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Biomass-Fired District Energy for Santa Fe

Emission Estimate

INTERNAL REPORT

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Abbreviations and Notation

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BTU	British Thermal Unit
CHP	combined heat and power plant
CO	carbon monoxide
CO_2	carbon dioxide
CSF	College of Santa Fe
C_xH_y	hydrocarbons
d.b.	dry base
EIA	US Energy Information Administration
EPA	Environmental Protection Agency
kW	Kilowatt
kWh	Kilowatt-hour
LA	Los Arroyos Compound
MMBTU	1 Million British Thermal Units (=293.07 kWh)
MW	Megawatt
MWh	Megawatt-hour
NCV	net calorific value
NO	nitrogen oxide
NO_2	nitrogen dioxide
NO_x	sum of NO and NO_2
percent (w/w)	weight percent
PM	particulate matter
RY	rail yard
SCC	South Capitol Complex
SFCC	Santa Fe Community College
SNCR	selective non-catalytic reduction
SO_2	sulfur dioxide
w.b.	wet base

Abstract

This report documents the methodology, results, and conclusions for an emission estimate for various options of biomass-fired district energy systems investigated in Santa Fe. The emission estimate is part of the "Biomass-Fired District Energy for Santa Fe" project funded through the U.S. Department of Agriculture, which is an assessment of the feasibility of biomass district energy in downtown Santa Fe. The emission estimate supplies information about the expected environmental impact of biomass energy systems. The study consists of the determination of current emissions within the potential supply areas (base-line), the calculation of the emissions after construction of a biomass-fired district heating system, and the evaluation of the environmental impact of biomass-fired district energy systems by comparing the base-line scenarios with various bioenergy system options.

The results of the micro analysis regarding the main grid options, which considers only local emissions caused directly by the heating devices at the customers and the biomass district heating plant, revealed a significant reduction in CO_2 and hydrocarbon emissions for all options investigated. NO_x and CO emissions would slightly increase and even though total SO_2 and dust emissions of the biomass-fired boilers are low, these emissions would increase compared to the baseline, since natural gas (an almost sulphur and ash free fuel) is substituted. Heat only options showed slightly better results than CHP options, since CHP options require additional fuel for power generation.

The macro analysis regarding the main grid options, which in addition to the micro analysis also considers the emissions caused by fuel supply and by production of the electricity consumed, as well as the substitution of conventionally produced electricity (New Mexican Power supply mix) by green electricity generated in the biomass CHP plant, revealed better results for the CHP options. Total CO_2, CO and hydrocarbon emissions would be reduced significantly by all main grid options investigated. CHP options could additionally achieve a reduction of NO_x and SO_2 emissions due to the substitution of electricity mainly generated from coal with green electricity generated from biomass.

The micro analysis of micro grid options also concluded a significant reduction in CO_2 and hydrocarbon emissions for all options investigated. NO_x, CO, SO_2 and dust emissions of micro grids would increase on a local level, but the total amount of these emissions is low.

The results of the macro analysis of micro grid options showed considerable CO_2 reductions. Moreover, hydrocarbon and CO emissions would be reduced significantly. NO_x emissions will increase slightly compared to the baseline. Emissions of SO_2 and particulate matter (PM) would also rise, but the absolute emission level is low.

The significant reduction of greenhouse gases like CO_2 and hydrocarbons represents the main environmental advantage of the biomass-fired district heating systems investigated. In addition, the reduction of CO_2 emissions can also improve the economic performance of the district heating systems, if tradable CO_2 certificates will be generated. Furthermore, the utilization of a

sustainable and locally available fuel, which's production and transport causes considerably lower emissions in comparison to natural gas, further contributes to a positive environmental impact of biomass-fired energy systems and strengthens the local economy as well as the security of energy supply.

Kurzfassung

Der vorliegende Bericht fasst die Ergebnisse und Schlussfolgerungen der Emissionsprognose für ausgewählte Fernwärme- und Mikronetzvarianten auf Biomassebasis in Santa Fe zusammen. Diese Emissionsprognose ist Teil des vom U.S. Department of Agriculture geförderten Projekts “Biomass-Fired District Energy for Santa Fe”, das die Erstellung einer Machbarkeitsstudie für ein Biomassefernheizwerk in Santa Fe zum Ziel hat. Die Emissionsprognose gibt Aufschluss über die zu erwartenden Umwelteinflüsse der untersuchten Biomassefernwärmevarianten. Die Studie beschäftigt sich mit der Ermittlung der derzeitigen Emissionen innerhalb der potenziellen Fernwärmeversorgungsgebiete (Base-line), der Berechnung der zu erwartenden Emissionen nach Errichtung der Biomasseheizwerke, sowie der Bewertung der Auswirkungen der Biomasseheizwerke auf die Umwelt durch Vergleich der derzeitigen mit den erwarteten zukünftigen Emissionen.

Die regionale Emissionsprognose, in der nur direkte Emissionen der potenziellen Wärmeabnehmer im Versorgungsgebiet und des Heizwerkes berücksichtigt werden, ergab für alle großen Fernwärmevarianten eine deutliche Verringerung der CO_2- und Kohlenwasserstoffemissionen. NO_x- und CO-Emissionen steigen im Vergleich zur Base-line leicht an und trotz der geringen SO_2- und Staubemissionen der Biomassefernheizwerke, erfolgt ein Anstieg dieser Emissionen, da mit Erdgas ein fast schwefel- und aschefreier Brennstoff substituiert wird. Reine Wärmeerzeugungsvarianten zeigen leicht bessere Ergebnisse als Kraft-Wärme-Kopplungs-Varianten (KWK), da diese durch die Stromerzeugung mehr Biomassebrennstoff benötigen.

Bei der überregionalen Emissionsprognose für die großen Fernwärmevarianten, in der zusätzlich zu den in der regionalen Emissionsprognose berücksichtigten direkten Emissionen auch indirekte Emissionen durch die Brennstoffbereitstellung und die Erzeugung von Strom, sowie die Substitution von konventionell erzeugtem Strom (New Mexico Strom-Mix) durch Strom aus Biomasse berücksichtigt wurden, zeigen die KWK-Varianten die besseren Ergebnisse. CO_2-, CO- und Kohlenwasserstoffemissionen können bei allen großen Fernwärmevarianten deutlich reduziert werden. Darüber hinaus kann mit den KWK-Varianten auch eine Reduktion der NO_x- und SO_2-Emissionen erreicht werden, da hauptsächlich aus Kohle erzeugter Strom durch grünen Strom aus Biomasse ersetzt wird.

Die regionale Emissionsbetrachtung für Mikronetze ergab ebenfalls eine deutliche Reduktion der CO_2- und Kohlenwasserstoffemissionen für alle betrachteten Varianten. NO_x- CO-, SO_2- und Staubemissionen steigen allerdings bei der regionalen Betrachtungsweise an, die absoluten Emissionen dieser Komponenten sind aber gering.

Die überregionale Emissionsbetrachtung ergab für Mikronetze auch bedeutende CO_2-Reduktionen. Zusätzlich könnten auch die Kohlenwasserstoff- und CO-Emissionen deutlich gesenkt werden, NO_x-Emissionen würden im Vergleich zur Base-line leicht ansteigen. Die überregionalen SO_2- und Staubemissionen würden ebenfalls ansteigen, jedoch sind die absoluten Emissionen gering.

Insbesondere durch die deutliche Verringerung von Treibhausgasen wie CO_2 und Kohlenwasserstoffen sind die untersuchten Biomassefernwärmesysteme umweltverträglicher als die bestehenden Systeme zu beurteilen. Zusätzlich können die eingesparten CO_2-Emissionen in Form von handelbaren CO_2-Zertifikaten auch zur Verbesserung der wirtschaftlichen Situation der einzelnen Projekte beitragen. Weiters erfolgt durch den Einsatz eines nachhaltigen und lokal verfügbaren Brennstoffs, dessen Bereitstellung deutlich weniger Emissionen verursacht als jene für fossile Brennstoffe, eine deutliche Umweltentlastung sowie eine Stärkung der Volkswirtschaft und eine Verringerung der Importabhängigkeit der Energieversorgung

1 Introduction

This emission estimate report is a component of the project entitled “Biomass-Fired District Heating for Santa Fe” funded by the United States Department of Agriculture. The removal of biomass fuel from the forests of New Mexico can serve a dual function. While providing fuel for a district energy system, thinning forests also reduces the widely publicized fire danger that overburden in forests presents.

The urgent need to thin forests in New Mexico is currently 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 (one of the forest thinning projects investigated in this study is even more costly,) 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 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 this project. In structuring biomass energy systems in New Mexico as powerful tools of economic development, the safety and health of 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 understanding of that process, and to put it into practice locally. In addition, the effects of biomass energy systems on the environment are evaluated.

This report summarizes the investigations regarding the environmental impact of the installation of biomass-fired district energy systems in the City of Santa Fe by comparison of the current emissions of the installed heating systems (base-line) with the projected emissions after the installation of various options of biomass-fired district heating systems investigated. Moreover, the work implemented in this report serves as a basis for further investigations regarding the generation of tradable CO_2 certificates. The results of the emission estimate will also be used to determine the environmental feasibility of the three different approaches (centralized supply via biomass district energy systems or via CHP systems versus decentralized supply via various micro-grids) considered within the project.

2 Objectives

The purpose of this study is to gather and analyze the information and data needed to accurately estimate the emissions of a biomass-fired district energy system for downtown Santa Fe, New Mexico. The results of the emission estimate, including the potential reduction of annual CO_2-emissions allow an evaluation of the environmental impact of the operation of a biomass-fired district heating plant in Santa Fe.

The emission estimate addressed the following specific objectives:

- ***Determination of the current emissions in the respective target areas (base line):*** The study sought to identify the current emissions in the respective target areas (main grid and potential micro grids), using emission intensities of the utilized fuels for every investigated emission. The information about the amount and type of the utilized fuels was gathered through the results of the heat demand inquiry [2] performed in an earlier stage of this project. The values of emission intensities were gathered through studies in Europe or were calculated based on information from environmental agencies in the United States.
- ***Calculation of the emissions after construction of the biomass-fired district heating plant:*** The study sought to calculate the emissions within the respective target areas after the construction of the biomass-fired district heating system, considering the efficiency of the system and a realistic connection rate of the customers. The necessary information was gathered through the results of the preliminary design of the network of pipes and the heating plant [3].
- ***Evaluation of the environmental impact of the biomass-fired district heating system:*** The study sought to evaluate its environmental impact by comparing the baseline with the estimated emissions after the construction of the biomass-fired district heating system.

3 Methodology

3.1 Determination of the Type and Amount of the Currently Utilized Fuels (Base-Line)

The results of the heat demand inquiry [2] regarding the annual fuel consumption of all customers within the respective target areas (main grind and potential micro grid sites) were used to determine the type and amount of the currently utilized fuels.

The fuel consumption of buildings which were not assessed during the heat demand inquiry was calculated by using the estimated heat demand and the estimated average annual utilization rate of the heating system of each building.

3.2 Determination of the Type and Amount of the Utilized Fuels After the Installation of a Biomass-Fired District Heating System

The results obtained from the preliminary design report [3] were used to determine the type and the amount of utilized fuels after the installation of the respective biomass-fired district heating systems. A realistic connection rate of 80% for the main grid and the rail yard, and of 100% for the remaining potential micro grid sites, respectively, was used to determine the heat demand that would be substituted by the district heating system.

The total fuel demand at the district heating plant is then calculated by dividing the substituted heat demand by the annual utilization rate of the district heating system. The split of the annual heat production between biomass-fired and gas-fired boilers at the heating plant was considered to determine the annual fuel demand for biomass and natural gas at the heating plant.

If the connection rate within the supply area was below 100%, the gas demand of buildings not connected to the district heating system was also considered.

3.3 Investigated Emissions and Emission Intensities

The emissions of carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), hydrocarbons (C_xH_y), and particulate matter were considered in the emission estimate. The annual emissions were calculated based on the annual fuel demand and the emission intensity for each parameter.

The emission intensities for gas-fired boilers were taken from a comprehensive Austrian study [4]. For the purpose of this report, the results of that study represent accurate values, since the combustion technology for natural gas used in New Mexico is expected to be similar to Austria. Emission intensities regarding biomass-fired boilers were obtained form [5].

Data regarding the potential offset emissions from electrical power production were gathered from a variety of sources and from conversations with specialists in the field. Sources of information include:

The Environmental Protection Agency's (EPA) Technology Transfer Network [6]

The most important data gathered here consisted of emission factors for coal-fired power plants using a variety of combustion technologies. It was used primarily to estimate hydrocarbon, PM and CO emissions, as other data were available in a complete form from other studies.

US Energy Information Administration (EIA) Website [7]

The website of the US Energy Information Administration (EIA) was also used extensively. This site provided data on total emissions (CO_2, SO_x and NO_x) and total electricity production for the state of New Mexico.

New Mexico State Emissions Bureau [8]

Interviews with staff members of the New Mexico State Emissions Bureau were conducted, primarily with Mike Fowler and Mike Schneider. These interviews made aware of the interpretation of the data collected at the websites mentioned above. Roger Polisar, Environmental Compliance Specialist of the Air Quality Bureau, rounded out these interviews with specific knowledge regarding the combustion technologies used at the San Juan and Four Corners coal-fired power plants.

Abt Associates [9]

This for-profit government and business consulting firm, contracted by the EPA, provided data about the nomenclature used and different varieties of particulate emissions, and suggested methodologies by which to attribute emission factors to total electricity generation. Interviews with the Bethesda, Maryland office of ABT, also resulted in a reference to the database files from which EPA and EIA reports were generated.

United States Public Interest Research Group (PIRG) [10]

PIRG suggested methodologies by which to proceed in the analysis of particulate emissions, and prior studies that PIRG had conducted were used as guidelines.

Emission of **SO_x** was provided for the year 2002 in [7], along with power generation and retail sales of power. The emissions intensity (lbs/MWh) was then calculated by dividing the total emissions by the total electric power generation.

Emission of **NO_x** was also provided in the EIA reports, and total annual tonnage was divided by total electrical power generation to identify an emissions intensity of lbs/MWh.

Total annual emission of **CO_2** was similarly provided by the EIA, and was also divided by the total annual electricity production to identify an emissions intensity expressed in lbs/MWh.

Emission of methane and non-methane **hydrocarbons** was estimated by using the emission factors provided by the EPA. The emission factors are expressed in pounds of emission per ton of coal. To calculate lbs/MWh, the calculations are based on an average net calorific value for coal of 19.8 MMBTU/ton (6,400 kWh/metric ton), and that most coal fired power plants in New

Mexico operate near 30% electric efficiency (no heat utilization). It was therefore estimated that each ton of coal accounts for 1,740 kWh electricity generation. The emissions per ton were therefore divided by 1,740 to identify pounds per kWh and then multiplied by 1000 to identify the pounds of hydrocarbon emissions which result from the production of each MWh.

