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Biomass-Fired District Energy for Santa Fe

Heat Demand Inquiry

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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

The heat demand inquiry for the potential supply area of the planned biomass-fired district heating system represents the first important step of the "Biomass-fired District Energy for Santa Fe" project. The goal of this project is to provide a secure, affordable and sustainable energy supply for the City of Santa Fe.

The target area for a central district heating plant for downtown Santa Fe as well as potential sites for decentralized micro grids were investigated during the inquiry to identify the best options for the introduction of biomass based energy to Santa Fe.

During the precise survey of potential customers using standardized questionnaires, detailed knowledge of the type and state of the existing heating systems was gained. Furthermore, local constraints like weather data, altitude and duration of the heating season were investigated. The data was checked for plausibility using specific classification numbers and the large knowledge base accumulated from experience in more than 500 installed biomass district heating systems in Austria. Implausible data was corrected ensure the accuracy of the results.

Based on the information gathered, the substitutable annual heat demand and the connected heat load potential within the target areas were determined, with the consideration of the substitutability of the installed heating systems and the state of their control systems. The heat demand and the connected heat load potential of unvisited buildings within the target area were extrapolated based on the their size and type.

The results achieved show great potential for the installation of a district heating system as well as several micro grids in the city of Santa Fe. The high heat demand within a relatively small area and the high portion of hydronic heating systems that can be replaced easily with a district heating system are very promising because 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) can be realized.

Due to the relatively low number of full load operating hours of most of the systems investigated, a correct design of the biomass district heating system is of utmost importance. The biomass boiler should cover the base load and a gas-fired boiler should be used for peak load coverage and as a back-up system. Further measures like the implementation of a heat storage tank in the district heating system as well as in the micro grids and the attracting of process heat consumers with a constant heat load throughout the year that would increase the boiler full load operating hours at the heating plant, will be considered in design phase of the project.

Kurzfassung

Die Wärmebedarfserhebung innerhalb des potentiellen Versorgungsgebietes für das geplante Biomasseheizwerk repräsentiert den ersten wichtigen Schritt des Projekts “Biomass-fired District Energy for Santa FE”. Ziel dieses Projektes ist die Bereitstellung einer zukunftssicheren, kostengünstigen und nachhaltigen Energieversorgung für Santa Fe.

Neben dem Versorgungsgebiet für ein zentrales Fernwärmenetz für den Stadtkern von Santa Fe wurden auch mehrere potenzielle Standorte für dezentrale Mikronetze im Zuge der Wärmebedarfserhebung untersucht, um die bestmöglichen Varianten für den Aufbau einer auf Biomasse basierenden Energieversorgung in Santa Fe zu ermitteln.

Durch die detaillierte Erhebung potenzieller Abnehmer unter Verwendung von standardisierten Fragebögen konnten detaillierte Informationen über die Art und den Zustand der derzeit installierten Heizungssysteme gewonnen werden. Darüber hinaus wurden die örtlichen Rahmenbedingungen wie Klimadaten, die Höhenlage und die Dauer der Heizsaison untersucht und in die Berechnungen miteinbezogen. Die erhobenen Daten wurden anhand spezifischer Kennzahlen auf Plausibilität geprüft und unplausible Daten wurden entsprechend korrigiert. Dabei konnte auf die weitreichende Erfahrung aus mehr als 500 errichteten Biomassefernheizwerken in Österreich zurückgegriffen werden.

Basierend auf den erhobenen Daten wurden der ersetzbare jährliche Wärmeverbrauch und die potentielle Anschlussleistung aller Gebäude innerhalb der Versorgungsgebiete ermittelt. Dabei wurden sowohl die Art der vorhandenen Heizungssysteme als auch der Zustand der Regelsysteme berücksichtigt. Der Wärmebedarf und die Anschlussleistung von nichterhobenen Gebäuden innerhalb der potenziellen Versorgungsgebiete wurden abhängig von deren Größe und Verwendungszweck abgeschätzt.

Die erhaltenen Ergebnisse zeigen ein großes Potenzial sowohl für die Errichtung eines zentralen Fernwärmenetzes als auch die für die Realisierung mehrerer dezentraler Mikronetze in Santa Fe. Die hohe Dichte an großen Wärmeabnehmern innerhalb eines relativ kleinen Gebiets sowie der große Anteil an leicht durch Fernwärme ersetzbaren hydraulischen Heizungssystemen ermöglichen eine hohe Netzbelegung (Gesamte Abnehmeranschlussleistung innerhalb des Versorgungsgebiets dividiert durch die Trassenlänge des Fernwärmenetzes) und Wärmebelegung (Jährlicher Wärmeverkauf dividiert durch die Trassenlänge des Fernwärmenetzes) des Fernwärmenetzes und der Mikronetze.

Aufgrund der relativ niedrigen Volllaststunden der meisten untersuchten Systeme ist eine detaillierte und korrekte Auslegung der geplante Biomasseheizwerke von größter Wichtigkeit. Der Biomassekessel sollte dabei die Grundlast abdecken, während ein Gaskessel zur Spitzenlastabdeckung und als Ausfallsreserve dienen soll. Weitere Maßnahmen zur Steigerung der Volllaststunden der geplanten Biomasseheizwerke wie die Einbindung eines Pufferspeichers in das Fernwärmenetz und die Mikronetze sowie der Anschluss von Prozesswärmeabnehmern mit einer monatlich konstanten Wärmeabnahme werden im Rahmen der Vorauslegung der Heizwerke geprüft.

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 overburden in forests throughout the state offers a fuel resource many times that size. The removal of this overburden is a high priority for New Mexico due to the widely publicized fire danger that it presents.

Unfortunately, the urgent need to thin forests in New Mexico 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 are 70% above last year’s level, and continuing to climb on news of record low storage levels, poor drilling results, and high depletion rates in the most productive basins. 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 the project, “Biomass-Fired District Energy, A Source of Economic Development and Energy Security”. 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 potential supply area of the planned biomass-fired district heating grid. The supply area for a central district heating plant for downtown Santa Fe as well as potential sites for decentralized micro grids were investigated during the inquiry to identify the best options for the introduction of biomass based energy supply in Santa Fe. The work implemented in this report serves as a basis for all following development and engineering activities within this project. The results of the inquiry will be used to determine the economic and environmental feasibility of the two different approaches (centralized supply or decentralized supply).

2 Objectives

A detailed heat demand inquiry is essential for the design and dimensioning of the network of pipes and the heating plant. The results of the heat demand inquiry such as the substitutable heat demand of the potential customers, the heat load of the potential customers and the trend of the annual heat demand are important input parameters for all design calculations.

The heat demand inquiry covered the following tasks:

- Determination of the potential supply areas: the target area for a central district heating system as well as potential sites for decentralized heating systems (micro grids) were identified.
- Investigation of the local constraints that apply: local weather data, altitude and the duration of the heating season were analyzed.
- Gaining detailed knowledge about the type and state of the existing heating systems: based on a detailed and precise survey of the potential customers using standardized questionnaires, the type and state of the existing heating systems as well as the heat consumption behavior of the clients were investigated.
- Determination of the substitutable heat demand: based on the data gained from the survey the substitutable heat demand within the proposed supply area was identified.
- Determination of the connected heat load and the full load operating hours of each customer: considering the local climate conditions and based on a plausibility check of the data gained, the connected heat load and the full load operating hours of each customer were calculated.
- Estimation of the trend of the annual heat demand: based on the results mentioned above the trend of the annual heat demand for the proposed supply area was calculated.
- Furthermore, this inquiry was also taken as an opportunity to inform the potential customers about the advantages and possibilities of a future district heat supply based on bioenergy.

3 Methodology

3.1 Evaluation of Weather Data

3.1.1 Daily Mean, Minimum and Maximum Temperatures

Based on recorded weather data by local meteorological agencies the daily mean, minimum and maximum temperatures for the Santa Fe area were calculated and displayed in graphs (annual line of mean, minimum and maximum temperatures). If possible, the recorded weather data should be available for a period of at least 5 years.

This data was used to calculate the daily heating degrees (see chapter 3.1.2). The annual trends of mean, minimum and maximum temperatures were also required for the calculation of the annual heat demand line and the design of the network of pipes.

3.1.2 Daily Heating Degrees

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

Because a daily heating degree only occurs when additional heat is needed to maintain the room temperature, the trend of daily heating degrees over a full year gives a good indication of the to be expected trend of the heat demand for space heating (the domestic hot water demand is more or less independent from the ambient temperature). Therefore, the trend of the daily heating degrees was used to check the plausibility of the calculated monthly heat demand (see chapter 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 with a high density of heat consumers, such as hotels, office buildings, shopping centers and large apartment buildings because these areas are the most promising for the installation of a district heating grid. Furthermore, when visiting the large heat consumers first, the main portion of the total heat load in the targeted area can be assessed within a relatively short period of time.

Due to the fact that a main district heating system for downtown Santa Fe as well as micro grids outside the supply area of the main grid were considered in this project, the heat demand inquiry focused not only on the downtown area of Santa Fe but also on potential sites for the installation of micro grids. The two different approaches were chosen to identify the best options for the introduction of biomass based energy in Santa Fe.

3.2.1.1 Main District Heating System

Many large hotels, some of the large commercial buildings, and most of the federal, state, county and city buildings in Santa Fe are located between Paseo de Peralta and in downtown Santa Fe. Paseo de Peralta forms a loop, bordering this area on north, east and South, while Guadalupe Street forms the western border.

Another area with a high density of heat consumers is situated just southwest of downtown at the junction of St. Francis Drive and Cerrillos Road where the campus of the School for the Deaf and the Department of Transportation are located.

If the project proves feasible, these two areas would represent the main supply area of the main district heating system for downtown Santa Fe and therefore the main focus of the heat demand inquiry was on these areas. In addition, large buildings along the proposed path of the main supply line of the network of pipes between downtown and the possible site of the biomass-fired district heating plant west of downtown were also visited. Figure 1 shows the proposed path of the network of pipes and the target area for the heat demand inquiry.

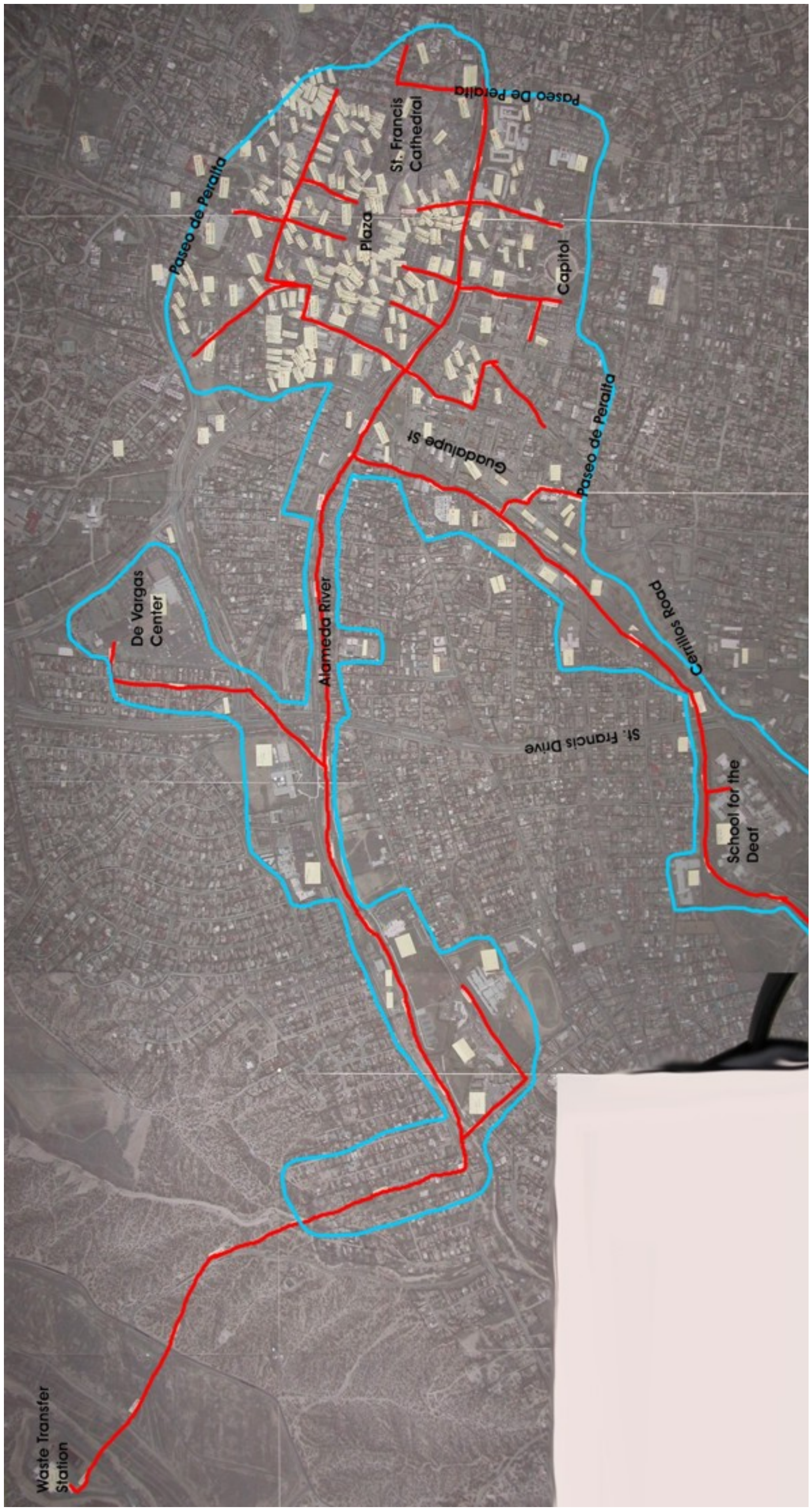

Figure 1: Target area and proposed path of the network of pipes – heat demand inquiry Santa Fe

Legend: Red line: proposed path for the network of pipes with the waste transfer station as a possible site for the heating plant. Blue line: target area for the heat demand inquiry.

3.2.1.2 Other Areas (Potential Sites for Micro Grids)

Apart from the main supply area many other promising areas were identified as potential sites for biomass-fired micro grids that could operate separately from the main system.

The installation of micro grids may be an alternative to a central district heating system for areas with a high heat demand that are too far away from the main district heating system to be connected.

Four of these sites were visited during the heat demand inquiry and are listed in Table 1. Other potential sites that have not been visited yet are the Indian School, the campus of the Institute of American Indian Arts and several apartment buildings along St. Francis Drive south of downtown and in other residential areas. All of these sites consist of several buildings within a relatively small area that are either owned or operated by a single organization, which enables the connection of all buildings in the area once the micro grid is installed. This is important to achieve the highest possible utilization rate of the heating system.

Table 1: List of visited 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	At St Francis Drive south of Cerrillos Road junction
Santa Fe Community College	10 miles south of downtown
College of Santa Fe	4 miles south of downtown

Although part of a future downtown district heating grid, the railyard area could also operate as a micro grid as a first step towards the large system. The railyard area can therefore be considered as a micro grid option. However, to avoid a confusion of results the railyard area is included in the main target area and is not considered separately in this report. A detailed investigation of this area as a micro grid opportunity will take place in the next step of this project (preliminary design of the network of pipes and the heating plant).

3.2.2 Heat Demand Inquiry Questionnaire

Standardized questionnaires with detailed questions about all relevant data of the potential future customers were used during the survey. The questions referred to annual heat consumption, fuels used, investigation of the existing heating system, insulation quality of the buildings, heated areas, room volumes, necessary feed and return temperatures as well as customer specific information concerning the heat consumption behavior.

Each survey was usually carried out either by one engineer of BIOS BIOENERGIESYSTEME GmbH or a staff member of Local Energy. During the first two weeks of the heat demand inquiry two or three persons visited the buildings together for training purposes.

Three different questionnaires focusing on the varying characteristics of residential buildings, hotels and service buildings as well as commercial and municipal buildings were used.

A fourth version of the questionnaire for process heat facilities was not used during this inquiry due to the lack of potential process heat consumers within the target areas.

3.2.2.1 Residential Buildings

The questionnaire for residential buildings served as the base for all questionnaires. It included questions about the customer (name, address), the annual fuel consumption (for the last 3 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 supply (DHW consumption, fuel supply) and the heating system (type of heating system, fuel input, 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 the same questions as the one for the residential buildings with the exception that instead of the number of persons living in the building the number of persons working there and their usual working hours were evaluated.

3.2.2.3 Hotels and Service Buildings

The specific characteristics of hotels and service buildings were considered in this questionnaire in addition to the standard questions. Detailed questions about the heat consumption behavior (peak hours, off-peak hours), special heat consumers like swimming pools, spas, dishwashers, washing machines etc., as well as the number of guest rooms and their occupancy throughout the year were part of this questionnaire.

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

The following specific classification numbers were used to evaluate the heating system of each building. They are essential for the plausibility check of the data gained (e.g. the identification of oversized heating systems) and the average classification numbers were used to estimate the heat demand and nominal heating capacity of buildings that weren't visited during the heat demand inquiry.

Average classification numbers were calculated for several different building categories to be able to consider the specific characteristics of every category (e.g. hotels, offices, homes).

3.3.1 Specific Nominal heating capacity

The specific nominal heating capacity equals the installed nominal heating capacity (without any back-up capacity) per heated area.

The specific nominal heating capacity of each building was compared to average numbers of similar buildings (e.g. hotels, residences, offices) to evaluate the design of the heating system. Hotels for instance have usually a higher specific nominal heating capacity than residential or office buildings because they often need additional heating capacity for service and recreational facilities (e.g. kitchen and swimming pool).

A higher specific nominal heating capacity than the average could either indicate an oversized heating system or poor thermal insulation of the building's exterior walls. It may also be an indication of a larger heated area than specified or several of these factors combined.

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

However, for an accurate plausibility check also the specific characteristics of a building had to be taken into account and the other specific classification numbers had to be compared.

3.3.2 Specific Heat Demand

The specific heat demand equals the annual heat demand (as calculated in step 6 of chapter 3.4) per heated area.

The specific heat demand of each building was compared to average numbers of similar buildings (e.g. hotels, residences, offices) to evaluate the heating behavior of the building. Buildings that need additional heat for service and recreational facilities (e.g. kitchen or swimming pool) usually have a higher specific heat demand than residential or office buildings.

A higher specific heat demand than the average could either indicate poor insulation or additional heat consumers that are not common in the average building of that category. A heated area specified too small or an overrated annual fuel consumption (e.g. some non heating gas consumers have not been considered) may also lead to a higher than average specific heat demand or several of these factors combined.

A lower specific heat demand than the average could indicate better than average insulation. An overestimation of the heated area of the building or an annual fuel consumption specified too low (e.g. because of incomplete gas bills) may also make for a lower than average specific heat demand or several of these factors combined.

However, for an accurate plausibility check also the specific characteristics of a building had to be taken into account and the other specific classification numbers had to be compared.

3.3.3 Boiler Full Load Operating Hours

The boiler full load operating hours equal 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 full load operating hours of each building were compared to average numbers of similar buildings (e.g. hotels, residential, office) to evaluate the design of the heating system as well as the heat demand. The longer the heating system operates per year, the higher are the full load operating hours. Therefore, full load operating hours are also an indicator of the length of the heating season.

Higher full load operating hours than the average could either indicate an undersized heating system, additional heat consumers with high full load operating hours that are not common in the average building of that category, poor insulation, or that the annual gas consumption is actually lower than specified (e.g. some non heating gas consumers have not been considered) or several of these factors combined.

Lower full load operating hours than the average could either indicate a oversized boiler, infrequent use of the building, a temporarily shutdown of parts of the building or that the actual heat demand is higher than calculated (e.g. because of incomplete gas bills) or several of these factors combined.

However, for an accurate plausibility check also the specific characteristics of a building had to be taken into account and the other specific classification numbers had to be compared.

3.3.4 Identification and Adjustment of Oversized Heating Systems

The identification and adjustment of oversized heating systems was carried out with a combined evaluation of all calculated specific classification numbers.

The approach for the identification could vary significantly from building to building. However, the most important indicator for an oversized heating system are full load operating hours that are significantly lower than the average of other buildings of the same type. Further indicators are a significantly higher specific nominal heating capacity compared to the average and a significantly higher specific heat demand with average full load operating hours and good insulation at the same time.

Apart from comparing specific classification numbers, the specific characteristics of the building (if applicable) were also taken into account.

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 undersizing, the maximum correction factor was set at 40% even if the specific classification numbers were still out of the target range.

A maximum correction factor of 40% was chosen because especially in larger buildings heating systems often operate with two boilers of the same size. While one boiler usually serves as a back-up, both boilers may be in operation during cold winter periods. So even if the sum of the nominal heating capacity of both boilers seems to be far oversized, the maximum required nominal heating capacity still exceeds 50% of the total capacity.

For systems with several different heating devices the nominal heating capacity of all devices was adjusted in the same way because it was usually not possible to evaluate the devices individually since the area heated by each device could not be specified.

After all heating systems were checked and adjusted, the average of each classification number was calculated for every building category. These average numbers were used to estimate the heat demand and nominal heating capacity of buildings that were not visited during the heat demand inquiry.

3.4 Calculation of the Substitutable Heat Demand and the Connected Heat Load

Based on the data gained during the heat demand inquiry the part of the annual heat demand for which district energy could be substituted was calculated. This happened in a nine-step process:

1. **Identification of other fuel consumers which are not used for heating**, e.g. dryers and flat ironers in laundries.

2. **Calculation of the annual fuel consumption of non heating devices** based on their specified fuel input and the information gained about the annual full load operating hours. (annual fuel consumption of non heating devices = specified fuel input*full load operating hours). This value is specified as “annual gas consumption for other purposes” in the spread sheets in the APPENDIX II of this report.

3. **Calculation of the annual fuel consumption of the heating devices**. (annual fuel consumption of heating devices = annual fuel consumption – annual fuel consumption of non heating devices). This value is specified as “annual gas consumption for heating purposes” in the spread sheets in the APPENDIX II of this report.

4. **Calculation of the efficiency of the heating system at nominal load**. According to the information on the specification plate of the heating device about the fuel input and the heat output the efficiency of the heating device was calculated (efficiency = heat output/fuel input). If only the heat input was specified the average efficiency of similar heating systems was used and the heat output was calculated.

5. **Determination of the annual utilization rate of the heating system**. The annual utilization rate of a heating system represents the ratio between the annual heat demand and 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 switched off and on many times during a heating season. Moreover, space heating systems usually operate at partial load conditions and only occasionally at full load. Every time a heating device is switched on again a part of the energy input has to be used to heat up the device which results in a loss of energy. Further energy losses occur during shut down and because of the lower efficiency at partial load. These energy losses lead to a lower annual utilization rate compared to the specified efficiency at full load. Based on results from a study carried out in Austria [2] the annual utilization rate was determined to be about 5% lower than the specified efficiency (i.e. a boiler with an efficiency of 80% has an annual utilization rate of 75%).

