.

Table 15 shows significant differences in installed specific nominal heating capacity for the different building categories as well as within each category. In general, nearly all of the specific nominal heating capacities seem too high. The maximum values are clearly indicative of oversized heating systems. For corrected results after accounting for oversized heating systems, see Section 4.3.1.3.

The comparatively low specific capacities found in shopping centers could be due to the use of lower thermostat settings (usually 65°F (18°C) compared to 68°F (20°C) in other buildings) as well as the relatively small number of domestic water heaters installed in large heated areas.

The average capacities found in offices, municipal buildings, and museums are lower than those found in residential buildings and hotels, and this seems plausible based on the difference in domestic hot water needs. Furthermore, office buildings generally need less installed heating capacity due to the contributions from heating, lighting, and other heat sources in the building.

Commercial buildings show a slightly higher average specific nominal heating capacity than the office/municipal/museum buildings discussed above. It is unlikely that this difference can be explained by differences in hot-water usage. A more likely explanation is that the ratio of room volume to heated area is generally greater in commercial buildings than in offices, municipal buildings and museums, necessitating a larger heating system. The large spread between maximum and minimum values indicates that not all systems are correctly designed, however.

Only one healthcare center was assessed, and its specific nominal heating capacity was expected to be higher based on our experience with full-service hospitals. La Familia Healthcare Center is a daycare facility only, however, so the domestic hot water needs are lower than for full-service hospitals. Even accounting for this, however, the specific nominal heating capacity still seems low for this building category.

The calculated value for the specific nominal heating capacity in schools seems plausible. Schools generally use more domestic hot water than offices, municipal buildings and museums, and the thermostats are generally set somewhat higher. Schools use thermostat settings between 70-77°F (21-25°C) whereas offices, municipal buildings and museums generally use 68-70°F (20-21°C). The relative values calculated for average specific capacity are thus as expected.

Apartments, homes, and hotels generally have a relatively high specific capacity due to higher thermostat settings and greater domestic hot water use, and the calculated values reflect this. However, the specific capacity for apartments and homes was expected to be lower than for hotels because hotels often use more domestic hot water for laundry and kitchen facilities as well as for swimming pools. In this case the higher specific capacity of the apartment complex comes from the fact that each residential unit of the complex has its own heating system. The total installed capacity at the complex is therefore higher than in an apartment complex (or other residential buildings with many separate residential units or guest rooms) of the same size with a central heating system that takes the simultaneity factor of all the units into account.

Only one restaurant was assessed, and its relatively high specific nominal heating capacity seems plausible based on the significant use of domestic hot water in the kitchen.

4.3.1.2 Specific Heat Demand and Total Heat Demand of the Assessed Buildings

Based on the data obtained during the heat demand inquiries, the specific heat demand of each building was calculated using the method described in Section 3.3.2 and considering the annual utilization rate of the installed heating systems. Table 16 gives an overview of the results of these calculations. The results are based solely on the information gathered during the assessments, although the estimates of heated area were checked for plausibility and adjusted if needed. If available, national-averages for specific heat demand in buildings of each category have been included in the table. National average data are from *USDOE Buildings Energy Data Book 2002* [4].

The data from the USDOE are averaged for all regions of the U.S., and therefore can only be used as a rough indication of the expected specific heat demand of buildings in the various categories. The value given by the USDOE for “households” has been inserted for both the “apartment buildings” and “residential” categories in the table.

Table 16: Specific Heat Demand of Assessed Buildings, by Category, in the Target Area of the Main District Heating System

TYPE OF BUILDING	SPECIFIC HEAT DEMAND Maximum		Minimum		Average		National Average	
	[BTU/sqft]	[kWh/m²]	[BTU/sqft]	[kWh/m²]	[BTU/sqft]	[kWh/m²]	[BTU/sqft]	[kWh/m²]
Apartments	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	36,540	115.3
Church	61,836	195.1	44,616	140.7	53,895	170.0	26,900	84.9
Commercial	88,598	279.5	25,495	80.4	40,358	127.3	42,800	55.8
Healthcare	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	118,200	372.9
Large_Hotel	95,915	302.6	49,602	156.5	66,377	209.4	74,100	233.8
Medium_Size_Hotel	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	74,100	233.8
Municipal	37,070	116.9	32,034	101.1	33,789	106.6	35,700	112.6
Museum	59,914	189.0	20,450	64.5	47,257	149.1	n.a.	n.a.
Offices	82,999	261.8	8,574	27.0	37,795	119.2	33,000	104.1
Residential	38,621	121.8	38,621	121.8	38,621	121.8	36,540	115.3
Restaurant	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	58,400	184.2
School	44,028	138.9	16,682	52.6	33,484	105.6	50,200	158.4
Shopping_Center	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	31,900	100.6
Small_Hotel	82,891	261.5	66,613	210.1	77,055	243.1	74,100	233.8
Theater	120,222	379.3	120,222	379.3	120,222	379.3	n.a.	n.a.

Note: Only buildings with complete gas bills are included; n.a. not available; national averages shown are from[4], the national average data do not distinguish between apartment buildings and residential homes, so the value for "households" was used for both categories.

The results from the heat-demand inquiry correspond well with the national averages except in the churches and schools categories.

The two churches we assessed consume thermal energy at a rate that is roughly twice the national average. This could be due to the fact that both of the churches are connected with other buildings that have a higher specific heat demand than the church itself.

The average specific heat demand for the schools we assessed is about 33 percent below the national average. This could be due to the fact that the schools assessed in Santa Fe are open approximately 6 hours per day (8 a.m. to 2 p.m.) whereas the national average data is for schools with an average occupancy of 8 hours per day on weekdays and 2 hours per day on weekends.

The total annual heat demand in assessed buildings for which utility-bill data were not available, as well as in buildings that were not assessed, was estimated using the heated square footage and a best estimate of the specific heat demand. The best estimates of specific heat demand for each building category were based on both calculated and national-average values, and are shown in Table 17. The resulting estimated total heat demand is shown in Table 18. A special approach was used for museums to account for the wide variety of different building envelopes among the museums. (Museum envelopes range from large galvanized metal buildings to small adobe buildings.) The heat demand in museums was therefore estimated based on available heat demand data from buildings with similar building envelopes.

Table 17: Best Estimates for Specific Heat Demand of Santa Fe Buildings, by Category

TYPE OF BUILDING	SPECIFIC HEAT DEMAND	
	[BTU/sqft]	[kWh/m²]
Apartments	36,540	115.3
Church	26,900	84.9
Commercial	40,400	127.4
Healthcare	78,000	246.1
Large_Hotel	66,400	209.5
Medium_Size_Hotel	66,400	209.5
Municipal	33,800	106.6
Museum	n.a.	n.a.
Offices	37,800	119.2
Residential	42,600	134.4
Restaurant	58,400	184.2
School	33,500	105.7
Shopping_Center	36,600	115.5
Small_Hotel	77,100	243.2
Swimming_Pool	n.a.	n.a.
Theater	120,300	379.5

Note: Museums must be estimated according to their building envelope; specific heat demand not applicable for pool heating; specific heat demand shown for healthcare buildings is for day-use only facilities, and represents two-thirds of the value applicable to full-time hospitals.

The total heat demand for all assessed buildings is shown by category in Table 18 and Figure 13. The largest portion of the assessed heat demand is in large hotels (30.9 percent) and office buildings (25.4 percent). Commercial buildings (8.6 percent), schools (7.7 percent), and shopping centers (7.1 percent) also contribute significantly to the total heat demand. All other building categories combined make up less than 21 percent of the total heat demand.

Table 18: Total Annual Heat Demand of Assessed Buildings, by Category, in the Target Area of the Main District Heating System

TYPE OF BUILDING	TOTAL HEAT DEMAND [BTU/yr]	[kWh/yr]	PERCENTAGE
Apartments	1,709,331,500	500,954	0.78%
Church	2,099,504,250	615,302	0.96%
Commercial	18,875,494,291	5,531,841	8.63%
Healthcare	1,404,000,000	411,470	0.64%
Large_Hotel	67,550,877,711	19,797,136	30.88%
Medium_Size_Hotel	9,450,114,400	2,769,545	4.32%
Municipal	1,123,704,540	329,324	0.51%
Museum	13,665,041,355	4,004,814	6.25%
Offices	55,552,398,321	16,280,741	25.39%
Residential	677,916,800	198,677	0.31%
Restaurant	262,800,000	77,019	0.12%
School	16,812,773,616	4,927,320	7.69%
Shopping_Center	15,629,517,600	4,580,543	7.14%
Small_Hotel	5,437,445,167	1,593,552	2.49%
Swimming_Pool	2,420,914,753	709,497	1.11%
Theater	6,098,644,035	1,787,330	2.79%
TOTAL	218,770,478,340	64,115,064	100.00%

Note: Annual heat demand based on annual gas consumption if available, otherwise based on best estimate of specific heat demand as specified in Table 17; the new construction of the Presbyterian Church and the expansion of the Museum of New Mexico are included in this table.

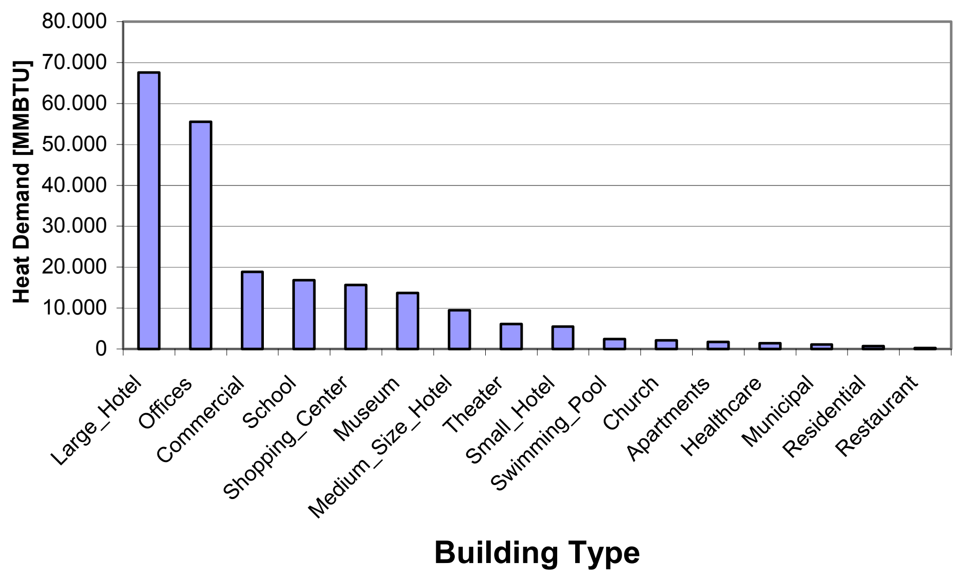

Figure 13: Total Annual Heat Demand of Assessed Buildings, by Category, in the Target Area of the Main District Heating System

4.3.1.3 Full-Load Operating hours, Adjustment of Oversized Heating Systems and Total Nominal heating capacity of all Assessed Buildings

The full-load operating hours was calculated for each building by dividing the total heat demand for the building (calculated or estimated as discussed in Section 4.3.1.2) by the installed nominal heating capacity. Table 19 gives an overview of the results of these calculations.

Table 19: Uncorrected Full-Load Operating Hours of Assessed Buildings, by Category, in the Target Area of the Main District Heating System

	FULL-LOAD OPERATING HOURS		
TYPE OF BUILDING	Maximum [hrs]	Minimum [hrs]	Average [hrs]
Apartments	485	485	485
Church	872	794	840
Commercial	1,494	234	741
Healthcare	2,186	2,186	2,186
Large_Hotel	1,284	451	1,064
Medium_Size_Hotel	1,493	426	989
Municipal	1,148	399	919
Museum	1,455	799	1,068
Offices	2,218	216	794
Residential	861	437	628
Restaurant	730	730	730
School	738	237	621
Shopping_Center	902	773	871
Small_Hotel	1,829	718	1,258
Swimming_Pool	833	833	833
Theater	1,494	941	1,109

Note: Based on both calculated (from utility-bill data) and estimated values for the heat demand.

Table 19 shows a significant variation in full-load operating hours within nearly every category, and between the categories as well. Specific characteristics of the buildings like occupancy, insulation or special use can explain some of this variation, but it is also clear that some heating systems are oversized.

The oversized heating systems were identified using the guidelines outlined in Section 3.3.4. Depending on the amount of variation between the specific building's full-load operating hours and the average building full-load operating hours, correction factors were applied. Due to the 7,000 ft (2,170 m) altitude of Santa Fe, oversized boilers must be installed to compensate for the poorer performance in thin air. The nominal heating capacity of a boiler must be de-rated 4 percent per 1,000 ft (305 m) above its design altitude (i.e. a boiler with a capacity of 1,000,000 BTU/hr at an altitude of 7,000 ft equals the capacity of a boiler with a capacity of 800,000 BTU/hr at an altitude of 2,000 ft.)

According to information gained from manufacturers, the heating devices are usually designed for an operation from 0 ft/m to between 2,000 ft (305 m) [5] and 5,000 ft (1,524°m) [6], so the design capacity of the installed boilers in Santa Fe has to be de-rated between 8 percent and 20 percent to account for a 2,000 ft (610 m) to 5,000 ft (1,524 m) increase in altitude, respectively. Based on this information, the average design altitude for all installed heating devices was set at 4,000 ft/1,220 m, which means that the actual nominal heating capacity is 12 percent lower than the nominal heating capacity specified. Boilers with an already adjusted nominal heating capacity (according to their specification plate) were not considered.

It is likely that the heating systems are even more oversized, because according to the information gathered from [7], the design altitude is often set at sea level, which would mean that the actual nominal heating capacity is 28 percent lower than the nominal heating capacity specified To verify this assumption, detailed information from the engineers who designed the respective heating systems would be necessary. The engineers were approached, but except for one reply [7], no information could be obtained. Therefore, the very conservative approach described above was used to adjust for altitude.

After applying an altitude correction to the heating capacity for all buildings and re-calculating the corrected specific capacity for each building, the buildings with oversized heating systems were identified. To identify these buildings, we simultaneously considered the (corrected) specific capacity and the full-load operating hours for the buildings. Buildings with low full-load operating hours and a specific capacity significantly higher-than-average were considered oversized, and the nominal heating capacity was adjusted using the method described in Section 3.3.4. In a few cases, including several commercial and office buildings and one school, the full-load operating hours and the specific nominal heating capacity were both low. This suggests that either sections of the buildings are not in use, or the gas bills we obtained are not complete. Since neither assumption could be verified by the building operators, correction factors were not applied to these buildings.

The results of the adjustments are shown in Table 20. For more detailed information, see APPENDIX II.