Particulate matter is divided by the EPA into several categories depending on the size of the particulate. The most common categories are PM10 and PM2.5. In each case, the number in the category name refers to the maximum diameter of particles, in microns, referred to within that classification. Therefore, the emission factors from these two categories were summed to get an overview of total particulate emissions. It was noted that particulate sizes could be higher than 10 microns, but the agencies with which Local Energy consulted did not have statistics on these larger particulates. The total emission of PM2.5 and PM10, in pounds per ton of coal, was used to calculate the pounds of emission per MWh electricity produced using the same formula than mentioned above. Since the results represent uncontrolled particulate emissions, an efficiency of the flue gas cleaning system of almost 99% (baghouse) was assumed to calculate the actual particulate emissions.

CO emissions were estimated also by using emission factors provided by the EPA. Again, the number available from the EPA was expressed in pounds emitted per ton of coal, so the same calculations as those used above were applied.

The EPA provides a variety of emission factors accounting for a great number of ways in which coal is burned to produce electricity. The emission factors used to acquire these data apply to the utilization of pulverized sub-bituminous coal in wall fired combustion systems. The selection of this combustion technology as standard for this study was arrived at through conversations with Roger Polisar [8]. It was also verified by comparison of the sum determined with the data ABT had reported.

Abt Associates had reported on the emission of volatile organic compounds, while the EPA had reported on methane and non-methane compounds. It was difficult to ascertain what exactly volatile organic compounds consisted of, but the total was roughly equivalent to the sum of methane and non-methane compounds. There are also about 25 organic compounds emitted in very small quantities that are not considered within this study.

All emission data were confirmed to be true by cross-reference with the EPA data files from which the EIA reports were generated. The cross-reference material, from the data files pointed out by Abt Associates, consists of charting emissions production by all sources within the state of New Mexico. These data were sorted by Local Energy to isolate the power plant emissions. The resulting subset of data was summed in a new spreadsheet, and emission intensities were calculated based on these sums and the same electricity generation figure used previously, provided by the EPA.

3.4 Emission Estimation

The prediction of emissions is carried out with a specially developed software program. The programme enables the calculation of two different scenarios, described below:

Micro Analysis

In this scenario only direct emissions from the heating plant and the customers of the district heating system (local emissions) are considered for calculating the baseline and the future estimate.

Macro Analysis

In this scenario, in addition to the direct emissions of the plant and from the customers, all emissions which are caused by the fuel supply (fossil fuel which is utilized during the fuel transport and processing) as well as the emissions caused by the electricity which is necessary to run the heating plant (auxiliary energy) are considered (according to the New Mexican power supply mix). In addition, for the CHP plant options investigated, the green electricity produced, which substitutes conventional power production is also considered.

For a correct calculation of the emission estimation the following input parameters are necessary:

- Type and amount of the currently utilized fuels (base-line).
- Type and amount of the utilized fuels after construction of the biomass-fired district heating system.
- The realistic connection rate of the district energy system.
- The average annual utilization rates of the heating systems at the customers.
- The annual utilization rate of the district heating system.
- Emission intensities of all utilized fuels (direct and indirect emissions) and from electric power generation (New Mexican power supply mix).
- Nominal heating capacities of the installed boilers at the district heating plant.
- Specifications of the combustion technology and the flue gas cleaning system of the district heating plant.

The program compares the emission estimation between the status-quo (baseline) and the future scenario. For every option considered, the local impact of direct emissions (micro analysis) as well as the total effects (macro analysis) were estimated. The results were prepared as tables and charts (percentage and absolute values). See Section 4.4 for more details.

4 Results

4.1 Type and Amount of Currently Utilized Fuels (Base-Line)

Natural gas is the predominant fuel in Santa Fe. A few buildings within the supply area of the district heating plant are heated electrically. Since electrically heated systems are considered non-substitutable by district heating, they were neither considered in the base line scenario nor in the future scenario. All other non-substitutable heating devices were also not considered in the calculations.

The annual utilization rate of the heating systems of the customers was calculated as described in [2], Section 3.5, Step 5.

4.1.1 Main Grid

Two possible options for the main grid were investigated. See [3] for more details. Option 1 represents the main district heating system with the waste transfer station northwest of downtown Santa Fe as the possible site of the heating plant. Option 2 represents the main district heating system with the site of the former coal fired power plant southwest of downtown Santa Fe as the possible site of the heating plant. Table 1 shows the current fuel demand of all substitutable heating devices in the target area of the two respective options for the main grid.

Table 1: Type and Amount of Currently Utilized Fuels within the Supply Area of the Main Grid

Option	Used Fuel	Annual Utilization Rate	Fuel Demand [MMBTU/yr]	Fuel Demand [MWh/yr]
Option 1	natural gas	75%	287,241	84,182
Option 2	natural gas	75%	276,944	81,164

Notes: Only the fuel demand of substitutable heating devices within the respective supply areas is listed in the table. Option 1 represents the option with the waste transfer station as the possible site of the heating plant. Option 2 represent the option with the site of the former coal-fired power plant as the possible site of the heating plant. The annual utilization rates are based on the results of the heat demand inquiry [2] and refer to the whole biomass district heating system (energy conversion and heat distribution); the fuel demand refers to the net calorific value (NCV).

4.1.2 Micro Grid Sites

Five micro grid options were investigated in the Preliminary Design Report [3]. Los Arroyos Compound, South Capitol Complex, Santa Fe Community College und College of Santa Fe represent stand-alone micro grid solutions outside the supply area of the main grid. The micro grid at the rail yard is located within the supply area of the main grid. Since the rail yard can be considered as a first step towards a main grid for downtown Santa Fe, it is also investigated as a micro grid option. Table 2 gives an overview of the type and amount of utilized fuels within the investigated micro grids.

Table 2: Type and Amount of Currently Utilized Fuels within the Investigated Micro Grids

Option	Used Fuel	Annual Utilization Rate	Fuel Demand [MMBTU/yr]	Fuel Demand [MWh/yr]
LA	natural gas	75%	8,217	2,408
SCC	natural gas	75%	13,305	3,899
CSF	natural gas	72%	11,531	3,379
SFCC	natural gas	77%	36,922	10,821
RY	natural gas	75%	34,619	10,146

Notes: "LA" represents Los Arroyos Compound. "SCC" represents South Capitol Complex. "SFCC" represents Santa Fe Community College. "CSF" represents College of Santa Fe. "RY" represents rail yard. The annual utilization rates are based on the results of the heat demand inquiry. and refer to the whole biomass micro grid system (energy conversion and heat distribution); the fuel demand refers to the net calorific value (NCV).

4.2 Type and Amount of Utilized Fuels After the Installation of a Biomass-Fired District Heating System

4.2.1 Main Grid

The high annual heat demand of the two options for the main district heating grid in Santa Fe implies a high annual fuel demand of the heating plant. Therefore, a wide selection of different fuel sources is needed to provide a secure fuel supply throughout the year. This leads to fluctuations in fuel type (wood chips, sawdust, bark) and fuel quality (moisture content, ash content, particle size etc.) which has to be considered regarding the estimation of the emissions of the biomass-fired district heating plant.

A fuel mix consisting of the weighted averages of all biomass samples analyzed (Fuel mix 1 consisting of bark, wood chips and sawdust, as defined in the Fuel Study [11]) was therefore used for the calculations. A content of 25% bark in the fuel mix was assumed to estimate the emission intensity of SO_2. See also Section 4.3.

A realistic connection rate of 80% (i.e. 80% of the substitutable heat demand within the supply area is replaced by district energy) was assumed to calculate the fuel demand after the construction of the biomass district heating plant. See Section 3.2 as well as Table 3 for more details.

Table 3: Input Parameters for the Calculation of the Fuel Demand after the Construction of the Biomass District Heating Plant - Main Grid Santa Fe

	Connection Rate	Annual Utilization Rate		Heat Generation at Heating Plant/CHP	
Option		Gas Boilers	Grid	Biomass	Natural Gas
Option 1a	80.0%	75.0%	81.1%	93.2%	6.8%
Option 1b	80.0%	75.0%	81.1%	93.8%	6.2%
Option 2a	80.0%	75.0%	85.4%	92.3%	7.7%
Option 2b	80.0%	75.0%	85.4%	92.2%	7.8%

Notes: "Option 1a" represents Option Waste Transfer Station, Heat only. "Option 1b" represents Option Waste Transfer Station, CHP. "Option 2a" represents Option Coal-Fired Power Plant, Heat only. "Option 2b" represents Option Coal-Fired Power Plant, CHP. Data derived from [3].

Table 4 gives an overview of the type and amount of utilized fuels after the construction of a biomass-fired district heating plant. For both options, a heat only production and a combined heat and power production were investigated. For a more detailed description of the respective options, see [3].

Table 4: Type and Amount of Utilized Fuels after the Installation of a Biomass-Fired District Heating System - Main Grid Santa Fe

	Biomass Demand		Natural Gas Demand	
Option	[MMBTU/yr]	[MWh/yr]	[MMBTU/yr]	[MWh/yr]
Option 1a	216,287	63,387	76,674	22,471
Option 1b	260,595	76,372	74,973	21,972
Option 2a	196,210	57,503	75,871	22,236
Option 2b	230,506	67,554	75,082	22,004

Notes: "Option 1a" represents Option Waste Transfer Station, Heat only. "Option 1b" represents Option Waste Transfer Station, CHP. "Option 2a" represents Option Coal-Fired Power Plant, Heat only. "Option 2b" represents Option Coal-Fired Power Plant, CHP. The annual fuel demand was calculated based on the procedure outlined in Section 3.2, using the input parameters listed in Table 3. For options 1b and 2b the fuel demand for combined heat and power generation was considered.

Table 4 shows that the natural gas demand for all options is almost equal. Whereas the biomass demand for Option 1 is about 10% higher than for Option 2. This is caused as a result of the consideration of different supply areas (different numbers of customers) and different lengths of pipe networks which led to different heat losses.

4.2.2 Potential Micro Grid Sites

The annual heat demand and annual fuel demand of the micro grid options is significantly lower compared to the two options for the main district heating system in Santa Fe. This allows the selection of biomass sources of a certain fuel type and with a high and constant quality.

A fuel mix consisting of a mixture of sawdust and wood chips with a particle size lower than 2 inches (5 cm) (Fuel mix 2, as defined in the Fuel Study [11]) was therefore used for the calculations. Since no bark is considered in the fuel mix, the emission intensity of SO_2 is lower compared to the fuel mix used for the main grid options. See also Section 4.3 for more details.

Table 5 gives an overview of the input parameters used for the calculation of the fuel demand after construction of the district heating plant. All micro grid options except for the rail yard were designed with a realistic connection rate of 100%. The rail yard option can be seen as a first step towards a main grid and therefore the realistic connection rate was assumed with 80%.

Table 5: Input Parameters for the Calculation of the Fuel Demand after the Construction of the Biomass District Heating Plant - Potential Micro Grid Sites

Option	Connection Rate	Annual Utilization Rate		Heat Generation at Heating Plant/CHP	
		Gas Boilers	Grid	Biomass	Natural Gas
LA	100.0%	75.0%	93.2%	88.4%	11.6%
SCC	100.0%	75.0%	92.0%	82.6%	17.4%
SFCC	100.0%	75.0%	96.4%	96.0%	4.0%
CSF	100.0%	75.0%	86.6%	92.0%	8.0%
RY	80.0%	75.0%	73.4%	93.5%	6.5%

Notes: "LA" represents Los Arroyos Compound. "SCC" represents South Capitol Complex. "SFCC" represents Santa Fe Community College. "CSF" represents College of Santa Fe. "RY" represents rail yard. Data derived from [3].

Table 6 gives an overview of the type and amount of utilized fuels after the construction of a biomass-fired district heating plant. For a more detailed description of the respective options, see [3].

Table 6: Type and Amount of Utilized Fuels after the Installation of a Biomass-Fired District Heating System - Potential Micro Grid Sites

Option	Biomass Demand [MMBTU/yr]	Natural Gas Demand [MMBTU/yr]	Natural Gas Demand [MWh/yr]
LA	6,604	1,025	300
SCC	10,124	2,517	738
SFCC	31,879	1,558	457
CSF	9,171	1,954	573
RY	29,910	9,369	2,746

Notes: The annual fuel demand was calculated based on the procedure outlined in Section 3.2, using the input parameters listed in Table 5. "LA" represents Los Arroyos Compound. "SCC" represents South Capitol Complex. "SFCC" represents Santa Fe Community College. "CSF" represents College of Santa Fe. "RY" represents rail yard. Data derived from [3].

Table 6 shows that the Micro Grid options "Los Arroyos" and South "Capitol Complex" require the highest relative natural gas demand. Both options are designed with only one biomass boiler. Due to the limited partial-load operation capability of biomass combustion plants, the low base-load (during summer months) must be covered by the gas-fired boiler.

4.3 Emission Intensities

4.3.1 Micro Analysis

Table 7: Characteristic Emission Coefficients of Heat and Power Generation – Micro Analysis

Characteristic Figures of Emissions	Natural Gas	Power Generation	Biomass Boiler Main Grid	Biomass Boiler Micro Grid (LA,SCC,CSF)	Biomass Boiler Micro Grid (SFCC,RY)	Unit
CO_2	64	300	0	0	0	x 10^3 [ton/BTU NCV]
SO_2	2	976	44	28	28	x 10^3 [lb/BTU NCV]
NO_x	140	1,511	224	224	224	x 10^3 [lb/BTU NCV]
C_xH_y	14	15	6	16	10	x 10^3 [lb/BTU NCV]
CO	93	84	160	321	240	x 10^3 [lb/BTU NCV]
PM	1	293	32	192	192	x 10^3 [lb/BTU NCV]
Characteristic Figures of Emissions	**Natural Gas**	**Power Generation**	**Biomass Boiler Main Grid**	**Biomass Boiler Micro Grid (LA,SCC,CSF)**	**Biomass Boiler Micro Grid (SFCC,RY)**	**Unit**
CO_2	55	258	0	0	0	[t/TJ NCV]
SO_2	1	420	19	12	12	[kg/TJ NCV]
NO_x	60	650	96	97	97	[kg/TJ NCV]
C_xH_y	6	7	3	7	4	[kg/TJ NCV]
CO	40	36	69	138	103	[kg/TJ NCV]
PM	1	126	14	83	83	[kg/TJ NCV]

Notes: "LA" represents Los Arroyos Compound. "SCC" represents South Capitol Complex. "SFCC" represents Santa Fe Community College. "CSF" represents College of Santa Fe. "RY" represents rail yard. Emission intensities consider all emissions which are caused by the energy conversion as well as by the heat distribution. Emission intensities which were used in the estimation concerning the gas fired boilers were taken from [4]. Emission intensities concerning the biomass fired boilers were taken from [5] under consideration of the combustion and the gas cleaning technologies selected according to [2]. The emission coefficients for carbon dioxide (CO2) are zero for renewable resources under certain conditions [12.]. The emission coefficients regarding the electricity consumption (auxiliary energy) and power generation are acquired values, which were derived from different sources, basically from the US Energy Information Administration (EIA) website [7] and the Environmental Protection Agency's (EPA)[6] and refer to the New Mexican power supply mix.