6. **Calculation of the annual heat demand.** The annual heat demand of a building was calculated from the annual fuel consumption of the 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. **Determination of the substitutable nominal heating capacity**. Not all existing heating devices can be easily replaced by a district energy system. On the contrary the type of

heating system can be a limiting factor. Basically, systems that do not use water as a heat carrier (hydronic) can not be replaced by a district energy system without any further retrofit of the heating system. However, heating systems that use low pressure steam may not need large investments to transform them into a hydronic system because the existing pipes can be used. But single forced air units, small forced air distribution systems, gas-fired radiators and electric heaters can not be replaced without virtually installing a complete new heating system. Therefore, these systems were quoted nonsubstitutable heating systems whereas all hydronic and steam systems were considered substitutable heating systems. On the other hand the location of the heating device in the building determines if a heating device can be substituted or not. This is especially true for DHW boilers that are not situated in the same room as the space heating system, boosters for dish washers and boilers for pool heating and other boilers that are not easily accessible (that's another reason why rooftop units are usually not suitable for substitution). Table 2 gives an overview of nonsubstitutable heating devices. However, depending on the size, the annual heat demand, the fuel used and the location of a building, installing a new heating system may be beneficial, especially if propane or electricity are used to heat the building. See for details in the detailed building description in the APPENDIX II of this report. Based on the type and the location of the installed heating devices the substitutable nominal heating capacity of each building was determined.

8. **Calculation of the connected heat load potential:** The connected heat load represents the nominal heating capacity that can be replaced by a district heating system and is equivalent to the output capacity of the heat transfer station to be installed at the customer. It is calculated from the nominal heating capacity of the substitutable heating devices multiplied by the correction factor for oversized heating systems if necessary.

9. **Calculation of the substitutable heat demand**. The substitutable heat demand equals the total annual heat demand less the heat demand of nonsubstitutable heating devices. If the full load operating hours were considered equal for all heating devices the substitutable and nonsubstitutable heat demand were calculated according to the portion of the total installed capacity for substitutable and nonsubstitutable devices (i.e. if the output of the substitutable heat device, is 900,000 BTU/hr (90% of the total output), the output of the nonsubstitutable heat device is 100,000 BTU/hr (10% of the total output) and the annual heat demand is 1,200 MMBTU, the substitutable heat demand amounts to 1,080 MMBTU/yr (or 90%)). If the full load operating hours were calculated separately for individual heating devices (e.g. one boiler for space heating and one boiler for pool heating that operates 365 days per year) the annual heat demand was calculated according to the full load operating hours of the substitutable system.

Table 2: Determination of nonsubstitutable heating devices

Depending on the size, the annual heat demand, the fuel used and the location of the buildings, the replacement of these heating systems may be beneficial in some cases.

Nonsubstitutable because of type of heating system
Single forced air units
Rooftop units (forced air distribution systems)
Gas-fired radiators
Electrically heated systems
Nonsubstitutable 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 reachable)

3.5 Extrapolation of the Substitutable Heat Demand and the Connected Heat Load for Non-Visited Buildings within the Target Area

The extrapolation of the substitutable heat demand and the connected heat load of buildings within the target area which were not visited during the heat demand inquiry was based on the information gained from visited buildings of the same category.

Average specific classification numbers were calculated for every building type. Based on these numbers, the annual heat demand and the nominal heating capacity of the non-visited buildings were calculated according to their size (actual square footage if available or otherwise an estimate) and type.

3.6 Determination of the Achievable ΔT at the Heat Transfer Station

3.6.1 Evaluation of the Temperature Level and the ΔT of the Existing Heating System and Determination of the Achievable Return Temperature at the Existing Heating System

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

The achievable ΔT in the hydronic system is determined by the specifications for entering water temperature and exiting water temperature of the heat distribution device (e.g. fan coil unit, baseboards, radiant floors), the flow rates of the pumps and the level of the supply temperature. The state of the system and which measures can be taken within a moderate cost range (e.g. for the installation of a mixing valve) determine the degree of change in achievable ΔT.

According to the supply temperature and the achievable ΔT the achievable return temperature of each heating system was determined.

3.6.2 Determination of the Achievable ΔT at the Primary Side of the Heat Transfer Station

The achievable ΔT at the primary cycle of the heat transfer stations at each customer is the determining factor for the achievable ΔT within the district network of pipes. A higher ΔT means that a higher rate of energy per gallon of hot water can be transferred to the heating system of each customer which leads to a decrease of pumping costs because less water needs to be pumped through the system to deliver the same amount of heat to the customers. The reduction in water flow also results in a reduction of pipe diameters and therefore investment costs savings.

The ΔT at the primary side of the heat transfer station is determined by the entering water temperature on the primary side (supply from the heating plant), the temperature difference between the primary and secondary side for which the heat exchanger is designed and the return temperature of the heating system on the secondary side.

In design figures from heat transfer stations used in central Europe, the temperature difference between the return of the primary side and the return of the secondary side is usually 5.4°F or 3°C, e.g. with a minimum return temperature at the secondary side of the heat exchanger (=heating system at the customer) of 140°F/60°C the minimum return temperature of the primary side of the heat exchanger (=network of pipes) would be 145.4°C/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 return on primary and secondary side)

3.7 Estimation of the Annual Trend of the Heat Demand

The annual trend of the heat demand line gives an indication of the expected heat demand at the heating plant over a full year (annual heat demand line). The annual heat demand line is essential for the calculation of the performance of the network of pipes and the heating plant over a full year. It is also important for the determination of the size of the biomass-fired boilers and the peak load boiler.

However, for an exact calculation of the annual heat demand line of the heating plant the simultaneity factor and the heat losses of the network of pipes have to be taken into account. Both parameters will be determined in the next phase of the project (preliminary design of the network of pipes and the heating plant). Therefore, only the annual trend of the heat demand of the buildings within the target areas was calculated, based on the calculations of the substitutable heat demand, the connected heat load and the information gained about the heating season.

3.7.1 Heating Season

Based on the information gained during the heat demand inquiry about the heat consumption behavior, the periods of high and low heat demand were identified. The determination of the duration of the period with high heat demand (heating season) and the period with very low heat demand (mostly for domestic hot water heating) is important for the calculation of the annual heat demand line.

3.7.2 Estimation of the Annual Trend of the Heat Demand

The annual trend of heat demand represents the heat demand within the target area over a full year based on monthly averages sorted from the highest heat demand of the year to the lowest. Based on the information about the heating season of all visited buildings and the calculated and extrapolated monthly substitutable heat demand of the buildings within the target area, the trend of the heat demand was estimated.

4 Results

4.1 Meteorological Conditions

Santa Fe (35.7° N 106.0° W) is situated at 7,000 ft/2,170 m above sea level, resulting in thin and very dry air. The city is located in a valley formed by the Rio Grande River, bordered on the west by the volcanic Jemez Mountains and on the east by the Sangre de Cristo range of the Rocky Mountains. Here the high desert meets the Ponderosa Pine and Aspen forests. This high-desert climate has four distinct seasons: warm springs, hot summers, crisp falls and tolerably cool winters.

Summer temperatures routinely reach the high 80s and low 90s °F/low 30s °C, with pleasantly warm nights. Rains (locals call them "monsoons") roll in during in July and August, dump a lot of water and lightning for a few hours, and then clear off. Temperatures slowly come down by October, but fall months are still very pleasant, with temperatures often in the 60s °F/15-20°C or even higher. Nights, though, are considerably cooler. When winter finally hits in late November, Santa Fe might get snow showers, but the snow rarely lasts for more than a day. In the surrounding mountains, the snow may remain for several months.

4.1.1 Daily Mean, Minimum and Maximum Temperatures

Several resources of weather data were examined during the heat demand inquiry. Many of them have recorded only wet bulb temperatures which could not be used for the calculation of the daily heating degrees because the humidity data was not available. However, at www.weather.com detailed records of daily averages for mean, minimum and maximum temperatures were found (data recorded since 1948) for Santa Fe [3]. The graphs in Figure 2, Figure 3 and Figure 4 are based on the data from this source.

Figure 2 shows that the mean temperatures reach the high 60s°F (10s°C) in summer and drop to freezing point in winter. The graphs of the daily average maximum and minimum temperatures show that the days can become quite hot in summer (around 85°F/30°F), although it cools down during the night (around 50°F/10°C). Warm winter days reach average temperatures as high as 50°F/10°C whereas the nights cool down to average temperatures of 15 to 20°F/ -10 to -6°C.

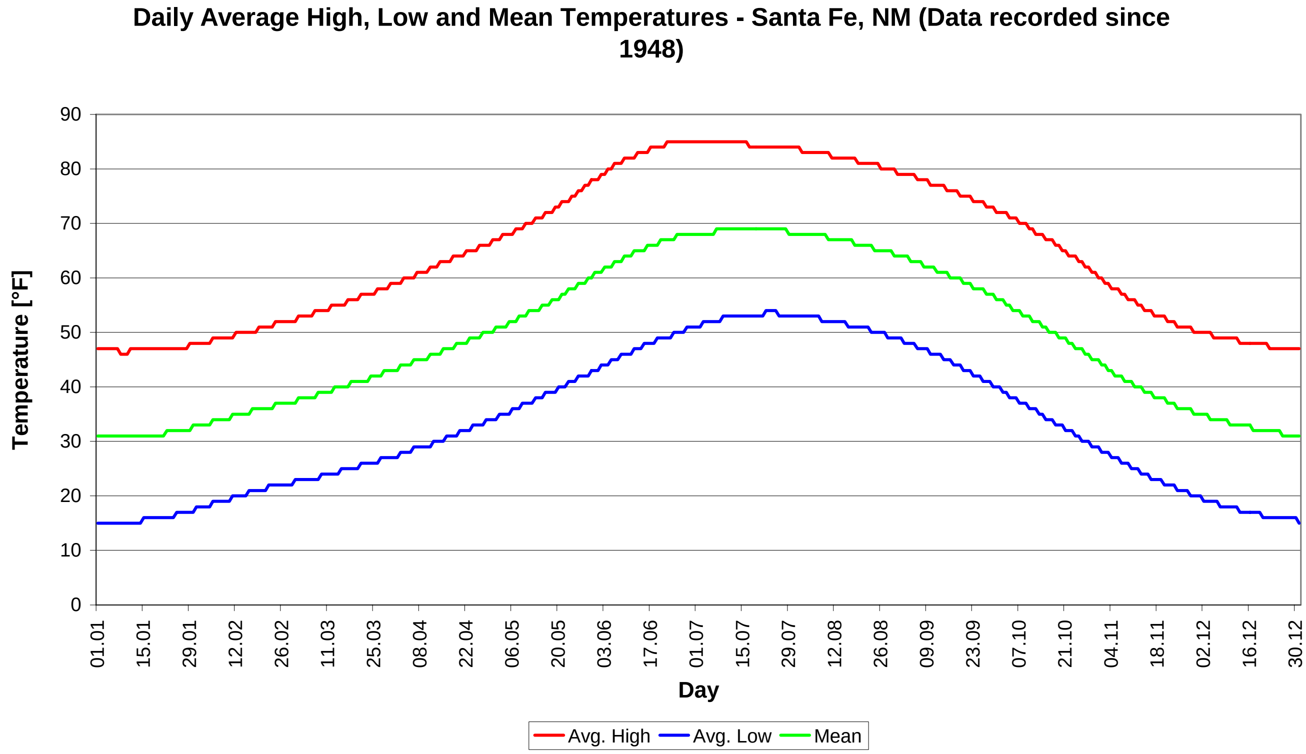

Figure 2: Daily average mean, maximum and minimum temperatures for Santa Fe

Legend: source [3]

4.1.2 Daily Heating Degrees

The average mean temperatures of each day were used to calculate the average heating degrees for every day of the year. Figure 3 shows the average daily heating degrees for Santa Fe. From mid June until the end of August no heating degrees occur which means 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 occur because other heat sources within the building (especially in office buildings with a large amount of computers and additional lighting) generate some waste heat to keep the buildings warm enough during the warmer months of spring and autumn. On the other hand even in summer the outside temperature can drop below the inside room temperature during the night. However, usually the energy stored in the building walls during the warmer summer days is sufficient to keep the buildings warm enough during the cooler summer nights.

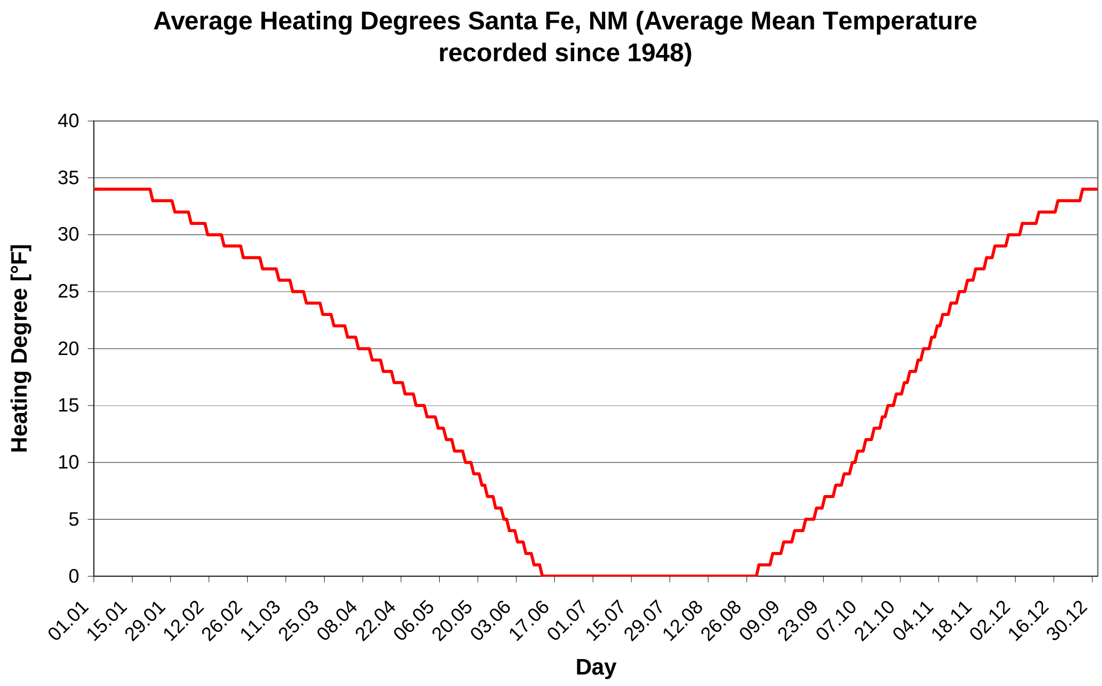

Figure 3: Daily average heating degrees for Santa Fe

Legend: heating degrees calculated according to chapter 3.1.2, source [3]

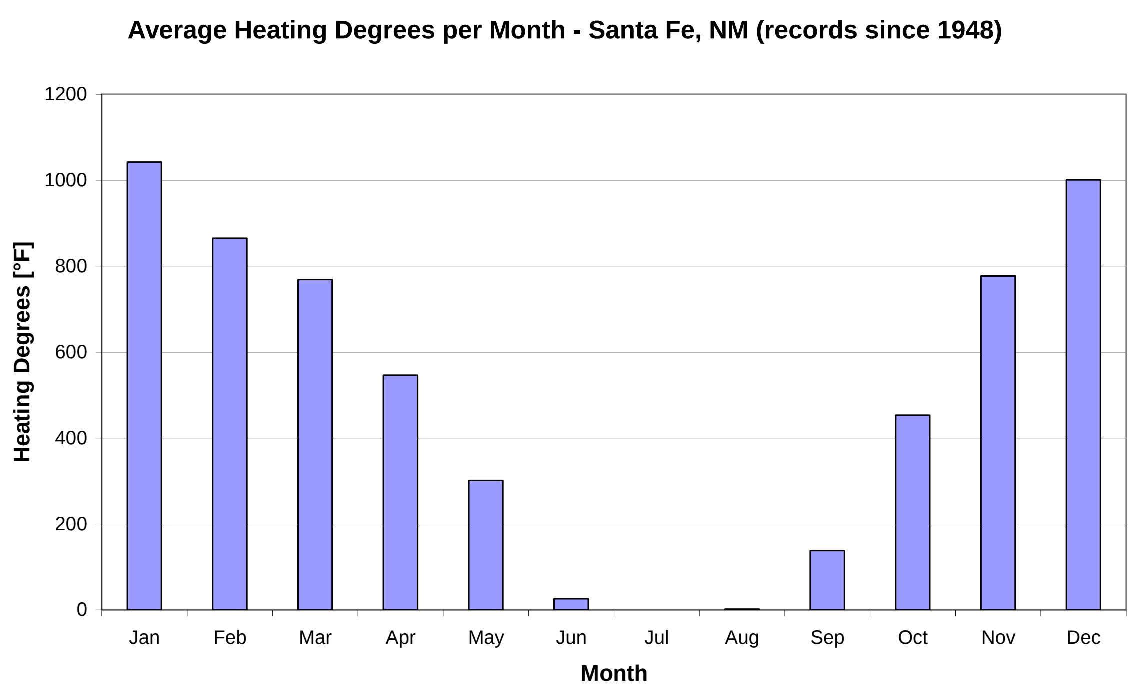

Figure 4: Monthly average heating degrees for Santa Fe

Legend: Heating Degrees calculated according to chapter 3.1.2, source [3]

To make the graph of the daily average heating degrees more practicable for a comparison with the annual heat demand of a building (which was calculated based on monthly gas bills), the daily heating degrees were summarized for every month. The graph shown in Figure 4 was then used to check the plausibility of the trend of the calculated annual heat demands of the investigated customers.

4.2 Heat Demand Inquiry

4.2.1 Visited Buildings

The heat demand inquiry started in the second week of February 2004 at the Los Arroyos Home Owners Association and ended in the second week of April. During that period approximately 160 potential customers were contacted with approx. 120 of them accepting appointments (downtown area and sites outside the target area combined). These 120 buildings represent the main part of the largest heat consumers as well as some smaller buildings such as residential homes, shops and restaurants within the target area and the four potential sites for micro grids.

Only a few large buildings (El Castillo retirement home, P.E.R.A Building to name a few) could not be visited, mainly because the owners or operators rejected any appointments at all or the appointments could not be made within the 2 months where the inquiry took place.

Other organizations like the State General Services Department, the county and the city of Santa Fe as well as the Railyard Community Corporation were very helpful in organizing appointments at their buildings.

The tables and graphs in the following two chapters show an overview of the type and the number of visited buildings.

4.2.1.1 Downtown Santa Fe

106 buildings within the target area specified in Figure 1 were visited during the heat demand inquiry. Among the visited buildings were single family homes, apartment buildings, museums, office buildings (private, federal, state, county and city), municipal buildings, schools, recreational buildings, commercial buildings (shopping centers, plazas, shops), churches, theaters and small, medium sized and large hotels. Table 3, Figure 5 and Figure 6 give an overview of the different types of buildings that were visited during the inquiry and their total heated area.

Table 3: Number and heated area of visited buildings during the heat demand inquiry

For buildings without available data about the heated area the heated area was estimated based on the footprint of the buildings and the number of floors. The area for the swimming pool is not shown because its not a heated area.

TYPE OF BUILDING	AMOUNT	PERCENTAGE of the # of BUILDINGS	HEATED AREA [sqft]	HEATED AREA [m²]	PERCENTAGE of the TOTAL AREA
Apartments	1	0.94%	46,831	4,351	1.04%
Church	2	1.89%	37,410	3,476	0.83%
Commercial	18	16.98%	467,605	43,442	10.34%
Healthcare	1	0.94%	18,000	1,672	0.40%
Large_Hotel	12	11.32%	1,046,388	97,213	23.15%
Medium_Size_Hotel	3	2.83%	142,321	13,222	3.15%
Municipal	3	2.83%	33,200	3,084	0.73%
Museum	7	6.60%	159,811	14,847	3.53%
Offices	27	25.47%	1,470,900	136,651	32.54%
Residential	10	9.43%	16,252	1,510	0.36%
Restaurant	1	0.94%	4,500	418	0.10%
School	8	7.55%	504,087	46,831	11.15%
Shopping_Center	3	2.83%	427,036	39,673	9.45%
Small_Hotel	7	6.60%	71,568	6,649	1.58%
Swimming_Pool	1	0.94%	0	0	0.00%
Theater	2	1.89%	75,000	6,968	1.66%
TOTAL	**106**	**100.00%**	**4,520,910**	**420,006**	**100.00%**

Office (federal, state, county, city and private) buildings make up for the largest portion with 25.5% of the visited buildings (32.5% of the total heated area) which shows the importance of Santa Fe as a center of administration. The office buildings are followed by hotels (all sizes) with 20.8% (27.9% of the total heated area) and commercial buildings (shops, galleries, plazas) with 17.0% (10.3% of the total heated area). The remaining 29.3% consist of 10 residential homes (9.4%; 0.4% of the total heated area), 8 Schools (7.6%; 11.2% of the total heated area), 7 Museums (6.6%; 3.5% of the total heated area), 3 shopping centers, 3 municipal buildings (2.8% each; 9.5% and 0.7% of the total heated area, respectively), 2 Churches, 2 Theaters (1.9% each; 0.8% and 1.7% of the total heated area, respectively) as well as one apartment complex, one healthcare center, one restaurant and one public outdoor swimming pool.