Table 20: Corrected Specific Nominal Heating Capacity and Full-Load Operating Hours, by Category, in the Target Area of the Main District Heating System

TYPE OF BUILDING	SPECIFIC NOMINAL CAPACITY Maximum [BTU/hr*sqft]	SPECIFIC NOMINAL CAPACITY Minimum [BTU/hr*sqft]	SPECIFIC NOMINAL CAPACITY Average [BTU/hr*sqft]	FULL-LOAD OPERATING HOURS Maximum [hrs]	FULL-LOAD OPERATING HOURS Minimum [hrs]	FULL-LOAD OPERATING HOURS Average [hrs]
Apartments	48.88	48.88	48.88	747	747	747
Church	62.23	52.49	56.77	994	632	806
Commercial	104.34	25.54	41.87	1,704	387	964
Healthcare	35.68	35.68	35.68	2,186	2,186	2,186
Large_Hotel	73.11	37.16	54.94	1,464	752	1,175
Medium_Size_Hotel	93.54	47.57	56.76	1,396	710	1,170
Municipal	60.68	24.47	31.14	1,309	569	1,087
Museum	50.42	26.59	44.42	1,659	912	1,231
Offices	78.12	17.04	37.58	2,218	308	1,005
Residential	64.40	39.33	52.47	982	624	795
Restaurant	56.89	56.89	56.89	1,027	1,027	1,027
School	53.04	34.40	44.77	841	338	745
Shopping_Center	41.52	35.60	36.83	1,028	882	994
Small_Hotel	64.96	36.96	49.65	2,086	1,025	1,530
Swimming_Pool	n.a.	n.a.	n.a.	950	950	950
Theater	112.02	32.50	64.31	1,704	1,073	1,264

Notes: Corrections applied include altitude adjustments and adjustments for oversized heating systems. Other adjustments made previously based on plausibility checks on the heated area are also included here.

As a result of applying the correction factors, the range between minimum and maximum heating capacity decreased, and the average full-load operating hours increased. The average full-load operating hours for some building categories is still lower than expected, however. Apartments and homes usually have higher full-load operating hours than churches, but in our study the opposite was true. This discrepancy can be explained to some extent by the specific characteristics of the churches assessed in Santa Fe (i.e. there are other buildings are attached to them.) The low full-load operating hours of the apartment complex can be explained by the fact that it has separate heating systems for every unit, which leads to a higher specific nominal heating capacity and therefore lower full-load operating hours. The superior insulation in residential buildings compared to churches may also contribute to the lower full-load operating hours of residential buildings.

For the most part, the corrected values for specific nominal heating capacity and full-load operating hours in the remaining building categories appear plausible and correspond well with their specific heat demand. The low full-load operating hours for schools corresponds well with the low specific heat demand. Hotels have higher full-load operating hours, as expected, because they generally have a higher summer base-load due to their kitchen, laundry, and swimming pool facilities.

The results for full-load operating hours for heating systems in Santa Fe are generally lower than in Central Europe. The main reasons are a shorter heating season and the shutdown of most heating systems during the summer months.

Using the corrected nominal heating capacities, the total nominal heating capacity of all assessed buildings was calculated. Results are shown in Table 21. The corrected nominal heating capacity is approximately 18 percent lower than the total installed capacity in assessed buildings.

Table 21: Corrected Nominal Heating Capacity of All Assessed Buildings, by Category, in the Target Area of the Main District Heating System

TYPE OF BUILDING	INSTALLED CAPACITY		CORRECTED HEATING CAPACITY		
	[BTU/hr]	[kW]	[BTU/hr]	[kW]	PERCENTAGE
Apartments	3,521,760	1,032	2,289,144	671	65.0%
Church	3,116,800	913	2,603,581	763	83.5%
Commercial	25,506,040	7,475	19,578,924	5,738	76.8%
Healthcare	642,240	188	642,240	188	100.0%
Large_Hotel	69,191,555	20,278	57,493,177	16,850	83.1%
Medium_Size_Hotel	9,871,089	2,893	8,077,999	2,367	81.8%
Municipal	1,222,700	358	1,033,952	303	84.6%
Museum	13,285,450	3,894	11,097,155	3,252	83.5%
Offices	70,021,942	20,521	55,279,951	16,201	78.9%
Residential	1,079,200	316	852,782	250	79.0%
Restaurant	320,000	94	256,000	75	80.0%
School	27,050,330	7,928	22,569,868	6,615	83.4%
Shopping_Center	17,934,087	5,256	15,728,194	4,609	87.7%
Small_Hotel	4,387,490	1,286	3,553,229	1,041	81.0%
Swimming_Pool	2,906,700	852	2,549,176	747	87.7%
Theater	5,499,500	1,612	4,823,062	1,413	87.7%
TOTAL	**255,556,883**	**74,896**	**208,428,434**	**61,084**	**81.6%**

Note: Corrections include altitude adjustments and adjustments for oversized heating systems.

4.3.2 Potential Micro-Grid Sites

4.3.2.1 Specific Nominal Heating Capacity

Los Arroyos Compound

The specific nominal heating capacities for the seven apartment buildings and the administration building at Los Arroyos Compound were calculated using the data obtained during the heat-demand inquiry. Table 22 gives an overview of the results of these calculations. The results are based solely on the information gathered during the assessments, although the estimates of heated area were checked for plausibility and adjusted if needed. Altitude adjustments and any corrections to account for oversized heating systems will be applied later in Section 4.3.2.3.

Table 22: Uncorrected Specific Nominal Heating Capacity of Assessed Buildings at Los Arroyos Compound

TYPE OF BUILDING	SPECIFIC NOMINAL CAPACITY	
	[BTU/hr*sqft]	[kW/m²]
Block 1A	52.5	0.166
Block 1B	55.0	0.174
Block 1C	52.5	0.166
Block 1D	52.3	0.165
Block 2A	51.0	0.161
Block 2B	48.2	0.152
Block 3A	48.8	0.154
Community Building	174.2	0.550
AVERAGE	**53.6**	**0.169**

Notes: Values shown are based on boiler nameplate capacities and other information taken during site assessments. Only corrections for implausible estimates of the heated area have been made.

The calculated values for these seven apartment buildings correspond well with the average specific nominal heating capacity for apartment buildings shown in Table 20. Since all seven buildings were constructed at the same time using the same materials, there is no apparent reason for the specific nominal heating capacity to be different from building to building. It therefore seems plausible that the smallest specific nominal heating capacity (Block 2B) is adequate for all seven apartment buildings.

The specific nominal heating capacity of the community building is well above average, undoubtedly due to the swimming pool.

South Capitol Complex

The specific nominal heating capacities for the four office buildings at the South Capitol Complex were calculated using data gathered during the heat-demand inquiry. Table 23 gives an overview of the results of these calculations. The results are based solely on the information gathered during the assessments, although the estimates of heated area were checked for plausibility and adjusted if needed. Altitude adjustments and any corrections to account for oversized heating systems will be applied later in Section 4.3.2.3.

Table 23: Uncorrected Specific Nominal Heating Capacity of Assessed Buildings at the South Capitol Complex

BUILDING	SPECIFIC NOMINAL CAPACITY [BTU/hr/sqft]	SPECIFIC NOMINAL CAPACITY [kW/m²]
JOSEPH MONTOYA BUILD.	22.86	0.072
HAROLD RUNNELS BUILD.	36.21	0.114
JOHN F SIMMS BUILD.	31.13	0.098
MANUEL LUJAN SR BUILD.	25.78	0.081
AVERAGE	**29.71**	**0.094**

Notes: Values shown are based on boiler nameplate capacities and other information taken during site assessments. Only corrections for implausible estimates of the heated area have been made.

The calculated numbers for the office buildings are about 25 percent lower than the average specific nominal heating capacity for offices in downtown Santa Fe (Table 20.) The low specific nominal heating capacity of the Joseph Montoya Building suggests that the wrong nominal heating capacity from the boiler specification plate was used. This error is corrected in Section 4.3.2.3.

Santa Fe Community College

The specific nominal heating capacities of all buildings at the Santa Fe Community College were calculated using data gathered during the heat-demand inquiry. Table 24 gives an overview of the results of these calculations. The results are based solely on the information gathered during the assessments, although the estimates of heated area were checked for plausibility and adjusted if needed. Altitude adjustments and any corrections to account for oversized heating systems will be applied later in Section 4.3.2.3.

Table 24: Uncorrected Specific Nominal Heating Capacity of Assessed Buildings at Santa Fe Community College

BUILDING	SPECIFIC NOMINAL CAPACITY [BTU/hr/sqft]	SPECIFIC NOMINAL CAPACITY [kW/m²]
MAIN BUILDING	21.74	0.069
FITNESS EDUCATION CENTER	21.74	0.069
VISUAL ARTS CENTER	56.81	0.179
EARLY CHILDHOOD DEVELOPMENT	100.00	0.315
AVERAGE	**30.25**	**0.095**

Notes: All numbers are based on data taken during assessments, with no adjustment to the capacities. Only corrections for implausible estimates of the heated area have been made. Specific nominal capacities of Main Building and Fitness Center are averaged together since they are connected by a micro-grid.

The heating systems of the Visual Arts Center and the Early Childhood Development Center are clearly oversized, but according to the building manager, both systems were designed to allow future expansion. The heating systems of the main building and the fitness education center appear to be undersized compared to other buildings in the “schools” category. There were no reports of cold spots within the buildings, however, so it is more likely that the unheated area is higher than estimated.

College of Santa Fe

At the College of Santa Fe, only one boiler in the buildings we assessed had a specification plate showing its nominal heating capacity. Due to the lack of available information about the heating systems installed at the campus, the nominal heating capacity was estimated based on the averages shown in Table 20. Using this method, the estimated total nominal heating capacity of all buildings at the campus is 26,349,000 BTU/hr (7,722 kW). The results are discussed in detail in Section 4.4.2.

4.3.2.2 Specific Heat Demand and Total Heat Demand of the Assessed Buildings

Los Arroyos Compound

Based on the data gathered during the heat-demand inquiry, the specific heat demand at Los Arroyos Compound was calculated according to the guidelines described in Section 3.3.2. The buildings at Los Arroyos do not have dedicated gas meters, so there was no building-specific gas data available. The swimming pool also does not have a dedicated gas meter, so its heat consumption is mixed in with the space-heating loads. Based on information gathered during our site assessment, we estimate that the pool boiler operates 6 hours per day (2,190 hours per year). The resultant heat demand for the pool was then calculated (nominal output capacity * operating hours per year) and subtracted from the total heat demand to determine the heat demand of the apartment buildings. The heat demand of the apartment buildings was then multiplied by the estimated annual utilization rate of 0.75, and then divided by the actual heated area of the seven apartment buildings to calculate the specific heat demand. It is very important to measure the actual operating hours of the pool boiler, since it significantly influences the estimated heat demand of the apartment buildings.

Table 25 gives an overview of the results of these calculations. These results are based solely on the information gathered during the assessments, but they do include any needed corrections to the heated area based on plausibility checks including consideration of the building envelope.

Table 25: Specific Heat Demand of Assessed Buildings at Los Arroyos Compound

	HEAT DEMAND		SPECIFIC HEAT DEMAND	
	[BTU]	[kWh]	[BTU/sqft]	[kWh/m²]
Complex (all buildings)	6,163,042,217	1,806,203	45,829	145
Pool	700,800,000	205,383	n.a.	n.a.
Apartments	5,462,242,217	1,600,819	41,231	130

Note: The heat demand was calculated from the available gas bills and using an estimated annual utilization rate of 75 percent.

The results correspond well with the national average specific heat demand for apartments given in the *USDOE Buildings Energy Data Book 2002* [4]. (See Table 16.) The specific heat demand at Los Arroyos is nearly 13 percent above the national average for apartments, which is likely due to substandard insulation at the complex.

South Capitol Complex

Based on the data gained during the heat-demand inquiry, the specific heat demand for each building at the South Capitol Complex was calculated according to the guidelines described in Section 3.3.2.

Table 26 gives an overview of the results of these calculations. These results are based solely on the information gathered during the assessments, but they do include any needed corrections to the heated area based on plausibility checks including consideration of the building envelope. For the nationwide average number for office buildings according to the *USDOE Buildings Energy Data Book 2002* [4], See Table 16.

Table 26: Annual Heat Demand and Specific Heat Demand of Assessed Buildings at the South Capitol Complex

BUILDING	ANNUAL HEAT DEMAND		SPECIFIC HEAT DEMAND	
	[BTU]	[kWh]	[BTU/sqft]	[kWh/m²]
JOSEPH MONTOYA BUILD.	2,661,750,000	780,079	22,237	70.2
HAROLD RUNNELS BUILD.	4,298,250,000	1,259,688	27,433	86.5
JOHN F SIMMS BUILD.	2,281,883,767	668,752	31,948	100.8
MANUEL LUJAN SR BUILD.	735,750,000	215,626	9,648	30.4
TOTAL/AVERAGE	**9,977,633,767**	**2,924,145**	**23,528**	**74.2**

Note: The heat demand was calculated from the available gas bills and an annual utilization rate of 75 percent.

The average specific heat demand of all four buildings is about 40 percent lower than the average for office buildings in Santa Fe. The specific numbers from the Runnels and Simms buildings appear to be plausible, but the Montoya building and especially the Lujan building are too low. Further inquires with the General Service Division are currently underway to try to determine the reason for the low specific heat demand of these two buildings.

Santa Fe Community College

Based on the data gathered during the heat-demand inquiry the specific heat demand was calculated according to the guidelines described in Section 3.3.2.

Table 27 gives an overview of the results of these calculations. These results are based solely on the information gathered during the assessments, but they do include any needed corrections to the heated area based on plausibility checks including consideration of the building envelope. For the nationwide average number for schools according to the *USDOE Buildings Energy Data Book 2002* [4], see Table 16.

Table 27: Annual Heat Demand and Specific Heat Demand of Assessed Buildings at the Santa Fe Community College

BUILDING	ANNUAL HEAT DEMAND		SPECIFIC HEAT DEMAND	
	[BTU]	[kWh]	[BTU/sqft]	[kWh/m²]
MAIN BUILDING	14,550,059,230	4,264,186	53,799	169.7
FITNESS EDUCATION CEN.	8,476,971,763	2,484,346	75,351	237.7
VISUAL ARTS CENTER	3,559,640,509	1,043,224	62,450	197.0
EARLY CHILDHOOD DEV.	1,752,467,790	513,596	70,099	221.1
TOTAL/AVERAGE	**28,339,139,292**	**8,305,352**	**60,951**	**192.3**

Notes: Values are calculated using the available gas bills and an average utilization rate of 76.5 percent. (The efficiency of the installed boilers at the Community College is around 81.5 percent.) Electrical consumption for the domestic water heaters in the Visual Arts Center is not included.

The specific heat demand of all four buildings is significantly higher than the average for schools. This is due to the higher occupancy of the buildings (approximately 108 hours per week) compared to schools (approximately 35 to 40 hours per week.) The high heat demand of the Fitness Education Center results from the additional heat demand of the swimming pool. The actual annual and specific heat demand of the Visual Arts Center is higher than shown, because the electric consumption of the electric domestic water heater is not included in these calculations.

College of Santa Fe

Based on the data gathered during the heat-demand inquiry, the average specific heat demand for the entire campus of the College of Santa Fe was calculated. The calculation of individual demands for each building was not possible because the buildings are not sub-metered.