Differences of the emission intensities shown in Table 7 between main grids and micro grids are caused by different flue gas cleaning systems and different process control technologies applied. Also the different biomass fuels utilized for the main grids and the micro grids influence the emission intensities. The main grid options use mixtures of 25% bark and 75% wood chips and sawdust, the micro grid options use 100% wood chips and sawdust.

4.3.2 Macro Analysis

Table 8: Characteristic Emission Coefficients of Heat and Power Generation – Macro Analysis

Characteristic Figures of Emissions	Natural Gas	Power Generation	Biomass Boiler Main Grid Heat Only	Biomass Boiler Main Grid CHP	Biomass Boiler Micro Grid (LA,SCC,CSF)	Biomass Boiler Micro Grid (SFCC,RY)	Unit
CO_2	69	300	8	10	7	7	x 10^3 [ton/BTU NCV
SO_2	19	976	71	78	50	50	x 10^3 [lb/BTU NCV]
NO_x	170	1,511	308	318	301	301	x 10^3 [lb/BTU NCV]
C_xH_y	1,163	15	23	23	33	26	x 10^3 [lb/BTU NCV]
CO	302	84	180	181	341	260	x 10^3 [lb/BTU NCV]
PM	5	293	42	45	201	201	x 10^3 [lb/BTU NCV]

Characteristic Figures of Emissions	Natural Gas	Power Generation	Biomass Boiler Main Grid Heat Only	Biomass Boiler Main Grid CHP	Biomass Boiler Micro Grid (LA,SCC,CSF)	Biomass Boiler Micro Grid (SFCC,RY)	Unit
CO_2	59	258	7	9	6	6	[t/TJ NCV]
SO_2	8	420	30	33	21	21	[kg/TJ NCV]
NO_x	73	650	132	137	129	129	[kg/TJ NCV]
C_xH_y	500	7	10	10	14	11	[kg/TJ NCV]
CO	130	36	77	78	146	112	[kg/TJ NCV]
PM	2	126	18	19	87	87	[kg/TJ NCV]

Notes: "LA" represents Los Arroyos Compound. "SCC" represents South Capitol Complex. "SFCC" represents Santa Fe Community College. "CSF" represents College of Santa Fe. "RY" represents rail yard. In the macro analyses the emissions caused by fuel supply, electricity consumption (auxiliary energy supply) and power generation are considered in addition to the results of the micro analysis. Emission intensities which were used in the estimation concerning the gas fired boilers were taken from [4]. Emission intensities concerning the biomass fired boilers were taken from [5]. The emission coefficients for carbon dioxide (CO2) are zero for renewable resources under certain conditions [12]. The emission coefficients regarding the power generation are acquired values, which were derived from different sources, basically from the US Energy Information Administration (EIA) website [7] and the Environmental Protection Agency's (EPA)[6].

The different electricity consumption (auxiliary energy supply) and electricity generation (for the CHP options) values of the investigated main and micro grids, which influence the emission intensities, are based on experiences from biomass district heating and CHP plants in Europe [13, 14]. The biomass-fired CHP plants were designed as Organic Ranking Cycle processes (ORC). Electric efficiencies and other details are described in the preliminary design study [3].

4.4 Emission Estimate

4.4.1 Main Grid

4.4.1.1 Waste Transfer Station (WTS): Option Heat Only

4.4.1.1.1 Micro Analysis

Table 9 and Figure 1 show the results regarding the micro analysis of the emission estimate of the option "waste transfer station, heat only".

Table 9: Comparison of Current and Future Emissions after Installation of a Biomass District Heating Plant (WTS – Heat only) – Micro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[t/yr]	16,668.0	4,449.2	-12,218.7	-73.3
SO_2	[kg/yr]	303.1	4,335.8	4,032.7	1,330.7
NO_x	[kg/yr]	18,183.3	21,967.3	3,784.1	20.8
C_xH_y	[kg/yr]	1,818.3	628.0	-1,190.3	-65.5
CO	[kg/yr]	12,122.2	15,690.7	3,568.5	29.4
PM	[kg/yr]	151.5	3,137.5	2,986.0	1,970.6
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[ton/yr]	18,373.4	4,904.5	-13,468.9	-73.3
SO_2	[lb/yr]	668.1	9,558.8	8,890.7	1,330.7
NO_x	[lb/yr]	40,087.4	48,429.9	8,342.5	20.8
C_xH_y	[lb/yr]	4,008.7	1,384.5	-2,624.3	-65.5
CO	[lb/yr]	26,724.9	34,592.3	7,867.3	29.4
PM	[lb/yr]	334.1	6,917.1	6,583.1	1,970.6

Note: The emission coefficients correspond with Table 7. The emissions of the new biomass district heating plant are related to an energy based (NCV) ratio of 93.2% biomass (water content 27 wt.%, w.b.) and 6.8% natural gas utilization.

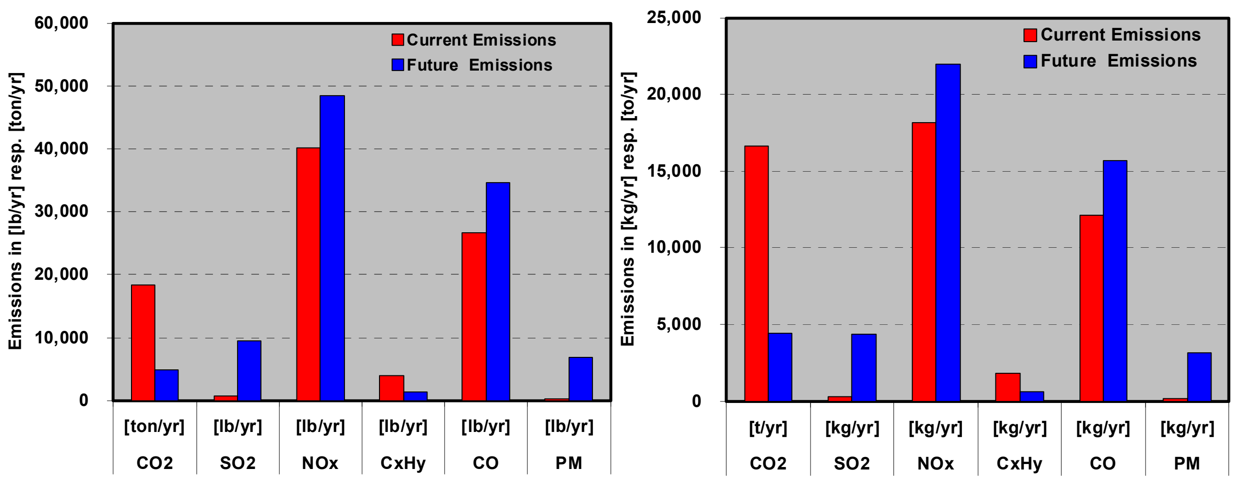


Figure 1: Current and Future Gaseous and Solid Emissions after Installation of a Biomass District Heating Plant (WTS - Heat Only) – Micro Analysis

Note: See notes of Table 9 for details.

The results of the micro analysis shown in Table 9 and Figure 1 indicate that after the installation of the WTS-Heat Only plant option a substantial reduction of CO_2 emissions from about 18,400 tons/yr to 4,900 tons/yr (16,700 metric tons/yr to 4,500 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 13,500 tons/yr (12,200 metric tons/yr) or 73% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Emissions of NO_x and CO will increase slightly on a local level. Emissions of SO_2 and of particulate matter (PM) will also increase on a local level. In this respect it has to be stated that SO_2 and dust emissions of the biomass combustion system investigated are low (efficient flue gas cleaning considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions.

4.4.1.1.2 Macro Analysis

Table 10 and Figure 2 show the results regarding the macro analysis of the emission estimate of the option “waste transfer station, heat only”.

Table 10: Comparison of Current and Future Emissions after Installation of a Biomass District Heating Plant (WTS – Heat only) – Macro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	19,709.6	7,035.3	-12,674.3	-64.3
SO_2	[lb/yr]	5,345.0	15,290.5	9,945.5	186.1
NO_x	[lb/yr]	48,773.0	66,541.1	17,768.1	36.4
C_xH_y	[lb/yr]	334,061.8	5,059.8	-329,002.0	-98.5
CO	[lb/yr]	86,856.1	38,997.4	-47,858.6	-55.1
PM	[lb/yr]	1,336.2	9,192.3	7,856.1	587.9
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	17,880.2	6,382.3	-11,497.9	-64.3
SO_2	[kg/yr]	2,424.4	6,935.6	4,511.2	186.1
NO_x	[kg/yr]	22,123.0	30,182.4	8,059.4	36.4
C_xH_y	[kg/yr]	151,527.1	2,295.1	-149,232.0	-98.5
CO	[kg/yr]	39,397.0	17,688.8	-21,708.2	-55.1
PM	[kg/yr]	606.1	4,169.5	3,563.4	587.9

Note: The emission coefficients correspond with Table 8. The emissions of the new biomass district heating plant are related an energy based (NCV) ratio of 93.2% biomass (water content 27 wt.%, w.b.) and 6.8% natural gas utilization.

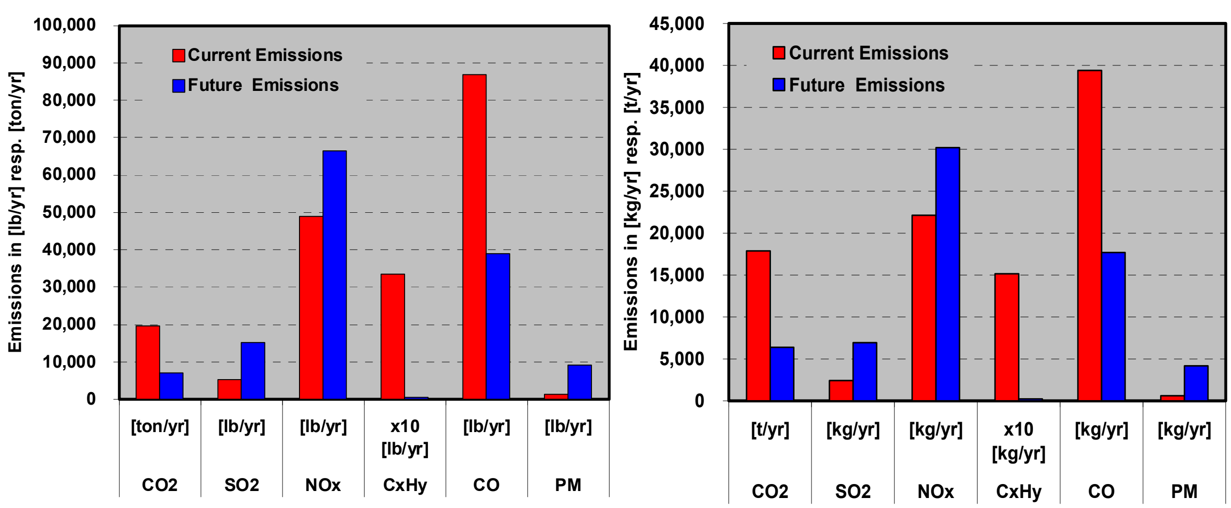


Figure 2: Current and Future Gaseous and Solid Emissions after Installation of a Biomass District Heating Plant (WTS - Heat Only) – Macro Analysis

Note: See notes of Table 10 for details.

The results of the macro analysis shown in Table 10 and Figure 2 indicate that after the installation of the WTS-Heat Only plant option a substantial reduction of CO_2 emissions from about 19,700 tons/yr to 7,000 tons/yr (17,900 metric tons/yr to 6,400 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 12,700 tons/yr (11,500 metric tons/yr) or 64% compared to the base line. In addition, the achievable reduction of hydrocarbon and of CO emissions will be significant. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to the high C_xH_y and CO emissions caused during the production and transport of natural gas. NO_x emissions will increase slightly. Emissions of SO_2 and of particulate matter (PM) will also increase based on the macro analysis. Due to the fact that biomass is a locally available fuel, emissions caused by production and transport are considerably lower in comparison to natural gas, which is obvious when comparing the micro and the macro analysis results.

4.4.1.2 Waste Transfer Station (WTS): Option CHP

4.4.1.2.1 Micro Analysis

Table 11 and Figure 3 show the results regarding the micro analysis of the emission estimate of the option "waste transfer station, CHP".

Table 11: Comparison of Current and Future Emissions after Installation of a Biomass District Heating and CHP Plant (WTS – CHP) – Micro Analysis

Parameter		Current emissions	Future emissions	difference	difference %
CO_2	[ton/yr]	18,373.4	4,795.7	-13,577.7	-73.9
SO_2	[lb/yr]	668.1	11,516.9	10,848.8	1,623.8
NO_x	[lb/yr]	40,087.4	58,348.5	18,261.1	45.6
C_xH_y	[lb/yr]	4,008.7	1,667.8	-2,340.9	-58.4
CO	[lb/yr]	26,724.9	41,677.0	14,952.1	55.9
PM	[lb/yr]	334.1	8,334.1	8,000.0	2,394.8
Parameter		**Current emissions**	**Future emissions**	**difference**	**difference %**
CO_2	[t/yr]	16,668.0	4,350.5	-12,317.4	-73.9
SO_2	[kg/yr]	303.1	5,224.0	4,920.9	1,623.8
NO_x	[kg/yr]	18,183.3	26,466.3	8,283.0	45.6
C_xH_y	[kg/yr]	1,818.3	756.5	-1,061.8	-58.4
CO	[kg/yr]	12,122.2	18,904.3	6,782.1	55.9
PM	[kg/yr]	151.5	3,780.3	3,628.7	2,394.8

Notes: The emission coefficients correspond with Table 7. The emissions of the new biomass district heating and CHP plant are related to an energy based (NCV) ratio of 93.8% biomass (water content 27 wt.%, w.b.) and 6.2% natural gas utilization.

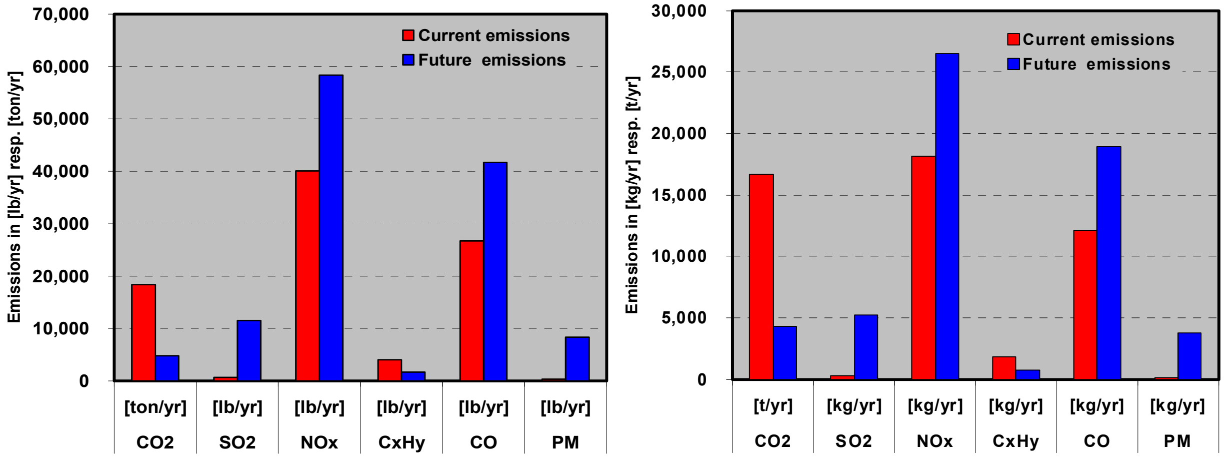


Figure 3: Current and Future Gaseous and Solid Emissions after Installation of a Biomass District Heating and CHP Plant (WTS – CHP) – Micro Analysis

Note: See notes of Table 11 for details.