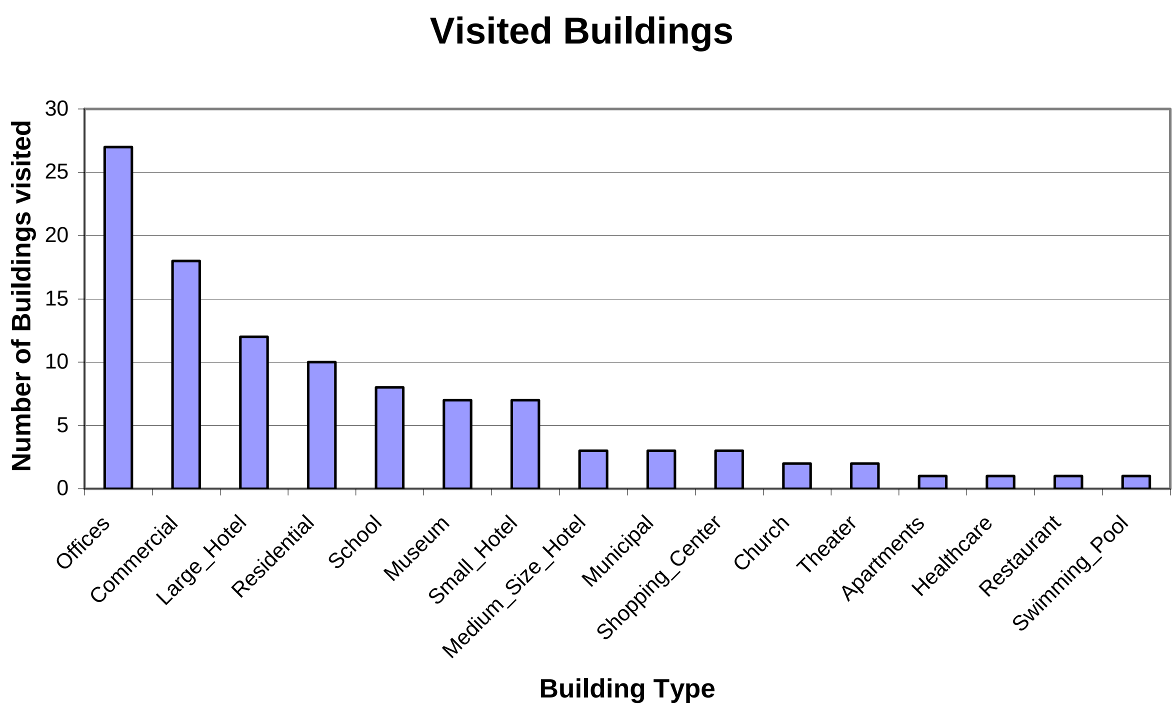

Figure 5: Number of buildings visited during the heat demand inquiry

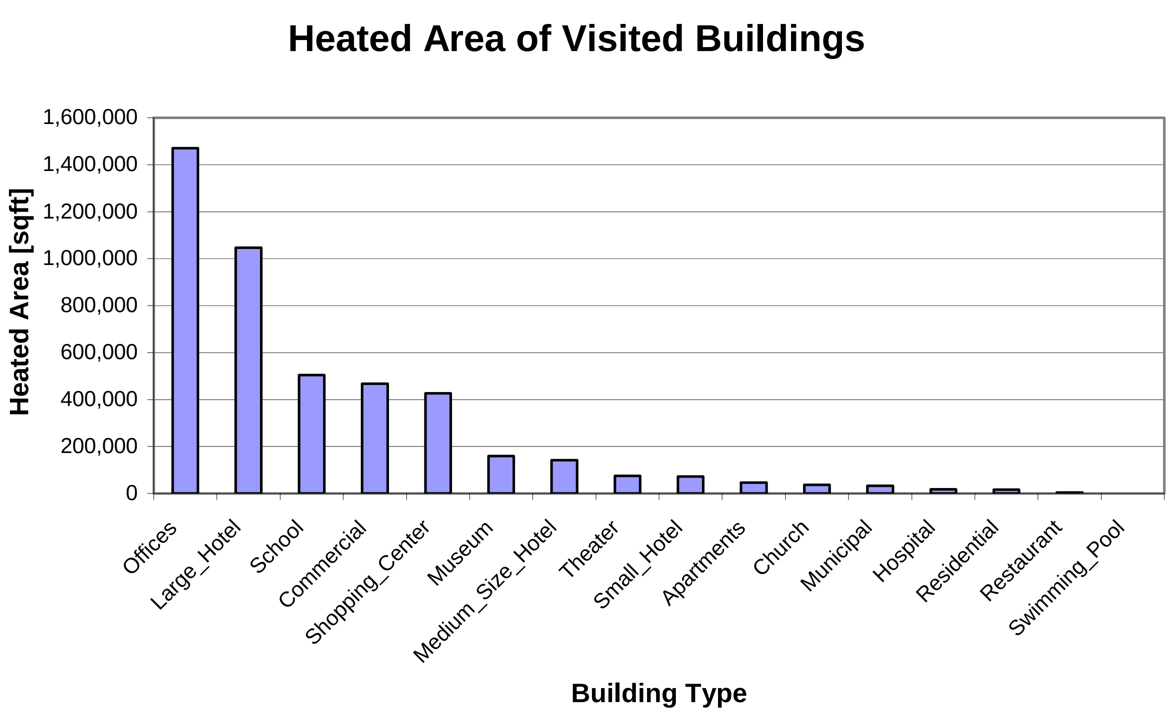

Figure 6: Total heated area of buildings visited in downtown Santa Fe

Legend the heated area of buildings without any available information was estimated based on the footprint of the buildings.

Figure 7: Location of the visited buildings during the heat demand inquiry

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

87 of the 106 buildings are located within or near the Paseo de Peralta and Guadalupe Street loop and around the junction of Cerrillos Road and St. Francis Drive. The other 19 buildings are located along the proposed path of the network of pipes between the one of the proposed sites of the heating plant at the western part of the city and downtown.

At this early stage of the project, the future site of the heating plant cannot be definitely determined. Apart from the potential site at the waste transfer station at the northwest end of the city (shown in Table 7), another potential site for the district heating plant could be the site of the old coal-fired power plant southwest of the School for the Deaf. A more detailed description of potential sites will be given in the report regarding the preliminary design of the network of pipes and the heating plant.

Figure 7 shows the location of all visited buildings. The IDs on the map correspond to the list of the buildings visited in the APPENDIX I of this report.

4.2.1.2 Other Areas (Potential Sites for Micro Grids)

Los Arroyos Home Owners Association

The Los Arroyos Home Owners Association apartment complex is located on a hill south west of the St. Vincent's Hospital. It consists of seven apartment buildings and one administration building with an indoor swimming pool. Four of the apartment buildings house 24 residential units the other three apartment buildings house 18 units.

The total heated area of the complex amounts to approx. 135,000 sqft/12,500 m² (see also Table 4). Each of the seven apartment buildings has its own boiler and domestic hot water heater. The administration building has a boiler for the pool, a domestic hot water heater and a rooftop unit for room heating.

Table 4: Heated area of the Los Arroyos Home Owners Association

The area for administration building was estimated according to available drawings.

TYPE OF BUILDING	NUMBER OF BUILDINGS	TOTAL HEATED AREA [sqft]	[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**

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 and consists of 4 office buildings that house several state divisions. The buildings were built between 1974 and 1986 and are operated and maintained by the General Services Division of New Mexico.

The total area of the four buildings amounts to approx. 455,000 sqft/42,250 m² (see also Table 5). Each building has its own heating and cooling system and domestic hot water heater. The Montoya building also has solar panels on the roof to pre-heat the domestic hot water.

The buildings are connected by a system of tunnels. The chillers of all four buildings are connected with pipes that run through the tunnels to serve as one another's back-up if any of the chillers break down. There is still enough space for another pair of pipes in the tunnels so the supply and return pipe of a micro grid could be installed, reducing the installation costs of the micro grid significantly.

Table 5: Total area and heated area of the South Capitol Complex

The heated area of the Runnels and the Montoya building were considered 10% smaller than the total area (unheated storage rooms, unheated parts of the basement)

	TOTAL AREA		TOTAL HEATED AREA	
NAME OF BUILDING	**[sqft]**	**[m²]**	**[sqft]**	**[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**

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 buildings that house classrooms.

The total area of all permanent buildings amounts to approx. 508,000 sqft/47,100 m² (see also Table 6). Several expansion of the existing buildings are planned within the next 5 years. Parts of the main building and the Fitness Education Center are hooked up to a small micro grid which is heated by two gas-fired boilers. This small micro grid may be a potential starting point for a first demonstration project to prove the reliability of a biomass fired heating systems. The other part of the main building (Visual Arts Center) and the Early Childhood Education Center have separate heating systems. The Visual Arts Center has several electrically heated domestic hot water heaters scattered throughout the building. The other part of the main building and the two other large buildings on campus each have one centralized domestic hot water boiler.

Table 6: Total area and heated area of the Santa Fe Community College

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

	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**

Apart from the planned expansion on the campus the Archdiocese of Santa Fe plans to build the new St. Francis School just opposite the street of the community college which gives this site a promising potential for further development of a biomass-fired micro grid which could be realized at this site.

College of Santa Fe

The campus of the College of Santa Fe houses 46 buildings of varying ages and functions and is situated about 4 miles south of downtown Santa Fe.

The total area of all buildings on the campus amounts to approx. 568,000 sqft/52,700 m² (see also Table 7). Three buildings are currently connected to a small micro grid that supplies heat for a total amount of 58,400 sqft/5,400 m². The replacement of the existing old gas-fired boiler that heats this micro grid with a new biomass-fired boiler also looks promising for a demonstration project. Most of the other buildings have also hydronic heating systems, so further development of a micro grid seems possible.

Table 7: Total area of the College of Santa Fe

NAME OF BUILDING	TOTAL AREA [sqft]	TOTAL AREA [m²]
Alumin 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**

4.2.2 Utilized Fuels

4.2.2.1 Downtown Santa Fe

Santa Fe is connected to a natural gas pipeline system that covers the whole city. Not surprisingly, nearly every assessed building uses natural gas for heating. A few buildings use electrical heating systems and electrical domestic hot water heaters. One assessed building is partly heated by propane-fired forced air heaters.

Unfortunately, it was not possible to receive information regarding the gas consumption (i.e. gas bills) from all visited buildings. At the deadline for this report the gas bills of 58 of the 106 visited buildings in downtown Santa Fe were available. The annual gas consumption of these 58 buildings amounted to 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 from most of the buildings.

The gas consumption of all other buildings within the target area had to be estimated based on the size and type of each building. The results of the extrapolation of non-visited buildings are outlined in chapter 4.4.1. According to the results of the extrapolation, the total gas consumption of all buildings within the target area amounts to 298,357°MMBTU/87,440 MWh per year.

In addition, there are larger residential areas situated south of downtown with a significant electrical heat load ("Golden Homes") that appear to be potential sites for a replacement of the existing heating systems with a biomass-fired heating unit. Due to the comprehensive amount of work which had to be performed within the heat demand inquiry, these areas couldn't be visited, but will be kept under consideration if a biomass district heating system is realized.

4.2.2.2 Other Areas (Potential Sites for Micro Grids)

Los Arroyos Home Owners Association

All heating devices at the Los Arroyos apartment complex use natural gas as a fuel. There are four gas meters that serve the complex. With the exception of 1997, 1998 and 2003, the gas bills since 1990 are available (see Figure 8).

The drop of the annual gas consumption by 20% between 1995 and 1996 could not be explained properly. The most likely reason for that drop might be the replacement of the old gas meters with new ones, but the exact date of the replacement was not known and therefore this assumption could not be verified.

The average annual gas consumption of the whole complex from 1999 until 2002 was 8,217 MMBTU/2,408 MWh per year.

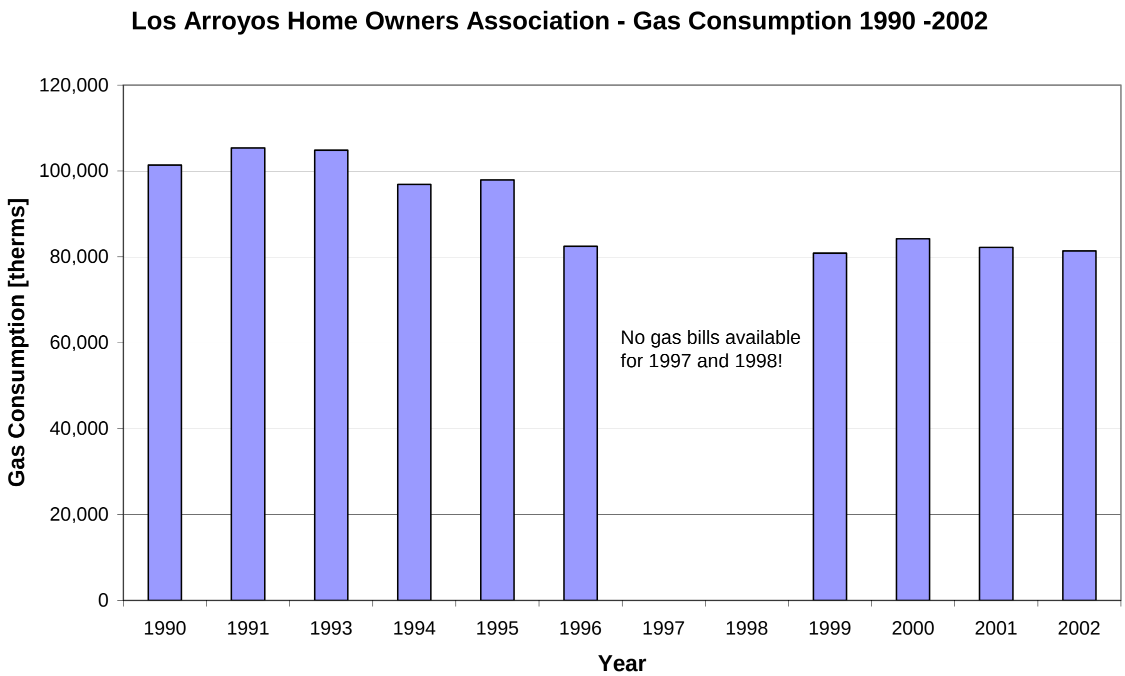

Figure 8: Annual gas consumption of the Los Arroyos Home Owners Association

Legend: total gas consumption calculated from four different meter readings.

South Capitol Complex

All heating devices at the South Capitol Complex use natural gas as a fuel. The exception is the storage tank for domestic hot water in the Montoya building which is preheated by solar panels installed on the roof of the building. Gas bills for all four buildings were available from February 2001 to September 2003.

The data from 2001 was inconsistent with the data from 2002 and 2003, so only the last two years of gas bills were used. The last three months of 2003 were estimated according to the gas consumption of the same months the year before. Figure 9 shows the annual gas consumption of the four buildings of the South Capitol Complex.

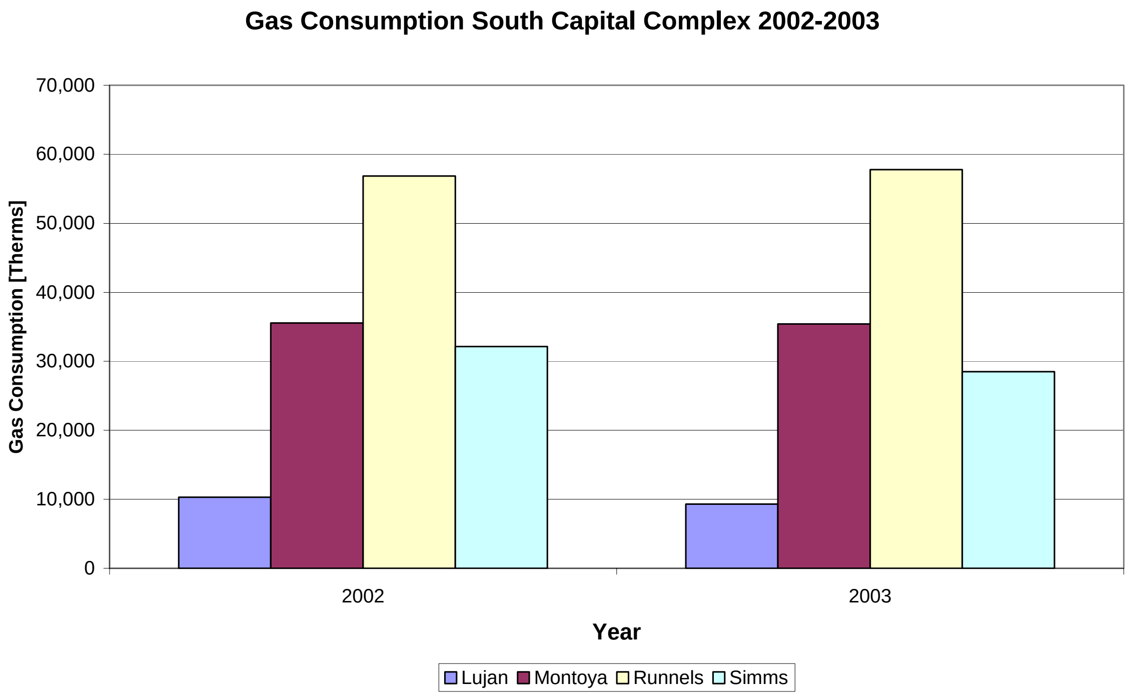

Figure 9: Annual gas consumption of the South Capitol Complex

Legend: the gas consumption for the last three months was estimated according to the gas consumption in the respective period 2002

The average annual gas consumption of the whole complex during the last two years (2002 and 2003) was 13,293 MMBTU/3,896 MWh per year.

Santa Fe Community College

All room heating systems on the entire campus and all domestic water heaters for all buildings except the Visual Arts center use natural gas as a fuel. Gas bills for a period of one year (September 2000 – September 2001) were available. The annual energy consumption of the electrically heated domestic hot water heaters could not be specified, because the nominal heating capacity of the two installed DHW heaters was not known.

Figure 10 shows the annual gas consumption of the four permanent buildings of the college.

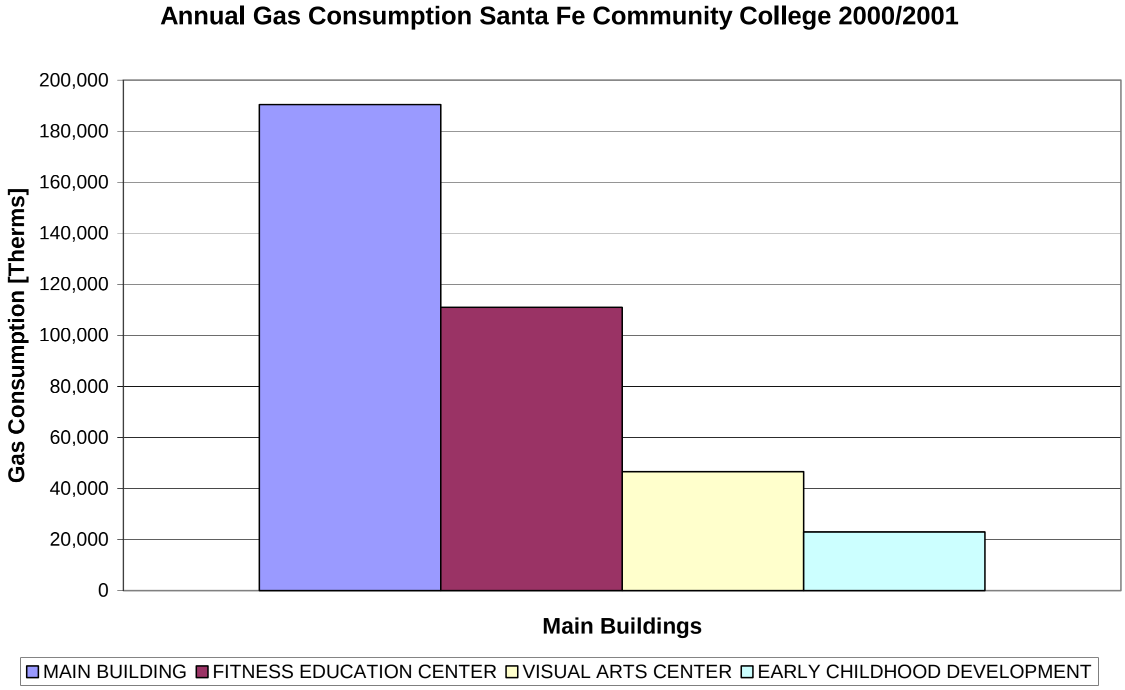

Figure 10: Annual gas consumption of the four permanent buildings at the campus of the Santa Fe Community College

Legend: the portion of the total gas consumption of the Main Building and the Fitness Education Center had to be estimated according to their heated area because these buildings are connected to the micro grid and have therefore only one gas meter reading.

The annual gas consumption of the whole complex was 37,091 MMBTU/10,870 MWh per year during the period investigated (September 2000 – 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 whole campus could be determined which was approx. 45,400 MMBTU/ 13,305 MWh in 2001.

4.2.3 Installed Heating Systems

A detailed assessment of the installed heating systems was essential for the determination of the substitutable heat demand and the connected heat load in the target area, and the achievable temperature differential between supply and return line of the district heating grid.

4.2.3.1 Downtown Santa Fe

Type of Heating Systems

During the heat demand inquiry many different heating systems of various age, size and complexity were identified. Table 8 gives an overview of the installed heating systems in the visited buildings.

Table 8: Types of installed heating systems in the visited buildings in downtown Santa Fe

The classification of the type of heating system refers to the way the produced heat leaves the heating device (water, steam, air, radiation)

TYPE OF HEATING SYSTEM	DESCRIPTION
Hydronic	gas-fired boilers with hydronic system from boiler to heating units (radiators, fancoils, heat pumps etc.)
Forced Air With Distribution	gas-fired boilers with forced air distribution system in the building
Forced Air Single Units	gas-fired single heating units with a fan but without a distribution system
Steam Only	gas-fired steam boilers with steam from boiler to heating units (radiators, fancoils etc.)
Steam To Water	gas-fired steam boilers with steam from boiler to heat exchanger and hydronic system from heat exchanger to heating units (radiators, fancoils, heat pumps etc.)
Gas Radiators	gas-fired single radiation heating units
Domestic Hot Water	gas-fired domestic hot water boilers
Pool Heating	gas-fired boilers for pool heating (hydronic)
Electric Heating	electric space heating units
Electric Domestic Hot Water	electric domestic hot water boilers

Table 9 shows these varieties in order of installed nominal heating capacity in the assessed area.

Some of the specified types of heating systems in Table 8 are more common than others. They also vary significantly from type to type. Table 9 and Figure 11 show the total installed nominal heating capacity of each heating system.

Hydronic systems make up 48.4% of the installed nominal heating capacity followed by domestic hot water heaters (16.6%) and forced air distribution systems (15.5%). 11.5% of the nominal heating capacity come from steam-water systems while electric heating systems, pool heating systems, steam only systems, single forced air systems, gas radiators and electric domestic hot water heaters make up the remaining 8.0%.

Table 9: Installed total nominal capacities of the different heating systems – heat demand inquiry downtown Santa Fe

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

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

Based on the this information the substitutable nominal heating capacities of the visited buildings were identified according to the guidelines outlined in chapter 3.4, step 8, see Table 10 and Figure 12 for details. Apart from the type of the heating system the location of the heating system is also an important factor that determines whether a heating system is replaceable or not. 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 results show that replaceable heating systems amount for more than three quarters (78.2%) of the installed nominal heating capacity of the visited buildings. The actual nominal heating capacity of the heat transfer stations at the customers (connected heat load) that replace these heating devices is lower and dependent on how oversized the installed heating systems are. The results of the calculations of the connected heat load are discussed in chapter 4.5.1.