The annual gas consumption of the entire campus was 454,177 in 2000/2001. Taking the age of the boilers into account (most of them are more than 30 years old), the average annual utilization rate of the boilers was estimated to be 72 percent. Using this estimate, the total annual heat demand averages 32,701 MMBTU (9,584 MWh).

Using the total area of the campus (Table 7), the average specific heat demand of buildings at the campus is estimated to be 57,597 BTU/ft² (181.7 kWh/m²).

The specific heat demand corresponds well with the specific heat demand of the Santa Fe Community College. The 46 buildings at the College of Santa Fe vary considerably in age, function, and occupancy, however, and so having this "average" number may be of limited value.

4.3.2.3 Full-Load Operating Hours, Adjustment of Oversized Heating Systems, and Total Nominal Heating Capacity of all Assessed Buildings

Los Arroyos Compound

The full-load operating hours for the heating system in each building was calculated using the heat demand (calculated from the information gathered during the inquiry and the specific heat demand shown in Table 25) and the installed nominal heating capacity. Table 28 gives an overview of the results of these calculations.

Table 28: Uncorrected Heating Capacity, Demand, and Full-Load Operating Hours of Assessed Buildings at Los Arroyos Compound

TYPE OF BUILDING	TOTAL NOMINAL CAPACITY		HEAT DEMAND		FULL-LOAD OPERATING HOURS
	[BTU/h]	[kW]	[BTU]	[kWh]	
Block 1A	1,158,400	339	910,373,703	266,803	786
Block 1B	1,215,200	356	910,373,703	266,803	749
Block 1C	1,158,400	339	910,373,703	266,803	786
Block 1D	1,155,200	339	910,373,703	266,803	788
Block 2A	750,000	220	606,915,802	177,869	809
Block 2B	709,200	208	606,915,802	177,869	856
Block 3A	718,000	210	606,915,802	177,869	845
Community Building	348,400	102	700,800,000	205,383	2,011
TOTAL	**7,212,800**	**2,114**	**6,163,042,217**	**1,806,203**	**854**

Note: Values are based on gathered information and estimated values for the heat demand.

The results obtained for full-load operating hours vary slightly from building to building. According to Section 4.3.2.1, Block 2B appears to have the most optimized system, so all other residential buildings were adjusted to match its specific nominal heating capacity. The capacity of each boilers was then adjusted for altitude. The installed Raypak boilers are designed for an altitude of up to 5,000 ft (1,524 m) [6], and therefore must be de-rated by 8 percent from their nameplate capacity to reflect their actual performance at 7,000 ft. The results of these correction calculations are shown in Table 29.

Table 29: Corrected Nominal Heating Capacity, Specific Nominal Heating Capacity, and Full-Load Operating Hours at Los Arroyos Compound

TYPE OF BUILDING	CORRECTED CAPACITY		SPECIFIC CAPACITY		FULL-LOAD OPERATING HOURS
	[BTU/hr]	[kW]	[BTU/hr/sqft]	[kW/m²]	
Block 1A	978,750	287	44.327	0.140	930
Block 1B	978,750	287	44.327	0.140	930
Block 1C	978,750	287	44.327	0.140	930
Block 1D	978,750	287	44.327	0.140	930
Block 2A	652,500	191	44.327	0.140	930
Block 2B	652,500	191	44.327	0.140	930
Block 3A	652,500	191	44.327	0.140	930
Community Building	320,500	94	n.a.	n.a.	2,187
TOTAL	**6,193,000**	**1,815**			**995**

Note: Corrections are based on altitude and adjustment of oversized heating systems. n.a. not applicable.

The net result of the corrections was a 14.1 percent decrease in the total nominal heating capacity and a 16.4 percent increase in full-load operating hours. A further reduction of the nominal heating capacity is possible by improving the substandard insulation of the buildings.

South Capitol Complex

The full-load operating hours of the heating system in each of the four buildings at the South Capitol Complex was determined using the heat demand (calculated from the information gathered during the inquiry) and the installed nominal heating capacity for each building. Table 30 gives an overview of the results of these calculations.

Table 30: Uncorrected Full-Load Operating Hours of Assessed buildings at the South Capitol Complex

BUILDING	FULL-LOAD OPERATING HOURS
JOSEPH MONTOYA BUILD.	973
HAROLD RUNNELS BUILD.	758
JOHN F SIMMS BUILD.	1,026
MANUEL LUJAN SR BUILD.	374
AVERAGE	**792**

Note: Data based on gathered information.

The results show an average full-load operating hours at the complex that is about 15 percent lower than the average for office buildings in Santa Fe. (See Table 20.) The full-load operating hours of the Simms building appear to be plausible. The Runnels building has low full-load operating hours and also has the highest specific nominal heating capacity of the four buildings at the complex, indicating that the nominal heating capacity of the Runnels Building needs to be corrected. The previously discussed problem with very low heat demand at the Manuel Lujan Building also shows up here in the very low full-load operating hours.

The full-load operating hours of the Montoya building appear to be plausible, but the value shown in Table 30 above does not include a needed adjustment to the boiler size. Based on the specific nominal heating capacity calculated in Section 4.3.2.1, it is estimated that the boiler in this building is 25 percent larger than reported by maintenance personnel. This correction reduces the full-load operating hours to the value shown below in Table 31.

The boiler capacity of the Runnels Building was decreased by 10 percent to match the specific nominal heating capacity of the Simms Building.

The results of these adjustments on the specific classification numbers are shown in Table 31.

Table 31: Corrected Nominal Heating Capacity, Specific Nominal Heating Capacity, and Full-Load Operating Hours at the South Capitol Complex

TYPE OF BUILDING	CORRECTED CAPACITY		SPECIFIC CAPACITY		FULL-LOAD OPERATING HRS
	[BTU/hr]	[kW]	[BTU/hr/sqft]	[kW/m²]	
JOSEPH MONTOYA BUILD.	3,276,000	960	27.37	0.086	813
HAROLD RUNNELS BUILD.	5,106,240	1,496	32.59	0.103	842
JOHN F SIMMS BUILD.	2,223,200	652	31.13	0.098	1,026
MANUEL LUJAN SR BUILD.	1,966,000	576	25.78	0.081	374
TOTAL/AVERAGE	**12,571,440**	**3,684**	**29.64**	**0.094**	**794**

Note: The reason for the low full-load operating hours of the Manuel Lujan Building still needs to be determined.

Correcting the nominal heating capacity of the Montoya and Runnels buildings reduced the variation in specific capacity between all of the buildings. The average specific capacity is still about 25 percent below the average for office buildings in Santa Fe, however. The buildings are relatively new and are better insulated than most offices in downtown Santa Fe, which explains at least some of the difference.

Santa Fe Community College

The full-load operating hours of the heating systems at the Santa Fe Community College were calculated using the calculated heat demand (from the information gathered during the assessment) and installed nominal heating capacity for each building. Table 32 gives an overview of the results of these calculations.

Table 32: Uncorrected Full-Load Operating Hours of Assessed Buildings at the Santa Fe Community College

BUILDING	FULL-LOAD OPERATING HOURS
MAIN BUILDING	2,766
FITNESS EDUCATION CENTER	2,766
VISUAL ARTS CENTER	1,277
EARLY CHILDHOOD DEVELOPMENT	701
AVERAGE	**2,082**

Note: Values shown are based on gathered information; the full-load operating hours of the Visual Arts Center was calculated from the nominal heating capacity of the gas-fired boiler and the annual heat demand (based on the annual gas consumption.)

The full-load operating hours for the Main and Fitness Education buildings seem to be too high. The additional heat needed for the swimming pool (which is heated year-round) accounts for some of this. In an attempt to verify the high heat demand, gas bills for 2002 and 2003 were requested, but at the time of this writing these bills were not available.

The Visual Arts Building also has higher-than-average full-load operating hours compared to other schools in Santa Fe. This difference is likely due to the higher occupancy of buildings at the college (approximately 108 hours per week) compared to other schools (35 to 40 hours per week.)

According to the boiler specification plates, all boilers at the College are designed for an altitude between 6,000 and 8,000 ft (1,830 to 2,440 m), so no altitude adjustment to boiler capacities are necessary. The boiler at the Early Childhood Development Center seems to be oversized, however. According to maintenance personnel, the boiler is sized to allow for future expansion. Nevertheless, the nominal heating capacity of this building was adjusted to the current needs of the building. The result of this adjustment on the specific classification numbers is shown in Table 33.

Table 33: Corrected Nominal Heating Capacity, Specific Nominal Heating Capacity, and Full-Load Operating Hours at the Santa Fe Community College

TYPE OF BUILDING	CORRECTED CAPACITY		SPECIFIC CAPACITY		FULL-LOAD OPERATING HRS
	[BTU/hr]	[kW]	[BTU/hr/sqft]	[kW/m²]	
MAIN BUILDING	5,824,600	1,707	21.74	0.069	2,766
FITNESS EDUCATION CTR.	2,500,000	733	21.74	0.069	2,766
VISUAL ARTS CENTER	3,238,000	949	56.81	0.179	1,277
EARLY CHILDHOOD DEVT.	1,500,000	440	60.00	0.189	1,168
TOTAL/AVERAGE	**13,062,600**	**3,828**	**28.09**	**0.089**	**2,247**

Notes: The full-load operating hours parameter for the Visual Arts Center is based only on the capacity of the space-heating boiler (2,788,000 BTU) and the annual heat demand calculated from utility-bill data.

Following the corrections, the total nominal heating capacity for the campus was lower by 7 percent. Further investigation is underway to determine the reason for the low specific nominal heating capacity and the high full-load operating hours of the Main and Fitness buildings.

College of Santa Fe

Based on the estimate of the total nominal heating capacity of the campus (Section 4.4.2) and the calculated heat demand (Section 4.3.2.2), the average full-load operating hours of the College of Santa Fe are estimated to be approximately 1,310 hours. This value is mostly based on estimates, however, and more investigation is necessary to verify them before a district heating system could be installed.

4.4 Extrapolation of Heat Demand and Installed Nominal Heating Capacity to Non-Assessed Buildings, and Determination of Maximum Heat Demand and Maximum Installed Nominal Heating Capacity Within the Target Area

4.4.1 Main District Heating System

4.4.1.1 Existing Buildings

Using aerial photographs of downtown Santa Fe, the number and type of non-assessed buildings within the target area were determined. The heated area of each building was estimated from the footprint of the building and the number of floors. The annual heat demand and installed nominal heating capacity were then calculated using the average specific heat demand (Table 17) and the average specific nominal heating capacity (Table 20) of the respective building types.

Table 34 gives an overview over the results of this extrapolation.

Table 34: Estimated Heated Area, Heat Demand, and Nominal Heating Capacity of Non-Assessed Buildings Within the Target Area of the Main District Heating System, by Building Category

		HEATED AREA		HEAT DEMAND		NOM. HEAT. CAP.	
TYPE OF BUILDING	**QUANTITY**	**[sqft]**	**[m²]**	**[BTU/yr]**	**[kWh/yr]**	**[BTU/hr]**	**[kW]**
Apartments	0	0	0	0	0	0	0
Church	1	13,900	1,291	373,910,000	109,582	789,136	231
Commercial	101	835,000	77,574	33,734,000,000	9,886,423	34,961,991	10,246
Healthcare	0	0	0	0	0	0	0
Large_Hotel	0	0	0	0	0	0	0
Medium_Size_Hotel	0	0	0	0	0	0	0
Municipal	5	63,460	5,896	2,144,948,000	628,620	1,976,343	579
Museum	1	13,300	1,236	688,940,000	201,908	590,815	173
Offices	29	365,300	33,937	13,808,340,000	4,046,810	13,728,847	4,024
Residential	240	578,200	53,717	24,517,700,000	7,185,402	30,298,222	8,879
Restaurant	11	31,200	2,899	1,822,080,000	533,997	1,774,933	520
School	1	43,100	4,004	2,099,775,000	615,381	2,159,600	633
Shopping_Center	0	0	0	0	0	0	0
Small_Hotel	3	14,600	1,356	1,065,800,000	312,354	724,865	212
Swimming_Pool	0	0	0	0	0	0	0
Theater	0	0	0	0	0	0	0
TOTAL	**392**	**1,958,060**	**181,910**	**80,255,493,000**	**23,520,477**	**87,004,752**	**25,498**

Notes: Heated areas are based on footprint and number of floors. The actual number of buildings that connect to the district heating network (and thus the annual heat demand and nominal heating capacity) may change depending on the actual path of the network of pipes.

4.4.1.2 Future Potential

Downtown Santa Fe already has a high building density, and only a few new buildings are planned for construction within the coming years. A new hotel is planned next to the Lensic Theater on West San Francisco Street, however, and the rail yard area on the southwestern side of downtown has a master plan calling for construction of 26 buildings.

The heated area of these planned buildings was estimated using available information about the footprint and number of floors of each building. The annual heat demand and the installed nominal heating capacity were then calculated using the average specific heat demand (Table 17) and the average specific nominal heating capacity (Table 20) of the respective building types.

The results of the extrapolation are shown in Table 35. Most of the buildings planned in the rail yard area are warehouses, residential buildings and artist's studios. In addition, the construction of a cinema and an expansion of the existing Site Santa Fe (an art exhibition hall at the south end of the rail yard area) are planned.

Table 35: Estimated Heated Area, Heat Demand, and Nominal Heating Capacity of Planned New Buildings Within the Target Area of the Main District Heating System, by Building Category

TYPE OF BUILDING	QUANTITY	HEATED AREA		HEAT DEMAND		NOM. HEAT. CAP.	
		[sqft]	[m²]	[BTU/yr]	[kWh/yr]	[BTU/hr]	[kW]
Apartments	0	0	0	0	0	0	0
Church	0	0	0	0	0	0	0
Commercial	20	180,070	16,729	7,274,828,000	2,132,034	8,099,978	2,374
Healthcare	0	0	0	0	0	0	0
Large_Hotel	1	70,875	6,585	4,706,100,000	1,379,217	3,894,184	1,141
Medium_Size_Hotel	0	0	0	0	0	0	0
Municipal	0	0	0	0	0	0	0
Museum	1	13,000	1,208	575,350,812	168,618	495,130	145
Offices	1	17,000	1,579	642,600,000	188,327	666,906	195
Residential	4	58,100	5,398	2,231,040,000	653,851	3,160,659	926
Restaurant	0	0	0	0	0	0	0
School	0	0	0	0	0	0	0
Shopping_Center	0	0	0	0	0	0	0
Small_Hotel	0	0	0	0	0	0	0
Swimming_Pool	0	0	0	0	0	0	0
Theater	0	0	0	0	0	0	0
TOTAL	**27**	**339,045**	**31,498**	**15,429,918,812**	**4,522,046**	**16,316,857**	**4,782**

Notes: Heated areas are based on footprint and number of floors. The actual number of buildings that connect to the district heating network (and thus the annual heat demand and nominal heating capacity) may change depending on the actual path of the network of pipes.