The results of the micro analysis shown in Table 11 and Figure 3 indicate that after the installation of the WTS-CHP plant option a substantial reduction of CO_2 emissions from about 18,400 tons/yr to 4,800 tons/yr (16,700 metric tons/yr to 4,400 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 13,600 tons/yr (12,300 metric tons/yr) or 74% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Emissions of NO_x and CO will increase on a local level. Emissions of SO_2 and of particulate matter (PM) will also increase. In this respect it has to be stated that SO_2 and dust emissions of the biomass combustion system investigated are low (efficient flue gas cleaning considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions. The higher emissions of the CHP plant in comparison to the heat only option on a local level are due to the additional biomass demand for power generation.

4.4.1.2.2 Macro Analysis

Table 12 and Figure 4 show the results regarding the macro analysis of the emission estimate of the option "waste transfer station, CHP".

Table 12: Comparison of Current and Future Emissions after Installation of a Biomass District Heating and CHP Plant (WTS – CHP) – Macro Analysis

Parameter		Current emissions	Future emissions	Difference	Difference %
CO_2	[ton/yr]	19,709.6	-974.3	-20,683.9	-104.9
SO_2	[lb/yr]	5,345.0	-7,212.9	-12,557.9	-234.9
NO_x	[lb/yr]	48,773.0	46,098.6	-2,674.5	-5.5
C_xH_y	[lb/yr]	334,061.8	6,300.1	-327,761.7	-98.1
CO	[lb/yr]	86,856.1	49,719.3	-37,136.8	-42.8
PM	[lb/yr]	1,336.2	3,974.5	2,638.3	197.4
Parameter		**Current emissions**	**Future emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	17,880.2	-883.8	-18,764.0	-104.9
SO_2	[kg/yr]	2,424.4	-3,271.7	-5,696.1	-234.9
NO_x	[kg/yr]	22,123.0	20,909.9	-1,213.1	-5.5
C_xH_y	[kg/yr]	151,527.1	2,857.6	-148,669.4	-98.1
CO	[kg/yr]	39,397.0	22,552.2	-16,844.9	-42.8
PM	[kg/yr]	606.1	1,802.8	1,196.7	197.4

Notes: The emission coefficients correspond with Table 8 .The emissions of the new biomass district heating and CHP plant are related to an energy based (NCV) ratio of 93.8% biomass (water content 27 wt.%, w.b.) and 6.2% natural gas utilization.

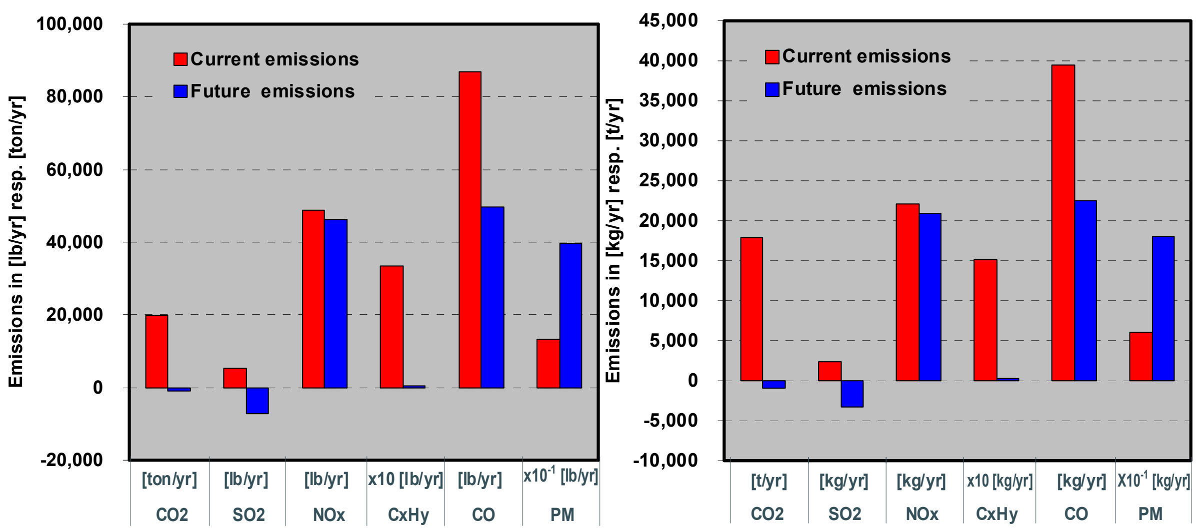


Figure 4: Current and Future Gaseous and Solid Emissions after Installation of a Biomass District Heating and CHP Plant (WTS – CHP) – Macro Analysis

Note: See notes of Table 12 for details.

The results of the macro analysis shown in Table 12 and Figure 4 indicate that after the installation of the WTS-Heat CHP-plant option a substantial reduction of CO_2 emissions from about 19,700 tons/yr to -1,000 tons/yr (17,900 metric tons/yr to -900 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 20,700 tons/yr (18,800 metric tons/yr) or 105% compared to the base line. In addition, the achievable reduction of hydrocarbon, of CO and of SO_2 emissions will be significant. Moreover, NO_x emissions also decrease slightly. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to the high C_xH_y and CO emissions caused during the production and transport of fossil fuels. The emission reduction concerning SO_2 and NO_x is due to the comparably high SO_2 and NO_x emissions caused by fossil fuel fired power stations. Only the emissions of particulate matter (PM) will increase based on the macro analysis.

Negative values in Table 12 and Figure 4 are caused by the substitution of electricity, which is currently generated by power plants fired with fossil fuels. This New Mexican power plant mix causes considerably higher CO_2, SO_2, NO_x and dust emissions than the biomass CHP system, which can even result in negative emissions compared to the baseline. Moreover, due to the fact that biomass is a locally available fuel, the emissions caused by production and transport are considerably lower in comparison to fossil fuels, which also influences the results of the macro analysis.

By comparing the results of the micro and macro analysis concerning the WTS-Heat-only and the WTS-CHP option, it becomes obvious that on a local level the heat only solution is the environmentally better option. If all direct and indirect emissions caused by heat and power generation are considered (macro analysis), the CHP option shows clear environmental advantages.

4.4.1.3 Former Coal-Fired Power Plant (CFPP): Option Heat Only

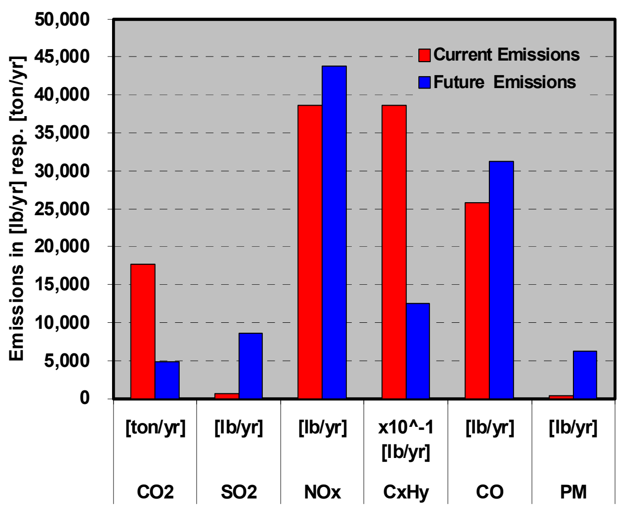
4.4.1.3.1 Micro Analysis

Table 13 and Figure 5 show the results regarding the micro analysis of the emission estimate of the option “former coal-fired power plant, heat only”.

Table 13: Comparison of Current and Future Emissions after Installation of a Biomass District Heating Plant (CFPP – Heat only) – Micro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	17,714.8	4,849.1	-12,865.6	-72.6
SO_2	[lb/yr]	644.2	8,645.2	8,001.0	1,242.1
NO_x	[lb/yr]	38,650.4	43,801.8	5,151.4	13.3
C_xH_y	[lb/yr]	3,865.0	1,252.2	-2,612.8	-67.6
CO	[lb/yr]	25,767.0	31,286.5	5,519.6	21.4
PM	[lb/yr]	322.1	6,256.0	5,933.9	1,842.3
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	16,070.5	4,399.0	-11,671.5	-72.6
SO_2	[kg/yr]	292.2	3,921.4	3,629.2	1,242.1
NO_x	[kg/yr]	17,531.4	19,868.1	2,336.6	13.3
C_xH_y	[kg/yr]	1,753.1	568.0	-1,185.1	-67.6
CO	[kg/yr]	11,687.6	14,191.3	2,503.6	21.4
PM	[kg/yr]	146.1	2,837.7	2,691.6	1,842.3

Note: The emission coefficients correspond with Table 7. The emissions of the new biomass district heating plant are related to an energy based (NCV) ratio of 92.3% biomass (water content 27 wt.%, w.b.) and 7.7% natural gas utilization.



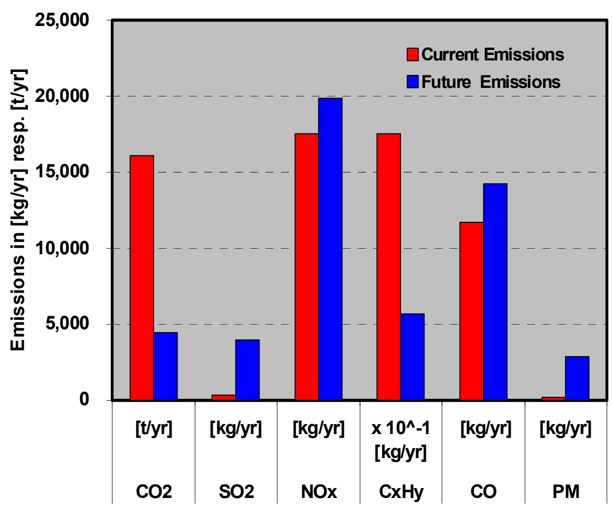


Figure 5: Current and Future Gaseous and Solid Emissions after Installation of a Biomass District Heating Plant (CFPP – Heat only) – Micro Analysis

Note: See notes of Table 13 for details.

The results of the micro analysis shown in Table 13 and Figure 5 indicate that after the installation of the CFPP-Heat Only plant option a substantial reduction of CO_2 emissions from about 17,700 tons/yr to 4,800 tons/yr (16,100 metric tons/yr to 4,400 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 12,900 tons/yr (11,700 metric tons/yr) or 73% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Emissions of NO_x and CO will increase slightly on a local level. Emissions of SO_2 and of particulate matter (PM) will also increase on a local level. In this respect it has to be stated that the SO_2 and dust emissions of the biomass combustion system investigated are low (efficient flue gas cleaning considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions.

4.4.1.3.2 Macro Analysis

Table 14 and Figure 6 show the results regarding the macro analysis of the emission estimate of the option "former coal-fired power plant, heat only".

Table 14: Comparison of Current and Future Emissions after Installation of a Biomass District Heating Plant (CFPP – Heat only) – Macro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	19,003.1	6,806.4	-12,196.7	-64.2
SO_2	[lb/yr]	5,153.4	13,829.1	8,675.7	168.3
NO_x	[lb/yr]	47,024.7	60,182.1	13,157.5	28.0
C_xH_y	[lb/yr]	322,086.9	4,583.7	-317,503.2	-98.6
CO	[lb/yr]	83,742.6	35,272.0	-48,470.6	-57.9
PM	[lb/yr]	1,288.3	8,313.7	7,025.4	545.3
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	17,239.3	6,174.6	-11,064.6	-64.2
SO_2	[kg/yr]	2,337.5	6,272.7	3,935.2	168.3
NO_x	[kg/yr]	21,329.9	27,298.0	5,968.1	28.0
C_xH_y	[kg/yr]	146,095.4	2,079.1	-144,016.3	-98.6
CO	[kg/yr]	37,984.8	15,999.0	-21,985.8	-57.9
PM	[kg/yr]	584.4	3,771.0	3,186.6	545.3

Note: The emission coefficients correspond with Table 8. The emissions of the new biomass district heating plant are related to an energy based (NCV) ratio of 92.3% biomass (water content 27 wt.%, w.b.) and 7.7% natural gas utilization].

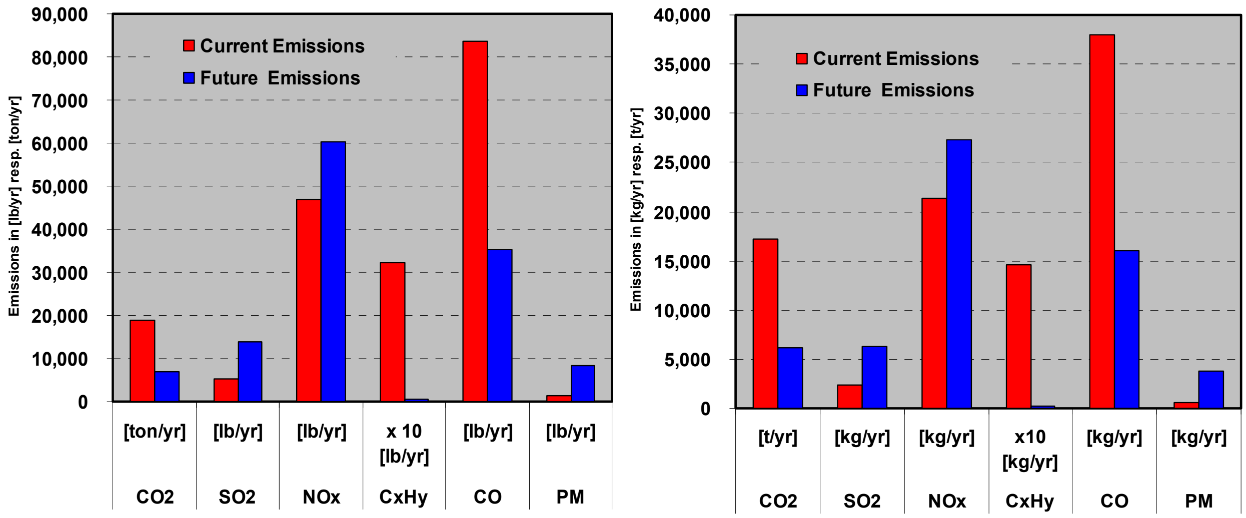


Figure 6: Current and Future Gaseous and Solid Emissions after Installation of a Biomass District Heating Plant (CFPP – Heat only) – Macro Analysis

Note: See notes of Table 14 for details.