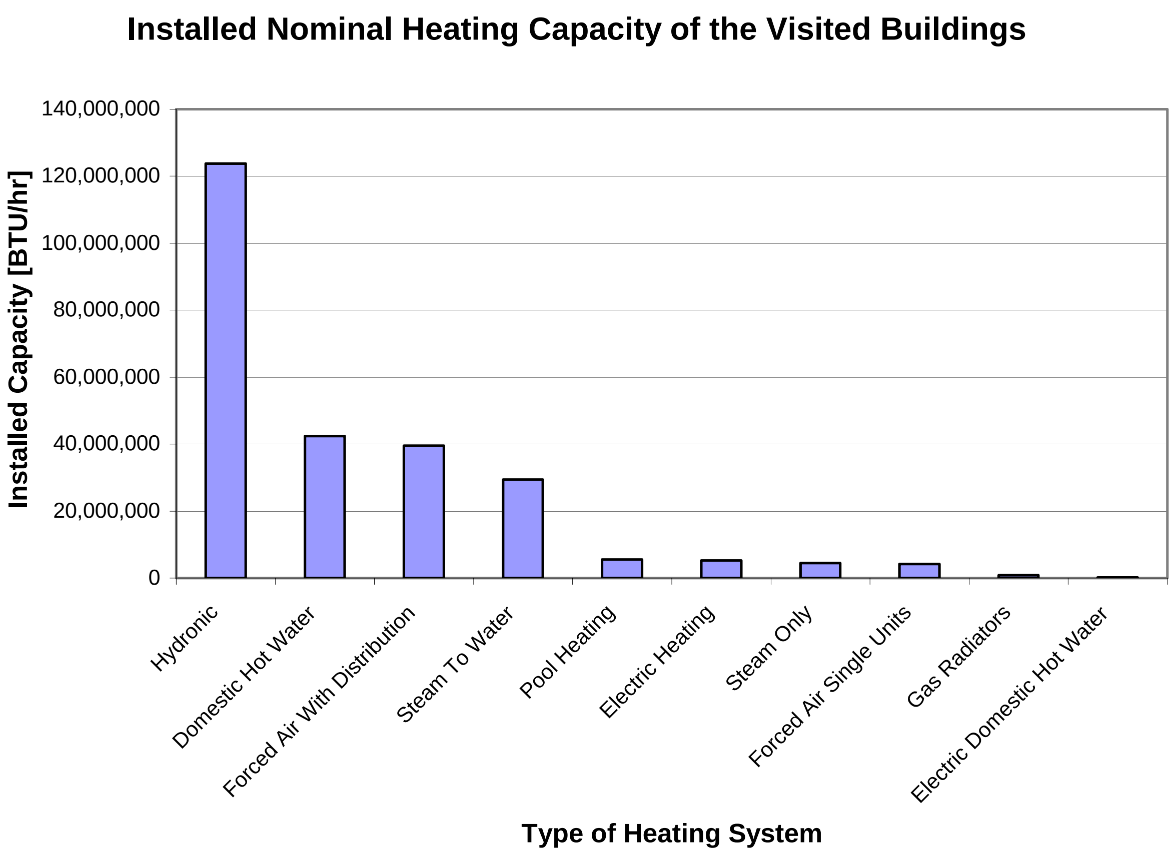

Figure 11: Installed nominal heating capacity of each heating system – heat demand inquiry downtown Santa Fe

Legend: back-up capacity is not considered; see Table 8 for a description of the different heating systems

The feasibility of the replacement of other heating systems (forced air, electrical heating) is dependent on the costs for adjusting the systems for connection to a district system. A more detailed assessment of this potential is possible after the economic calculations are completed.

Table 10: Replaceable installed nominal heating capacity of assessed heating systems, downtown Santa Fe

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

	INSTALLED CAPACITY		SUBSTITUTABLE CAPACITY		
TYPE OF HEATING SYSTEM	**[BTU/hr]**	**[kW]**	**[BTU/hr]**	**[kW]**	**PERCENTAGE**
Hydronic	123,740,695	36,265	120,746,711	35,387	97.6%
Domestic Hot Water	42,399,251	12,426	39,045,411	11,443	92.1%
Steam To Water	29,369,000	8,607	29,369,000	8,607	100.0%
Pool Heating	5,524,700	1,619	4,885,500	1,432	88.4%
Steam Only	4,483,500	1,314	4,483,500	1,314	100.0%
Forced Air With Distribution	39,571,717	11,597	653,000	191	1.7%
Electric 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 Single Units	4,186,800	1,227	0	0	0.0%
Gas Radiators	836,000	245	0	0	0.0%
TOTAL	**255,556,883**	**74,896**	**199,750,522**	**58,541**	**78.2%**

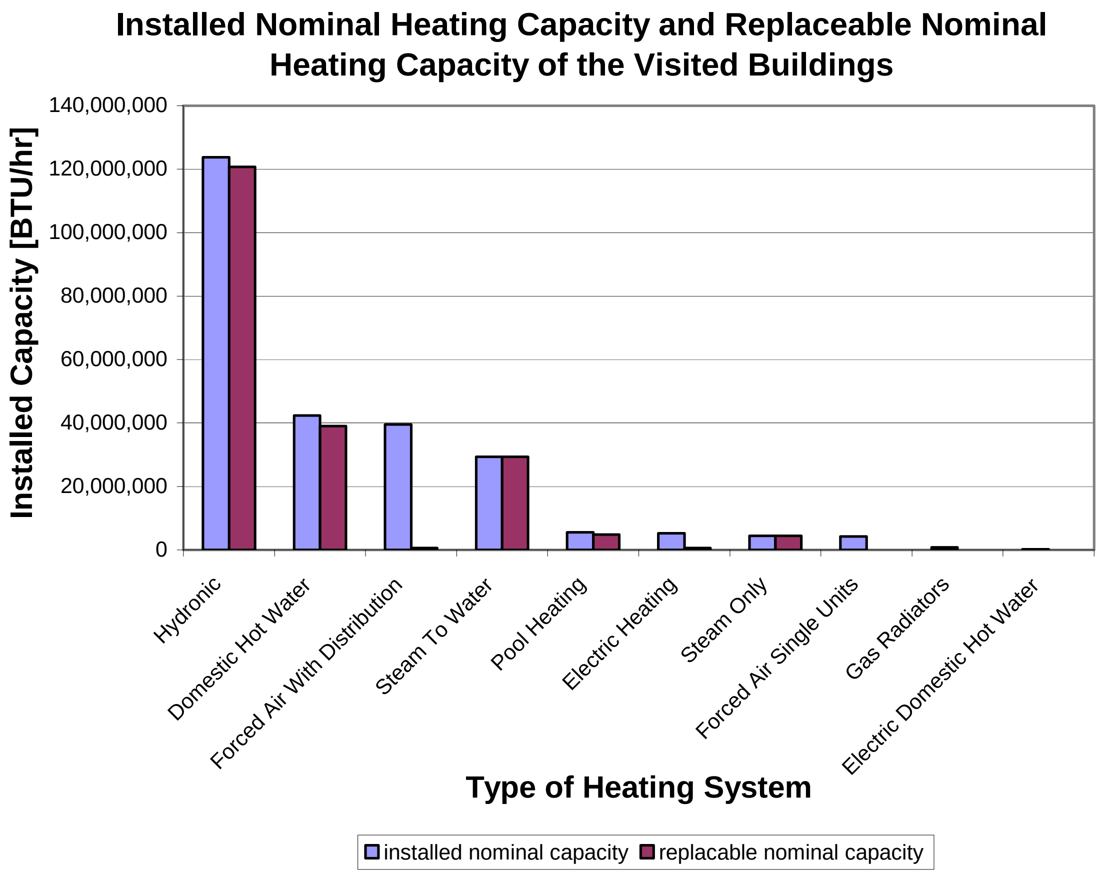

Figure 12: Installed nominal heating capacity of visited heating systems and nominal heating capacity suitable for replacement by district heating, downtown Santa Fe

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

Supply and Return Temperatures

One important task of the heat demand inquiry was the determination of the current and achievable supply and return temperatures of hydronic systems and the operating temperatures of other heating systems. Because of the many different heating systems installed in the target area it goes beyond the scope of this report to discuss the specific operating temperatures of every visited building. So only a general overview is given below (see also Table 11). For more detailed information about operating temperatures of the various systems see the APPENDIX II of this report.

1. Hydronic Systems

   The supply temperatures vary from about 130°F/54°C to 180°F/82°. Apart from a few radiant floor heating systems in residential buildings and one installed heating system with heat pumps (City Hall) that achieve return temperatures below 80°F/27°C the return temperatures are usually only a few degrees lower than the supply temperature thus the temperature differential between supply and return is usually very low (5°- 10°F/3°- 6°C).

2. Forced Air Heating Systems (Single Units and Distribution Systems)

   Forced air systems usually use a mixture of internal and outside air that is heated and then blown into the room or distributed via a duct system. The important parameters for such systems are the temperature rise between input air and output air and the maximum achievable output air temperature. The air temperature rise varies from 30°F/17°C to 65°F/36°C with maximum output air temperatures of 170°F/77°C to 175°F/79°C.

3. Domestic Hot Water Systems

   The supply temperature for domestic hot water varies from 100°F/38°C to 140°F/60°C for personal use (bathrooms, showers, sinks) and from 160°F/71°C to 190°F/88°C for commercial use (kitchen, laundry). Many DHW-systems are equipped with a circulation pump to save water (though this leads to higher heat losses). These values apply for gas-fired and electrical domestic hot water heaters alike.

4. Pool Heating Systems

   The supply temperatures vary depending on the type of the pool (swimming pool or spa) between 84°F/29°C and 104°/40°C.

5. Other Systems

   Steam only systems transfer the heat through the condensation of low pressure steam (latent heat) to the heat distribution units, so supply and return temperatures are not applicable for steam only systems. The steam pressure varies from 5 to 15 psi/0,34 to 1,0 bar.

   Gas radiators transfer the heat mainly by radiation so supply and return temperatures do not apply for these systems, too.

The current average temperature differential of the installed systems is far too low for an optimized operation of a district heating system where a temperature differential of 54°F/30°C or higher should be achieved between the supply and the return temperature of the network of pipes. However, due to the relatively low supply temperatures of the installed systems and thus the low return temperatures a high temperature differential at the primary side of the heat exchanger seems to be achievable (see chapter 4.6.1).

Table 11: Overview of supply and return temperatures of hydronic systems as well as air temperature rise and maximum output air temperature of forced air systems, respectively

Legend: Values represent average numbers, for more detailed values see the APPENDIX II of this report

HYDRONIC SYSTEMS	°F	°C
Supply Temperature	130-180	54-82
Return Temperature	125-170	52-76
Temperature Differential	5-10	3-6
FORCED AIR SYSTEMS	**°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
POOL HEATING	**°F**	**°C**
Supply Temperature	84-104	29-40

Control Systems

The assessment of the actual state of the control systems was another important task of this inquiry. An overview of the gained information is listed below. For more detailed information about the installed control systems see the APPENDIX II of this report.

1. Hydronic systems

   Depending on the age and size of the building the installed control systems vary significantly. Smaller buildings usually lack any control devices others than thermostats that control the room temperature by switching the boiler on or off. Pumps usually have no flow control systems.

   In larger buildings mixing valves for temperature and flow control (either supply or return temperature control) are used sometimes, but outside air thermostats are only rarely used. The boilers usually maintain a certain water temperature and the pumps are switched on when the thermostats call for heat.

   The most advanced control systems are used in hydronic systems combined with big fan coil or other air handling units. Depending on the outside, inside and circulating air temperatures the entering water flow into the heating coils is usually controlled by mixing or other flow control valves. The air fans can control the air flow with variable speeds. Many of these systems are linked to a computer for controlling and monitoring the complete system.

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

2. Forced Air Systems

   Single forced air units are usually controlled by thermostats or are manually switched on and off.

   Forced air distribution systems are usually controlled by inside thermostats. Outside air thermostats are rarely used. Usually single speed air fans are installed.

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

3. Domestic Hot Water Systems

   The domestic hot water heaters usually maintain a certain supply temperature according to the setting of the thermostat in the storage tank. The circulation pumps usually run 24 hours a day.

4. Pool Heating Systems

   Pool heating systems usually maintain a certain set temperature. Depending on the use of the pool or spa the heating system is operating during summer months only or throughout the year.

5. Other Systems

   Steam systems usually maintain a certain steam pressure. The steam valves are opened or closed depending on whether the thermostats in the building are calling for heat.

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

Generally speaking, most of the installed control systems would need some upgrades to be able to capitalize on all benefits of a district heating system (fully automatic operation, variable temperature settings for different periods etc.) and to achieve a high temperature differential at the primary cycle (supply side) of the heat transfer stations at the customers. The most important upgrade would usually be the installation of mixing valves to control the flow rate and the temperatures in the secondary cycle (load side) of the heat transfer station.

4.2.3.2 Other Areas (Potential Sites for Micro Grids)

Los Arroyos Home Owners Association

Every building of the complex has its own heating and domestic hot water system. All heating systems are hydronic. Depending on the size and the use of the building (residential or administration) the heating systems vary in size and numbers. Table 12 gives an overview of the installed systems.

Table 12: Installed nominal heating capacity, Los Arroyos Home Owners Association

The roof-top unit at the administrative building is not included in the numbers, because it was not possible to get information about its capacity, Blocks 1A – 1D house 24 residential units, Blocks 2A, 2B and 3A house 16 residential units; all units are of the same size (920 sqft/85m²).

	CAPACITY HEATING		CAPACITY DHW		TOTAL	
BUILDING	**[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**

In all likelihood the difference in the total installed capacity between apartment buildings of the same size shown in Table 12 can be accounted for by retrofits of old boilers in the past.

The supply temperature in six of seven apartment buildings is 130°F/54°C, in one block the temperature is around 150°F/66°C. Originally, all seven apartment buildings had a supply temperature of 150°F/66°C but problems with several boilers and the piping system in the blocks forced the operator to lower the supply temperature to 130°F/54°C. The temperature differential between supply and return line is around 15°F/8°C. The supply temperature of the domestic hot water is 140°C/60°C. Each domestic hot water system has a circulation pump.

The boilers are controlled (on/off) by outside thermostats. The outside thermostat is switched off from May until the end of August, therefore no heating occurs during that period. The temperature in each unit is controlled by a single thermostat that opens or closes a valve, depending on whether heat is needed or not. All pumps are on/off only, so no flow control is possible.

The supply temperature for the swimming pool varies between 84°F/29°C in summer and 88°F/31°C in winter.

To achieve a high temperature differential in the primary cycle at the heat transfer station the installation of a mixing valve at the heating system of each building (secondary side) would be required. 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 usual supply temperature for the baseboards (130 or 150°F). The mixing valve would be controlled by the control system of the heat transfer station.

South Capitol Complex

Each building in the complex has its own heating and domestic hot water system. Except for the Simms Building, which has a steam-only system, all heating systems are hydronic. Depending on the size of the buildings the heating systems vary in size. Table 13 gives an overview of the installed systems.

Table 13: Installed nominal heating capacity, South Capitol Complex

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

	CAPACITY HEATING		CAPACITY DHW		TOTAL	
BUILDING	**[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**

The two larger buildings, the Joseph Montoya and the Harold Runnels Building, are each equipped with two Kewanee boilers. The information gained from the specification plate about the nominal heating capacity was not clear (two different values of the nominal heating capacity are listed on the specification plate). Unfortunately, Kewanee no longer exists and no further information could be obtained. According to the maintenance personnel, the lower value represents the actual nominal heating capacity of the boilers, so the values shown in Table 13 represent the lower value. Further adjustments of the capacities were performed according to the guidelines discussed in chapter 3.4 (see chapter 4.3.2)

Furthermore, it was not possible to receive any information about the domestic hot water system of the Simms Building so the nominal heating capacity of the domestic hot water boiler had to be estimated. However, the domestic hot water heater is not located in the boiler room, so a replacement of the boiler with a heat transfer station would be difficult and most probably very expensive.

The supply temperature at the three hydronic heating systems is 160°F/71°C (maximum temperature setting at the boiler) and the steam boiler in the Simms building operates with a maximum steam pressure of 15 psi/1 bar. According to the maintenance personnel the temperature differential between supply and return is only around 5°F/3°C. As all boilers were out of operation during the visit, this information could not be verified on-site. The supply temperature of the domestic hot water is 140°C/60°C. On the roof of the Joseph Montoya Building six solar panels with a total area of 600 sqft/56°m² are installed, to pre-heat the domestic hot water. Each domestic hot water system is equipped with a circulation pump.

The boilers of the hydronic systems maintain a certain set temperature (min 120°F/49°C, max 160°F/71°C). 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.

To achieve a high temperature differential in the primary cycle at the heat transfer station the installation of a mixing valve at the heating system of each building (secondary cycle) will be required. In addition, the flow through the air handling units has to be reduced to achieve a higher temperature differential between entering (supply) and exiting (return) water flow (see also chapter 4.6.2 for more details).

Santa Fe Community College

The main building at the campus consists of two large sections. The older part houses classrooms, laboratories, meeting and conference rooms, a bookstore, and a cafeteria. A 1994 addition included more classrooms, offices, and administrative space, as well as a large lecture hall, planetarium, and an atrium. The heating system of this part of the main building also heats the Fitness Education Center, which is connected to a small micro grid. The indoor swimming pool and the domestic hot water at the Fitness Education Center are heated by separate boilers.

The Visual Arts wing, opened in 1999, contains laboratory/classrooms, exhibition and gallery space, and more administrative areas has its own heating and electric domestic hot water system. The third main building at the campus, the Early Childhood Development Center also has its own heating and domestic hot water system. All heating systems are hydronic. Depending on the size of the building the heating systems vary in size. Table 14 gives an overview of the installed systems.

Table 14: Installed nominal heating capacity, Santa Fe Community College

The quoted heating capacity for the Fitness Education Center is for pool heating only. No information about the electrical water heaters in the Visual Arts Center was available, so capacity was estimated based on the size and the use of the building. The back-up capacity installed at the Visual Arts center and the Early Childhood Development Center is not considered.

	CAPACITY HEATING		CAPACITY DHW		TOTAL	
BUILDING	**[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 C.	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 DEV.	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**

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 as back-up systems. The replacement of one of the two gas-fired boilers in the main building with a biomass-fired boiler may be a promising project 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. The measured temperature differential between supply and return line was only around 5°F/3°C. The boilers in the other buildings were not in operation during the visit. The supply temperature of the domestic hot water varies from 106°/41°C to 120°F/49°C. All domestic hot water systems have a circulation pump. The pool temperature is maintained at 82°F/28°C throughout the year.

The boilers of the heating systems are controlled by outside thermostats. In the main building, where both boilers are in operation, the first boiler starts at outside temperatures below 63°F/17°C and the second boiler starts at outside temperatures below 55°F/13°C. Hot water is pumped into air handling units using flow controlled pumps that maintain a certain water flow according to the heat demand of the air-handling units. The air handlers are turned off by the control system at 10:30 pm each night after the buildings close. The entire heating system of each building is controlled by a computer system. However, due to continuing problems with the system several changes to the control system are planned in the near future.

Depending on the potential for improvements at the existing computer control system it may not be necessary to mechanically upgrade the existing system to achieve a higher temperature differential. Otherwise, the installation of a mixing valve at the heating system of each building may be required (see also chapter 4.6.2 for more details).

College of Santa Fe

Many heating systems at the campus of the College of Santa Fe date back to the original year of construction of the building. Most of the boilers lack any specification plates so no information about the installed capacity was available. Therefore, the required nominal heating capacity and the annual heat demand had to be estimated based on the average classification numbers gained from the heat demand inquiry of the buildings in downtown Santa Fe. The result of these calculations are discussed in chapter 4.4.2.

Due to their age most of the boilers and their accompanying control systems are outdated and often cause problems. Several energy efficiency studies were carried out in the last few years to solve these problems but have not been very successful so far.

For this reason the switch from gas-fired boilers to biomass-fired boilers accompanied by an upgrade of the control systems would be a unique opportunity to upgrade the heating system and use a new promising and 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 only have two pipe systems for their heating and cooling systems, which means that there is heating only in winter and cooling only in summer.

Generally, the heating season begins between October and early November and ends between late March and April. In a few buildings the heating season begins in late September and may end as late as early May (however, during the visits in the last weeks of March most of the heating systems were already out of operation). These results also correspond 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 about half a month to a month shorter. Therefore, the boiler full load operating hours of heating systems in Santa Fe were expected to be generally lower than in central Europe. The results gained from the data evaluation shown in chapter 4.3 confirm this assumption.

4.2.4.2 Other Areas (Potential Sites for Micro Grids)

Los Arroyos Home Owners Association

According to the maintenance personnel, the outside thermostats that control the boilers are switched off every year at the 1st of May and are switched on again at the 1st of September. Within this period only the domestic hot water heaters and the swimming pool need heat. Furthermore, the length of the annual heating season is determined by the outside temperatures between September and April.

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 only domestic hot water is heated.

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 different purposes situated on the campus, the main heating season may differ from building to building. However, according to the annual heat demand line (see Figure 22) the heating season is expected to begin between mid October and is expected to end between late March and mid April.

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

4.3.1 Downtown Santa Fe

4.3.1.1 Specific Nominal heating capacity

Based on the data gained during the heat demand inquiry the specific nominal heating capacity for all visited buildings was calculated. Table 15 gives an overview of the results of these calculations. The results are based solely on the information gathered during the visits and the plausibility checks concerning the heated area of each building and the information about back-up facilities. The adjustment of oversized heating systems and the results are outlined in chapter 4.3.1.3.

Table 15: Specific nominal heating capacity of the visited buildings, downtown Santa Fe

Back-up boilers are not considered. All numbers as specified during the visits, no adjustment of the capacities made.

	SPECIFIC NOMINAL CAPACITY					
	Maximum		Minimum		Average	
TYPE OF BUILDING	[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

Table 15 shows significant differences between the different building categories and also within each category. Generally, the level of the specific nominal heating capacity seems too high. In particular, the maximum values indicate oversized heating systems. For the adjustment of oversized heating systems, see chapter 4.3.1.3.

The low specific capacity of shopping centers can be explained by the lower temperature settings (usually 65°F/18°C) compared to other buildings (usually (68°F/20°C) and the small consumption of domestic hot water compared to the heated area.

The low average numbers for offices, municipal buildings and museums look plausible because of their low domestic hot water use compared to residential buildings and hotels. Furthermore, offices usually need less heating capacity due to several excess heat sources (computers, office facilities) in the buildings.

Commercial buildings show a higher average specific nominal heating capacity than those three categories, although the domestic hot water use may not be greater. An explanation for the higher specific capacity might be the usually higher room volume per heated area in commercial buildings than in offices, municipal buildings and museums. However, the large spread between maximum and minimum values indicates that not all systems are well designed.

The specific nominal heating capacity of the health care center was expected to be higher than calculated, but the La Familia Healthcare Center is a day care center only, so the domestic hot water consumption is lower than in full service hospitals which have a much higher specific nominal heating capacity. However, the specific nominal heating capacity still seems too low for that building category.

The dimension of the specific nominal heating capacity of schools seems plausible. Schools use more domestic hot water (showers) than offices, municipal buildings and museums, and the set temperature is also slightly higher than in the buildings mentioned above (between 70°F/21°C and 77°F/25°C compared to temperatures from 68°F/20°C to 70°F/21°C in offices, municipal buildings and museums), so an average specific capacity higher than the average of these buildings can be expected.

Apartments, homes and hotels have a higher specific capacity due to usually higher set temperatures and the higher domestic hot water use of these buildings. However, the specific capacity for apartments and residential homes should be lower than the specific capacity of hotels because of the usually higher domestic hot water use in hotels (laundry and kitchen facilities as well as 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.

The relatively high specific nominal heating capacity of the only evaluated restaurant seems to be plausible, because a significant amount of domestic hot water is used in the kitchen.

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

Based on the data gained during the heat demand inquiry the specific heat demand of each building was calculated according to the guidelines described in chapter 3.3.2. Table 16 gives an overview of the results of these calculations. The results are based solely on the information gathered during the visits and the plausibility checks concerning the heated area of each building and the information about the building envelope. The nationwide average numbers for buildings of each category according to the USDOE Buildings Energy Data Book 2002 [4] are included in the table, if available.

The data of the Buildings Energy Databook [4] are national average numbers for all regions of the U.S. Therefore, they can only be used as a rough indication of the actual specific heat demand of the different building categories. The available data from [4] does not distinguish between apartment buildings and residential homes, so the available number of "households" is shown for both categories in Table 16.

Table 16: Specific heat demand of the buildings visited, downtown Santa Fe

Only buildings with complete gas bills are included in this table; n.a. not available; source of the nationwide averages [4],the available data from [4] does not distinguish between apartment buildings and residential homes, so the available number for "households" is shown for both categories.

	SPECIFIC HEAT DEMAND							
	Maximum		Minimum		Average		National Average	
TYPE OF BUILDING	[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.