4.4.1.3 Determination of Maximum Heat Demand and Maximum Nominal Heating Capacity Within the Target Area

Based on the results for assessed buildings (Section 4.3.1.2), non-assessed buildings (4.4.1.1), and planned buildings (4.4.1.2), the total heat demand and nominal heating capacity of all buildings within the target area were calculated. The results are shown in Table 36.

Table 36: Estimated Heated Area, Total Heat Demand, and Total Nominal Heating Capacity of Existing and Planned Buildings Within the Target Area of the Main District Heating System, by Building Category

TYPE OF BUILDING	QUANTITY	HEATED AREA		HEAT DEMAND		NOM. HEAT. CAP.	
		[sqft]	[m²]	[BTU/yr]	[kWh/yr]	[BTU/hr]	[kW]
Apartments	1	46,831	4,351	1,709,331,500	500,954	2,289,144	671
Church	3	51,310	4,767	2,473,414,250	724,884	3,392,717	994
Commercial	139	1,482,675	137,745	59,884,322,291	17,550,298	62,640,893	18,358
Healthcare	1	18,000	1,672	1,404,000,000	411,470	642,240	188
Large_Hotel	13	1,117,263	103,797	72,256,977,711	21,176,352	61,387,361	17,991
Medium_Size_Hotel	3	142,321	13,222	9,450,114,400	2,769,545	8,077,999	2,367
Municipal	8	96,660	8,980	3,268,652,540	957,944	3,010,295	882
Museum	9	186,111	17,290	14,929,332,167	4,375,339	12,183,101	3,571
Offices	57	1,853,200	172,168	70,003,338,321	20,515,878	69,675,703	20,420
Residential	254	652,552	60,624	27,426,656,800	8,037,930	34,311,663	10,056
Restaurant	12	35,700	3,317	2,084,880,000	611,016	2,030,933	595
School	9	547,187	50,835	18,912,548,616	5,542,701	24,729,468	7,247
Shopping_Center	3	427,036	39,673	15,629,517,600	4,580,543	15,728,194	4,609
Small_Hotel	10	86,168	8,005	6,503,245,167	1,905,906	4,278,094	1,254
Swimming_Pool	1	0	0	2,420,914,753	709,497	2,549,176	747
Theater	2	75,000	6,968	6,098,644,035	1,787,330	4,823,062	1,413
TOTAL	**525**	**6,818,015**	**633,414**	**314,455,890,152**	**92,157,588**	**311,750,043**	**91,365**

Notes: The heated areas are based on footprint and number of floors. The actual number of buildings that connect to the district heating network (and thus the annual heat demand and nominal heating capacity) may change depending on the actual path of the network of pipes.

Large and medium sized hotels (26.0 percent of the heat demand), office buildings (22.3 percent), and schools (6.0 percent) account for more than 56 percent of the total heat demand within the target area, but make up only 15.6 percent of all buildings. The acquisition of customers should therefore focus first on these categories, and a few large commercial buildings, before customers in other categories are pursued.

According to Table 19, Table 22, Table 23, and Table 24, the assessed buildings comprise nearly three quarters of the total heat demand within the target area, but account for less than one quarter of the total number of buildings. These numbers confirm that most of the large heat consumers within the target area were assessed during the heat-demand inquiry.

4.4.2 Potential Micro-Grid Sites

No extrapolation for Los Arroyos, South Capitol Complex and the Santa Fe Community College was necessary, because all buildings were assessed during the heat-demand inquiry. The extrapolation for the College of Santa Fe is described below.

College of Santa Fe

Only one boiler in the assessed buildings had a specification plate with information about its nominal heating capacity. The nominal heating capacity for all other buildings on the campus therefore had to be estimated based on the average nominal specification numbers listed in Table 20. The nominal heating capacity of the boiler in the Visual Arts Center was reduced by 12.0 percent to account for altitude. (See also Section 4.3.1.3.) The results are shown in Table 37.

Table 37: Estimated Nominal Heating Capacity of the College of Santa Fe, by Building

NAME OF BUILDING	TOTAL AREA		BUILDING	SPEC. NOM. CAP.	NOMINAL CAPACITY	
	[sqft]	[m²]	TYPE	[BTU/hr/sqft]	[BTU/hr]	[kW]
Alumin Hall	11,742	1,091	Apartment	48.88	574,000	168
Cafeteria	17,836	1,657	Restaurant	56.89	1,015,000	297
Brothers Residence	19,517	1,813	Apartment	48.88	954,000	280
Onate Hall	6,550	609	Apartment	48.88	320,000	94
11 smaller buildings (T-38-T45, T63-T65)	54,441	5,058	Office	37.58	2,046,000	600
St. Michael's Chapel	2,550	237	Church	56.77	145,000	42
St. Michael's Hall	30,319	2,817	Apartment	48.88	1,482,000	434
King Hall	46,109	4,284	Apartment	48.88	2,254,000	661
La Salle Hall	24,764	2,301	Apartment	48.88	1,210,000	355
Alexis Hall	14,844	1,379	Apartment	48.88	726,000	213
Kennedy Hall	25,295	2,350	Apartment	48.88	1,236,000	362
Benildus Hall	16,280	1,512	Apartment	48.88	796,000	233
Luke Hall	26,177	2,432	Apartment	48.88	1,280,000	375
Garson Theater	32,628	3,031	Theater	64.31	2,098,000	615
Administration Building	8,680	806	Office	37.58	326,000	96
Fogelson Complex (micro grid)	58,457	5,431	Municipal	31.14	1,821,000	534
Garson Communications Center	49,200	4,571	Municipal	31.14	1,532,000	449
Driscoll Fitness Center	22,200	2,062	Recreation	60.00	1,332,000	390
Bookstore	2,912	271	Municipal	31.14	91,000	27
Center for Academic Excellence	1,693	157	Municipal	31.14	53,000	16
Development Office	3,441	320	Office	37.58	129,000	38
Humanities/Education Dept. Offices	1,500	139	Office	37.58	56,000	16
Student Apartments (1 & 2)	30,000	2,787	Apartment	48.88	1,466,000	430
Visual Arts Center Phase 1	54,615	5,074		38.55	2,105,000	617
TOTAL	**561,750**	**52,188**			**25,047,000**	**7,341**

Note: The capacity of boiler in the Visual Arts Center is as specified on the boiler nameplate.

The estimated total nominal heating capacity of all buildings on the campus was estimated at 25,047,000 BTU/hr (7,341 kW). The calculated average specific nominal heating capacity of the entire campus is about 44 BTU/hr/ft^2. Further investigation is needed to verify these results.

4.5 Substitutable Heat Demand and Connected Heat Load Potential Within the Target Area

Accurate determination of the substitutable heat demand is essential for the evaluation of the economic performance of a district heating system, because it forms the basis for determination of the potential annual revenues of the system through the sale of heat.

4.5.1 Main District Heating System

4.5.1.1 Calculation of the Connected Heat Load Potential

The calculation of the connected heat load of all assessed buildings was carried out according to the method described in Section 3.4. Considering the type and location of assessed heating systems in the target area, more than 77 percent of the nominal heating capacity can be replaced by a district heating system.

For non-assessed buildings, the portion of the substitutable nominal heating capacity had to be estimated, since information about the installed heating systems was unavailable. The substitution rate for non-assessed buildings was estimated at 50 percent because the average size of these buildings is smaller than the average size of the assessed buildings. The experience gained during the heat-demand inquiry showed that hydronic and steam systems are more common in larger buildings, while forced-air units and gas radiators are more common in smaller buildings. Therefore the substitution rate for non-assessed buildings was expected to be lower than for assessed buildings, and was set at 50 percent.

The substitution rate for planned buildings also had to be estimated. We estimated this rate at 75 percent because it can be expected that once the district heating system is in operation, the heating systems of most new buildings will be designed to accommodate district heating.

Table 38 and Figure 14 show the connected heat load potential. Almost 70 percent of the total nominal heating capacity, or 218 MMBTU/hr (63,900 kW) could be substituted by a district heating system.

Table 38: Total Nominal Heating Capacity and Connected Heat Load Potential (Substitutable Nominal Heating Capacity) Within the Target Area of the Main District Heating System

CATEGORY	TOTAL CAPACITY		CONNECTED HEAT LOAD		
	[BTU/hr]	[kW]	[BTU/hr]	[kW]	PERCENTAGE
Visited Buildings	208,428,434	61,084	162,241,023	47,548	77.84%
Other existing Buildings	87,004,752	25,498	43,502,376	12,749	50.00%
New Buildings	16,316,857	4,782	12,237,643	3,586	75.00%
TOTAL	**311,750,043**	**91,365**	**217,981,042**	**63,884**	**69.92%**

Note: The actual number of buildings that connect to the district heating network (and thus the annual heat demand and nominal heating capacity) may change depending on the actual path of the network of pipes.

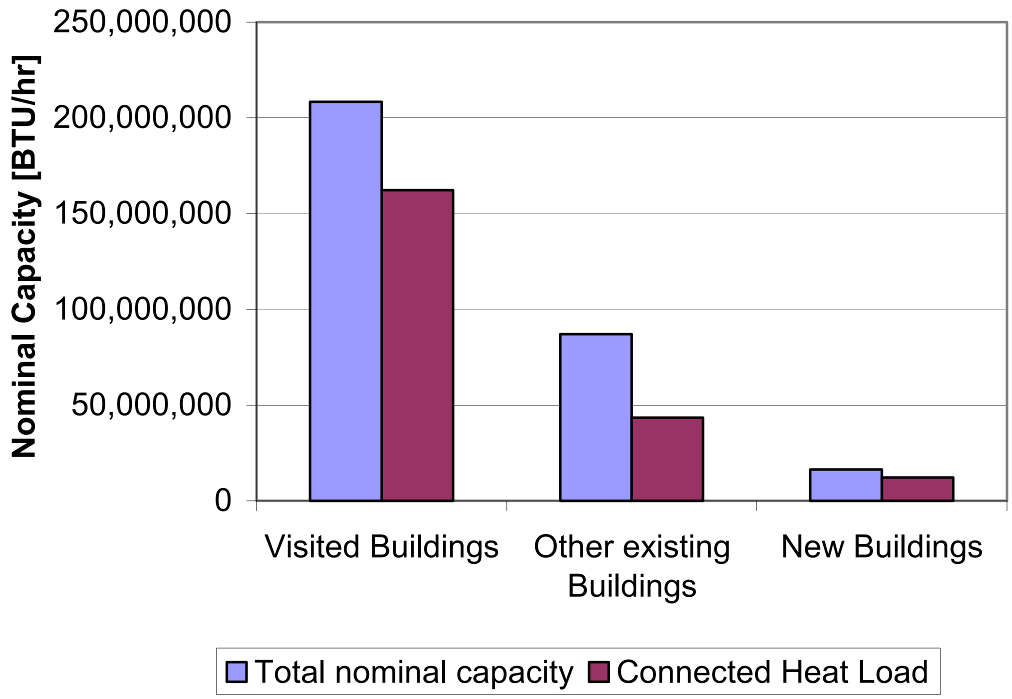

Figure 14: Total Nominal Heating Capacity and Connected Heat Load (Substitutable Nominal Heating Capacity) Within the Target Area of the Main District Heating System

4.5.1.2 Calculation of the Substitutable Heat Demand

The calculation of the substitutable heat demand of all assessed buildings was carried out according to methods described in Section 3.4. About 78.6 percent of the total heat demand of all assessed buildings could be replaced by the district heating system.

To estimate the substitutable annual heat demand of non-assessed and planned buildings within the target area, the same ratios used for the calculation of connected heat load were used. Thus we assumed a 50 percent substitution rate for non-assessed buildings, and a 75 percent rate for buildings to be built in the near future.

The results of these calculations are shown in Table 39 and Figure 15. Within the target area of the main district heating grid for downtown Santa Fe, approximately 71.2 percent of the total heat demand, or 223,768 MMBTU per year (65,580 MWh per year) could be replaced by district energy.

Table 39: Total Annual Heat Demand and Substitutable Annual Heat Demand of All Buildings Within the Target Area, Main District Heating System

CATEGORY	TOTAL HEAT DEMAND		SUBSTITUTABLE HEAT DEMAND		
	[BTU]	[kWh]	[BTU]	[kWh]	PERCENTAGE
Visited Buildings	218,770,478,340	64,115,064	172,067,729,550	50,427,889	78.65%
Other existing Buildings	80,255,493,000	23,520,477	40,127,746,500	11,760,239	50.00%
New Buildings	15,429,918,812	4,522,046	11,572,439,109	3,391,535	75.00%
TOTAL	**314,455,890,152**	**92,157,588**	**223,767,915,159**	**65,579,663**	**71.16%**

Note: The actual number of connected buildings and thus the annual heat demand may change depending on the actual path of the network of pipes.

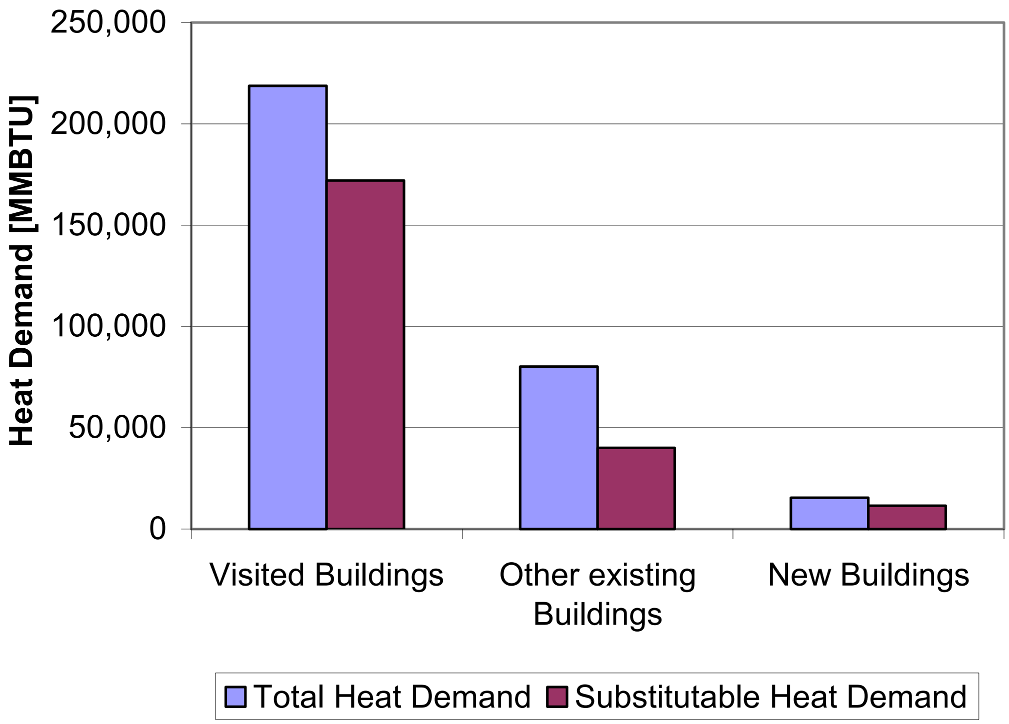

Figure 15: Total Annual Heat Demand And Substitutable Annual Heat Demand of All Buildings Within the Target Area, Main District Heating System

If all of the substitutable heat demand within the target area connects to the district energy system, the average full-load operating hours of the total connected load would amount to about 1,027 hours per year. This value is based on conservative estimates (Section 4.3.1.3) that should be refined so that the system design is based on the most accurate values available. Additionally, opportunities to improve the efficiency of the system by increasing the full-load operating hours should be investigated. Possible methods include connecting process heat consumers with a year-round heat demand, and installing absorption chillers for space cooling to increase the heat demand during summer.