The results of the macro analysis shown in Table 14 and Figure 6 indicate that after the installation of the CFPP -Heat Only plant option a substantial reduction of CO_2 emissions from about 19,000 tons/yr to 6,800 tons/yr (17,200 metric tons/yr to 6,200 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 12,200 tons/yr (11,000 metric tons/yr) or 64% compared to the base line. In addition, the achievable reduction of hydrocarbon and of CO emissions will be significant. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to the high C_xH_y and CO emissions caused during the production and transport of natural gas. NO_x emissions will increase slightly. Emissions of SO_2 and of particulate matter (PM) will also increase based on the macro analysis. Due to the fact that biomass is a locally available fuel, the emissions caused by production and transport are considerably lower in comparison to natural gas, which is obvious when comparing the micro and the macro analysis results.

4.4.1.4 Former Coal-Fired Power Plant (CFPP): Option CHP

4.4.1.4.1 Micro Analysis

Table 15 and Figure 7 show the results regarding the macro analysis of the emission estimate of the option “former coal-fired power plant, CHP”.

Table 15: Comparison of Current and Future Emissions after Installation of a Biomass District Heating and CHP Plant (CFPP – CHP) – Micro Analysis

Parameter		Current emissions	Future emissions	Difference	Difference %
CO_2	[ton/yr]	17,714.8	4,802.6	-12,912.1	-72.9
SO_2	[lb/yr]	644.2	10,187.2	9,543.0	1,481.4
NO_x	[lb/yr]	38,650.4	51,612.6	12,962.2	33.5
C_xH_y	[lb/yr]	3,865.0	1,475.4	-2,389.6	-61.8
CO	[lb/yr]	25,767.0	36,865.7	11,098.7	43.1
PM	[lb/yr]	322.1	7,371.8	7,049.7	2,188.8
Parameter		**Current emissions**	**Future emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	16,070.5	4,356.9	-11,713.6	-72.9
SO_2	[kg/yr]	292.2	4,620.8	4,328.6	1,481.4
NO_x	[kg/yr]	17,531.4	23,411.0	5,879.5	33.5
C_xH_y	[kg/yr]	1,753.1	669.2	-1,083.9	-61.8
CO	[kg/yr]	11,687.6	16,721.9	5,034.3	43.1
PM	[kg/yr]	146.1	3,343.8	3,197.7	2,188.8

Notes: The emission coefficients correspond with Table 7. The emissions of the new biomass district heating and CHP plant are related to an energy based (NCV) ratio of 92.2% biomass (water content 27 wt.%, w.b.) and 7.8% natural gas utilization.

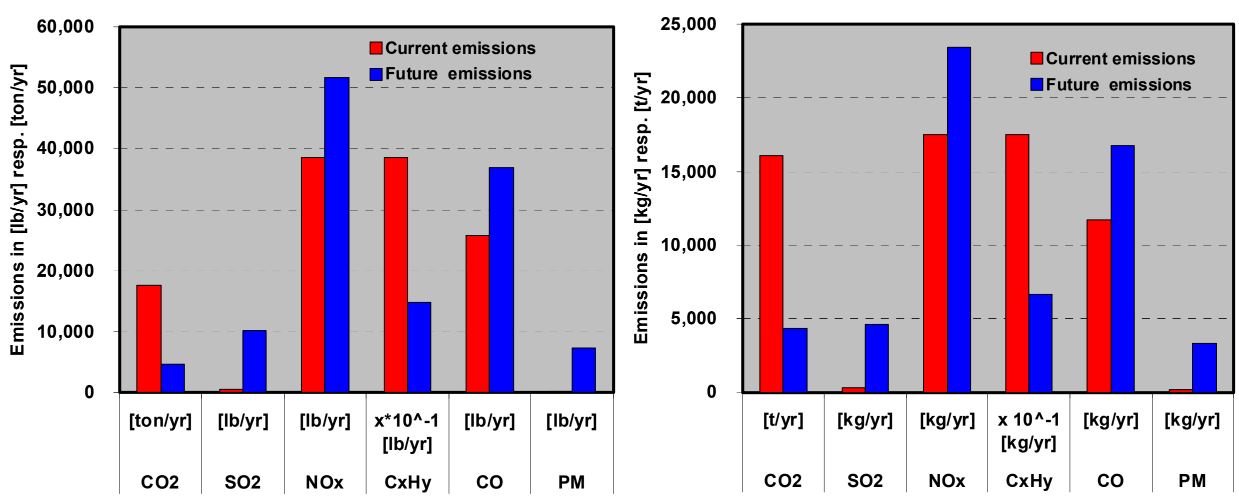


Figure 7: Current and Future Gaseous and Solid Emissions after Installation of a Biomass District Heating and CHP Plant (CFPP – CHP) – Micro Analysis

Note: See notes of Table 15 for details.

The results of the micro analysis shown in Table 15 and Figure 7 indicate that after the installation of the CFPP-CHP plant option a substantial reduction of CO_2 emissions from about

17,700 tons/yr to 4,800 tons/yr (16,100 metric tons/yr to 4,400 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 12,900 tons/yr (11,700 metric tons/yr) or 73% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Emissions of NO_x and CO will increase on a local level. Emissions of SO_2 and of particulate matter (PM) will also increase. In this respect it has to be stated that SO_2 and dust emissions of the biomass combustion system investigated are low (efficient flue gas cleaning considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions. The higher emissions of the CHP plant in comparison to the heat only option on a local level are due to the additional amount of biomass required for electricity generation.

4.4.1.4.2 Macro Analysis

Table 16 and Figure 8 show the results regarding the macro analysis of the emission estimate of the option "former coal-fired power plant, CHP".

Table 16: Comparison of Current and Future Emissions after Installation of a Biomass District Heating and CHP Plant (CFPP – CHP) – Macro Analysis

Parameter		Current emissions	Future emissions	Difference	Difference %
CO_2	[ton/yr]	19,003.1	487.3	-18,515.8	-97.4
SO_2	[lb/yr]	5,153.4	-4,069.0	-9,222.4	-179.0
NO_x	[lb/yr]	47,024.7	43,800.2	-3,224.5	-6.9
C_xH_y	[lb/yr]	322,086.9	5,557.3	-316,529.6	-98.3
CO	[lb/yr]	83,742.6	43,691.7	-40,050.9	-47.8
PM	[lb/yr]	1,288.3	4,150.5	2,862.2	222.2
Parameter		**Current emissions**	**Future emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	17,239.3	442.0	-16,797.2	-97.4
SO_2	[kg/yr]	2,337.5	-1,845.7	-4,183.2	-179.0
NO_x	[kg/yr]	21,329.9	19,867.3	-1,462.6	-6.9
C_xH_y	[kg/yr]	146,095.4	2,520.7	-143,574.7	-98.3
CO	[kg/yr]	37,984.8	19,818.1	-18,166.7	-47.8
PM	[kg/yr]	584.4	1,882.6	1,298.3	222.2

Notes: The emission coefficients correspond with Table 8. The emissions of the new biomass district heating and CHP plant are related to an energy based (NCV) ratio of 92.2% biomass (water content 27 wt.%, w.b.) and 7.8% natural gas utilization.

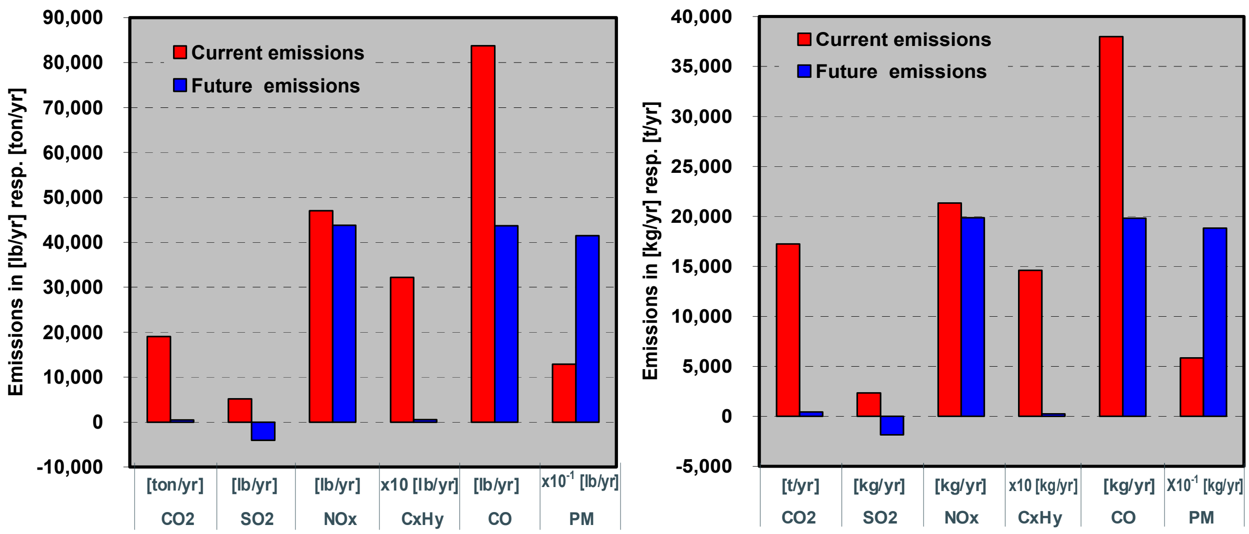


Figure 8: Current and Future Gaseous and Solid Emissions after Installation of a Biomass District Heating and CHP Plant (CFPP – CHP) – Macro Analysis

Note: See notes of Table 16 for details.

The results of the macro analysis shown in Table 16 and Figure 8 indicate that after the installation of the CFPP-CHP plant option a substantial reduction of CO_2 emissions from about 19,000 tons/yr to 500 tons/yr (17,200 metric tons/yr to 400 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 18,500 tons/yr (16,800 metric tons/yr) or 97% compared to the base line. In addition, the achievable reduction of hydrocarbon, of CO and of SO_2 emissions will be significant. Moreover, NO_x emissions also decrease slightly. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to the high C_xH_y and CO emissions caused during the production and transport of fossil fuels. The emission reduction concerning SO_2 and NO_x is due to the comparably high SO_2 and NO_x emissions caused by fossil fuel fired power stations. Only emissions of particulate matter (PM) will increase based on the macro analysis.

Negative values in Table 16 and Figure 8 are caused by the substitution of electricity, which is currently generated by power plants fired with fossil fuels. This New Mexican power plant mix causes considerably higher CO_2, SO_2, NO_x and dust emissions than the biomass CHP system, which can even result in negative emissions compared to the baseline. Moreover, due to the fact that biomass is a locally available fuel, the emissions caused by production and transport are considerably lower in comparison to fossil fuels, which also influences the results of the macro analysis.

By comparing the results of the micro and macro analysis concerning the CFPP-Heat-only and the CFPP-CHP option, it becomes obvious that on a local level the heat only solution is the environmentally better option. If all direct and indirect emissions caused by heat and power generation are considered, the CHP option shows clear environmental advantages.

4.4.2 Potential Micro Grid Sites

4.4.2.1 Los Arroyos

4.4.2.1.1 Micro Analysis

Table 17 and Figure 9 show the results regarding the micro analysis of the emission estimate of the option “Los Arroyos”.

Table 17: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (Los Arroyos) – Micro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	525.6	89.0	-436.6	-83.1
SO_2	[lb/yr]	19.1	174.1	155.0	810.9
NO_x	[lb/yr]	1,146.8	1,400.3	253.4	22.1
C_xH_y	[lb/yr]	114.7	100.0	-14.7	-12.8
CO	[lb/yr]	764.5	2,000.2	1,235.7	161.6
PM	[lb/yr]	9.6	1,200.0	1,190.5	12,457.0
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	476.8	80.7	-396.1	-83.1
SO_2	[kg/yr]	8.7	79.0	70.3	810.9
NO_x	[kg/yr]	520.2	635.1	115.0	22.1
C_xH_y	[kg/yr]	52.0	45.4	-6.6	-12.8
CO	[kg/yr]	346.8	907.3	560.5	161.6
PM	[kg/yr]	4.3	544.3	540.0	12,457.0

Note: The emission coefficients correspond with Table 7. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 88.4% biomass (water content 28 wt.%, w.b.) and 11.6% natural gas utilization.

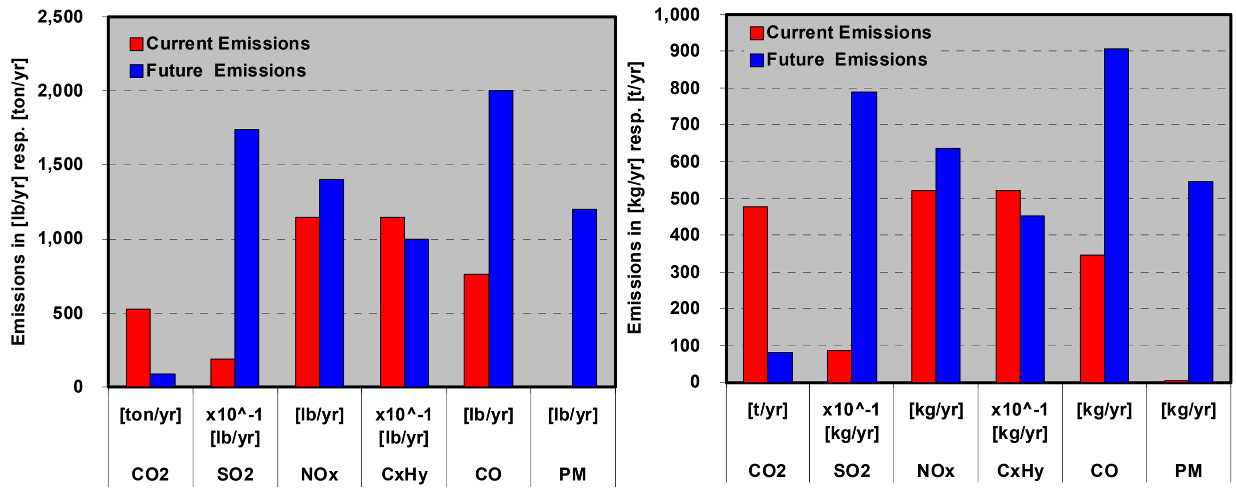


Figure 9: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (Los Arroyos) – Micro Analysis

Note: See notes of Table 17 for details.