Apart from churches, commercial buildings and schools the results from the heat demand inquiry correspond well with the national average numbers.

The discrepancy between the calculated specific heat demand of churches and the national average may be explained by the fact that the churches visited in Santa Fe are connected with other buildings that need more heat than a church alone.

The reason for the lower calculated heat demand of schools compared to the national average may be due to the fact that the schools visited in Santa Fe are open approx. 6 hours a day (8am to 2 pm) but the national average represents schools with an average occupancy of 8 hours a day during the week and 2 hours a day on weekends.

The numbers shown in Table 17 were used to estimate the annual heat demand of all visited buildings without any information about their fuel consumption (no gas bills available, see Table 18) and to extrapolate the heat demand of other buildings in the target area that were not visited during the heat demand inquiry (see chapter 4.4.1). The numbers are either based on the results shown in Table 16 or the national average. A different approach was used for museums to allow for the differences in the building envelopes among the museums without available gas bills (one large building with a galvanized metal exterior finish and several smaller adobe buildings). The heat demand of these buildings was estimated based on the available heat demand of buildings with a similar building envelope.

Table 17: Average specific heat demand per building category

Museums were estimated according to their building envelope; specific heat demand not applicable for pool heating; the specific heat demand for healthcare buildings (day use only) represents two thirds of full time hospitals.

	SPECIFIC HEAT DEMAND	
TYPE OF BUILDING	**[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

The total heat demand of each building category of all visited buildings is shown in Table 18 and Figure 13.

Large hotels (31.6%) and office buildings (26.1%) account for the largest portion of the total heat demand of all visited buildings. Commercial buildings (8.9%), schools (7.9%) and shopping centers (7.3%) also add a significant amount to the total heat demand. All other building categories combined required less than 19% of the total heat demand.

Table 18: Total annual heat demand of all visited buildings – downtown Santa Fe

Annual heat demand based on annual gas consumption or average specific heat demand as specified in Table 17 if gas consumption was not available; the new construction of the Presbyterian Church and the expansion of the Museum of New Mexico are already considered in this table.

	TOTAL HEAT DEMAND		
TYPE OF BUILDING	[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%

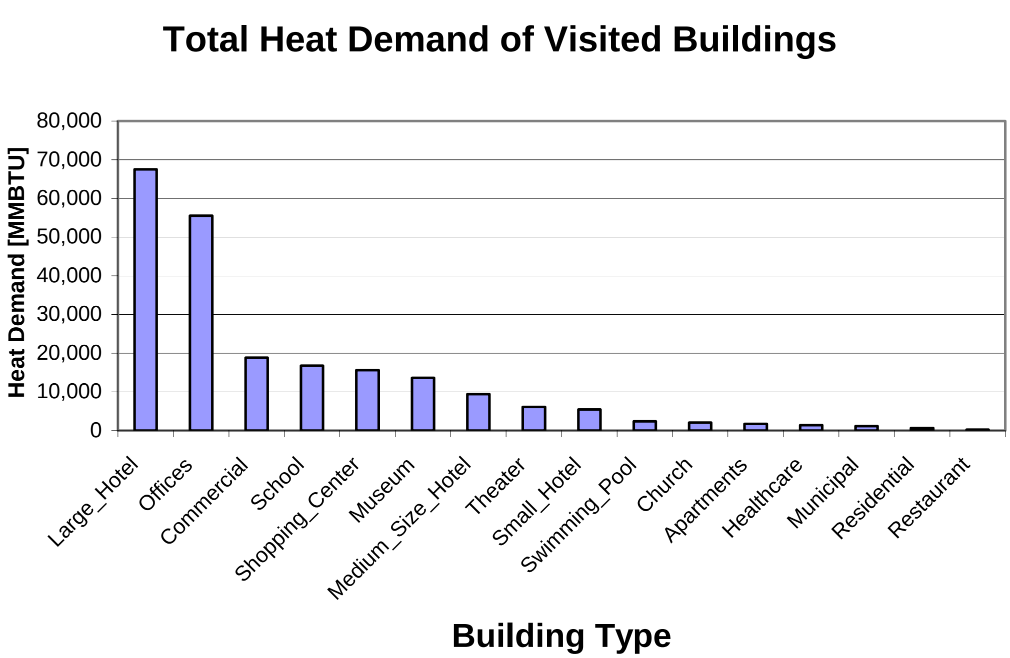

Figure 13: Total annual heat demand of all visited buildings – downtown Santa F

Legend: MMBTU: Million BTU

4.3.1.3 Full Load Operating Hours, Adjustment of Oversized Heating Systems and Total Nominal heating capacity of all Buildings Visited

Based on the heat demand (calculated from the information gathered during the inquiry or estimated based on the average specific heat demand listed in Table 17) and the installed nominal heating capacity of each building the full load operating hours of the heating system were calculated. Table 19 gives an overview of the results of these calculations.

Table 19: Full load operating hours of the buildings visited

Based on gathered information and estimated values for the heat demand

FULL LOAD OPERATING HOURS			
TYPE OF BUILDING	Maximum [hrs]	Minimum [hrs]	Average [hrs]
Apartments	485	485	485
Church	872	794	840
Commercial	1494	234	741
Healthcare	2186	2186	2186
Large_Hotel	1284	451	1064
Medium_Size_Hotel	1493	426	989
Municipal	1148	399	919
Museum	1455	799	1068
Offices	2218	216	794
Residential	861	437	628
Restaurant	730	730	730
School	738	237	621
Shopping_Center	902	773	871
Small_Hotel	1829	718	1258
Swimming_Pool	833	833	833
Theater	1494	941	1109

Table 19 shows a high variation within each category and between the categories as well. Specific characteristics of the buildings like occupancy, insulation or special use can explain the variation to some extent but it is also obvious that some heating systems are oversized.

Based on the guidelines outlined in chapter 3.3.4 oversized heating systems were identified. Depending on the variance between the specific building's full load operating hours and the average building full load operating hours some adjustments were required. Due to the high altitude of Santa Fe (7,000 ft/2,170 m) the capacity of most installed boilers is oversized to compensate for the poorer performance caused by higher altitude. According to a local engineering company [5], a boiler is oversized by 4% for every 1,000 ft/305 m above the design altitude (i.e. a boiler with a capacity of 1,000,000 BTU/hr at an altitude of 2,000 ft equals the capacity of a boiler with a capacity of 1,200,000 BTU/hr at an altitude of 7,000 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 [6] and 5,000 ft/1,524°m [7], so the design capacity of the installed boilers in Santa Fe has to be between 8% and 20% higher to compensate for a 2,000 ft/610 m and 5,000 ft/1,524 m higher altitude, respectively. Based on this information, the average design altitude for all installed heating devices was set at 3,500 ft/1,067 m, which means that the actual nominal heating capacity is 12,3% lower than the nominal heating capacity specified (or the specified capacity is 14% higher than the actual capacity). 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 [5], the design altitude is often set at sea level, which would mean that the actual nominal heating capacity is 21.9% lower than the nominal heating capacity specified (or the specified capacity is 28% higher than the actual capacity). 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 [5], no information could be obtained. Therefore, the methodology described above was used to adjust for altitude.

After the adjustment based on altitude, the specific capacity of each building was considered in the adjustments. Buildings with full load operating hours around or significantly below the average and a specific capacity significantly around or below the average were not considered oversized. On the other hand, buildings with low full load operating hours and a specific capacity significantly higher than the average were considered oversized and the nominal heating capacity was adjusted. The results of the adjustments are shown in Table 20. For more detailed information see the APPENDIX II of this report.

Table 20: Corrected specific nominal heating capacity and full load operating hours per building type

Legend: n.a. not applicable

	SPECIFIC NOMINAL CAPACITY			FULL LOAD OPERATING HOURS		
TYPE OF BUILDING	**Maximum [BTU/hr*sqft]**	**Minimum [BTU/hr*sqft]**	**Average [BTU/hr*sqft]**	**Maximum [hrs]**	**Minimum [hrs]**	**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

Due to the adjustment of the nominal heating capacity the difference between minimum and maximum values could be reduced and the average full load operating hours could be increased.

However, the average full load operating hours of some building categories are still lower than expected. Apartments and homes usually have higher full load operating hours than churches and in our study the opposite was true. This discrepancy can be explained to some extent by the specific characteristics of the churches visited in Santa Fe (other buildings are attached to them). On the other hand, 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 leading to a higher specific nominal heating capacity and therefore to lower full load operating hours. The better insulation of residential buildings compared to churches also may be a reason for the lower full load operating hours of residential buildings.

The specific nominal heating capacity and the full load operating hours of other building types appear plausible according to their specific heat demand with the exception of a few commercial and office buildings and one school. The low full load operating hours and the low specific nominal heating capacity suggest that parts of the buildings are not in permanent use or the received gas bills are not complete. Since this assumption could not be verified by the building operators, the available data has not yet been adjusted.

The generally low full load operating hours of schools correspond with their low specific heat demand referred previously (see also chapter 4.3.1.2).

Hotels have higher full load operating hours due to their generally higher base load in summer (kitchen and laundry facilities, pool heating).

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

Based on the adjustments that were made on the nominal heating capacity of several heating systems the total nominal heating capacity of all visited buildings was calculated. The results are shown in Table 21. Compared to the total installed capacity of all visited buildings the corrected nominal heating capacity is approx. 18% lower.

Table 21: Corrected nominal heating capacity of all visited buildings, downtown Santa Fe

	INSTALLED CAPACITY		CORRECTED HEATING CAPACITY		
TYPE OF BUILDING	[BTU/hr]	[kW]	[BTU/hr]	[kW]	PERCENTAGE
Apartments	3,521,760	1032.122203	2,289,144	671	65.0%
Church	3,116,800	913.440576	2,603,581	763	83.5%
Commercial	25,506,040	7475.055143	19,578,924	5,738	76.8%
Healthcare	642,240	188.2212768	642,240	188	100.0%
Large_Hotel	69,191,555	20277.96902	57,493,177	16,850	83.1%
Medium_Size_Hotel	9,871,089	2892.920053	8,077,999	2,367	81.8%
Municipal	1,222,700	358.336689	1,033,952	303	84.6%
Museum	13,285,450	3893.566832	11,097,155	3,252	83.5%
Offices	70,021,942	20521.33054	55,279,951	16,201	78.9%
Residential	1,079,200	316.281144	852,782	250	79.0%
Restaurant	320,000	93.7824	256,000	75	80.0%
School	27,050,330	7927.640213	22,569,868	6,615	83.4%
Shopping_Center	17,934,087	5255.942877	15,728,194	4,609	87.7%
Small_Hotel	4,387,490	1285.841694	3,553,229	1,041	81.0%
Swimming_Pool	2,906,700	851.866569	2,549,176	747	87.7%
Theater	5,499,500	1611.738465	4,823,062	1,413	87.7%
TOTAL	**255,556,883**	**74,896**	**208,428,434**	**61,084**	**81.6%**

4.3.2 Other Areas (Potential Sites for Micro Grids)

4.3.2.1 Specific Nominal heating capacity

Los Arroyos Home Owners Association

Based on the data gained during the heat demand inquiry the specific nominal heating capacity for the seven apartment buildings and the administration building was calculated. Table 22 gives an overview of the results of these calculations. The results are based solely on the information gathered during the visits and the plausibility checks concerning the heated area of each building. The adjustments regarding oversized heating systems and the results are outlined in chapter 4.3.2.3.

Table 22: Specific nominal heating capacity of the buildings visited, Los Arroyos Home Owners Association

Legend: all numbers as specified during the visits, no adjustment of the capacities made.

	SPECIFIC NOMINAL CAPACITY	
TYPE OF BUILDING	**[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**

The calculated numbers for the seven apartment buildings correspond with the specific nominal heating capacity for apartment buildings (see Table 20). Due to the fact that all seven apartment buildings were built at the same time and with the same materials, there is no apparent reason for the specific nominal heating capacity to be different from building to building. Therefore, it appears 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 far above average, because the indoor swimming pool is included in this building.

South Capitol Complex

Based on the data gathered during the heat demand inquiry the specific nominal heating capacities for the four office buildings were calculated. Table 23 gives an overview about the results of these calculations. The results are based solely on the information gathered during the visits and the plausibility checks performed concerning the heated area of each building. The adjustment regarding oversized heating systems and the results are outlined in chapter 4.3.2.3.

Table 23: Specific nominal heating capacity of the visited buildings, South Capitol Complex

All numbers as specified during the visits, no adjustment of the capacities made.

	SPECIFIC NOMINAL CAPACITY	
BUILDING	**[BTU/hr/sqft]**	**[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**

The calculated numbers for the office buildings are about 25% lower than the average specific nominal heating capacity for offices in downtown Santa Fe (see Table 20). The low specific nominal heating capacity of the Joseph Montoya Building indicates that the information of the actual nominal heating capacity gathered from the maintenance personnel is not correct. See chapter 4.3.2.3 for more details.

Santa Fe Community College

Based on the data gathered during the heat demand inquiry the specific nominal heating capacity of all buildings on the campus was calculated. Table 24 gives an overview of the results of these calculations. The results are based solely on the information gathered during the visits and the plausibility checks performed concerning the heated area of each building. The adjustment regarding oversized heating systems and the results are outlined in chapter 4.3.2.3.

Table 24: Specific nominal heating capacity of the visited buildings, Santa Fe Community College

All numbers as specified during the visits, no adjustment of the capacities made. Specific nominal capacities of Main Building and Fitness Center are averages of both buildings, because they are connected to the micro grid.

	SPECIFIC NOMINAL CAPACITY	
BUILDING	**[BTU/hr/sqft]**	**[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**

The results show two different groups of buildings. The heating systems of the Visual Arts Center and the Early Childhood Development Center seem to be 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 of a similar category (schools). However, there weren’t any reports of cold spots within the buildings, so it is more likely that the area of unheated rooms is higher than expected.

College of Santa Fe

Only one boiler in the visited buildings had a specification plate with information about its nominal heating capacity. Therefore, the nominal heating capacity had to be estimated based on the average nominal specification numbers listed in Table 20. The estimated total nominal heating capacity of all buildings on the campus was estimated at 26,349,000 BTU/hr/7,722 kW. The results are discussed in detail in chapter 4.4.2.

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

Los Arroyos Home Owners Association

Based on the data gathered during the heat demand inquiry the specific heat demand was calculated according to the guidelines described in chapter 3.3.2. The buildings are not sub-metered so there were no gas bills available for the individual buildings. According to the information gathered about the operating hours of the boiler for the pool (6 hours a day = 2,190 hours per year) the heat demand of the pool was calculated (nominal output capacity * operating hours per year) and was subtracted from the total heat demand to determine the heat demand of the apartment buildings. The heat demand of the apartment buildings was divided by the actual heated area of the seven apartment buildings to calculate a specific heat demand which is comparable with other apartment buildings.

Table 25 gives an overview of the results of these calculations. The results are based solely on the information gathered during the visits, the plausibility checks concerning the heated area of each building, and the information about the building envelope. For the nationwide average number for apartment buildings according to the USDOE Buildings Energy Data Book 2002 [4] see Table 16.

Table 25: Specific heat demand of the visited buildings, Los Arroyos Home Owners Association

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

	HEAT DMEAND		SPECIFIC HEAT DEMAND	
	[BTU]	[kWh]	[BTU/sqft]	[kWh/m²]
Complex (all buildings)	6,163,042,217	1,806,203	45,829	144.57
Pool	700,800,000	205,383	n.a.	n.a.
Apartments	5,462,242,217	1,600,819	41,231	130.07

The average number for all apartments corresponds with the national average shown in Table 16. The apartment buildings are not well insulated which may also explain the difference of 10% compared to the national average.

South Capitol Complex

Based on the data gained during the heat demand inquiry the specific heat demand was calculated according to the guidelines described in chapter 3.3.2.

Table 26 gives an overview about the results of these calculations. The results are based solely on the information gathered during the visits, the plausibility checks performed concerning the heated area of each building, and the information about 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 the buildings visited, South Capitol Complex

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

	ANNUAL HEAT DEMAND		SPECIFIC HEAT DEMAND	
BUILDING	**[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**

The average specific heat demand of all four buildings is about 40% lower than the average for office buildings in Santa Fe. The specific numbers from the Harold Runnels and the John F. Simms buildings appear to be plausible but the specific heat demand of the Joseph Montoya building and especially the Manuel Lujan Building are too low. Further inquires with the General Service Division are currently underway to discover 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 chapter 3.3.2.

Table 27 gives an overview of the results of these calculations. The results are based solely on the information gathered during the visits, the plausibility checks concerning the heated area of each building, and the information about 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 the visited buildings, Santa Fe Community College

The heat demand was calculated from the available gas bills and an average utilization rate of 76.5% (the efficiency of the installed boilers at the Community College is around 81.5%); electric consumption for the electric domestic hot water heaters in the Visual Arts Center not included.

	ANNUAL HEAT DEMAND		SPECIFIC HEAT DEMAND	
BUILDING	**[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**

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 (approx. 108 hours a week) compared to schools (approx. 35 to 40 hours a 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 hot 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 was calculated. The calculation of a specific number 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 expected to be about 72%. Therefore, the total annual heat demand averages 32,701 MMBTU/9,584 MWh.

According to the total area of the campus, shown in Table 7, the average specific heat demand of the campus amounts to about 57,597 BTU/sqft / 181.7 kWh/m².

The specific heat demand corresponds well with the specific heat demand of the Santa Fe Community College. However, considering the variety of age, function, and occupancy of the 46 buildings on campus, this number is of limited value.

4.3.2.3 Full Load Operating Hours, Adjustment of Oversized Heating Systems and Total Nominal heating capacity of all Buildings Visited

Los Arroyos Home Owners Association

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

Table 28: Full load operating hours of the buildings visited, Los Arroyos Home Owners Association

Data based on gathered information and estimated values for the heat demand.

	TOTAL NOMINAL CAPACITY		HEAT DEMAND		FULL LOAD
TYPE OF BUILDING	BTU/h	kW	[BTU]	[kWh]	OPERATING HOURS
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**

The full load operating hours vary slightly from one apartment block to the next. According to chapter 4.3.2.1, Block 2B appears to be the block with the optimized system so all other apartment buildings were adjusted to match its specific nominal heating capacity. Furthermore, the capacity of the boilers had to be adjusted to the altitude of Santa Fe (7,000 ft/2,170 m). Due to the fact that all installed boilers are Raypak boilers which are designed for an altitude of up to 5,000 ft/1,524 m [7], the boilers are oversized by 8%. Therefore, the actual nominal heating capacity of the boilers is 7.4% lower than the capacity specified on the specification plate.

A further reduction of the nominal heating capacity is possible if the very poor insulation of the buildings is improved.

Table 29: Corrected nominal heating capacity, specific nominal heating capacity and full load operating hours, Los Arroyos Home Owners Association

	CORRECTED CAPACITY		SPECIFIC CAPACITY		FULL LOAD
TYPE OF BUILDING	[BTU/hr]	[kW]	[BTU/hr/sqft]	[kW/m²]	OPERATING HOURS
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 results of the adjustments show a decrease in the total nominal heating capacity by 13.6% and an increase of the full load operating hours of the whole complex by 15.7%.

South Capitol Complex

Based on the heat demand (calculated from the information gathered during the inquiry) and the installed nominal heating capacity of each building the full load operating hours of the heating system were calculated. Table 30 gives an overview of the results of these calculations.

Table 30: Full load operating hours of the buildings visited, South Capitol Complex

Data based on gathered information.

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**

The average full load operating hours of all four buildings is about 15% lower than the average for office buildings in Santa Fe (see Table 20). The full load operating hours of the John F. Simms building appear to be plausible. The full load operating hours of the Montoya building appear to be plausible but the number shown above does not include any adjustments of the boiler size (see chapter 4.3.2.1) yet so the full load operating hours will decrease. Low full load operating hours at the Harold Runnels building and the highest specific nominal heating capacity of all four office buildings are an indication that the nominal heating capacity of the Runnels Building has to be adjusted, also. The problem with a far too low heat demand at the Manuel Lujan Building is also reflected in very low full load operating hours.

According to the findings discussed in chapter 4.3.2.1, the higher value of the specified boiler capacity of the boiler in the Montoya Building was chosen, which means an increase of the boiler capacity by 25%.

The boiler capacity of the Runnels Building was decreased by 10% to match the specific nominal heating capacity of the Simms Building. The impact of these adjustments on the specific classification numbers is shown in Table 31.

Table 31: Corrected nominal heating capacity, specific nominal heating capacity and full load operating hours, South Capitol Complex

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

	CORRECTED CAPACITY		SPECIFIC CAPACITY		FULL LOAD
TYPE OF BUILDING	[BTU/hr]	[kW]	[BTU/hr/sqft]	[kW/m²]	OPERATING HRS
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**

With the adjustments of the nominal heating capacity of the Montoya building and the Runnels Building the variation of the specific capacity is decreased. However, the average specific capacity is still about 25% lower than the average for office buildings in Santa Fe. The buildings are relatively new and better insulated than most of the offices in downtown Santa Fe, which can explain the lower specific capacity of the buildings of the South Capitol Complex to some extent.

Santa Fe Community College

Based on the heat demand (calculated from the information gathered during the inquiry) and the installed nominal heating capacity of each building the full load operating hours of the heating system were calculated. Table 32 gives an overview of the results of these calculations.

Table 32: Full load operating hours of the buildings visited, Santa Fe Community College

Data based on gathered information; the full load operating hours of the Visual Arts Center were calculated from the nominal heating capacity of the gas fired boiler and the annual heat demand (based on the annual gas consumption).

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**

The full load operating hours of the Main building and the Fitness Education Building seem to be too high. The additional heat that is needed for the swimming pool which is heated throughout the year can explain the high full load operating hours to some extent. To verify the high heat demand the gas bills for 2002 and 2003 were requested from the Santa Fe Community College but until the deadline for this report no gas bills for these years were available.

The Visual Arts Building has also higher full load operating hours than the average for schools in Santa Fe but this difference can be explained with the higher occupancy of the buildings of the community college (approx. 108 hours a week) compared to the schools (35 to 40 hours a week).

According to the information listed on the specification plates, all boilers at the Santa Fe Community College are designed for an altitude between 6,000 and 8,000 ft (1,830 to 2,440 m), so an adjustment of the boiler capacity because of the altitude of Santa Fe is not necessary. However, the boiler at the Early Childhood Development Center seems to be oversized. According to the 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 impact 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, Santa Fe Community College

Legend: the full load operating hours for the Visual Arts Center refer only to the capacity of the boiler for space heating (2,788,000 BTU) and the annual heat demand calculated from the gas bills.

TYPE OF BUILDING	CORRECTED CAPACITY [BTU/hr]	[kW]	SPECIFIC CAPACITY [BTU/hr/sqft]	[kW/m²]	FULL LOAD OPERATING HRS
MAIN BUILDING	5,824,600	1,707	21.74	0.069	2,766
FITNESS EDUCATION CENT	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 DEVEL	1,500,000	440	60.00	0.189	1,168
TOTAL/AVERAGE	**13,062,600**	**3,828**	**28.09**	**0.089**	**2,247**

The total nominal heating capacity for the whole campus was reduced by 7%. Further investigation is underway to determine the reason for the low specific nominal heating capacity of the Main Building and the Fitness Center as well as the high full load operating hours of these buildings.