The substitutable heat demand represents 298,357 MMBTU (87,440 MWh) of natural gas per year, assuming an average annual utilization rate of 75 percent. This amount of natural gas represents CO_2 emissions of 19,084 short tons (17,313 metric tons) per year based on a CO_2 emission rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If the biomass-fired district heating system is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed and reported with the forthcoming preliminary design of the network of pipes and heating plant.

4.5.2 Potential Micro-Grid Sites

4.5.2.1 Calculation of the Connected Heat Load Potential

Los Arroyos Compound

All of the installed heating systems identified in Table 12 at the Los Arroyos Compound apartment complex can be replaced by a micro-grid. Therefore, the corrected nominal heating capacity of the individual buildings equals the connected heat load. Table 40 gives an overview of the connected heat load potential, the specific heating capacity, and the corresponding full-load operating hours.

Table 40: Connected Heat Load Potential, Specific Heating Capacity, and Full-Load Operating Hours at Los Arroyos Compound

TYPE OF BUILDING	CORRECTED CAPACITY		SPECIFIC CAPACITY		FULL-LOAD OPERATING HOURS
	[BTU/hr]	[kW]	[BTU/hr/sqft]	[kW/m²]	
Block 1A	985,000	289	44.611	0.141	924
Block 1B	985,000	289	44.611	0.141	924
Block 1C	985,000	289	44.611	0.141	924
Block 1D	985,000	289	44.611	0.141	924
Block 2A	656,667	192	44.611	0.141	924
Block 2B	656,667	192	44.611	0.141	924
Block 3A	656,667	192	44.611	0.141	924
Community Building	322,593	102	n.a.	n.a.	2,172
TOTAL	**6,232,593**	**1,834**			**989**

The connected heat load is about 14 percent lower than the actual installed capacity. Depending on improvements to the insulation in the buildings, which is currently sub-standard, the annual heat demand and the connected heat load could be further decreased.

South Capitol Complex

All of the installed heating systems at the South Capitol Complex, with the exception of the domestic water heater in the Simms Building, can be replaced by a micro-grid. The connected heat load of all four office buildings was calculated out according to Section 3.4, and the results are presented in Table 41 and Figure 16. Nearly 100 percent of the total nominal heating capacity at the complex, or 12,355,000 BTU/hr (3,600 kW), could be replaced by a district heating system.

Table 41: Total Corrected Nominal Heating Capacity and Connected Heat Load Potential (Substitutable Nominal Heating Capacity) at the South Capitol Complex, by Building

CATEGORY	TOTAL CAPACITY		CONNECTED HEAT LOAD		PERCENTAGE
	[BTU/hr]	[kW]	[BTU/hr]	[kW]	
JOSEPH MONTOYA BUILDING	3,276,000	960	3,276,000	960	100.00%
HAROLD RUNNELS BUILDING	5,106,240	1,496	5,106,240	1,496	100.00%
JOHN F SIMMS BUILDING	2,223,200	652	2,007,200	588	90.28%
MANUEL LUJAN SR BUILDING	1,966,000	576	1,966,000	576	100.00%
TOTAL	**12,571,440**	**3,684**	**12,355,440**	**3,621**	**98.28%**

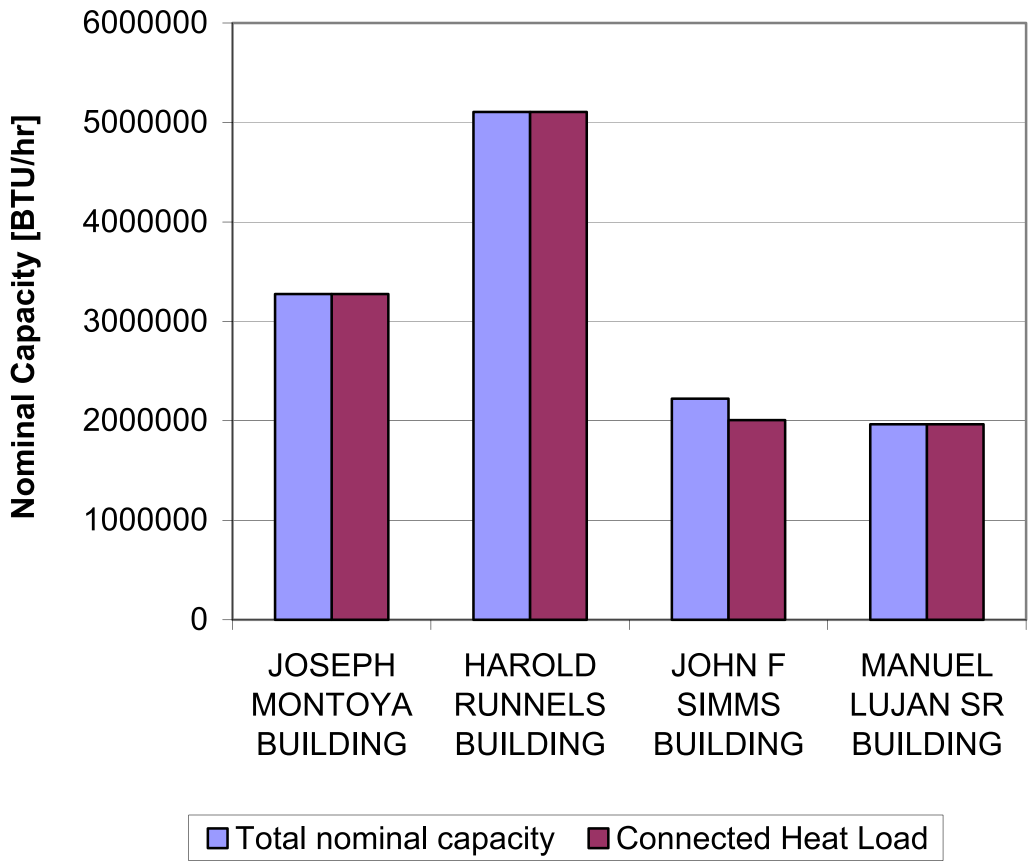

Figure 16: Total Corrected Nominal Heating Capacity and Connected Heat Load Potential (Substitutable Nominal Heating Capacity) at the South Capitol Complex, by Building

Santa Fe Community College

All heating systems installed at the Santa Fe Community College, with the exception of the domestic water heaters in the Visual Arts Center, could be replaced by a micro-grid. The calculation of the connected heat load potential of all buildings was carried out according to methods described in Section 3.4. Results of the calculations are given in Table 42 and Figure 17. More than 96 percent of the total nominal heating capacity, or 12,612,600 BTU/hr (3,700 kW) could be replaced by a micro-grid.

Table 42: Total Corrected Nominal Heating Capacity and Connected Heat Load Potential (Substitutable Nominal Heating Capacity) at the Santa Fe Community College, by Building

CATEGORY	TOTAL CAPACITY		CONNECTED HEAT LOAD		PERCENTAGE
	[BTU/hr]	[kW]	[BTU/hr]	[kW]	
MAIN BUILDING	5,824,600	1,707	5,824,600	1,707	100.00%
FITNESS EDUCATION CTR.	2,500,000	733	2,500,000	733	100.00%
VISUAL ARTS CENTER	3,238,000	949	2,788,000	817	86.10%
EARLY CHILDHOOD DEVT.	1,500,000	440	1,500,000	440	100.00%
TOTAL	**13,062,600**	**3,828**	**12,612,600**	**3,696**	**96.56%**

Notes: Nominal heating capacity of the Fitness Education Center represents only the nominal heating capacity of the pool boiler and the domestic hot-water boiler. The nominal heating capacity for space heating is included in the capacity of the Main Building.

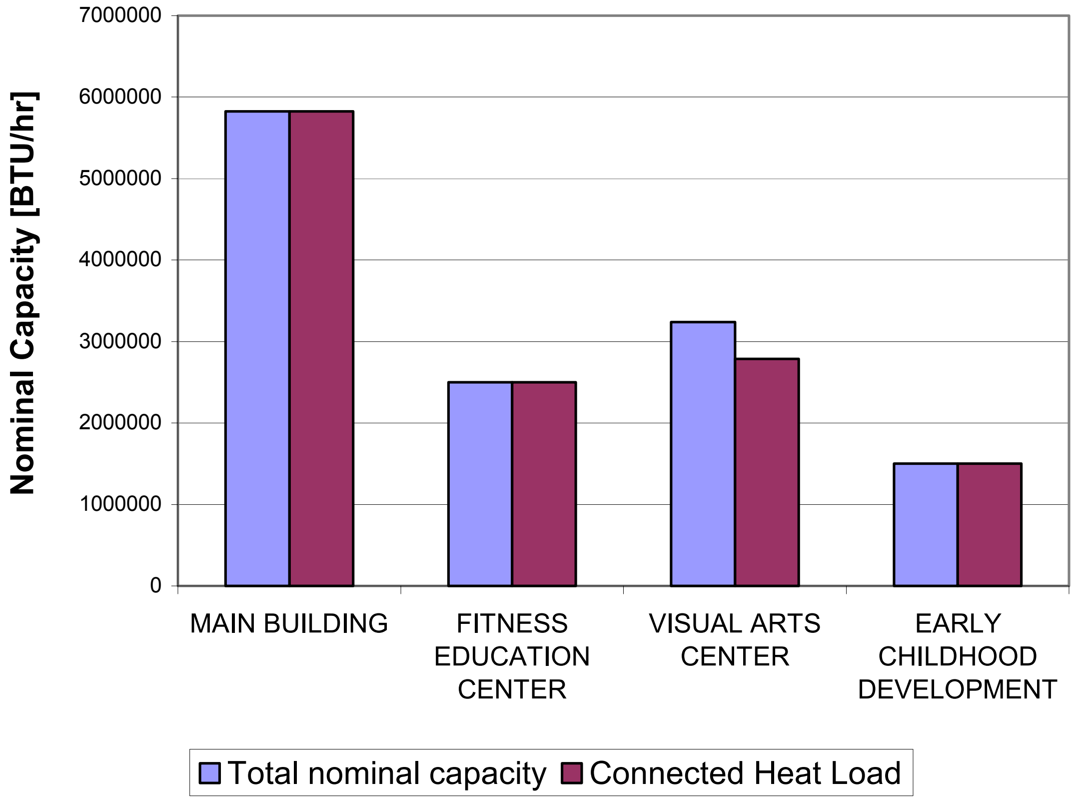

Figure 17: Total Corrected Nominal Heating Capacity and Connected Heat Load Potential (Substitutable Nominal Heating Capacity) at the Santa Fe Community College, by Building

Notes: Nominal heating capacity of the Fitness Education Center represents only the nominal heating capacity of the pool boiler and the domestic hot-water boiler. The nominal heating capacity for space heating is included in the capacity of the Main Building.

College of Santa Fe

Although not all of the heating systems at the College of Santa Fe were assessed, it was assumed that most of the buildings are heated by hydronic systems. Some of the smaller buildings are most likely heated by rooftop units. As a first estimate, it was assumed that substitutable heating systems comprise 75 percent of the total nominal heating capacity. Using this estimate, the substitutable nominal heating capacity (connected heat load potential) is approximately 18,786,000 BTU/hr (5,510 kW).

4.5.2.2 Calculation of the Substitutable Heat Demand

Los Arroyos Compound

Since all heating systems at the Los Arroyos Compound apartment complex can be replaced by a micro-grid, the substitutable heat demand equals the actual heat demand at the complex. The substitutable heat demand is therefore 6,163 MMBTU (1,806 MWh) per year. The results of the calculation are shown in Table 43.

Table 43: Total Annual Heat Demand and Substitutable Annual Heat Demand at the Los Arroyos Compound, by Building

TYPE OF BUILDING	TOTAL HEAT DEMAND		SUBSTITUABLE HEAT DEMAND	
	[BTU]	[kWh]	[BTU]	[kWh]
Block 1A	910,373,703	266,803	910,373,703	266,803
Block 1B	910,373,703	266,803	910,373,703	266,803
Block 1C	910,373,703	266,803	910,373,703	266,803
Block 1D	910,373,703	266,803	910,373,703	266,803
Block 2A	606,915,802	177,869	606,915,802	177,869
Block 2B	606,915,802	177,869	606,915,802	177,869
Block 3A	606,915,802	177,869	606,915,802	177,869
Community Building	700,800,000	205,383	700,800,000	205,383
TOTAL	**6,163,042,217**	**1,806,203**	**6,163,042,217**	**1,806,203**

The substitutable heat demand represents 8,217 MMBTU (2,408 MWh) of natural gas per year, assuming an average annual utilization rate of 75 percent. This amount of natural gas represents CO_2 emissions of 525 short tons (477 metric tons) per year based on a CO_2 emission rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If the biomass-fired micro-grid is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed and reported with the forthcoming preliminary design of the network of pipes and heating plant.

South Capitol Complex

All of the heat demand except for the heat required for domestic hot water in the Simms Building can be replaced by district heat from a micro-grid. The calculation of the substitutable heat demand of the four assessed buildings was carried out according to method described in Section 3.4.

The results of the calculations are shown in Table 44 and Figure 18. Around 98 percent of the total heat demand, or 9,756 MMBTU (2,859 MWh) per year could be replaced by district energy at the South Capitol Complex.