The results of the micro analysis shown in Table 17 and Figure 9 indicate that after the installation of the potential micro grid site at Los Arroyos a substantial reduction of CO_2 emissions from about 530 tons/yr to 90 tons/yr (480 metric tons/yr to 80 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 440 tons/yr (400 metric tons/yr) or 83% compared to the base line. In addition, the hydrocarbon emissions will also be reduced. Emissions of NO_x and CO will increase (regarding NO_x only slightly). Emissions of SO_2 and of particulate matter (PM) will also increase on a local level. In this respect it has to be stated that SO_2 and dust emissions of the biomass combustion system investigated are low (efficient combustion and appropriate flue gas cleaning for small-scale systems considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions.

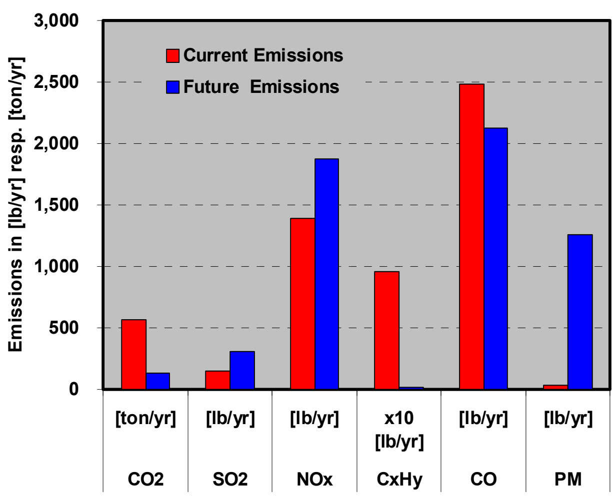
4.4.2.1.2 Macro Analysis

Table 18 and Figure 10 show the results regarding the macro analysis of the emission estimate of the option “Los Arroyos”.

Table 18: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (Los Arroyos) – Macro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	563.9	137.3	-426.6	-75.7
SO_2	[lb/yr]	152.9	308.9	156.0	102.0
NO_x	[lb/yr]	1,395.3	1,875.4	480.1	34.4
C_xH_y	[lb/yr]	9,556.8	204.6	-9,352.2	-97.9
CO	[lb/yr]	2,484.8	2,124.4	-360.3	-14.5
PM	[lb/yr]	38.2	1,256.5	1,218.3	3,186.9
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	511.5	124.5	-387.0	-75.7
SO_2	[kg/yr]	69.4	140.1	70.8	102.0
NO_x	[kg/yr]	632.9	850.7	217.8	34.4
C_xH_y	[kg/yr]	4,334.9	92.8	-4,242.1	-97.9
CO	[kg/yr]	1,127.1	963.6	-163.4	-14.5
PM	[kg/yr]	17.3	569.9	552.6	3,186.9

Note: The emission coefficients correspond with Table 8. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 88.4% biomass (water content 28 wt.%, w.b.) and 11.6% natural gas utilization.



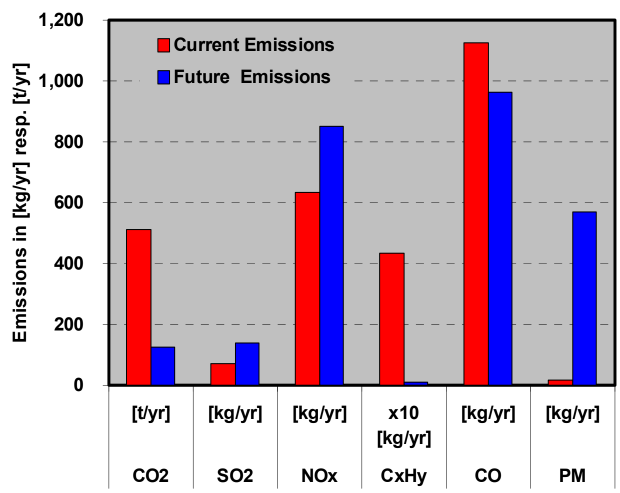


Figure 10: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (Los Arroyos) – Macro Analysis

Note: See notes of Table 18 for details.

The results of the macro analysis shown in Table 18 and Figure 10 indicate that after the installation of the potential micro grid site at Los Arroyos a substantial reduction of CO_2

emissions from about 560 tons/yr to 140 tons/yr (510 metric tons/yr to 120 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 420 tons/yr (390 metric tons/yr) or 76% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Moreover, CO emissions will also be reduced slightly. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to the high C_xH_y and CO emissions caused during the production and transport of natural gas. NO_x emissions will increase slightly. Emissions of SO_2 and of particulate matter (PM) will also increase based on the macro analysis. Due to the fact that biomass is a locally available fuel, the emissions caused by production and transport are considerably lower in comparison to natural gas, which is obvious when comparing the micro and the macro analysis results.

4.4.2.2 South Capitol Complex

4.4.2.2.1 Micro Analysis

Table 19 and Figure 11 show the results regarding the micro analysis of the emission estimate of the option "South Capitol Complex".

Table 19: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (South Capitol Complex) – Micro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	851.0	165.5	-685.6	-80.6
SO_2	[lb/yr]	30.9	280.6	249.7	806.8
NO_x	[lb/yr]	1,856.8	2,257.1	400.3	21.6
C_xH_y	[lb/yr]	185.7	161.2	-24.4	-13.2
CO	[lb/yr]	1,237.9	3,224.2	1,986.3	160.5
PM	[lb/yr]	15.5	1,934.4	1,918.9	12,401.4
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	772.0	150.1	-621.9	-80.6
SO_2	[kg/yr]	14.0	127.3	113.3	806.8
NO_x	[kg/yr]	842.2	1,023.8	181.6	21.6
C_xH_y	[kg/yr]	84.2	73.1	-11.1	-13.2
CO	[kg/yr]	561.5	1,462.5	901.0	160.5
PM	[kg/yr]	7.0	877.4	870.4	12,401.4

Note: The emission coefficients correspond with Table 7. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 82.6% biomass (water content 28 wt. %, w.b.) and 17.4% natural gas utilization.

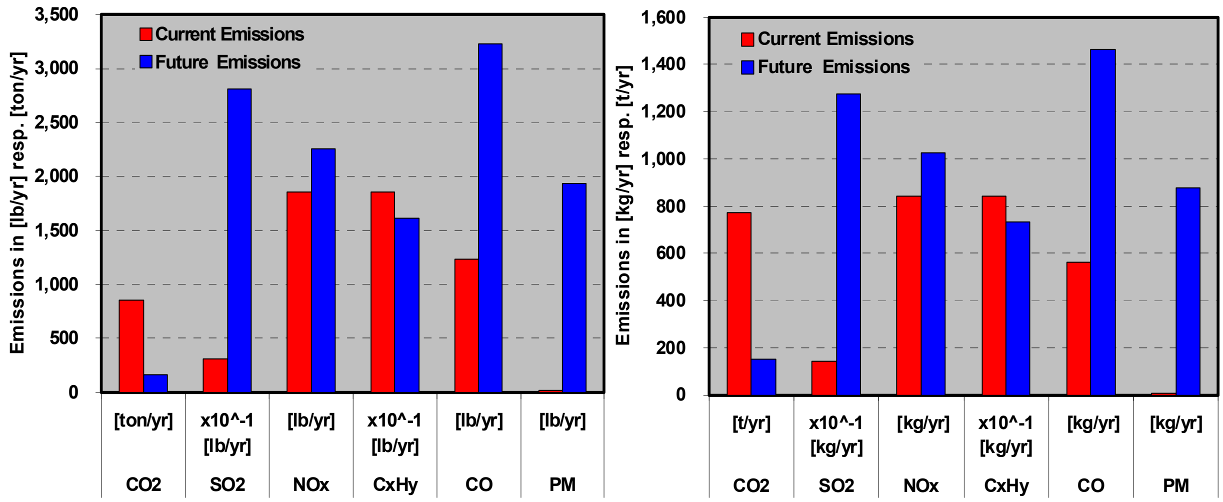


Figure 11: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (South Capitol Complex) – Micro Analysis

Note: See notes of Table 19 for details.

The results of the micro analysis shown in Table 19 and Figure 11 indicate that after the installation of the potential micro grid site at the South Capitol Complex a substantial reduction of CO_2 emissions from about 850 tons/yr to 170 tons/yr (770 metric tons/yr to 150 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 680 tons/yr (620 metric tons/yr) or 81% compared to the base line. In addition, the hydrocarbon emissions will also be reduced. Emissions of NO_x and CO will increase (regarding NO_x only slightly). Emissions of SO_2 and of particulate matter (PM) will also increase on a local level. In this respect it has to be stated that SO_2 and dust emissions of the biomass combustion system investigated are low (efficient combustion and appropriate flue gas cleaning for small-scale systems considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions.

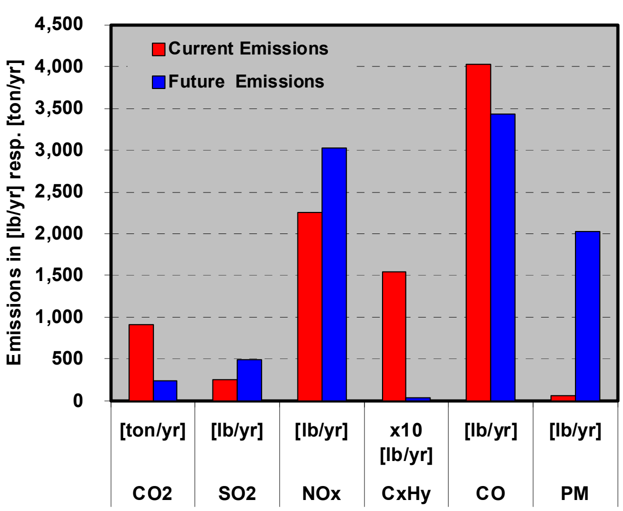
4.4.2.2.2 Macro Analysis

Table 20 and Figure 12 show the results regarding the macro analysis of the emission estimate of the option "South Capitol Complex".

Table 20: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (South Capitol Complex) – Macro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	912.9	244.9	-668.0	-73.2
SO_2	[lb/yr]	247.6	498.0	250.4	101.2
NO_x	[lb/yr]	2,259.1	3,023.0	763.9	33.8
C_xH_y	[lb/yr]	15,473.3	330.2	-15,143.1	-97.9
CO	[lb/yr]	4,023.1	3,424.5	-598.5	-14.9
PM	[lb/yr]	61.9	2,025.4	1,963.5	3,172.4
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	828.2	222.2	-606.0	-73.2
SO_2	[kg/yr]	112.3	225.9	113.6	101.2
NO_x	[kg/yr]	1,024.7	1,371.2	346.5	33.8
C_xH_y	[kg/yr]	7,018.5	149.8	-6,868.8	-97.9
CO	[kg/yr]	1,824.8	1,553.3	-271.5	-14.9
PM	[kg/yr]	28.1	918.7	890.6	3,172.4

Note: The emission coefficients correspond with Table 8. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 82.6% biomass (water content 28 wt.%, w.b.) and 17.4% natural gas utilization.



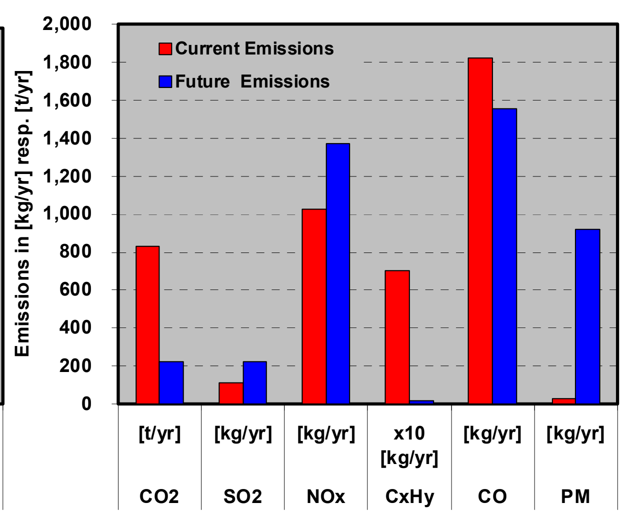


Figure 12: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (South Capitol Complex) – Macro Analysis

Note: See notes of Table 20 for details.

The results of the macro analysis shown in Table 20 and Figure 12 indicate that after the installation of the potential micro grid site at the South Capitol Complex a substantial reduction of CO_2 emissions from about 910 tons/yr to 240 tons/yr (830 metric tons/yr to 220 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 670 tons/yr (610 metric tons/yr) or 73% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Moreover, CO emissions will also be reduced slightly. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to the high C_xH_y and CO emissions caused during the production and transport of natural gas. NO_x emissions will increase slightly. Emissions of SO_2 and of particulate matter (PM) will also increase based on the macro analysis. Due to the fact that biomass is a locally available fuel, the emissions caused by production and transport are considerably lower in comparison to natural gas, which is obvious when comparing the micro and the macro analysis results.

4.4.2.3 Santa Fe Community College

4.4.2.3.1 Micro Analysis

Table 21 and Figure 13 show the results regarding the micro analysis of the emission estimate of the option "Santa Fe Community College".

Table 21: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (Santa Fe Community College) – Micro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	2,354.4	99.6	-2,254.8	-95.8
SO_2	[lb/yr]	85.6	889.8	804.2	939.3
NO_x	[lb/yr]	5,137.0	7,156.0	2,019.1	39.3
C_xH_y	[lb/yr]	513.7	306.7	-207.0	-40.3
CO	[lb/yr]	3,424.7	7,667.1	4,242.4	123.9
PM	[lb/yr]	42.8	6,133.6	6,090.7	14,228.0
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	2,135.9	90.4	-2,045.5	-95.8
SO_2	[kg/yr]	38.8	403.6	364.8	939.3
NO_x	[kg/yr]	2,330.1	3,245.9	915.8	39.3
C_xH_y	[kg/yr]	233.0	139.1	-93.9	-40.3
CO	[kg/yr]	1,553.4	3,477.7	1,924.3	123.9
PM	[kg/yr]	19.4	2,782.1	2,762.7	14,228.0

Note: The emission coefficients correspond with Table 7. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 96.0% biomass (water content 28 wt.%, w.b.) and 4.0% natural gas utilization.

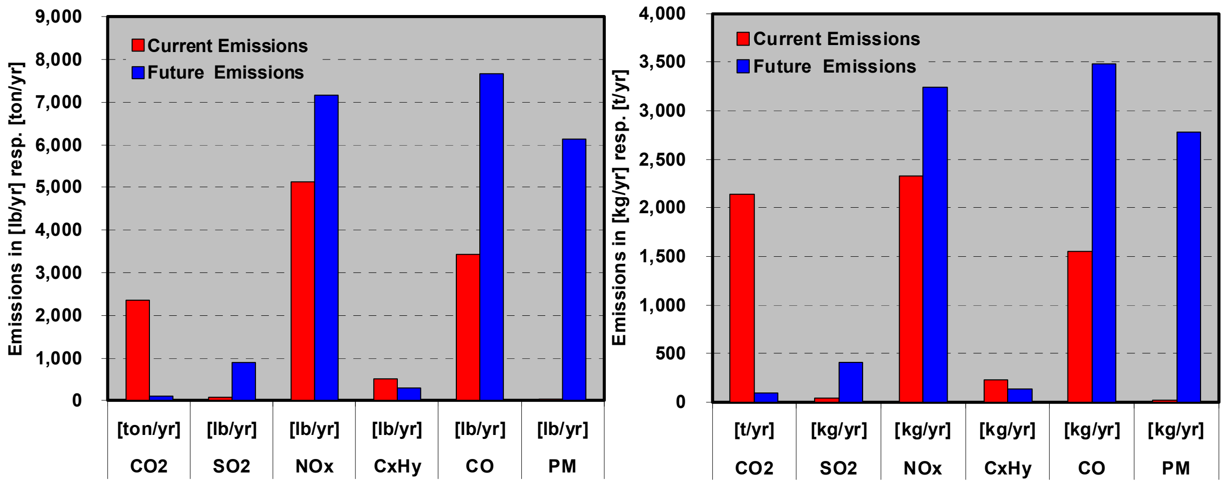


Figure 13: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (Santa Fe Community College) – Micro Analysis

Note: See notes of Table 21 for details.