College of Santa Fe

Based on the estimate of the total nominal heating capacity of the campus (see chapter 4.4.2) and the calculated heat demand (see chapter 4.3.2.2) the average full load operating hours of the College of Santa Fe would be approx. 1,310 hours.

However, the full load operating hours are mostly based on estimates, so more investigations will be necessary to verify these numbers before a district heating system could be installed.

4.4 Extrapolation of the Heat Demand and the Installed Nominal heating capacity for Non-Visited Buildings and Determination of the Maximum Heat Demand and the Maximum Installed Nominal heating capacity within the Target Area

4.4.1 Downtown Santa Fe

4.4.1.1 Existing Buildings

Based on the map of downtown Santa Fe the number and type of non-visited buildings within the target area were determined. The heated area was estimated according to the footprint of the building and the number of floors. Then the annual heat demand and the installed nominal heating capacity were calculated using the average specific heat demand (see Table 17) and the average specific nominal heating capacity (see Table 20) of the respective building types.

Table 34 gives an overview over the results of the extrapolation achieved by the heat demand and the nominal heating capacity of non-visited buildings within the target area.

Table 34: Building categories, estimated heated area, heat demand and nominal heating capacity of non-visited buildings within the target area – downtown Santa Fe

Heated area based on footprint and number of floors of each building. The actual number of connected buildings and thus the annual heat demand and nominal heating capacity may change depending on the actual path of the network of pipes.

		HEATED AREA		HEAT DEMAND		NOM. HEAT. CAP.	
TYPE OF BUILDING	**AMOUNT**	**[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**

4.4.1.2 Future Potential

Downtown Santa Fe already has a high building density, therefore only a few new buildings are planned for construction within the coming years. However, for the railyard area at the southwestern end of downtown there exists a master plan for the new construction of 26 buildings. Furthermore, next to the Lensic on W San Francisco Street the construction of a new hotel is planned.

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

The results of the extrapolation are shown in Table 35. Most of the buildings planned in the railyard 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 railyard area) are planned.

Table 35: Building categories, estimated heated area, heat demand and nominal heating capacity of planned buildings within the target area – downtown Santa Fe

Heated area based on footprint and number of floors of each building. The actual number of connected buildings and thus the annual heat demand and nominal heating capacity may change depending on the actual path of the network of pipes.

		HEATED AREA		HEAT DEMAND		NOM. HEAT. CAP.	
TYPE OF BUILDING	**AMOUNT**	**[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**

4.4.1.3 Determination of the Maximum Heat Demand and the Maximum Nominal heating capacity within the Target Area

Based on the results discussed in chapter 4.3.1.2, 4.4.1.1 and 4.4.1.2 the total heat demand and the nominal heating capacity of all buildings within the target area were calculated (see Table 36).

Large and medium sized hotels (26.0%), office buildings (22.3%) and schools (6.0%) account for more than 56.3% of the total heat demand within the target area but make up only 15.6% of all buildings.

Therefore, the acquisition of customers should 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 visited buildings make up for almost 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.

Table 36: Estimated heated area, total heat demand and total nominal heating capacity of existing and planned buildings within the target area – downtown Santa Fe

Heated area based on footprint and number of floors of each building. The actual number of connected buildings and thus the annual heat demand and nominal heating capacity may change depending on the actual path of the network of pipes.

		HEATED AREA		HEAT DEMAND		NOM. HEAT. CAP.	
TYPE OF BUILDING	**AMOUNT**	**[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**

4.4.2 Other Areas (Potential Sites for Micro Grids)

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 buildings visited had a specification plate with information about its nominal heating capacity. Therefore, the nominal heating capacity had to be estimated based on the average nominal specification numbers listed in Table 20. The nominal heating capacity of the boiler Visual Arts Center was adjusted by 12.3% to consider the altitude of Santa Fe (see also chapter 4.3.1.3). The results are shown in Table 37.

The estimated total nominal heating capacity of all buildings on the campus was estimated at 25,047,000 BTU/hr/7,341 kW.

Table 37: Estimated nominal heating capacity of buildings on the campus – College of Santa Fe

Boiler capacity of the Visual Arts Center as specified on the specification plate on the boiler.

	TOTAL AREA		BUILDING	SPEC. NOM. CAP.	NOMINAL CAPACITY	
NAME OF BUILDING	[sqft]	[m²]	TYPE	[BTU/hr/sqft]	[BTU/hr]	[kW]
Alumin Hall	11,742	1,091	Apartment	48.88	573,960	168
Cafeteria	17,836	1,657	Restaurant	56.89	1,014,670	297
Brothers Residence	19,517	1,813	Apartment	48.88	954,010	280
Onate Hall	6,550	609	Apartment	48.88	320,170	94
11 smaller buildings (T-38-T45, T63-T65)	54,441	5,058	Office	37.58	2,046,023	600
St. Michael's Chapel	2,550	237	Church	56.77	144,770	42
St. Michael's Hall	30,319	2,817	Apartment	48.88	1,482,022	434
King Hall	46,109	4,284	Apartment	48.88	2,253,852	661
La Salle Hall	24,764	2,301	Apartment	48.88	1,210,488	355
Alexis Hall	14,844	1,379	Apartment	48.88	725,589	213
Kennedy Hall	25,295	2,350	Apartment	48.88	1,236,444	362
Benildus Hall	16,280	1,512	Apartment	48.88	795,782	233
Luke Hall	26,177	2,432	Apartment	48.88	1,279,557	375
Garson Theater	32,628	3,031	Theater	64.31	2,098,225	615
Administration Building	8,680	806	Office	37.58	326,215	96
Fogelson Complex (micro grid)	58,457	5,431	Municipal	31.14	1,820,534	534
Garson Communications Center	49,200	4,571	Municipal	31.14	1,532,242	449
Driscoll Fitness Center	22,200	2,062	Recreation	60.00	1,332,000	390
Bookstore	2,912	271	Municipal	31.14	90,689	27
Center for Academic Excellence	1,693	157	Municipal	31.14	52,725	15
Development Office	3,441	320	Office	37.58	129,321	38
Humanities/Education Dept. Offices	1,500	139	Office	37.58	56,374	17
Student Apartments (1 & 2)	30,000	2,787	Apartment	48.88	1,466,429	430
Visual Arts Center Phase 1	54,615	5,074		38.55	2,105,263	617
TOTAL	**561,750**	**52,188**			**25,047,352**	**7,341**

The calculated average specific nominal heating capacity of the entire campus is about 44 BTU/hr/sqft. Further investigation has to be carried out to verify these results.

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

The determination of the substitutable heat demand is essential for the evaluation of the economic performance of the system, because it forms the basis for the definition of the possible annual income of the system through heat sales.

4.5.1 Downtown Santa Fe

4.5.1.1 Calculation of the Connected Heat Load Potential

The calculation of the connected heat load of all buildings visited was carried out according to methods described in chapter 3.4. Taking the type and the location of the heating systems into account, more than 77% of the nominal heating capacity can be replaced by a district heating system.

For all other buildings the portion of the substitutable nominal heating capacity had to be estimated because no information about the installed heating systems was available. The substitution rate for other existing buildings was set at 50% because the average size of these buildings is smaller than the average size of the buildings visited. The experience gained during the heat demand inquiry showed that hydronic and steam systems are more common in larger buildings and forced air units and gas radiators are more common in smaller buildings. Therefore the substitution rate at the unvisited buildings was expected to be lower and was set at 50%.

The substitution rate for newly built buildings was set at 75% because it can be expected that once the district heating system is in operation the heating systems of most of the newly built buildings would be appropriately designed for district heating.

Table 38: Total nominal heating capacity and connected heat load potential (substitutable nominal heating capacity) within the target area, downtown Santa Fe

The actual number of connected buildings and thus the connected heat load potential may change depending on the actual path of the network of pipes.

	TOTAL CAPACITY		CONNECTED HEAT LOAD		
CATEGORY	[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%**

Table 38 and Figure 14 show the connected heat load potential. Almost 70% of the total nominal heating capacity or 218,000,000 BTU/hr (63,900 kW) could be substituted by a district heating system.

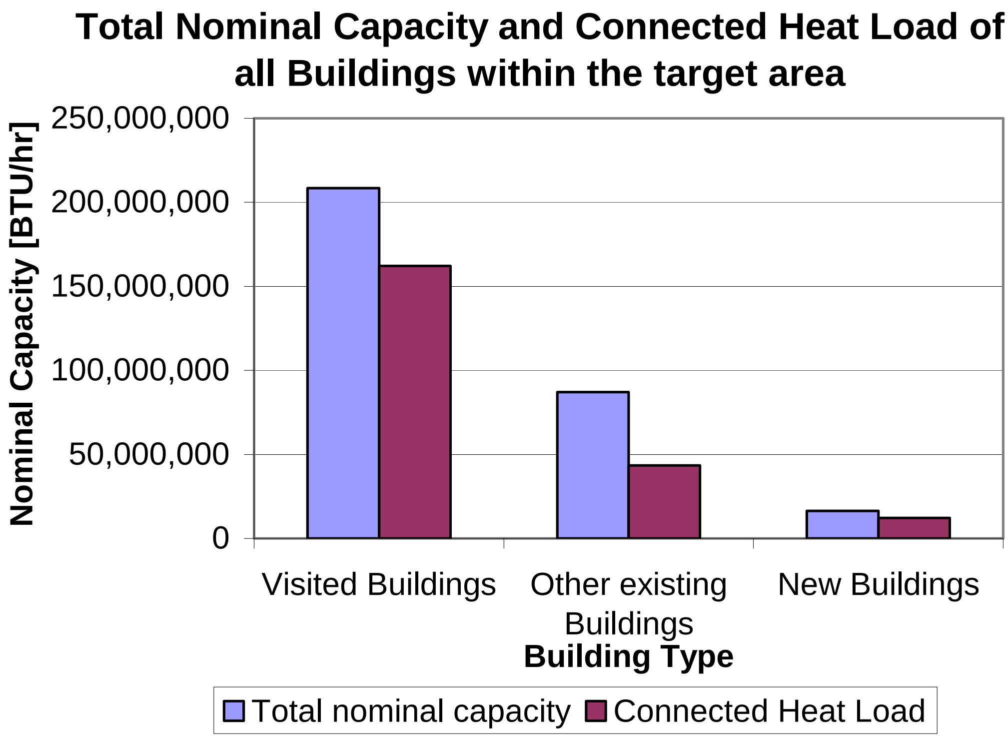

Figure 14: Total nominal heating capacity and connected heat load (substitutable nominal heating capacity) within the target area, downtown Santa Fe

4.5.1.2 Calculation of the Substitutable Heat Demand

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

For the estimation of the substitutable annual heat demand of all other buildings the same ratio as for the calculation of the connected heat load was used. This ratio is 50% for existing buildings and 75% for buildings to be built in the near future.

The substitutable heat demand for downtown Santa Fe is shown in Table 39 and Figure 15. Around 71.2% of the total heat demand or 223,768 MMBTU/65,580 MWh per year within the target area of the main district heating grid for downtown Santa Fe could be replaced by district energy.

The average full load operating hours of the total connected load within the target area would amount to about 1,027 hours per year. For an efficient operation of a district heating system an increase of the full load operating hours within the target area is necessary. This can be achieved either by the connection of process heat consumers with a constant heat demand throughout the year and/or by the installation of absorption chillers for space cooling to increase the heat demand during summer.

Table 39: Total annual heat demand and substitutable annual heat demand of all buildings within the target area, downtown Santa Fe

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

	TOTAL HEAT DEMAND		SUBSTITUTABLE HEAT DEMAND		
CATEGORY	**[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%**

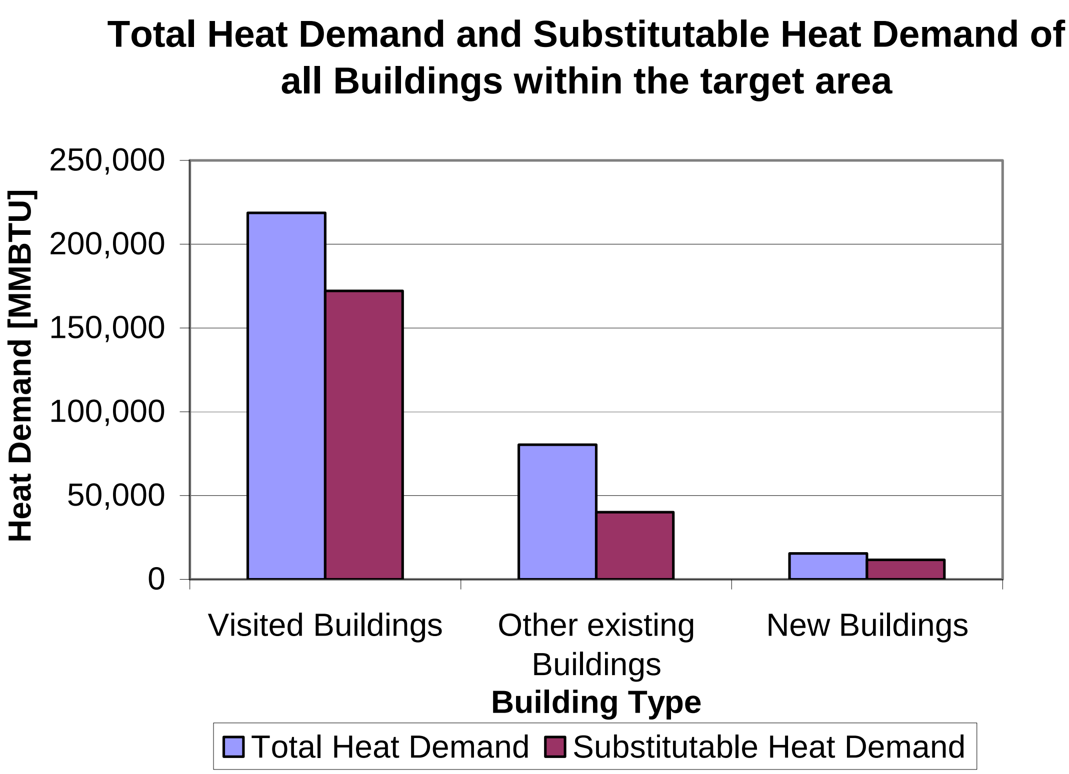

Figure 15: Total annual heat demand and substitutable annual heat demand of all buildings within the target area, downtown Santa Fe

The substitutable heat demand represents 298,357°MMBTU/87,440 MWh of natural gas per year, assuming an average annual utilization rate of 75%. This amount of natural gas represents CO_2-emissions of 19,084 short tons/17,313 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 district heating system a significant amount of these emissions can be reduced. A more detailed investigation regarding 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.

4.5.2 Other Areas (Potential Sites for Micro Grids)

4.5.2.1 Calculation of the Connected Heat Load Potential

Los Arroyos Home Owners Association

All of the installed heating systems specified in Table 12 at the Los Arroyos 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, Los Arroyos Home Owners Association

	CORRECTED CAPACITY		SPECIFIC CAPACITY		FULL LOAD
TYPE OF BUILDING	[BTU/hr]	[kW]	[BTU/hr/sqft]	[kW/m²]	OPERATING HOURS
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% lower than the actual installed capacity. Depending on improvements to the poor insulation of the buildings the annual heat demand and the connected heat load may further decrease in the future.

South Capitol Complex

Except for the domestic hot water heater in the Simms Building, all of the installed heating systems of the South Capitol Complex can be replaced by a micro grid. The calculation of the connected heat load of all four office buildings was carried out according to chapter 3.4. Table 41 gives an overview of the connected heat load.

Table 41: Total corrected nominal heating capacity and connected heat load potential (substitutable nominal heating capacity) within the target area, South Capitol Complex

	TOTAL CAPACITY		CONNECTED HEAT LOAD		
CATEGORY	**[BTU/hr]**	**[kW]**	**[BTU/hr]**	**[kW]**	**PERCENTAGE**
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%**

Table 41 and Figure 16 show the connected heat load potential at the South Capitol Complex. Nearly 100% of the total nominal heating capacity or 12,355,000 BTU/hr (3,600 kW) could be replaced by a district heating system.

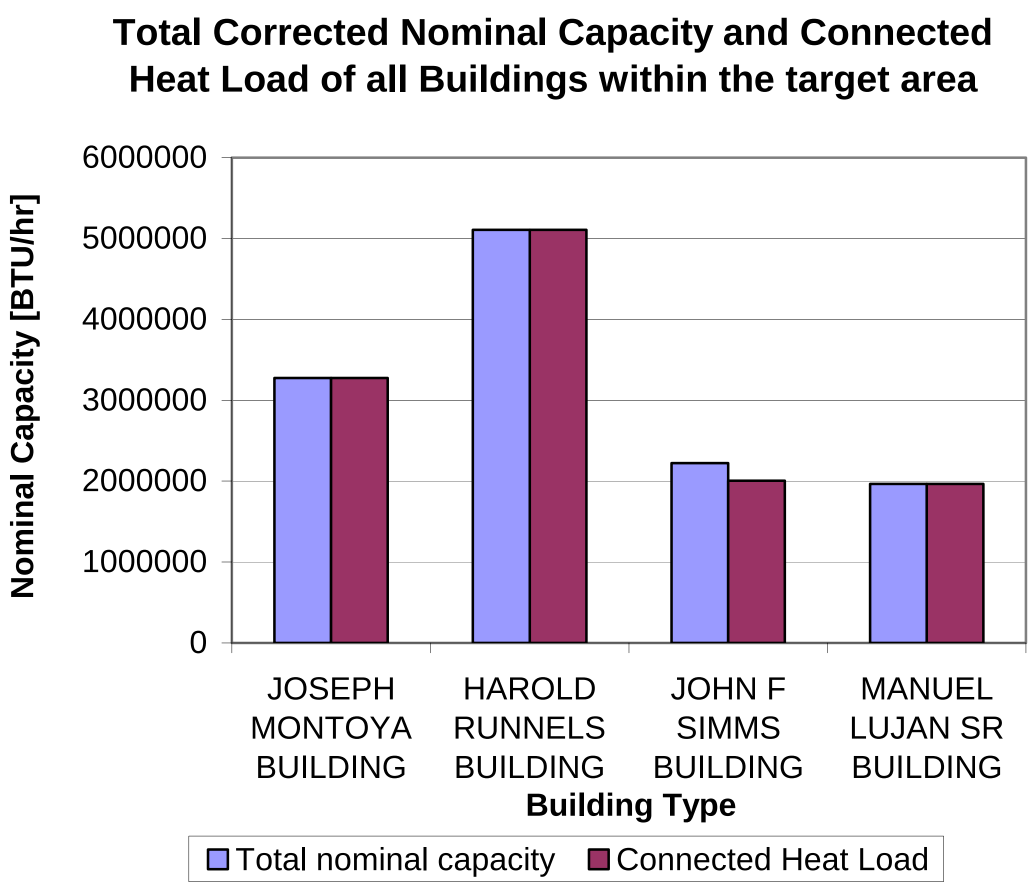

Figure 16: Total corrected nominal heating capacity and connected heat load potential (substitutable nominal heating capacity) within the target area, South Capitol Complex

Santa Fe Community College

Except for the domestic hot water heaters in the Visual Arts Center all heating systems installed at the Santa Fe Community College 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 chapter 3.4. Table 42 gives an overview of the total heating capacity as well as the connected heat load potential.

Table 42: Total corrected nominal heating capacity and connected heat load potential (substitutable nominal heating capacity) within the target area, Santa Fe Community College

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.

	TOTAL CAPACITY		CONNECTED HEAT LOAD		
CATEGORY	**[BTU/hr]**	**[kW]**	**[BTU/hr]**	**[kW]**	**PERCENTAGE**
MAIN BUILDING	5,824,600	1,707	5,824,600	1,707	100.00%
FITNESS EDUCATION CENTER	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 DEVELOPI	1,500,000	440	1,500,000	440	100.00%
TOTAL	**13,062,600**	**3,828**	**12,612,600**	**3,696**	**96.56%**

Table 42 and Figure 17 show the connected heat load potential at the Santa Fe Community College. More than 96% of the total nominal heating capacity or 12,612,600 BTU/hr (3,700 kW) could be replaced by a micro grid.

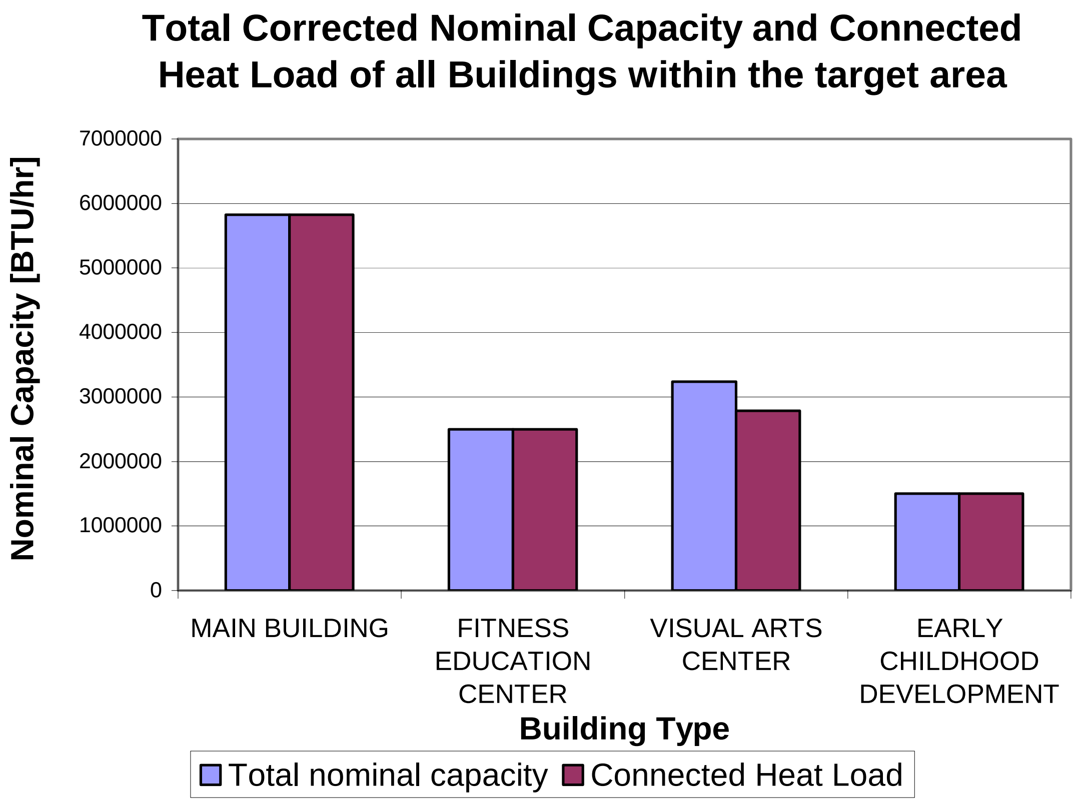

Figure 17: Total corrected nominal heating capacity and connected heat load (substitutable nominal heating capacity) within the target area, Santa Fe Community College

Legend: 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 heating systems were visited it was assumed that most of the buildings are heated by hydronic systems. Some of the smaller buildings are most likely heated by roof-top units. As a first estimate the ratio of substitutable heating systems was set at 75% which represents a substitutable nominal heating capacity (connected heat load potential) of approx. 18,786,000 BTU/hr/5,510 kW.