Table 44: Total Annual Heat Demand and Substitutable Annual Heat Demand at the South Capitol Complex, by Building

BUILDING	TOTAL HEAT DEMAND		SUBSTITUTABLE HEAT DEMAND		
	[BTU]	[kWh]	[BTU]	[kWh]	PERCENTAGE
JOSEPH MONTOYA BUILDING	2,661,750,000	780,079	2,661,750,000	780,079	100.00%
HAROLD RUNNELS BUILDING	4,298,250,000	1,259,688	4,298,250,000	1,259,688	100.00%
JOHN F SIMMS BUILDING	2,281,883,767	668,752	2,060,182,214	603,778	90.28%
MANUEL LUJAN SR BUILDING	735,750,000	215,626	735,750,000	215,626	100.00%
TOTAL	**9,977,633,767**	**2,924,145**	**9,755,932,214**	**2,859,171**	**97.78%**

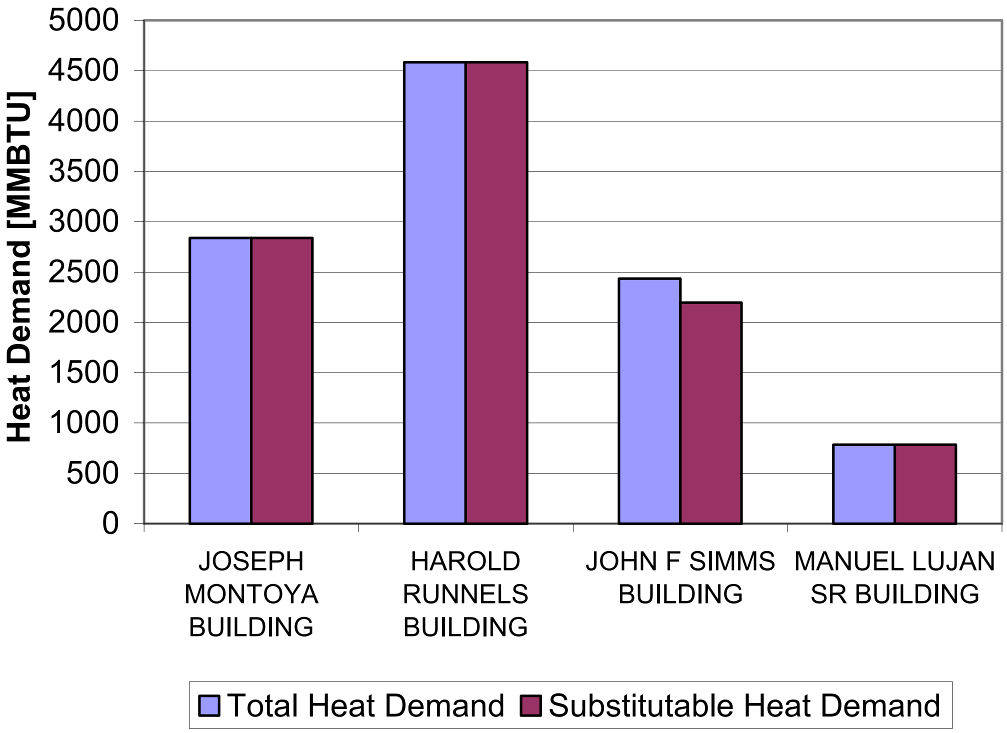

Figure 18: Total Annual Heat Demand and Substitutable Annual Heat Demand at the South Capitol Complex, by Building

The substitutable heat demand represents 12,998 MMBTU (3,809 MWh) of natural gas per year, assuming an average annual utilization rate of 75 percent. This amount of natural gas represents CO_2 emissions of 831 short tons (754 metric tons) per year based on a CO_2 emission rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If the biomass-fired micro-grid is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed and reported with the forthcoming preliminary design of the network of pipes and heating plant.

Santa Fe Community College

Only the heat required to heat domestic hot water in the Visual Arts Center cannot be substituted by district heat from a micro-grid. The calculation of the substitutable annual heat demand of the four main buildings was carried out according to methods described in Section 3.4.

Since the electric energy used to heat the domestic hot water in the Visual Arts Center was not considered in the calculations, the substitutable heat demand equals the annual heat demand specified in Table 27, around 28,339 MMBTU/8,305 MWh per year. This heat demand could be replaced by district energy within the target area of the micro-grid for the Santa Fe Community College.

The substitutable heat demand represents 37,091°MMBTU/10,870 MWh of natural gas per year, assuming an average annual utilization rate of 76.5 percent. This amount of natural gas represents CO_2 emissions of 2,372 short tons/2,152 metric tons per year according to CO_2 emissions of 12.79 lbs/therm/55,000 kg/TJ gas input. With the installation of a biomass-fired micro-grid a significant amount of these emissions can be reduced. A more detailed investigation of the achievable reduction of CO_2 emissions will be given in the following report regarding the preliminary design of the network of pipes and the heating plant.

College of Santa Fe

To estimate the substitutable annual heat demand of all buildings at the College of Santa Fe, the same 75 percent ratio used for the calculation of connected heat load potential was used. Using this ratio, the substitutable heat demand amounts to 24,526 MMBTU (7,188 MWh) per year.

The substitutable heat demand represents 34,063 MMBTU (9,983 MWh) of natural gas per year, assuming an average annual utilization rate of 72 percent. This amount of natural gas represents CO_2 emissions of 2,179 short tons (1,977 metric tons) per year based on a CO_2 emission rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If the biomass-fired micro-grid is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed and reported with the forthcoming preliminary design of the network of pipes and heating plant.

4.6 Achievable ΔT for the District Heating Grid

4.6.1 Main District Heating System

The achievable ΔT at a heat distribution device (e.g. a fancoil unit, baseboard, or radiant floor) is usually determined by the flow rate of the pump and the specifications for entering water temperature and exiting water temperature at the distribution device.

In general there are only limited opportunities to increase the temperature differential of existing hydronic systems without investing a lot of money, because most of the systems are not designed for high temperature differentials. Examples of methods to increase the differential include decreasing the water flow by changing the settings of flow control valves or the speed of the pumps and/or decreasing the supply temperature. Only radiant floor heating systems, heat pumps, and some large air handling systems already operate with relatively high temperature differentials between the supply and return.

Fortunately, the maximum supply temperature of nearly all of the hydronic heating systems we assessed does not exceed 160°F (71°C). Many of them are actually operating with temperatures as low as 130°F (54°C). The forced-air units we assessed also operate with a maximum air temperature of 170°F (76°C) and an air-temperature rise between 30-65°F (17-36°C), which means the return temperature at the fancoils are approximately 120-150°F (49-150°C).

Assuming a supply temperature in the primary cycle of the customer's heat-transfer station (i.e. in the network of pipes) of 203°F (95°C), and a temperature difference between the hot (primary) and cold (secondary) side of the heat-transfer station of 5.4°F (3°C), then a temperature differential between 33-83°F (18-45°C) can be achieved in the primary cycle of the heat-transfer station.

The supply temperature of 203°F (95°C) needed to achieve this differential, however, will result in supply temperatures on the customer side of the heat-transfer station that are above the design temperature of the heat delivery devices. Mixing valves will therefore need to be installed in the secondary cycle to accommodate most of the heating systems. This investment will pay off within a few years considering the significant savings in pumping costs for every degree of increased temperature differential in the primary cycle.

Table 45: Overview of Achievable Temperature Differentials for Several Heating Systems

HYDRONIC SYSTEMS	°F	°C
Supply Temperature Heating Plant	203	95
Return Temperature Heating System	125-170	52-76
Temperature Difference Primary/Secondary Return	5.4	3.0
Achievable Temperature Differential	28-73	16-40
FORCED AIR SYSTEMS	**°F**	**°C**
Supply Temperature Heating Plant	203	95
Temperature Rise	30-65	17-36
Maximum Output Temperature	170-175	77-79
Temperature Difference Primary/Secondary Return	10.8	6.0
Achievable Temperature Differential	48-88	27-48
DOMESTIC HOT WATER	**°F**	**°C**
Supply Temperature Heating Plant	203	95
Supply Temperature Residential	100-140	38-60
Supply Temperature Commercial	160-180	71-88
Temperature Difference Primary/Secondary Return	10.8	6.0
Achievable Temperature Differential	13-93	7-51
POOL HEATING	**°F**	**°C**
Supply Temperature Heating Plant	203	95
Supply Temperature	84-104	29-40
Temperature Difference Primary/Secondary Return	10.8	6.0
Achievable Temperature Differential	89-109	49-60

Note: Values represent average numbers. For more detailed values, see APPENDIX II.

4.6.2 Potential Micro-Grid Sites

Los Arroyos Compound

The actual supply and return temperatures at the residential buildings and swimming pool at Los Arroyos Compound are relatively low. A further decrease in the return temperature as a means to increase the temperature differential is therefore very unlikely. On the other hand, the problems with the pipes in most of the buildings prevent an increase in the supply temperature.

To achieve a high temperature differential in the primary cycle at the heat-transfer station, a mixing valve would need to be installed in the heating system of each building (secondary cycle). The mixing valves would mix the low-temperature return from the baseboards with the high-temperature supply from the heat-transfer station to maintain an appropriate supply temperature for the baseboards (130 or 150°F). The mixing valves would be controlled by the control system of the heat-transfer station.

Based on a supply temperature at the heating plant of 194°F (90°C), the achievable temperature differential in the primary cycle at the heat-transfer station is estimated to be 50°F (27°C) for space-heating loads. Higher temperature differentials are possible for domestic water heating and at the swimming pool. (Differentials of 70°F (39°C) or even higher could possibly be achieved. See also Table 46.) Space heating in the apartments makes up the main part of the heat demand, however, and therefore the average temperature differential for the whole micro-grid is estimated to be 55°F (30°C).

Table 46: Achievable Temperature Differentials at the Heat Transfer Stations, Los Arroyos Compound

SPACE HEATING	°F	°C
Supply Temperature Heating Plant	194	90
Return Temperature Heating System	140	60
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	49	27
DOMESTIC HOT WATER	**°F**	**°C**
Supply Temperature Heating Plant	194	90
Supply Temperature Domestic Hot Water	120	49
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	69	38
POOL HEATING	**°F**	**°C**
Supply Temperature Heating Plant	194	90
Return Temperature Heating System	84	29
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	105	58

Note: The values shown for temperature difference between primary and secondary cycle are based on typical specifications from European heat-transfer stations.

South Capitol Complex

The actual supply temperatures for the three hydronic systems at the South Capitol Complex is between 120°F (49°C) (minimum supply temperature of the boilers) and 160°F (71°C (maximum supply temperature of the boilers). The temperature differential between supply and return, according to maintenance personnel, is only 5°F (3°C). All boilers were out of operation during the assessment, however, so this information could not be verified.

The setpoint temperature for the hot air leaving all of the air-handling units is 120°F (49°C). All heating systems have flow control valves in the supply lines feeding the coils in the air-handling units. The hydronic heating system at the Montoya Building is also equipped with a mixing valve in the return to the boiler. Set-point temperatures for domestic hot-water systems at the site range from 106-115°F (41-46°C).

The heating systems of the Montoya and Runnels building are controlled by their own computer systems. It may be possible to increase the temperature differential by changing some of the setpoints in these control systems. The installed pumps are single-speed, however, and therefore the only way to control the flow within the system is with the flow control valves at the air-handling units. The heating systems of the Simms and Lujan building are not controlled by a central computer control system, so adjustments to these systems may be more difficult.

Another opportunity to achieve a high temperature differential in the primary cycle at the heat-transfer station is by installing a mixing valve in the supply line to the heating system of each building (secondary cycle). The mixing valve would mix the low-temperature return from the air-handling units with the high-temperature supply from the heat-transfer station to maintain an appropriate supply temperature to the air-handling units. (The minimum is 120°F (49°C), maximum is 160°F (71°C).) The mixing valve would be controlled by the control system of the heat-transfer station.

Based on a supply temperature from the heating plant of 194°F (90°C) and the required entering water temperature for the air-handling units, the achievable temperature differential in the primary cycle at the heat-transfer station is estimated to fall in the range of 29-69°F (16-38°C) for space heating. Even higher temperature differentials (74-83°F (41-46°C)) are possible for domestic hot-water heating. See also Table 47). Space heating once again represents the majority of the heat demand, and therefore an average temperature differential for the whole micro-grid is estimated at 29-29°F (16-38°C).

Table 47: Achievable Temperature Differential at the Heat Transfer Station, South Capitol Complex

SPACE HEATING	°F	°C
Supply Temperature Heating Plant	194	90
Return Temperature Heating System	120-160	49-71
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	29-69	16-38
DOMESTIC HOT WATER	**°F**	**°C**
Supply Temperature Heating Plant	194	90
Supply Temperature Domestic Hot Water	106-115	41-46
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	74-83	41-46

Note: The values shown for temperature difference between primary and secondary cycle are based on typical specifications from European heat-transfer stations.

Santa Fe Community College

The measured supply temperature in the heating system at the Main Building at Santa Fe Community College was 135°F (57°C), and the measured temperature differential between the supply and return lines was only around 5°F (3°C). The boilers in the other buildings were not in operation during the assessment, but it is estimated that the supply temperature for all heating systems is between 135-160°F (57-71°C). The supply temperature of the domestic hot water range from 106-120° (41-49°C). Each domestic hot-water systems has a circulation pump. The pool temperature is maintained at 82°F (28°C) throughout the year.

The heating system of each building on the campus is controlled by its own computer system. Adjustment of the control systems may help to increase the temperature differential, especially by adjusting the variable speed of the pumps.

Table 48: Achievable Temperature Differential in the Primary Cycle at the Heat Transfer Station, Santa Fe Community College

SPACE HEATING	°F	°C
Supply Temperature Heating Plant	194	90
Return Temperature Heating System	135-160	57-71
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	34-59	19-33
DOMESTIC HOT WATER	**°F**	**°C**
Supply Temperature Heating Plant	194	90
Supply Temperature Domestic Hot Water	106-120	41-49
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	69-83	38-46
POOL HEATING	**°F**	**°C**
Supply Temperature Heating Plant	194	90
Return Temperature Heating System	82	28
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	107	59

Note: The values shown for temperature difference between primary and secondary cycle are based on typical specifications from European heat-transfer stations.

Another opportunity to achieve a high temperature differential in the primary cycle of the heat-transfer station is by installing a mixing valve in the heating system of each building (secondary cycle). The mixing valve would mix the low-temperature return from the air-handling units with the high-temperature supply from the heat-transfer station to maintain an appropriate supply temperatures to the air-handling units. The mixing valve would be controlled by the control system of the heat-transfer station.

Based on a supply temperature from the heating plant of 194°F (90°C) and the measured return temperature, the achievable temperature differential in the primary cycle at the heat-transfer station is estimated to range from 34-59°F (19-33°C) for space heating. Even higher temperature differentials are possible for domestic hot water and pool heating (69-107°F or 38-59°C, see also Table 48). Since space heating represent the majority of the heat demand, an average temperature differential for the primary cycle of the micro-grid is estimated to range from 34-59°F (19-33°C) during winter operation. During the summer a higher temperature differential is possible since only domestic hot water and pool heating are required.

College of Santa Fe

The supply temperatures of the heating systems on the campus range from 140-160°F (60-71°C). The temperature differentials could not be determined but are estimated to be very low, perhaps around 5°F (3°C). The supply temperature of the domestic hot-water systems range from 125-140°F (52-60°C). Each domestic hot-water system has a circulation pump.

Most of the heating systems are very old, and their control systems are outdated and require constant maintenance. Therefore, an increase of the temperature differential by adjustments to the process control system does not seem likely.

The only option to achieve a high temperature differential in the primary cycle at the heat-transfer station is to install a mixing valve in the heating system of each building (secondary cycle). The mixing valve mixes the low-temperature return from the air-handling units with the high-temperature supply from the heat-transfer station to maintain an appropriate supply temperature for the air-handling units. The mixing valve would be controlled by the control system of the heat-transfer station.