The results of the micro analysis shown in Table 21 and Figure 13 indicate that after the installation of the potential micro grid site at the Santa Fe Community College a substantial reduction of CO_2 emissions from about 2,350 tons/yr to 100 tons/yr (2,140 metric tons/yr to 90 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 2,250 tons/yr (2,050 metric tons/yr) or 96% compared to the base line. In addition, the hydrocarbon emissions will also be reduced. Emissions of NO_x and CO will increase. Emissions of SO_2 and of particulate matter (PM) will also increase on a local level. In this respect it has to be stated that SO_2 and dust emissions of the biomass combustion system investigated are low (efficient combustion and appropriate flue gas cleaning for small-scale systems considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions.

4.4.2.3.2 Macro Analysis

Table 22 and Figure 14 show the results regarding the macro analysis of the emission estimate of the option “Santa Fe Community College”.

Table 22: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (Santa Fe Community College) – Macro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	2,525.7	320.6	-2,205.0	-87.3
SO_2	[lb/yr]	684.9	1,578.9	894.0	130.5
NO_x	[lb/yr]	6,250.0	9,584.3	3,334.3	53.3
C_xH_y	[lb/yr]	42,808.1	834.8	-41,973.3	-98.0
CO	[lb/yr]	11,130.1	8,300.9	-2,829.2	-25.4
PM	[lb/yr]	171.2	6,422.1	6,250.9	3,650.5
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	2,291.2	290.9	-2,000.4	-87.3
SO_2	[kg/yr]	310.7	716.2	405.5	130.5
NO_x	[kg/yr]	2,834.9	4,347.3	1,512.4	53.3
C_xH_y	[kg/yr]	19,417.3	378.7	-19,038.7	-98.0
CO	[kg/yr]	5,048.5	3,765.2	-1,283.3	-25.4
PM	[kg/yr]	77.7	2,913.0	2,835.3	3,650.5

Note: The emission coefficients correspond with Table 8. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 96.0% biomass (water content 28 wt.%, w.b.) and 4.0% natural gas utilization

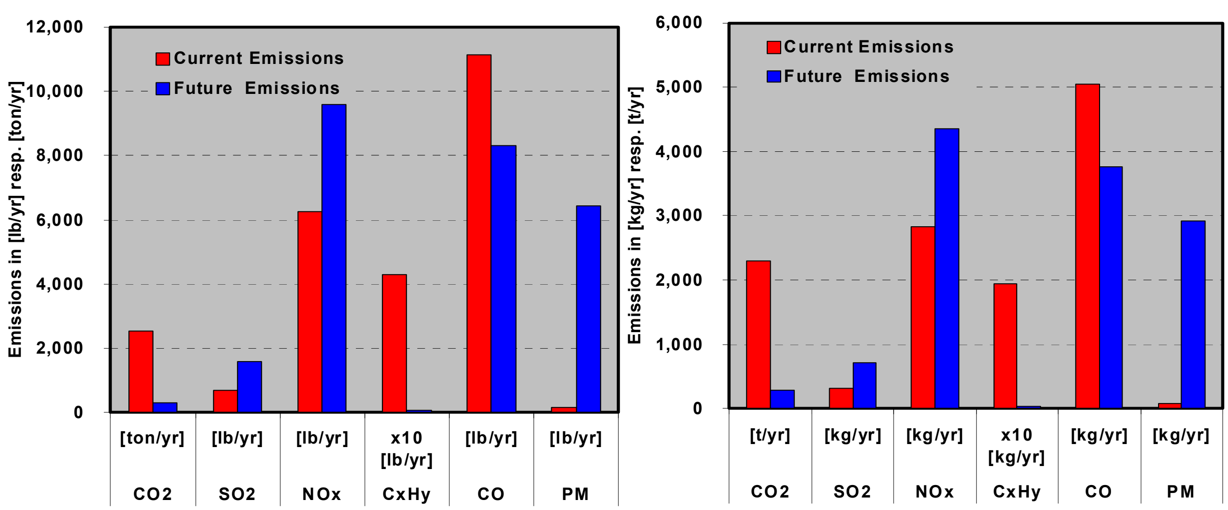


Figure 14: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (Santa Fe Community College) – Macro Analysis

Note: See notes of Table 22 for details.

The results of the macro analysis shown in Table 22 and Figure 14 indicate that after the installation of the potential micro grid site at the Santa Fe Community College a substantial reduction of CO_2 emissions from about 2,530 tons/yr to 320 tons/yr (2,290 metric tons/yr to 290 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 2,210 tons/yr (2,000 metric tons/yr) or 87% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Moreover, CO emissions will also be reduced slightly. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to high C_xH_y and CO emissions caused during the production and transport of natural gas. NO_x emissions and emissions of SO_2 and of particulate matter (PM) will increase based on the macro analysis. Due to the fact that biomass is a locally available fuel, the emissions caused by production and transport are considerably lower in comparison to natural gas, which is obvious when comparing the micro and the macro analysis results.

4.4.2.4 College of Santa Fe

4.4.2.4.1 Micro Analysis

Table 23 and Figure 15 show the results regarding the micro analysis of the emission estimate of the option “College of Santa Fe”.

Table 23: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (College of Santa Fe) - Micro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	737.6	125.0	-612.6	-83.1
SO_2	[lb/yr]	26.8	256.0	229.2	854.4
NO_x	[lb/yr]	1,609.2	2,058.8	449.6	27.9
C_xH_y	[lb/yr]	160.9	147.1	-13.9	-8.6
CO	[lb/yr]	1,072.8	2,940.9	1,868.1	174.1
PM	[lb/yr]	13.4	1,764.4	1,751.0	13,057.4
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	669.1	113.4	-555.7	-83.1
SO_2	[kg/yr]	12.2	116.1	103.9	854.4
NO_x	[kg/yr]	729.9	933.8	203.9	27.9
C_xH_y	[kg/yr]	73.0	66.7	-6.3	-8.6
CO	[kg/yr]	486.6	1,334.0	847.3	174.1
PM	[kg/yr]	6.1	800.3	794.3	13,057.4

Note: The emission coefficients correspond with Table 7. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 92.0% biomass (water content 28 wt.%, w.b.) and 8.0% natural gas utilization.

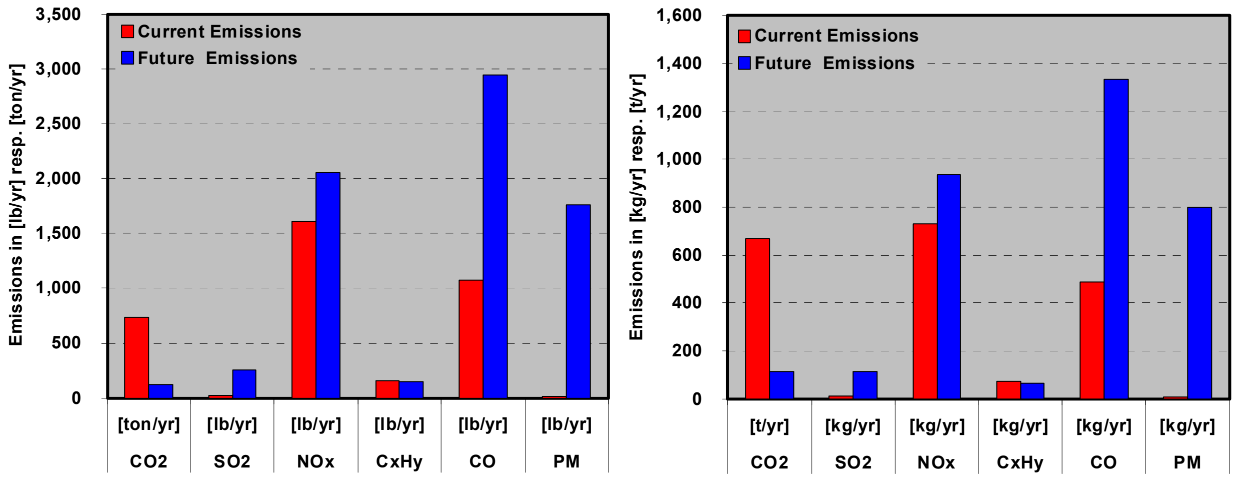


Figure 15: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (College of Santa Fe) - Micro Analysis

Note: See notes of Table 23 for details.

The results of the micro analysis shown in Table 23 and Figure 15 indicate that after the installation of the potential micro grid site at the College of Santa Fe a substantial reduction of CO_2 emissions from about 740 tons/yr to 130 tons/yr (670 metric tons/yr to 110 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 610 tons/yr (560 metric tons/yr) or 83% compared to the base line. In addition, hydrocarbon emissions will also be slightly reduced. Emissions of NO_x and CO will increase (regarding NO_x only slightly). Emissions of SO_2 and of particulate matter (PM) will also increase on a local level. In this respect it has to be stated that SO_2 and dust emissions of the biomass combustion system investigated are low (efficient combustion and appropriate flue gas cleaning for small-scale systems considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions.

4.4.2.4.2 Macro Analysis

Table 24 and Figure 16 show the results regarding the macro analysis of the emission estimate of the option "College of Santa Fe".

Table 24: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (College of Santa Fe) - Macro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	791.2	195.6	-595.6	-75.3
SO_2	[lb/yr]	214.6	454.2	239.7	111.7
NO_x	[lb/yr]	1,957.9	2,757.4	799.5	40.8
C_xH_y	[lb/yr]	13,410.3	300.7	-13,109.6	-97.8
CO	[lb/yr]	3,486.7	3,123.6	-363.1	-10.4
PM	[lb/yr]	53.6	1,847.5	1,793.8	3,344.1
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	717.8	177.4	-540.3	-75.3
SO_2	[kg/yr]	97.3	206.0	108.7	111.7
NO_x	[kg/yr]	888.1	1,250.7	362.6	40.8
C_xH_y	[kg/yr]	6,082.8	136.4	-5,946.4	-97.8
CO	[kg/yr]	1,581.5	1,416.8	-164.7	-10.4
PM	[kg/yr]	24.3	838.0	813.7	3,344.1

Note: The emission coefficients correspond with Table 8. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 92.0% biomass (water content 28 wt.%, w.b.) and 8.0% natural gas utilization.

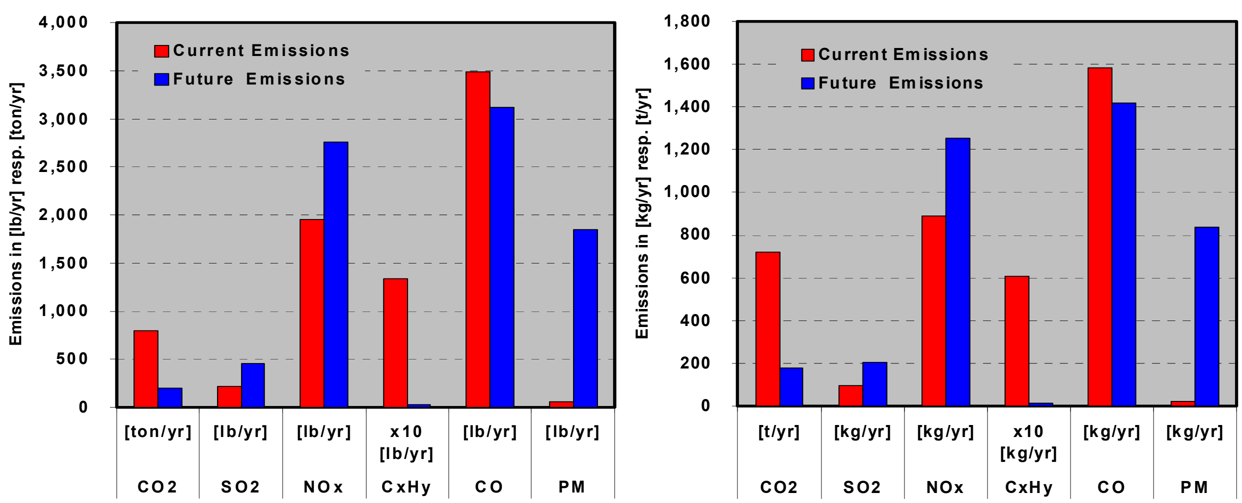


Figure 16: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (College of Santa Fe) - Macro Analysis

Note: See notes of Table 24 for details.

The results of the macro analysis shown in Table 24 and Figure 16 indicate that after the installation of the potential micro grid site at the College of Santa Fe a substantial reduction of

CO_2 emissions from about 790 tons/yr to 200 tons/yr (720 metric tons/yr to 180 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 590 tons/yr (540 metric tons/yr) or 75% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Moreover, CO emissions will also be reduced slightly. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to high C_xH_y and CO emissions caused during the production and transport of natural gas. NO_x emissions and emissions of SO_2 and of particulate matter (PM) will increase based on the macro analysis. Due to the fact that biomass is a locally available fuel, the emissions caused by production and transport are considerably lower in comparison to natural gas, which is obvious when comparing the micro and the macro analysis results.

4.4.2.5 Rail Yard

4.4.2.5.1 Micro Analysis

Table 25 and Figure 17 show the results regarding the micro analysis of the emission estimate of the option “Rail Yard”.

Table 25: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (Rail Yard) – Micro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	2,214.4	599.3	-1,615.1	-72.9
SO_2	[lb/yr]	80.5	834.9	754.3	936.8
NO_x	[lb/yr]	4,831.4	6,715.0	1,883.7	39.0
C_xH_y	[lb/yr]	483.1	287.9	-195.3	-40.4
CO	[lb/yr]	3,220.9	7,194.2	3,973.3	123.4
PM	[lb/yr]	40.3	5,754.6	5,714.4	14,193.2
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	2,008.8	543.7	-1,465.2	-72.9
SO_2	[kg/yr]	36.5	378.7	342.2	936.8
NO_x	[kg/yr]	2,191.5	3,045.9	854.4	39.0
C_xH_y	[kg/yr]	219.1	130.6	-88.6	-40.4
CO	[kg/yr]	1,461.0	3,263.2	1,802.2	123.4
PM	[kg/yr]	18.3	2,610.2	2,592.0	14,193.2

Note: The emission coefficients correspond with Table 7. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 93.5% biomass (water content 27 wt.%, w.b.) and 6.5% natural gas utilization.