4.5.2.2 Calculation of the Substitutable Heat Demand

Los Arroyos Home Owners Association

Since all heating systems at the Los Arroyos apartment complex are replaceable by a micro grid the substitutable heat demand equals the actual heat demand of the complex. The results of the calculation are shown in Table 43.

The substitutable heat demand amounts to 6,163 MMBTU/1,806 MWh per year. This heat demand could be replaced by district energy within the target area of the micro grid for the Los Arroyos apartment complex.

Table 43: Total annual heat demand and substitutable annual heat demand within the target area, Los Arroyos Home Owners Association

	TOTAL HEAT DEMAND		SUBSTITUABLE HEAT DEMAND	
TYPE OF BUILDING	**[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%. This amount of natural gas represents CO_2-emissions of 525 short tons/477 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.

South Capitol Complex

Only the heat required to heat domestic hot water in the Simms Building cannot be replaced by district heat from a micro grid. The calculation of the substitutable heat demand of the four Office buildings was carried out according to methods described in chapter 3.4.

The results of the calculation are shown in Table 44 and Figure 18. Around 98% of the total heat demand or 9,756 MMBTU/2,859 MWh per year could be replaced by district energy within the target area of the micro grid for the South Capitol Complex.

Table 44: Total annual heat demand and substitutable annual heat demand within the target area, South Capitol Complex

	TOTAL HEAT DEMAND		SUBSTITUTABLE HEAT DEMAND		
CATEGORY	**[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%**

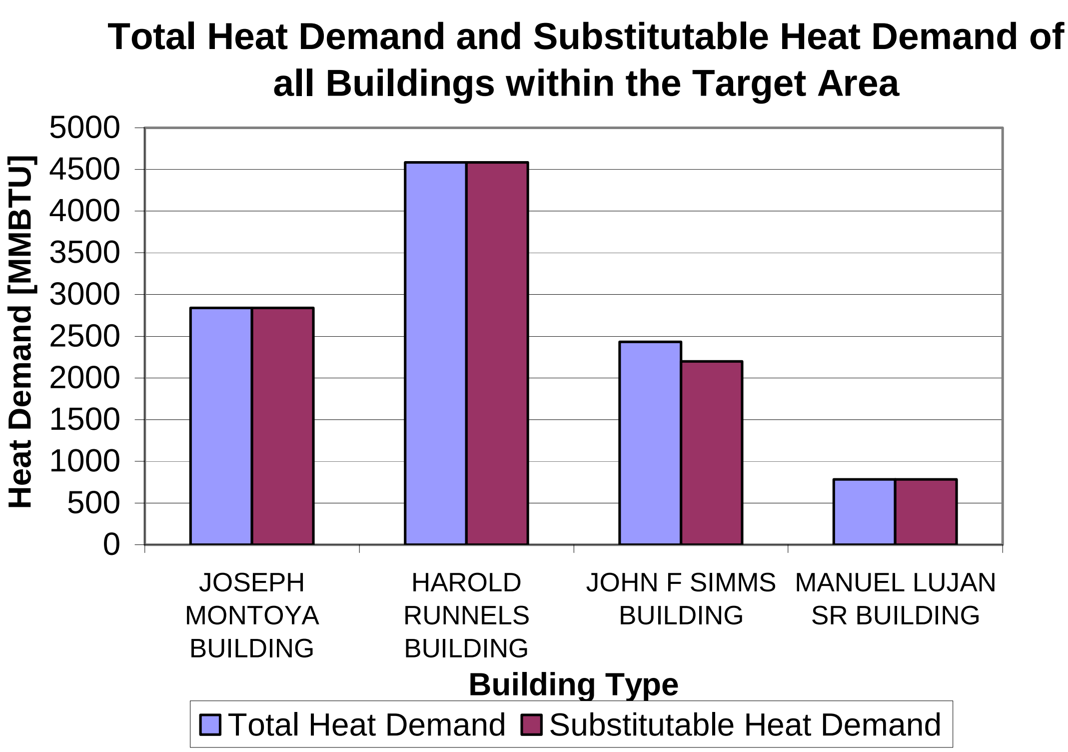

Figure 18: Total heat demand and substitutable heat demand within the target area, South Capitol Complex

The substitutable heat demand represents 12,998°MMBTU/3,809 MWh of natural gas per year, assuming an average annual utilization rate of 75%. This amount of natural gas represents CO_2-emissions of 831 short tons/754 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.

Santa Fe Community College

Only the heat required to heat domestic hot water in the Visual Arts Center can not 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 chapter 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%. 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

The same ratio was used for the estimation of the substitutable annual heat demand of all buildings on the campus and the calculation of the connected heat load potential. The calculated 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%. This amount of natural gas represents CO_2-emissions of 2,179 short tons/1,977 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.

4.6 Achievable ΔT for the District Heating Grid

4.6.1 Downtown Santa Fe

The achievable ΔT at the heat distribution device (e.g. fan coil unit, baseboards, radiant floors) is usually determined by the flow rates of the pumps and the specifications for entering water temperature and exiting water temperature of the distribution devices.

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

Fortunately, the temperature level of nearly all of the hydronic heating systems does not exceed 160°F/71°C for the supply temperature. Actually, many of them operate with temperatures as low as 130°F/54°C.

Forced air units also operate with a maximum air temperature of 170°F/76°C and an air temperature rise between 30°F/17°C and 65°F/36°C which means the return temperature of the fan coils in such systems are between approx. 120°F/49°C and 150°F/66°C.

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

However, the supply temperature at the customer side has to be adjusted to the supply temperatures for which the heating system is designed. Therefore, the installation of a mixing valve in the secondary cycle will be required for 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.

Table 45: Overview of achievable temperature differentials for several heating systems

Values represent average numbers, for more detailed values see the APPENDIX II of this report

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

4.6.2 Other Areas (Potential Sites for Micro Grids)

Los Arroyos Home Owner Association

The levels of the actual supply and return temperatures at the apartment buildings and the swimming pool are relatively low. A further decrease of the return temperature is therefore very unlikely. On the other hand, the problems with the pipes in most of the apartment buildings prevent an increase of the supply temperature.

To achieve a high temperature differential at the primary cycle at the heat transfer station the installation of a mixing valve in the heating system of each building (secondary cycle) would be the only available option. The mixing valve mixes the low temperature return from the baseboards with the high temperature supply from the heat transfer station to maintain the usual supply temperature for the baseboards (130 or 150°F). The mixing valve will 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 at 50°F/27°C for space heating. Even higher temperature differentials are possible for domestic hot water heating and the heating of the swimming pool (70°F/39°C or even higher, see also Table 46) but room heating in the apartments makes up the main part of the heat demand and therefore an average temperature differential for the whole micro grid of about 55°F/30°C can be estimated.

Table 46: Achievable temperature differential at the heat transfer station, Los Arroyos Home Owner Association

Legend: temperature Difference between primary cycle and secondary cycle according to standard specification of European heat transfer stations.

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

South Capitol Complex

The level of the actual supply and return temperatures at the South Capitol Complex for the three hydronic systems 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 the maintenance personnel, is only 5°F/3°C. However, all boilers were out of operation during the visit, so this information could not be verified on-site.

The set temperature for the hot air at the air handling units is 120°F/49°C. The domestic hot water is heated to temperatures between 106°F/41°C and 115°F/46°C. The hydronic heating system at the Montoya Building is equipped with a mixing valve in the return line of the boiler and flow control valves located before the air handling units. All other systems only have flow control valves located before the air-handling units.

The heating systems of the Montoya and Runnels building are controlled by their own computer systems. An adjustment of the control systems may help to increase the temperature differential. However, the installed pumps are single speed only; therefore the only way to control the flow within the system is with the flow control valves before the air-handling units. The heating systems of the Simms and Lujan building don't have a centralized computer control system, so adjustment of these systems seems to be more difficult.

Another opportunity to achieve a high temperature differential in the primary cycle at the heat transfer station is the installation of a mixing valve at 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 the usual supply temperature for the air handling units (minimum 120°F/49°C, maximum 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 may vary between 29°F/16°C and 69°F/38°C for space heating. Even higher temperature differentials are possible for domestic hot water heating (74°F/41°C to83°F/46°C, see also Table 47). But space heating represents the far higher heat demand, therefore an average temperature differential for the whole micro grid between 29°F/16°C and 69°F/38°C was estimated.

Table 47: Achievable temperature differential at the heat transfer station, South Capitol Complex

Temperature difference between primary cycle and secondary cycle according to standard specification of European heat transfer stations.

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

Santa Fe Community College

The measured supply temperature in the heating system at the main building was 135°F/57°C. The measured temperature differential between supply and return line was only around 5°F/3°C. The boilers in the other buildings were not in operation during the visit, but it is expected that the supply temperature for all heating systems will be between 135°F/57°C and 160°F/71°C. The supply temperature of the domestic hot water varies between 106°/41°C and 120°F/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

Temperature difference between primary cycle and secondary cycle according to standard specification of European heat transfer stations.

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

Another opportunity to achieve a high temperature differential in the primary cycle of the heat transfer station is the installation of 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 the usual 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 the achievable temperature differential in the primary cycle at the heat transfer station may vary from 34°F/19°C to about 59°F/33°C for space heating. Even higher temperature differentials are possible for domestic hot water and pool heating (69°F/38°C to 107°F/59°C, see also Table 48). But space heating represents the far higher heat demand, therefore an average temperature differential for the primary cycle of the micro grid between 34°F/19°C and 59°F/33°C during operation in winter time can be estimated. During summer, a higher temperature differential is possible because only domestic hot water and pool heating are required.

College of Santa Fe

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

Because most of the heating systems are very old, their control systems are outdated and cause problems regularly. Therefore, an increase of the temperature differential by adjustments at the process control system does not seem to be possible.

The only option to achieve a high temperature differential in the primary cycle at the heat transfer station is the installation of 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 the usual 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 may vary between 34°F/19°C and about 54°F/30°C for space heating. Even higher temperature differentials are possible for domestic hot water heating (54°F/30°C to69°F/38°C, see also Table 49). Since space heating represents the highest heat demand, an average temperature differential in the primary cycle of the micro grid between 34°F/19°C and 54°F/30°C can be estimated.

Table 49: Achievable temperature differential in the primary cycle at the heat transfer station, College of Santa Fe

Temperature Difference between primary cycle and secondary cycle according to standard specification of European heat transfer stations.

SPACE HEATING	°F	°C
Supply Temperature Heating Plant	194	90
Return Temperature Heating System	140-160	60-71
Temperature Difference Primary/Secondary	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	5.40	3.00
Achievable Temperature Differential	54-69	30-38

4.7 Annual Trend of the Heat Demand

4.7.1 Downtown Santa Fe

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

The available and estimated monthly substitutable heat demand of all buildings visited within the target area was then summed for each month and sorted from the highest heat demand to the lowest. This column was the input for Figure 19.

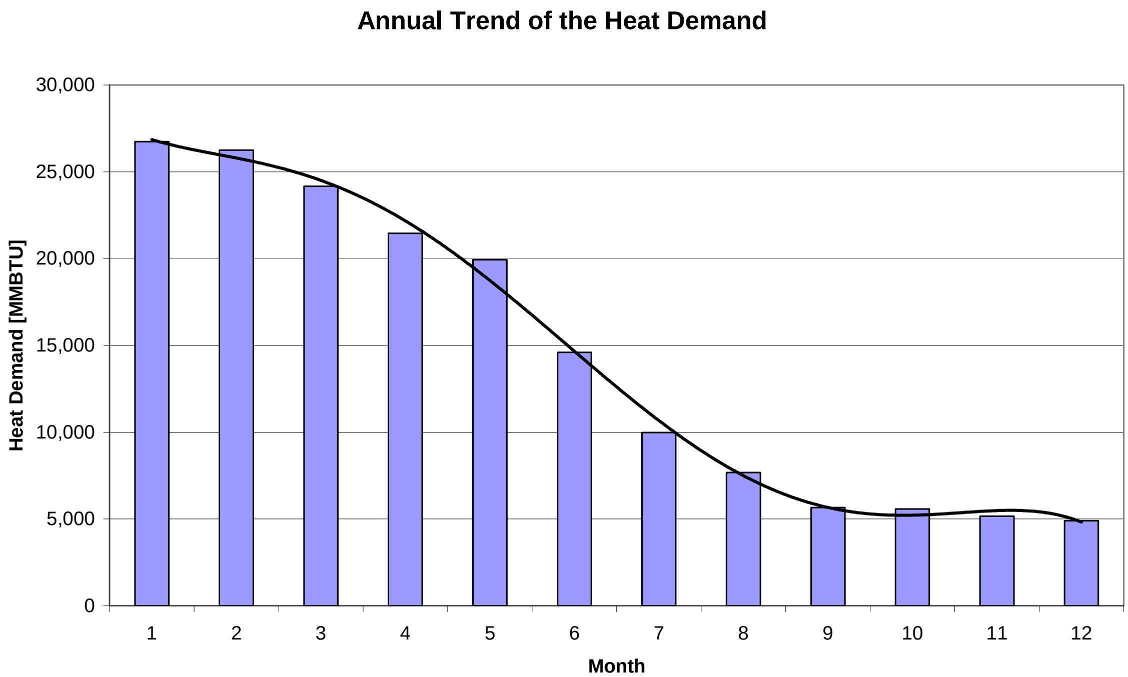

Figure 19: Annual trend of the heat demand of all buildings visited in the target area, based on monthly averages, downtown Santa Fe

<u>Legend:</u> monthly heat demand based on monthly gas bills for 2003 and estimates for buildings without available gas bills according to chapter 4.3.1.2.

The trend of the heat demand 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% of the highest monthly heat demand. The trend of the heat demand 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 unvisited buildings are residential and commercial buildings with a low heat demand during the warmer months.

4.7.2 Other Areas (Potential Sites for Micro Grids)

Los Arroyos Home Owners Association

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

The trend of the heat demand 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% of the highest monthly heat demand. The trend of the heat demand 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.

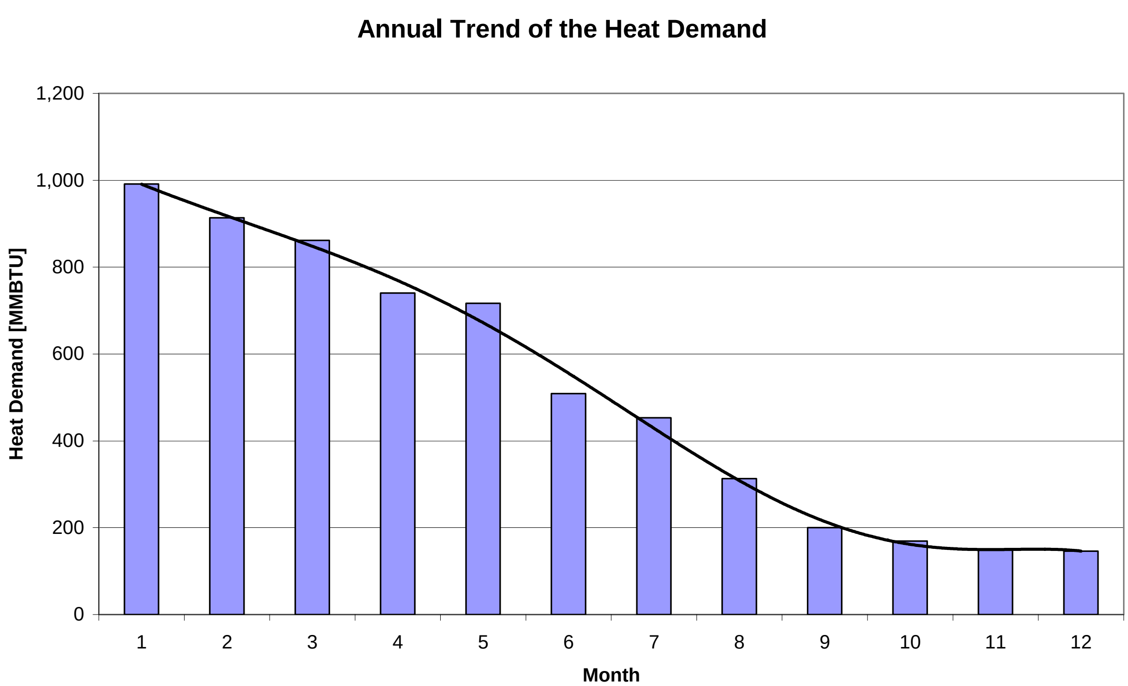

Figure 20: Annual trend of the heat demand of all customers in the target area, based on monthly averages, Los Arroyos Home Owners Association

Legend: 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 annual trend of the heat demand with a monthly scale was prepared (see Figure 21).

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

Compared to the annual trend of the heat demand of Los Arroyos with a minimum monthly heat demand that represents 15% 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.

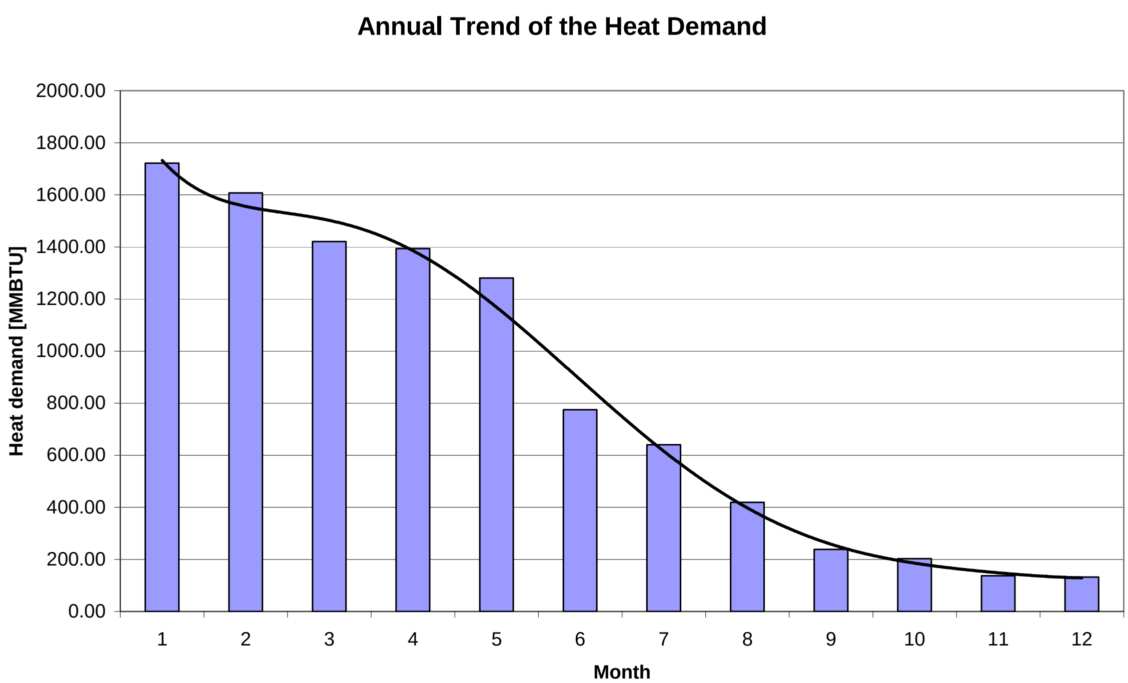

Figure 21: Annual trend of the heat demand of all customers in the target area, based on monthly averages, South Capitol Complex

Legend: monthly heat demand based on monthly gas bills of 2002 and 2003

Santa Fe Community College

The calculation of the annual trend of the heat demand was not possible, because monthly gas bills were only available. for two buildings The annual trend of the heat demand 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 annual trend of the heat demand with a monthly scale was prepared (see Figure 22).

The annual trend of the heat demand 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% of the highest monthly heat demand. The trend of the heat demand with a more detailed scale will show an even bigger difference between the maximum and the minimum demand. The annual trend of the heat demand may also vary from building to building because there are several buildings included that are not used throughout the year.

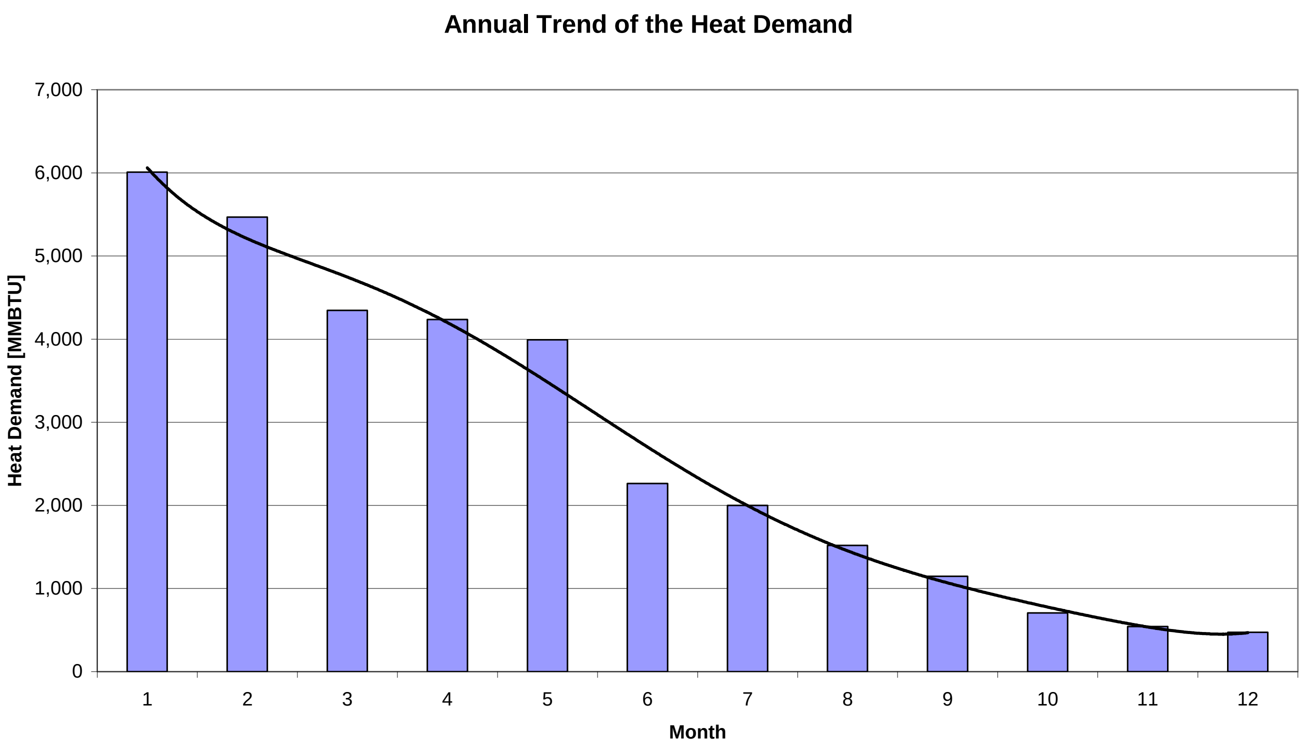

Figure 22: Annual trend of the heat demand of all customers in the target area, based on monthly averages,, College of Santa Fe

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

5 Conclusions

The heat demand inquiry performed in Santa Fe showed a high density of large heat consumers in the downtown area of the city and some potential sites for micro grids south of downtown.