Based on a supply temperature from the heating plant of 194°F (90°C) and the measured return temperature of the secondary cycle, the achievable temperature differential in the primary cycle at the heat-transfer station is estimated to range between 34-54°F (19-30°C) for space heating. Higher temperature differentials are possible for domestic hot-water heating (54-69°F or 30-38°C, see also Table 49.) Since space heating represents the majority of the heat demand, an average temperature differential in the primary cycle of the micro-grid between 34-54°F (19-30°C) can be estimated.

Table 49: Achievable Temperature Differential in the Primary Cycle at the Heat Transfer Station, College of Santa Fe

SPACE HEATING	**°F**	**°C**
Supply Temperature Heating Plant	194	90
Return Temperature Heating System	140-160	60-71
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	34-54	19-30
DOMESTIC HOT WATER	**°F**	**°C**
Supply Temperature Heating Plant	194	90
Supply Temperature Domestic Hot Water	125-140	52-60
Temperature Difference Primary/Secondary Return	5.40	3.00
Achievable Temperature Differential	54-69	30-38

Note: The values shown for temperature difference between primary and secondary cycle are based on typical specifications from European heat-transfer stations.

4.7 Heat Demand Characteristics Curve

4.7.1 Main District Heating System

The monthly substitutable heat demand for twelve months within the target area was calculated for every building assessed, or estimated if no gas bills were available.

Based on the method describe in Section 3.7 the heat-demand characteristics curve was calculated. See Figure 19.

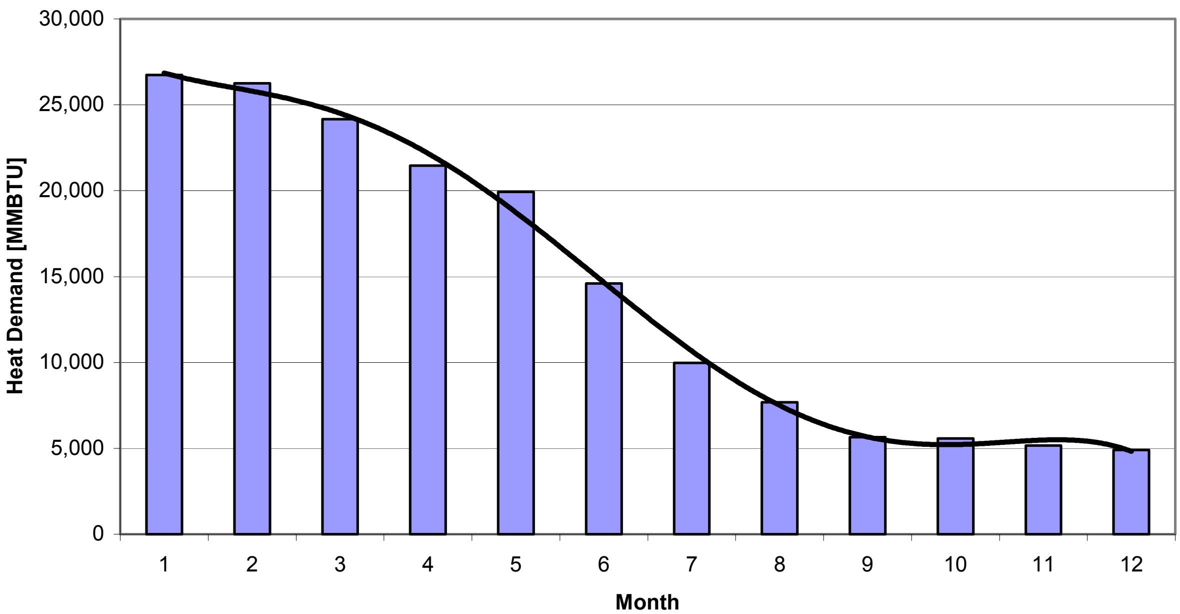

Figure 19: Heat-Demand Characteristics Curve of All Assessed Buildings in the Target Area, Based on Monthly Heat Demand, Main District Heating System

Note: Monthly heat demand based on monthly gas bills for 2003 and estimates for buildings without available gas bills according to Section 4.3.1.2.

The heat-demand characteristics curve shows a heating season of five months, two to three additional months with some heating, and an off-peak season of about four months with only a small heat demand (mainly domestic hot water and pool heating). The lowest monthly heat demand amounts to about 18 percent of the highest monthly heat demand. The heat-demand characteristics curve with a more detailed scale will show an even bigger difference between the maximum and the minimum demand.

The relatively high heat demand during summer in comparison to the South Capitol Complex and the College of Santa Fe is mainly due to the high heat demand of the hotels during summer (kitchen, laundry, pool heating). The difference between the highest and the lowest monthly heat demand is expected to increase when all buildings within the target area are considered, because most of the unassessed buildings are residential and commercial buildings with a low heat demand during the warmer months.

4.7.2 Potential Micro-Grid Sites

Los Arroyos Compound

Based on the monthly heat demand calculated from the available gas bills of all seven apartment buildings and the administration building, the heat-demand characteristics curve with a monthly scale was prepared (see Figure 20).

The heat-demand characteristics curve shows a heating season of five to six months, two to three additional months with some heating, and an off-peak season of about four months with only a small heat demand (domestic hot water and pool heating). The lowest monthly heat demand amounts to about 15 percent of the highest monthly heat demand. The heat-demand characteristics curve with a more detailed scale will show an even bigger difference between the maximum and the minimum demand.

The relatively high heat demand during summer (in comparison to customers who need domestic hot water only) is mainly due to the pool heating.

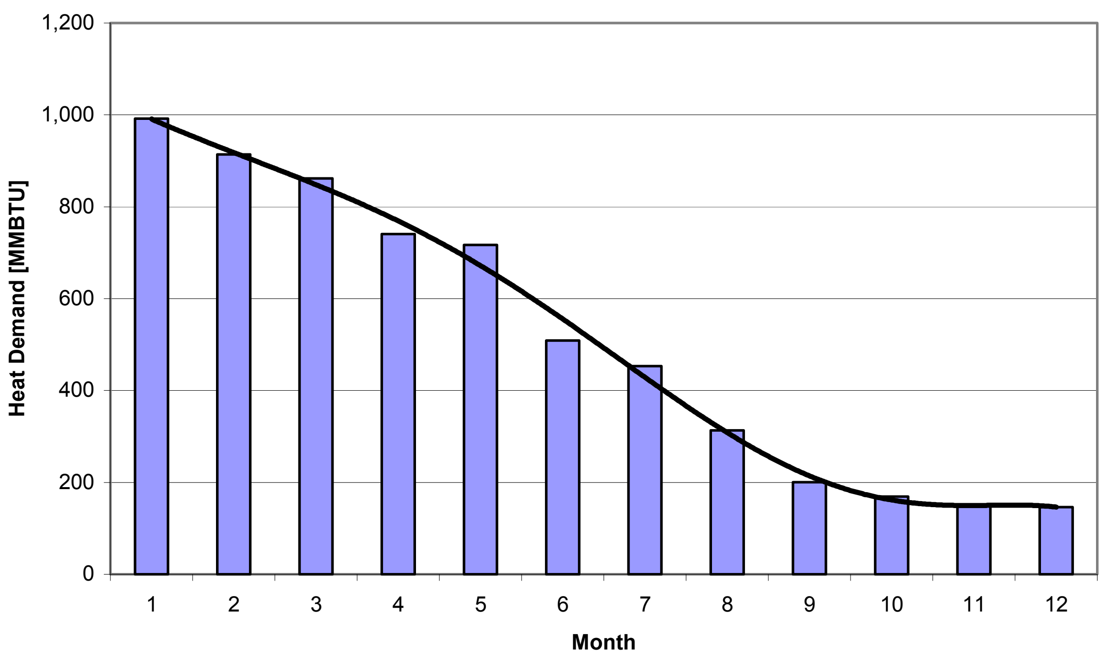

Figure 20: Annual Heat-Demand Characteristics Curve of All Customers in the Target Area, Based on Monthly Averages, Los Arroyos Compound

Note: Monthly heat demand based on monthly gas bills from 1999 to 2002

South Capitol Complex

Based on the monthly heat demand calculated from the available gas bills of all four office buildings, the heat-demand characteristics curve with a monthly scale was prepared (see Figure 21).

The annual heat-demand characteristics curve shows a heating season of five to six months and an off-peak season of about four months, during which there is only a very small heat demand (domestic hot water). The lowest monthly heat demand amounts to about 8 percent of the highest monthly heat demand. The heat-demand characteristics curve with a more detailed scale will show an even bigger difference between the maximum and the minimum demand.

Compared to the heat-demand characteristics curve of Los Arroyos Compound, which has a minimum monthly heat demand that represents 15 percent of the maximum monthly heat demand, the lower domestic hot-water consumption per square foot and the lack of a swimming pool in the South Capitol Complex is apparent.

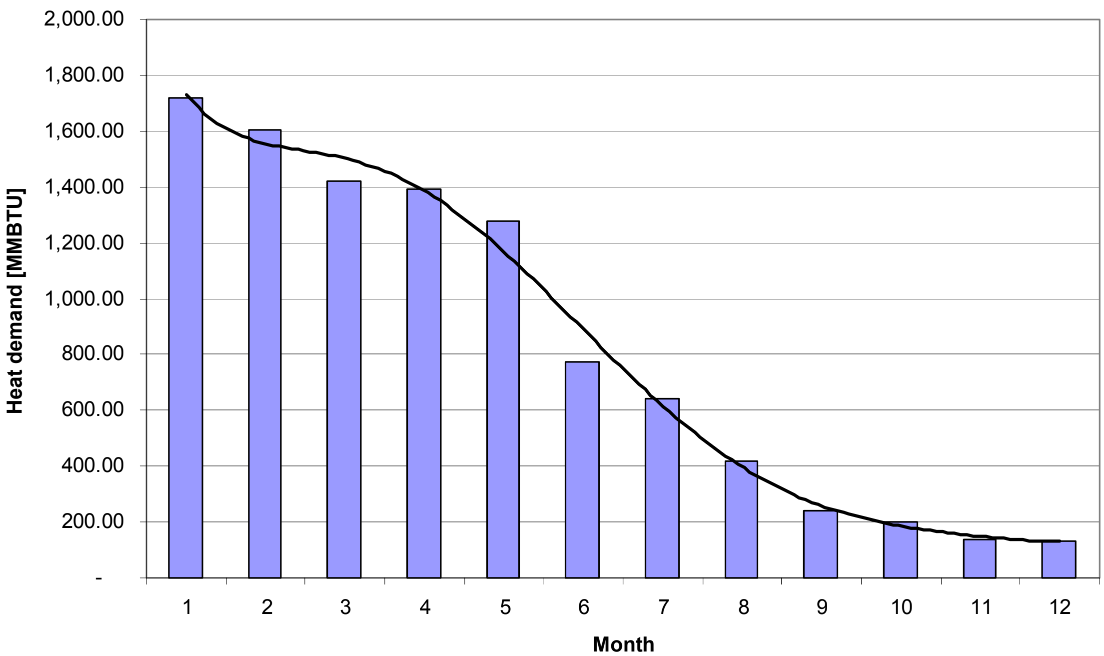

Figure 21: Annual Heat-Demand Characteristics Curve of All Customers in the Target Area, Based on Monthly Averages, South Capitol Complex

Note: Monthly heat-demand based on monthly gas bills of 2002 and 2003

Santa Fe Community College

The calculation of the heat-demand characteristics curve was not possible, because monthly gas bills were only available. for two buildings The heat-demand characteristics curve will be calculated after the requested gas bills for 2002 and 2003 are available.

College of Santa Fe

Based on the monthly heat demand calculated from the available gas bills of the main gas meter on the campus, the heat-demand characteristics curve with a monthly scale was prepared (see Figure 22).

The heat-demand characteristics curve shows a heating season of five months and an off-peak season of about four months with only a very small heat demand (domestic hot water demand). The lowest monthly heat demand amounts to about 8 percent of the highest monthly heat demand. The heat-demand characteristics curve with a more detailed scale will show an even bigger difference between the maximum and the minimum demand. The heat-demand characteristics curve may also vary from building to building because there are several buildings included that are not used throughout the year.

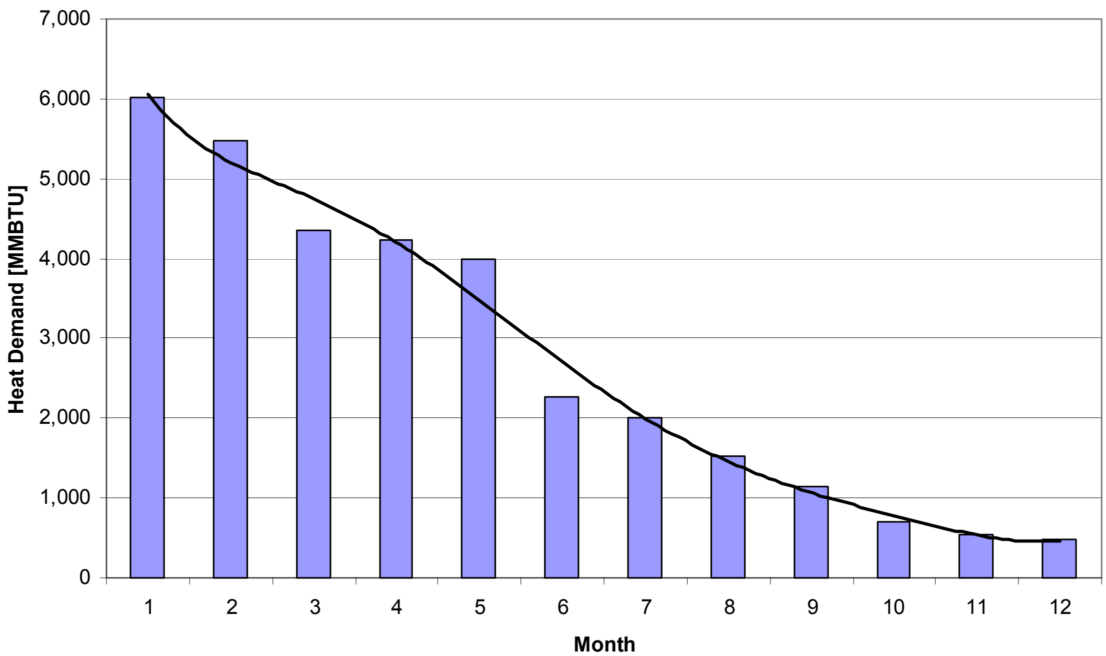

Figure 22: Annual Heat-Demand Characteristics Curve of All Customers in the Target Area, Based on Monthly Averages, College of Santa Fe

Note: Monthly heat demand based on monthly gas bills of 2000 and 2001

5 Conclusions

This heat-demand inquiry revealed a high density of large heat consumers in the downtown area of Santa Fe and identified some promising sites for micro-grids south of downtown.

5.1 Main District Heating System

The 106 buildings assessed within the target area represent about three quarters of the total heat demand in the area, but make up only one quarter of all buildings. The goal of efficiently assessing as much of the total heat demand as possible by focusing on the most energy-intensive buildings in the target area has therefore been achieved.