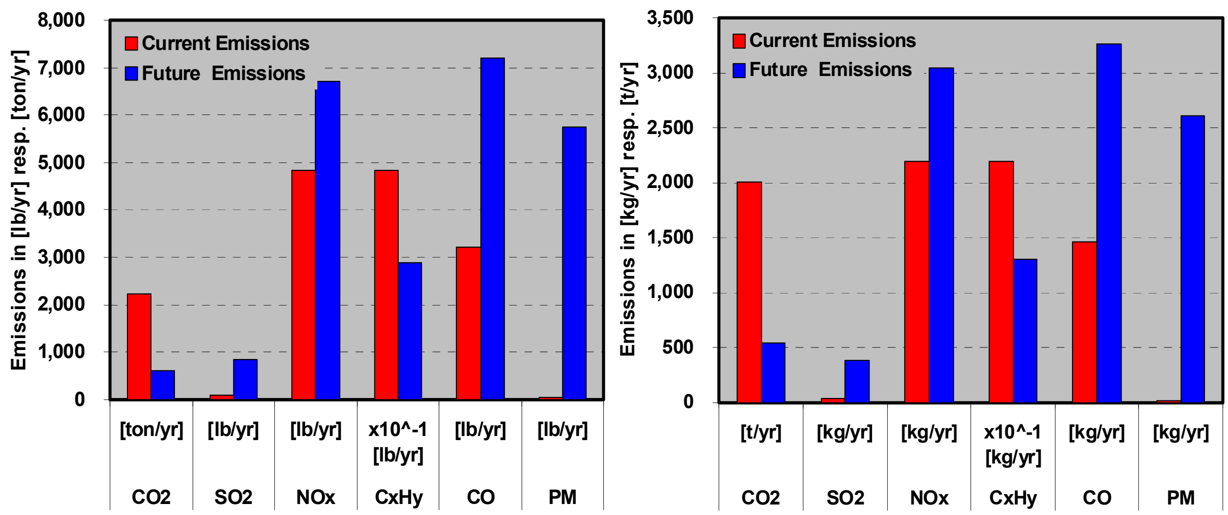


Figure 17: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (Rail Yard) – Micro Analysis

Note: See notes of Table 25 for details.

The results of the micro analysis shown in Table 25 and Figure 17 indicate that after the installation of the potential micro grid site at the rail yard a substantial reduction of CO_2 emissions from about 2,210 tons/yr to 600 tons/yr (2,010 metric tons/yr to 540 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 1,610 tons/yr (1,470 metric tons/yr) or 73% compared to the base line. In addition, hydrocarbon emissions will also be reduced. Emissions of NO_x and CO will increase. Emissions of SO_2 and of particulate matter (PM) will also increase on a local level. In this respect it has to be stated that SO_2 and dust emissions of the biomass combustion system investigated are low (efficient combustion and appropriate flue gas cleaning for small-scale systems considered) but the substitution of an almost sulphur and ash free fuel leads to a local increase of these emissions.

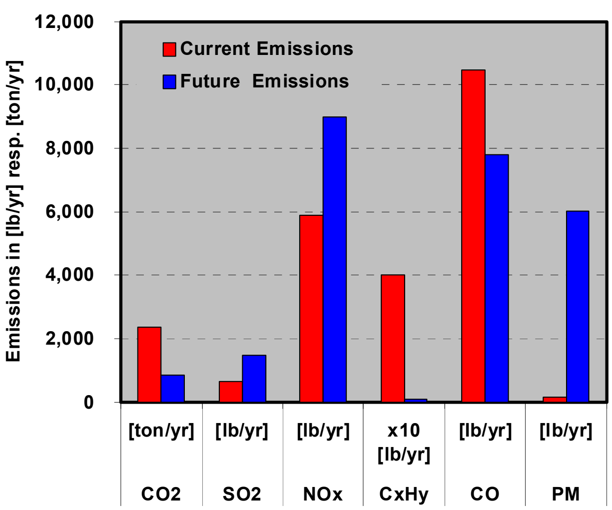
4.4.2.5.2 Macro Analysis

Table 26 and Figure 18 show the results regarding the macro analysis of the emission estimate of the option “Rail Yard”.

Table 26: Comparison of Current and Future Emissions after Installation of the Biomass-Fired Micro Grid (Rail Yard) – Macro Analysis

Parameter		Current Emissions	Future Emissions	Difference	Difference %
CO_2	[ton/yr]	2,375.4	843.4	-1,532.0	-64.5
SO_2	[lb/yr]	644.2	1,481.5	837.4	130.0
NO_x	[lb/yr]	5,878.2	8,993.5	3,115.4	53.0
C_xH_y	[lb/yr]	40,261.4	792.4	-39,469.0	-98.0
CO	[lb/yr]	10,468.0	7,790.5	-2,677.5	-25.6
PM	[lb/yr]	161.0	6,025.4	5,864.4	3,641.4
Parameter		**Current Emissions**	**Future Emissions**	**Difference**	**Difference %**
CO_2	[t/yr]	2,154.9	765.1	-1,389.8	-64.5
SO_2	[kg/yr]	292.2	672.0	379.8	130.0
NO_x	[kg/yr]	2,666.3	4,079.4	1,413.1	53.0
C_xH_y	[kg/yr]	18,262.2	359.4	-17,902.7	-98.0
CO	[kg/yr]	4,748.2	3,533.7	-1,214.5	-25.6
PM	[kg/yr]	73.0	2,733.1	2,660.0	3,641.4

Note: The emission coefficients correspond with Table 8. The emissions of the new biomass micro grid system are related to an energy based (NCV) ratio of 93.5% biomass (water content 27 wt.%, w.b.) and 6.5% natural gas utilization.



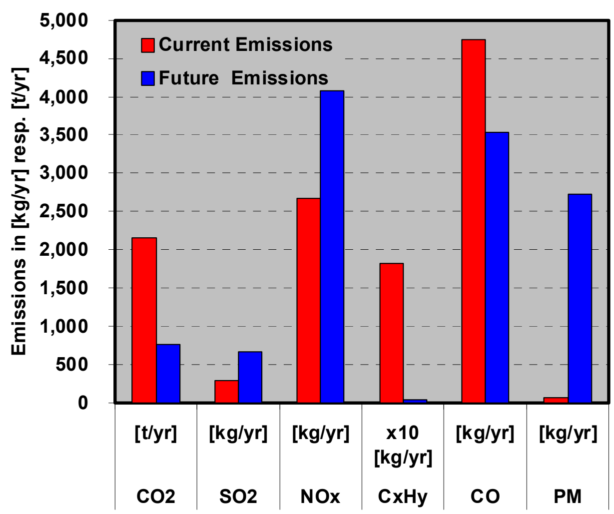


Figure 18: Current and Future Gaseous and Solid Emissions after Installation of the Biomass-Fired Micro Grid (Rail Yard) – Macro Analysis

Note: See notes of Table 26 for details.

The results of the macro analysis shown in Table 26 and Figure 18 indicate that after the installation of the potential micro grid site at the rail yard a substantial reduction of CO_2 emissions from about 2,380 tons/yr to 840 tons/yr (2,160 metric tons/yr to 770 metric tons/yr) is possible. The annual reduction of CO_2 emissions amounts to about 1,540 tons/yr (1,390 metric tons/yr) or 64% compared to the base line. In addition, the achievable reduction of hydrocarbon emissions will be significant. Moreover, CO emissions will also be reduced slightly. The considerable reduction of hydrocarbon and CO emissions as a result of the macro analysis is due to high C_xH_y and CO emissions caused during the production and transport of natural gas. NO_x emissions and emissions of SO_2 and of particulate matter (PM) will increase based on the macro analysis. Due to the fact that biomass is a locally available fuel, the emissions caused by production and transport are considerably lower in comparison to natural gas, which is obvious when comparing the micro and the macro analysis results.

5 Summary, Conclusions and Recommendations

5.1 Summary and Conclusions

5.1.1 Main Grid

The comparison between the current emissions of installed heating systems and projected emissions after the installation of a biomass-fired district heating system within the investigated supply area in downtown Santa Fe generally reveals a positive environmental impact of biomass energy systems in Santa Fe. Both potential main grid options, with the waste transfer station or the site of the former coal-fired power plant as possible locations for the heating plant, show similar results, since the substitutable heat demand within the respective supply areas varies only slightly between these options.

The results of the micro analysis, which considered only local emissions caused directly by the heating devices at the customers and the biomass-fired heating plant, show a significant reduction in CO_2 and hydrocarbon emissions for all main grid options. CO_2 and hydrocarbon emissions contribute to the greenhouse effect and thus their reduction is important to prevent global warming.

NO_x and CO emissions slightly increase on a local level. Even though total SO_2 and dust emissions of the biomass-fired boilers are low (efficient flue gas cleaning considered), these emissions rise, since natural gas (an almost sulphur and ash free fuel) is substituted.

On a local level, heat only options show slightly better results than CHP options, since CHP options require additional fuel for power generation.

The results of the macro analysis, which in addition to the emissions considered in the micro grid analysis also considers the emissions caused by fuel supply, by production of the electricity consumed in the heating/CHP plant, and the substitution of conventionally produced electricity by green electricity generated in the biomass CHP plant, show significant differences between heat only and CHP options.

Regarding heat only options, CO_2, hydrocarbon and CO emissions will be reduced significantly. For hydrocarbon and CO emissions, this is mainly due to the production and transport of natural gas which are considered in the macro analysis. NO_x emissions will increase slightly. Emissions of SO_2 and of particulate matter (PM) will also increase based on the macro analysis, but the total amount of the emissions is low.

On a global level (macro analysis) CHP options reveal a better environmental performance than heat only solutions. In addition to a considerable reduction of CO_2, CO, and hydrocarbon emissions, also SO_2 and NO_x emissions decrease, which is mainly due to the substitution of electricity produced in fossil fuel (mainly coal) fired power stations by green electricity from biomass. Only particulate emissions will increase but have a low total input.

By comparing the results of the micro and macro analysis regarding heat-only and CHP options, it becomes obvious, that on a local level, heat only options have a better environmental impact. If all direct and indirect emissions caused by heat and power generation are considered, the CHP options show clear environmental advantages. Due to the fact that biomass is a locally available fuel, emissions caused by production and transport are considerably lower in comparison to natural gas, which generally improves the results of the macro analysis compared to the micro analysis.

Particulate emissions increase for all plant options investigated due to the fact that an ash free fossil fuel (natural gas) is substituted. But the amount of particulate emissions caused from biomass district heating/CHP plants is small in comparison to the particulate emissions caused by traffic and other sources. If requested by the authorities, particulate emissions from the biomass district heating/CHP plants investigated could be reduced to about 25% of the values stated in this report by further increasing the precipitation effectiveness of the filters selected, but this reduction would increase the operating costs of the plant.

NO_x emissions could be reduced to about 40% of the values stated in this report by the installation of a SNCR (selective non-catalytic reduction) system, but would negatively influence the economic performance of the plant. The NO_x emissions caused by the biomass district heating/CHP plant are small in comparison to the emissions caused by traffic.

The significant reduction of greenhouse gases like CO_2 and hydrocarbons represents the main environmental advantage of the investigated main grid options. Depending on the selected option, a total reduction of CO_2 emissions between 12,200 tons (11,100 metric tons) and 20,700 tons (18,800 metric tons) could be achieved. In addition, a considerable improvement of the reputation of the City of Santa Fe as an environmental friendly community as well as an relevant step towards the goals foreseen in the Kyoto Protocol could be achieved by the installation of a district heating system.

5.1.2 Potential Micro Grid Sites

The comparison between the current emissions of installed heating systems and projected emissions after the installation of biomass-fired district heating systems at selected micro grid sites investigated generally reveals a positive environmental impact of biomass energy systems in Santa Fe. However, depending on the design of the respective heating plants, the results vary from option to option.

The micro analysis concludes a significant reduction in CO_2 and hydrocarbon emissions for all micro grid options. The micro grid of the Santa Fe Community College achieves the largest reduction in CO_2 and hydrocarbon emissions, since only a small amount of the annual heat demand is produced by the gas-fired peak-load boiler foreseen in the heating plant. CO_2 and hydrocarbon emissions contribute to the greenhouse effect and thus their reduction is important to prevent global warming.

NO_x and CO emissions of micro grids increase on a local level. Even though total SO_2 and dust emissions of the biomass-fired boilers are low (efficient flue gas cleaning considered), these emissions also increase, since natural gas (an almost sulphur and ash free fuel) is substituted.

The results of the macro analysis also reveal a considerable reduction of CO_2, hydrocarbon and CO emissions. This is mainly due to high hydrocarbon and CO emissions caused during the production and transport of natural gas. NO_x emissions will rise slightly, SO_2 and particulate emissions will also increase, but are low regarding the total amount released.

A comparison of the heat only main grid and micro grid options reveals higher specific dust and CO emissions for micro grids. This is caused by less complex flue gas cleaning and control systems which must be chosen for micro grid options to keep their investment and operating costs at an acceptable level. The installation of more sophisticated flue gas cleaning and combustion systems would significantly impair the economic performance of the micro grid options and is therefore not recommended.

The significant reduction of greenhouse gases like CO_2 and hydrocarbons represents the main environmental advantage of the micro grid options investigated and also represents the reason for the overall positive environmental evaluation of biomass heating systems in comparison to the current state-of-the-art. The installation of micro grids would be a positive example that even small communities can contribute to the reduction of greenhouse gases. In addition, the utilization of a sustainable and locally available fuel, which's production and transport causes considerably lower emissions in comparison to natural gas, supports the local economy as well as the security of energy supply, and contributes to a positive environmental impact of micro grids.

5.2 Recommendations

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

- The installation of a biomass fired district heating system can be recommended for all plant options investigated due to the fact that a fossil fuel will be substituted by a renewable and locally available fuel. All plant options contribute substantially to a considerable reduction of CO_2 and hydrocarbon emissions.
- The significant reduction of CO_2 emissions can also improve the economic performance of the district heating systems, if tradable CO_2 certificates can be generated. This option will be investigated in more detail by environmental specialist Robert J. Kerr.
- By comparison of all plant options investigated, the biomass district heating and CHP plants achieve the best results from an environmental point of view. This is due to the fact that not only natural gas but also coal utilized in the New Mexican power plants would be substituted. Therefore, the environmental advantage achieved increases further.
- The final decision which plant option(s) should be realized is strongly dependent on the economic performance of the systems. Therefore, an overall economic, technical and environmental evaluation has to be performed in order to be able to achieve a ranking of the different systems investigated.
- Due to the technological optimization of the biomass district heating plant systems investigated, a further reduction of emissions from the biomass-fired heating plant seems possible. This will be evaluated in detail in the final report of the ongoing feasibility study.

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