5.1 Downtown Santa Fe

The 106 buildings visited within the target area represent about three quarters of the total heat demand in the area but make up only for one quarter of all buildings. Therefore, one of the tasks of this inquiry, the assessment of as much of the total heat demand while focusing on the largest heat consumers first, has been achieved.

With the data gathered during the inquiry, a detailed knowledge of the heating systems, the buildings' structures, the heat demand and the heating behavior of the buildings in downtown Santa Fe is now available. Several different building types were visited and categorized in groups.

The available weather data and the trend of the daily heating degrees show that there is no space heating required from June to August, with little heat required in September and May. The actual heating season begins later than September and usually ends earlier than May. The daily heating degrees per month were used to check the trend of the monthly heat demand of the buildings. With the exception of a few buildings the monthly heat demand fit within the pattern generated from the daily heating degrees.

In addition to this technical data a lot of information was collected directly from the operators, owners or maintenance personnel of the heating systems concerning the heating season and the heating behavior per day and week. According to that information and the already mentioned findings from the examination of the daily heating degrees, the main heating season could be identified from October/November to March/April with few buildings require heat from September until May. In a few buildings the heating systems run throughout the year but are used infrequently during summer. Generally, between two heating seasons only heat the domestic hot water supply and pool heating is needed, and most space heating systems are switched off during that period.

Based on the information about fuel consumption, square footage and installed nominal heating capacity of the buildings the specific heat demand, the specific nominal heating capacity and the full load operating hours for every building visited were calculated. The national average values according to [4] for the specific heat demand corresponded with the results achieved from the heat demand inquiry for most of the building categories.

The comparison of the average classification numbers of each building category led to the identification of buildings with implausible heat demand, oversized nominal heating capacity (due to the high altitude of Santa Fe) or other data anomalies. The nominal heating capacity, heat demand and/or square footage of identified buildings were corrected in a way that they corresponded with the average specific classification numbers of the particular building category.

In addition, the fact that most of the heating systems are oversized, to compensate for the heating capacity loss due to the high altitude of Santa F,e was taken into account. Depending on the design altitude of the heating systems, the nominal heating capacity has to be decreased by 7 to 22% to identify the actual nominal heating capacity. Due to the comprehensive amount of work which had to be performed within the heat demand inquiry, it was not possible to evaluate the correction factor for every heating system within the target area, so an average correction factor of 12% (which represents an adjustment of 3,500 ft, which is half the altitude of Santa Fe) was used to adjust the oversized heating systems. A more detailed investigation will be carried out if a biomass district heating system is realized.

The specific heat demand and the specific nominal heating capacity were also used to extrapolate the heat demand and nominal heating capacity of buildings that weren't visited or from which data was not available. Moreover, apart from existing buildings, the potential of buildings to be constructed in the near future was also considered in the extrapolation. Furthermore, the substitutable heat demand and the connected heat load potential (substitutable nominal heating capacity) of all buildings within the target area was determined. Table 50 gives an overview of the connected heat load potential and the annual heat demand within the target area. Close to 70% 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, downtown Santa Fe

	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
CATEGORY	**[BTU/hr]**	**[kW]**	**[BTU/yr]**	**[kWh/yr]**
Visited Buildings	162,241,023	47,548	172,067,729,550	50,427,889
Other existing Building	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%. This amount of natural gas represents CO_2-emissions of 19,084 short tons/17,313 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 district heating system a significant amount of these emissions can be reduced. A more detailed investigation regarding 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.

Large and medium sized hotels (26.0%), office buildings (22.3%) and schools (6.0%) account for more than 56.3% of the total heat demand within the target area but make up only 15.6% of all buildings. Therefore, the acquisition of customers should focus first on these categories and a few large commercial buildings before customers in other categories are pursued.

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 because 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) can be expected.

The relatively short heating season and the fact that all heating systems have to be able to maintain a pleasant room temperature on the few very cold days per year lead to high specific heating capacities of the buildings but relatively low full load operating hours of the heating systems. The full load operating hours of all buildings with a substitutable heat demand average 1,027 hours.

Low full load operating hours at the clients also leads to low boiler full load operating hours for the heating plant. The lower the full load operating hours, the higher are the specific investment costs per produced BTU heat will be. Therefore, a correct design of the biomass heating plant (biomass-fired boiler for base load coverage, gas fired boiler for peak load coverage and back-up) is essential to increase the full load operating hours of the biomass-fired boiler. Furthermore, it will be very important for the economic success of this project to look for process heat consumers that need heat throughout the year, to increase the annual utilization rate of the heating plant.

The trend of the annual heat demand based on monthly averages of all buildings visited also indicates low full load operating hours, with the minimum monthly heat demand making up 18% of the highest monthly heat demand. 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 unvisited buildings are residential and commercial buildings with a low heat demand during the warmer months. The difference between the highest and the lowest heat demand on an hourly scale 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 calculation of the network of pipes.

Table 51: Average full load operating hours for different building categories, downtown Santa Fe

Boiler full load operating hours based on the connected heat load potential and the substitutable heat demand

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

5.2 Other Areas (Potential Sites for Micro Grids)

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

Los Arroyos Home Owners Association

The apartment complex with seven apartment buildings and one administration building with an indoor swimming pool is a very promising site for a micro grid. Table 52 shows the most important results gained during the heat demand inquiry.

Table 52: Connected heat load potential and substitutable annual heat demand within the target area, Los Arroyos Home Owners Association

CATEGORY	CONNECTED HEAT LOAD [BTU/hr]	[kW]	SUBSTITUT. HEAT DEMAND [BTU/yr]	[kWh/yr]
All Buildings	6,232,593	1,834	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%. This amount of natural gas represents CO_2-emissions of 525 short tons/477 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.

The average full load operating hours of the Los Arroyos apartment block is 989 hours. Low full load operating hours at the clients also mean low boiler full load operating hours for the heating plant. The lower the full load operating hours the higher the specific investment costs per produced BTU heat will be. Therefore, a correct design of the biomass heating plant (biomass-fired boiler for base load coverage, gas fired boiler for peak load coverage and back-up) is essential to increase the boiler full load operating hours of the biomass-fired boiler.

As there aren't any process heat consumers near the apartment complex the only possibility to increase the full load operating hours might be the installation of a heat storage tank which could be loaded in off-peak hours by the biomass boiler and emptied during peak hours. This measure would increase the operating hours and decrease the necessary size of the biomass-fired boiler and thus raise its full load operating hours.

South Capitol Complex

Except for the domestic hot 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 achieved from the heat demand inquiry.

Table 53: Connected heat load potential and substitutable annual heat demand within the target area, South Capitol Complex

	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
CATEGORY	[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%. This amount of natural gas represents CO_2-emissions of 831 short tons/754 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.

The average full load operating hours of the South Capitol Complex equals 790 hours. This number can change if the reason for the low heat demand of the Lujan Building is identified, but will remain comparatively low. To increase the full load operating hours the installation of a heat storage tank is recommended (see also suggestions regarding the Los Arroyos Apartment Complex).

The four office buildings at the South Capitol Complex are connected by a tunnel system. The pipes of the micro grid could be installed in this system which would decrease the investment cost for the micro grid significantly and lead to better economic performance of the heating system.

Santa Fe Community College

Only the heat required to heat domestic hot water in the Visual Arts Center cannot be replaced by district heat supplied by a micro grid. Table 54 shows the most important results achieved from the heat demand inquiry.

Table 54: Connected heat load potential and substitutable annual heat demand within the target area, Santa Fe Community College

	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
CATEGORY	[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%. 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.

The average full load operating hours of the Santa Fe Community College is 2,247 hours. The very high full load operating hours have yet to be verified with the most recent gas bills. If the high heat demand can be verified the Santa Fe Community College would be a promising site for the installation of a biomass-fired micro grid. Furthermore, the main building and the Fitness Education Center are already connected to a small micro grid which reduces the investment cost for the installation of a biomass based micro grid and leads to better economic performance of the heating system.

College of Santa Fe

Due to the fact that not all of the 46 buildings on the campus of the College of Santa Fe could be visited during the heat demand inquiry, the type of the installed heating systems of some buildings could not be specified. Therefore, a substitution rate for the entire campus had to be estimated. Based on the assumption that all larger buildings are equipped with hydronic heating systems, it was estimated that 75% of the installed nominal heating capacity could be replaced by district heat from a micro grid. Table 55 shows the most important results achieved from the heat demand inquiry.

Table 55: Connected heat load potential and substitutable annual heat demand within the target area, College of Santa Fe

	CONNECTED HEAT LOAD		SUBSTITUT. HEAT DEMAND	
CATEGORY	[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%. This amount of natural gas represents CO_2-emissions of 2,179 short tons/1,977 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.

The average full load operating hours at the South Capitol Complex equals 1,306 hours. The full load operating hours have yet to be verified with the most recent gas bills. If the high heat demand is verified, the College Santa Fe would be a promising site for a biomass-fired micro grid. Furthermore, a small micro grid of three buildings already exists on the campus, its existence will decrease the investment cost of installing a biomass based micro grid and lead to better economic performance of the heating system.

5.3 Recommendations

According to the results outlined in this report the following recommendations can be given:

- Generally, the results achieved from the heat demand inquiry show a great potential for the installation of a district heating system as well as several micro grids in the city of Santa Fe. The high heat demand within a relatively small area and the high portion of hydronic heating systems that can be replaced easily with a district heating system are very promising because 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) can be realized.
- Process heat consumers would increase the full load operating hours of the main district heating grid and should therefore be sought after.
- Due to the relatively low number of full load operating hours of most of the systems investigated, a correct design of the biomass district heating system is of utmost importance. The biomass boiler should cover the base load and a gas-fired boiler should be used for peak load coverage and as a back-up system.
- Implementation of a heat storage tank in the district heating system as well as in the micro grids to increase the full load operating hours and reduce the boiler size of the systems should be considered during the design phase of the project.
- From the South Capitol Complex, the Santa Fe Community College and the College of Santa Fe additional detailed data should be collected in order to verify the results achieved.
- The efforts to inform the community and the city, as well as the county and the state officials about the advantages of a biomass district heating system for the city of Santa Fe should be increased in order to promote awareness of the need of such a project and engender support.

APPENDIX

APPENDIX I - List of visited buildings

UNIQUE ID	NAME	TYPE OF BUILDING	HEATED AREA		TOTAL SUBSTITUTABLE HEAT DEMAND		CONNECTED HEAT LOAD	
			[SQ FT]	[m2]	[BTU/yr]	[kWh/yr]	[BTU/hr]	[kW]
001	EL MUSEO CULTURAL	Museum	30,000	2,787	0	0	0	0
002	SANTA FE CLAY	Commercial	9,360	870	0	0	0	0
003	ASIAN ADOBE	Commercial	2,400	223	0	0	0	0
004	RECOLLECTIONS	Commercial	1,250	116	0	0	0	0
005	BARKER REALTY	Offices	10,095	938	0	0	0	0
006	ANTIQUE WAREHOUSE	Commercial	4,200	390	0	0	0	0
007	CASA NOVA	Commercial	2,400	223	0	0	0	0
008	SITE SANTA FE	Museum	18,000	1,672	0	0	0	0
009	RAILYARD RESTAURANT	Restaurant	4,500	418	131,400,000	38,509	128,000	38
010	LA PUERTA	Commercial	12,000	1,115	0	0	0	0
011	BOXES, BUBBLES AND BEANS	Commercial	2,800	260	0	0	0	0
012	LA FONDA	Large_Hotel	155,700	14,465	11,038,345,569	3,235,008	7,539,394	2,210
013	INN ON THE ALAMEDA	Large_Hotel	36,647	3,405	2,099,443,737	615,284	2,507,840	735
014	INN ON THE ANASAZI	Large_Hotel	60,000	5,574	4,101,817,963	1,202,120	2,841,480	833
015	ST FRANCIS SCHOOL	School	36,175	3,361	1,023,798,827	300,045	1,595,160	467
016	OLD VILLAGRA BUILDING	Offices	25,000	2,323	945,000,000	276,951	1,015,200	298
017	NEW VILLAGRA BUILDING	Offices	40,000	3,716	1,512,000,000	443,122	983,000	288
018	BATAAN BUILDING	Offices	105,228	9,776	902,250,000	264,422	2,926,560	858
019	CITY HALL	Offices	45,984	4,272	1,497,289,725	438,811	2,041,200	598
020	SANTA FE PUBLIC LIBRARY	Municipal	20,000	1,858	640,683,415	187,765	489,366	143
021	SWEENEY CENTER	Commercial	60,000	5,574	1,881,486,324	551,407	1,532,200	449
022	LA POSADA	Large_Hotel	103,331	9,599	9,898,030,605	2,900,816	7,490,467	2,195
023	FIRST NORTHERN PLAZA	Commercial	22,500	2,090	573,635,205	168,115	975,856	286
024	NEW MEXICO EDUCATION ASSOC (NEA)	Offices	29,675	2,757	1,121,715,000	328,741	1,706,160	500
025	LAMY & LEW WALLACE BLDG.	Offices	33,119	3,077	1,058,250,000	310,141	1,403,200	411
026	EDUCATIONAL BUILDING	Offices	51,730	4,806	844,236,559	247,420	1,116,000	327
027	SANBUSCO CORP	Shopping_Center	57,375	5,330	0	0	0	0
028+029	FEDERAL POST OFFICE &COURT HOUSE	Offices	145,356	13,504	4,875,650,000	1,428,907	3,572,000	1,047
030	MARIAH PUBLICATIONS (Outside Mag.)	Offices	33,486	3,111	1,100,298,700	322,465	1,099,260	322
031	HOTEL ST. FRANCIS	Large_Hotel	55,221	5,130	2,974,650,000	871,781	3,955,200	1,159
032	ALVORD ELEMENTARY SCHOOL	School	30,730	2,855	413,451,850	121,170	623,602	183
033	CARLOS GILBERT ELEMENTARY SCHOOL	School	47,916	4,451	842,873,753	247,021	1,701,380	499
034	HOTEL PLAZA REAL	Large_Hotel	34,125	3,170	2,265,900,000	664,067	1,849,216	542
035	PLAZA MERCADO	Commercial	80,000	7,432	2,110,421,140	618,501	2,220,739	651
036	PLAZA SENA	Commercial	20,483	1,903	1,814,750,750	531,849	1,192,018	349
037	HOTEL SANTA FE	Large_Hotel	103,073	9,575	2,394,241,860	701,680	2,931,968	859
038	STATE LAND OFFICE	Offices	68,000	6,317	2,570,400,000	753,307	1,810,121	530
039	EL PARADERO HOTEL	Small_Hotel	10,575	982	815,332,500	238,949	476,386	140
040	CAPITOL BUILDING	Offices	160,358	14,897	6,061,532,400	1,776,453	5,796,000	1,699
041	OLD STATE LIBRARY	Offices	58,500	5,435	2,211,300,000	648,066	1,106,000	324
042	GARRET'S DESERT INN	Large_Hotel	40,000	3,716	2,892,185,363	847,613	2,062,704	605
043	THE LENSIC	Theater	30,000	2,787	3,606,665,025	1,057,005	3,360,664	985
044	SCOTTISH RITE TEMPLE	Theater	45,000	4,181	2,491,979,010	730,324	1,462,398	429
045	INN AT THE LORETTO	Large_Hotel	120,000	11,148	6,341,273,379	1,858,437	4,459,370	1,307

APPENDIX I - List of visited buildings (continued)

UNIQUE ID	NAME	TYPE OF BUILDING	HEATED AREA		TOTAL SUBSTITUTABLE HEAT DEMAND		CONNECTED HEAT LOAD	
			[SQ FT]	[m2]	[BTU/yr]	[kWh/yr]	[BTU/hr]	[kW]
046	GRANT AVE ASSOCIATION	Offices	12,950	1,203	463,470,200	135,829	341,000	100
047	INN OF THE GOVERNOR'S	Large_Hotel	46,000	4,273	3,538,174,953	1,036,933	3,363,264	986
048	BICENTENNIAL POOL	Swimming_Pool		0	2,256,005,708	661,168	2,375,530	696
049	ALAMEDA JR HIGH SCHOOL	School	65,000	6,039	1,804,748,604	528,918	2,235,999	655
050	GONZALES ELEMENTARY SCHOOL	School	48,500	4,506	736,872,860	215,955	944,354	277
051	WOOD GORMLEY MIDDLE SCHOOL	School	54,000	5,017	1,692,150,000	495,918	2,102,695	616
053	ELDORADO PARTNERSHIP	Large_Hotel	178,850	16,615	10,830,535,494	3,174,105	10,080,940	2,954
054	MUSEUM OF FINE ARTS	Museum	50,861	4,725	2,913,839,780	853,959	2,090,768	613
055	HEWITT HOUSE	Museum	6,750	627	330,000,000	96,713	245,560	72
056	MUSEUM OF NEW MEXICO / BLOCK HOUSE	Offices	950	88	0	0	0	0
057	STATEWIDE BUILDING	Museum	8,000	743	0	0	0	0
058	PALACE OF THE GOVERNOR'S	Museum	114,200	10,609	6,110,207,901	1,790,719	5,141,760	1,507
059	1ST PRESTBYTARIAN CHURCH	Church	25,700	2,388	852,900,000	249,959	1,349,120	395
060	OTRA VEZ EN SANTA FE	Medium_Size_Hotel	19,078	1,772	1,246,336,280	365,264	1,755,839	515
061	CASA DEL TORO	Small_Hotel	1,750	163	116,572,537	34,164	113,680	33
062	CHAPPELL STREET CASITAS	Small_Hotel	2,200	204	152,775,166	44,774	133,420	39
063	SALVATION ARMY	Commercial	12,000	1,115	246,285,975	72,179	235,036	69
064	LA FAMILIA MEDICAL CARE CENTER	Healthcare	18,000	1,672	708,295,964	207,580	324,000	95
065	FIRST INTERSTATE PLAZA	Commercial	78,351	7,279	3,030,150,000	888,046	2,511,728	736
066	FIRST INTERSTATE PLAZA	Commercial	56,801	5,277	2,216,745,556	649,662	2,400,000	703
067	BANK OF SANTA FE / WELLS FARGO	Commercial	17,200	1,598	621,625,408	182,180	595,834	175
068	SUPREME COURT	Offices	63,900	5,936	2,624,302,770	769,104	3,727,724	1,092
069	HILTON SANTA FE	Large_Hotel	113,441	10,539	5,500,200,000	1,611,944	4,354,130	1,276
070	ZORA ROSA INN	Small_Hotel	25,740	2,391	667,372,142	195,587	319,930	94
072	DE VARGAS MALL	Shopping_Center	290,661	27,002	0	0	0	0
073	DEPT. OF TRANSPORTATION	Offices	207,813	19,306	3,266,723,484	957,379	2,652,048	777
074	FORT MARCY INN	Medium_Size_Hotel	102,700	9,541	1,403,038,745	411,189	1,005,190	295
075	OLD SANTA FE INN	Medium_Size_Hotel	20,543	1,908	863,836,061	253,164	891,520	261
076	TERRETORIAL INN	Small_Hotel	15,000	1,394	639,909,948	187,538	476,560	140
077	DANCING GROUND OF THE SUN	Small_Hotel	10,303	957	740,756,359	217,093	602,500	177
078	SCHOOL FOR THE DEAF	School	192,766	17,908	8,107,672,323	2,376,116	9,637,178	2,824
079	INSTITUTE OF AMERICAN INDIAN ARTS	Museum	22,000	2,044	1,318,118,093	386,301	975,224	286
080	SOLANA CENTER	Shopping_Center	79,000	7,339	700,049,914	205,164	680,903	200
081	SANTA FE REPORTER	Offices	5,000	465	0	0	0	0
082	LA RESIDENCIA / MARION HALL	Offices	150,000	13,935	12,449,828,874	3,648,671	11,718,000	3,434
083	NEW MEXICAN INC	Offices	24,000	2,230	0	0	0	0
084	STATE LABOR BUILDING	Offices	9,151	850	345,907,800	101,375	603,400	177
085	GRANT CORNER INN	Small_Hotel	6,000	557	417,349,664	122,313	370,993	109
086	SF APARTMENTS	Apartments	46,831	4,351	620,953,826	181,983	831,584	244
087	RADIO PLAZA	Commercial	14,400	1,338	0	0	0	0
088	LAUGHLIN BUILDING	Commercial	42,660	3,963	1,011,422,535	296,418	877,000	257
089	PALAZIO FRANCISCO	Commercial	28,800	2,676	0	0	0	0

APPENDIX I - List of visited buildings (continued)

UNIQUE ID	NAME	TYPE OF BUILDING	HEATED AREA		TOTAL SUBSTITUTABLE HEAT DEMAND		CONNECTED HEAT LOAD	
			[SQ FT]	[m2]	[BTU/yr]	[kWh/yr]	[BTU/hr]	[kW]
090	SANTA FE BOYS AND GIRLS CLUB	School	29,000	2,694	225,891,527	66,202	668,080	196
095	ARCHDIOCESE / ST FRANCIS CATHEDRAL	Church	20,160	1,873	1,246,604,250	365,342	1,254,461	368
096	ARCHDIOCESE OF SANTA FE / HALLS	Municipal	2,500	232	0	0	0	0
097	ARCHDIOCESE OF SANTA FE / RECTORY	Municipal	10,700	994	396,646,125	116,245	392,896	115
098	ARCHDIOCESE OF SANTA FE / OFFICE	Offices	3,105	288	164,247,315	48,136	221,060	65
099	COUNTY ADMINISTRATION BUILDING	Offices	57,000	5,295	970,918,000	284,547	1,829,773	536
100	DISTRICT COURT HOUSE	Offices	60,000	5,574	1,708,800,000	500,798	2,271,781	666
101	DISTRICT ATTORNEY	Offices	20,000	1,858	672,198,750	197,001	613,198	180
102	MARCY PLAZA ASSOC	Offices	27,000	2,508	0	0	0	0
103	MARCY PLAZA ASSOC	Offices	23,500	2,183	888,300,000	260,334	725,454	213
104	HENRY FIELD	Residential	1,784	166	68,900,000	20,193	70,160	21
105	JOHN DEMAR	Residential	2,000	186	85,200,000	24,970	95,242	28
106	KOZ CHANNING	Residential	1,000	93	42,600,000	12,485	64,400	19
107	JULIA LARSON	Residential	1,358	126	0	0	0	0
108	JIM HACKLER	Residential	1,680	156	0	0	0	0
109	RICHARD DELGADO	Residential	1,710	159	0	0	0	0
110	MIGUEL ROMERO	Residential	1,800	167	0	0	0	0
111	MARKY STARK	Residential	1,800	167	0	0	0	0
112	JOSEFINE PADILLA	Residential	1,500	139	0	0	0	0
113	CHARLES MONTOYA	Residential	1,620	150	0	0	0	0

APPENDIX II - Recorded Data of the Visited Buildings

Literature

1 New Mexico's Natural Resources 2002, Data and Statistics for 2001. New Mexico Energy, Minerals and Natural Resources Department.

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 The Weather Channel, http://www.weather.com/weather/climatology/daily/USNM0292.

4 USDOE Buildings Energy Databook 2002

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

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

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