The data gathered during the inquiry has given us a detailed knowledge of the heating systems, building structures, heating behavior, and heat demand of the buildings in downtown Santa Fe and at several possible micro-grid sites. By strategically targeting a variety of building types, we were able to extrapolate building data taken during our assessments to buildings that could not be assessed within the allotted time. Using this technique we were able to create an accurate picture of the heating characteristics of all buildings within the target area of the main district heating system.

The available weather data and the trend of daily heating degrees show that no space heating is required from June to August, and very little heat is required in September and May. The actual heating season begins after September and usually ends before May. With few exceptions, the trend of heat demand in assessed buildings correlates well with our calculated trend of daily heating degrees, as expected.

In addition to the technical data taken during the assessments, we gathered significant and important information from building owners, maintenance personnel, and heating-system operators regarding the heating season and heating behavior in the buildings. This information further verified our conclusion that the primary heating season is from October/November to March/April, with a few buildings requiring heat from September until May. In a few buildings the heating systems run throughout the year, but are used infrequently during summer. Outside the heating season the only heat generally needed is for domestic hot water and pool heating, and most space-heating systems are switched off.

The specific heat demand, specific nominal heating capacity, and full-load operating hours were calculated for every building assessed, and the results show good correlation with the national average values from Reference [4] for most building categories.

The comparison of calculated classification numbers for each building with average classification numbers for each category enabled identification of buildings with implausible heat demands, oversized nominal heating capacities, and other data anomalies. Corrections were made to the nominal heating capacity, heat demand, and/or the square footage of suspect buildings in order to bring their classification numbers into range with average specific classification numbers for other buildings in the same category.

The practice of over-sizing heating systems to compensate for the altitude of Santa Fe was also taken into account. The range of design altitudes for heating systems in Santa Fe necessitated an 8 to 28 percent de-ration of the nameplate heating capacity to yield the actual nominal heating capacity. Time limitations prevented us from identifying the exact de-ration needed to correct every individual heating system within the target area, so a conservative reduction of 12 percent was used to correct all systems for altitude. This assumes an average design altitude of 4,000 ft (1,220 m). A more detailed investigation of design altitudes must be carried out if the biomass district heating system is realized.

The calculation of specific heat demand and specific nominal heating capacity of so many buildings enabled estimation of the heat demand and nominal heating capacity for buildings that were not assessed or for which data were not available. It furthermore enabled estimation of heating requirements in buildings to be constructed in the near future. The substitutable heat demand and the connected heat load potential (substitutable nominal heating capacity) of all buildings within the target area were also determined, and Table 50 shows an overview of these results. Nearly 70 percent of the total heat demand in the target area is considered replaceable with a district heating system.

Table 50: Connected Heat Load Potential and Substitutable Annual Heat Demand Within the Target Area, Main District Heating System

CATEGORY	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
	[BTU/hr]	[kW]	[BTU/yr]	[kWh/yr]
Visited Buildings	162,241,023	47,548	172,067,729,550	50,427,889
Other existing Buildings	43,502,376	12,749	40,127,746,500	11,760,239
New Buildings	12,237,643	3,586	11,572,439,109	3,391,535
TOTAL	**217,981,042**	**63,884**	**223,767,915,159**	**65,579,663**

The substitutable heat demand represents 298,357 MMBTU (87,440 MWh) of natural gas per year, assuming an average annual utilization rate of 75 percent. This amount of natural gas represents CO_2 emissions of 19,084 short tons (17,313 metric tons) per year assuming a CO_2 emission rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If the biomass-fired district heating system is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed during the forthcoming preliminary design of the network of pipes and heating plant.

The effort to acquire customers for the system should focus first on the few large commercial buildings and on buildings within the categories making up the greatest portion of the heat demand. To that end, the initial focus should be on large and medium sized hotels (26.0 percent of the heat demand), office buildings (22.3 percent), and schools (6.0 percent). Together these categories make up more than 56 percent of the total heat demand within the target area, yet they comprise only 15.6 percent of the buildings.

The high density of large buildings with high heat demand makes downtown Santa Fe a very promising area for the installation of a district heating system. The density will allow a high network utilization ratio (total customer connected heat load within the target area divided by the network length) and a high network heat utilization ratio (annual heat sold to the customers divided by the network length.)

The relatively short heating season in Santa Fe and the requirement that all heating systems must be capable of maintaining a comfortable room temperature on the coldest day of the year result in high specific heating capacities with relatively low full-load operating hours. The full-load operating hours of all buildings with a substitutable heat demand average 1,027 hours. This value is based on conservative estimates (Section 4.3.1.3) and must be refined prior to construction to ensure that the system is designed using the most accurate values available.

Low full-load operating hours at the clients also leads to low boiler full-load operating hours for the heating plant. Unfortunately, lower full-load operating hours result in higher specific investment costs per produced BTU. A correct design of the biomass heating plant using a biomass-fired boiler for the base load and a gas fired boiler for peak load and backup is therefore essential, as this configuration increases the full-load operating hours of the biomass boiler. It will furthermore be important for the economic success of this project to look for process heat consumers that need heat throughout the year, as this will increase the annual utilization rate of the heating plant.

Table 51: Average Full-Load Operating Hours for Different Building Categories, Main District Heating System

TYPE OF BUILDING	FULL-LOAD OPERATING HOURS Maximum [hrs]	Minimum [hrs]	Average [hrs]
Apartments	747	747	747
Church	994	632	806
Commercial	1,704	387	964
Healthcare	2,186	2,186	2,186
Large_Hotel	1,464	752	1,175
Medium_Size_Hotel	1,396	710	1,170
Municipal	1,309	569	1,087
Museum	1,659	912	1,231
Offices	2,218	308	1,005
Residential	982	624	795
Restaurant	1,027	1,027	1,027
School	841	338	745
Shopping_Center	1,028	882	994
Small_Hotel	2,086	1,025	1,530
Swimming_Pool	950	950	950
Theater	1,704	1,073	1,264
TOTAL			1,027

Note: Boiler full-load operating hours based on the connected heat load potential and the substitutable heat demand.

The trend of the annual heat demand based on monthly averages of all buildings assessed also indicates the potential for low full-load operating hours. For assessed buildings within the target area, the minimum monthly heat demand is only 18 percent of the highest monthly heat demand. The difference between the highest and the lowest monthly heat demand is expected to further increase when all buildings within the target area are considered, since most of the un-assessed buildings are residential and commercial buildings, which tend to have low heat demand during the warmer months. The difference between the highest and the lowest heat demand on an hourly basis will be even higher.

The annual heat-demand line, which shows the heat demand of the heating plant, will be calculated during the preliminary design of the network of pipes.

5.2 Potential Micro-Grid Sites

Outside the main target area, several potential sites for micro-grids were identified. Four of them were examined in detail during this heat-demand inquiry.

Los Arroyos Compound

Los Arroyos Compound, an apartment complex with seven residential buildings and an administration building with an indoor swimming pool, is a very promising site for a micro-grid. Table 52 shows the most important results obtained during the heat-demand inquiry.

Table 52: Connected Heat Load Potential and Substitutable Annual Heat Demand Within the Target Area, Los Arroyos Compound

CATEGORY	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
	[BTU/hr]	[kW]	[BTU/yr]	[kWh/yr]
All Buildings	6,193,000	1,815	6,163,042,217	1,806,203

The substitutable heat demand represents 8,217 MMBTU (2,408 MWh) of natural gas per year, assuming an average annual utilization rate of 75 percent. This amount of natural gas represents CO_2 emissions of 525 short tons (477 metric tons) per year based on a CO_2 emission rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If a biomass-fired micro-grid is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed during the forthcoming preliminary design of the network of pipes and heating plant.

The average full-load operating hours at Los Arroyos is very low, amounting to only 989 hours. Assuming the existing system is sized correctly, low full-load operating hours for the existing system will lead to low full-load operating hours for the boiler in a district heating plant. Low full-load operating hours result in higher specific investment costs per produced BTU. It is therefore essential to correctly design the biomass heating plant using a biomass-fired boiler for the base load and a gas-fired boiler for peak load and back-up. This configuration increases the full-load operating hours of the biomass-fired boiler, thereby improving the economics.

There are no process heat consumers nearby, so the best opportunity to increase the full-load operating hours may be to install a heat storage tank. The tank could be loaded during off-peak hours by the biomass boiler, and then emptied during peak hours. This technique would increase the operating hours and decrease the required size of the biomass boiler, thus raising its full-load operating hours.

South Capitol Complex

With the exception of the domestic water heater in the Simms Building, all of the installed heating systems in the South Capitol Complex can be replaced by a micro-grid. Table 53 shows the most important results of this heat-demand inquiry.

Table 53: Connected Heat Load Potential and Substitutable Annual Heat Demand Within the Target Area, South Capitol Complex

CATEGORY	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
	[BTU/hr]	[kW]	[BTU/yr]	[kWh/yr]
All buildings	12,355,440	3,621	9,755,932,214	2,859,171

The substitutable heat demand represents 12,998 MMBTU (3,809 MWh) of natural gas per year, assuming an average annual utilization rate of 75 percent. This amount of natural gas represents CO_2 emissions of 831 short tons (754 metric tons) per year assuming a CO_2 emission rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If a biomass-fired micro-grid is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed during the forthcoming preliminary design of the network of pipes and heating plant.

The average full-load operating hours of the South Capitol Complex is very low at 790 hours. Some of the lower-than-expected result may be due to the suspiciously low heat demand of the Lujan Building. If the problem with the data for the Lujan Building is discovered and corrected it could increase the full-load operating hours, but they will undoubtedly remain relatively low. Installation of a heat storage tank is recommended to increase the full-load operating hours at this location. (See also the suggestions for the Los Arroyos Compound.)

The four office buildings at the South Capitol Complex are connected by a network of tunnels. Utilizing these tunnels for the pipes of the micro-grid would significantly decrease the investment cost for the micro-grid, leading to better economic performance of the heating system.

Santa Fe Community College

With the exception of the heat required for domestic hot water in the Visual Arts Center, all of the heat at the Santa Fe Community College can be replaced by district heat supplied by a micro-grid. Table 54 shows the most important results of this heat-demand inquiry.

Table 54: Connected Heat Load Potential and Substitutable Annual Heat Demand Within the Target Area, Santa Fe Community College

CATEGORY	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
	[BTU/hr]	[kW]	[BTU/yr]	[kWh/yr]
Visited Buildings	12,612,600	3,696	28,339,139,292	8,305,352

The substitutable heat demand represents 37,091 MMBTU (10,870 MWh) of natural gas per year, assuming an average annual utilization rate of 76.5 percent. This amount of natural gas represents CO_2 emissions of 2,372 short tons (2,152 metric tons) per year based on a CO_2 emissions rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If a biomass-fired micro-grid is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed during the forthcoming preliminary design of the network of pipes and heating plant.

The average full-load operating hours of the Santa Fe Community College is very high at 2,247 hours. This result has yet to be verified using the most recent gas bills, but if accurate, the Santa Fe Community College is a very promising site for installing a biomass-fired micro-grid. The Main building and the Fitness Education Center are already connected by a small micro-grid, which will reduce the investment cost for a biomass system and improve the economic performance of such a system.

College of Santa Fe

It was not possible to assess all 46 buildings on the campus of the College of Santa Fe, and so the type of heating system installed in many of the buildings could not be specified. The substitution rate for heating systems throughout the campus also had to be estimated. Based on the assumption that all larger buildings are equipped with hydronic heating systems, it was estimated that 75 percent of the installed nominal heating capacity could be replaced by district heat from a micro-grid. Table 55 shows the most important results of this heat-demand inquiry.

Table 55: Connected Heat Load Potential and Substitutable Annual Heat Demand Within the Target Area, College of Santa Fe

CATEGORY	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
	[BTU/hr]	[kW]	[BTU/yr]	[kWh/yr]
All Buildings	18,785,514	5,505	24,525,547,825	7,187,702

The substitutable heat demand represents 34,063 MMBTU (9,983 MWh) of natural gas per year, assuming an average annual utilization rate of 72 percent. This amount of natural gas represents CO_2 emissions of 2,179 short tons (1,977 metric tons) per year based on a CO_2 emission rate of 12.79 lbs/therm (55,000 kg/TJ) of gas input. If a biomass-fired micro-grid is installed, a significant portion of these emissions will be eliminated. A more detailed investigation of the achievable reductions in CO_2 emissions will be performed during the forthcoming preliminary design of the network of pipes and heating plant.

The average full-load operating hours at the College of Santa Fe is 1,306 hours, although this result has yet to be verified using the most recent gas bills. If accurate, the College Santa Fe is a promising site for a biomass-fired micro-grid. A small micro-grid connecting three buildings already exists on the campus, which could decrease the investment cost for a biomass-based micro-grid and improve the economic performance of such a system.

5.3 Summary of Conclusions and Recommendations

The most important conclusions are as follows:

- The heat-demand inquiry shows very good potential for a district heating system and for several micro-grids in Santa Fe. The high heat demand within a relatively small area, and the prevalence of hydronic heating systems that can easily be replaced with district heating, are very promising. The high heating density will enable a high network utilization ratio (total customer connected heat load within the target area divided by the network length) and a high network heat utilization ratio (annual heat sold to the customers divided by the network length.)
- The addition of process-heat consumers would increase the full-load operating hours of the main district heating grid, improving the economic performance of the system.
- The relatively low full-load operating hours of most of the systems investigated increases the importance of correctly designing the biomass district heating system. The biomass boiler should provide the base load, and a gas-fired boiler should be used for peak load and backup.
- The advantages of using heat storage in both the main district heating system and in the micro-grids should be considered during the design phase of the project. This could increase the full-load operating hours and reduce the needed boiler size.
- Additional detailed data should be collected from the South Capitol Complex, the Santa Fe Community College, and the College of Santa Fe in order to verify the results achieved.
- Efforts to inform the community and public officials about the advantages of building biomass district heating systems in Santa Fe should be increased in order to promote awareness of the need for such projects, and to engender support for them.

References

1 New Mexico Energy, Minerals and Natural Resources Dept., 2002: *New Mexico's Natural Resources 2002: Statistics for 2001.* Available:http://www.emnrd.state.nm.us/Mining/ResRpt/5Renew.pf.Accessed 9/5/03.

2 Stanzel, W., Jungmeier, G., Spitzer, J, 1995: *Emissionsfaktoren und energietechnische Parameter für die Erstellung von Energie- und Emissionsbilanzen im Bereich Raumwärmeversorgung*, Endbericht, Institut für Energieforschung, Joanneum Research, Graz, Austria.

3 http://www.weather.com/weather/climatology/daily/USNM0292.

4 U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2003: *2002 Buildings Energy Databook*. Washington, U.S.A.

5 Reznor HVAC Division, http://www.rezspec.com/index.php?pageid=000000000014&mod_files[currpos]=000000000001

6 Raypak Inc., http://www.raypak.com/commframe.htm

7 John H. Baumgartel, e-mail from the 26th of April, 10:29 am