Municipal Electricity and Renewable Energy in Santa Fe

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1 Introduction

Over the past decade global carbon emissions, which have been linked with climate change, have become an issue worldwide. The Kyoto Protocol was created in 1997 to regulate these emissions; however, its goal is to reduce emissions by the end of 2012, after which the protocol has no further provisions. Recent climate conferences, such as the one in Copenhagen, Denmark, have failed to produce any legislation to supplement or replace the Kyoto Protocol. The U.S. is one of the world's largest producers of carbon emissions, emitting almost 6 billion metric tons of CO_2 in 2008[1], which is approximately 20% of the world's CO_2 emissions. Correlating with the carbon emissions increase is the fossil fuel usage increase in the latter half of the 20th Century, from 3 billion metric tons of fossil fuel in 1965 to over 7 billion metric tons in 2008[2]. According to the Statistical Review of World Energy 2009 there are 1.3 trillion barrels of oil left which, given current consumption rates, will last another 42 years[3]. Inevitably, non-renewable energy sources will become prohibitively expensive, so alternative sources of energy must be found and utilized.

The state of New Mexico was responsible for emitting 33 million metric tons of CO_2 in 2006[4] and, in Santa Fe, CO_2 emission has increased of 8.5% since the year 2000. In order to address this increase, the City has come up with the Sustainable Santa Fe Plan, part of which includes reducing carbon emissions by 18.9% by 2012[5]. PNM, the provider of Santa Fe's electricity, currently produces 71% of its output from coal and natural gas. While inexpensive, burning these fuels contributes to carbon production[6]. Also notable is the 20% increase in energy costs for residents in New Mexico since 1990[7].

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[1] (*Carbon dioxide emissions (CO2), thousand metric tons of CO2 (CDIAC).*)
[2] (BP, 2006)
[3] (BP, June 2009)
[4] (*New Mexico carbon dioxide emissions from fossil fuel consumption (1980 - 2007).*2010)
[5] (*Greenhouse gas emissions inventory.*)
[6] (*2007-2008 sustainability report shaping a sustainable future.*2008)

To counter both of the fore-mentioned problems pertaining to residential energy, Santa Fe has shown an interest in purchasing its electrical infrastructure.

The Sustainable Santa Fe Plan provides solutions for the municipality to provide services in an environmentally-conscious way. Part of the plan provides loans for residents to install solar panels on their homes, and any surplus electricity generated can be sold back to the grid at retail price. While the private solar panel installations aid in carbon reduction to a small extent, the carbon production of Santa Fe is influenced mostly by the practices of PNM which favors profit over the goals of sustainability. Thus, the lack of control over the electrical infrastructure is a limitation on the City's green efforts. Santa Fe purchased its water infrastructure in 2008 for the sum of $61 million as part of the Sustainable Santa Fe Plan[8]. Santa Fe is looking to buy its electrical infrastructure so that it can have the flexibility needed for greener power transmission and production practices. With control over the grid, the City can upgrade it to smart grid specifications and integrate solar and other renewable sources of power without dissent from PNM. As an example of this type of proposal, the town of Farmington, NM has owned its power infrastructure since 1965 and Farmington residents can tout that electricity rates saw no increase between 1982 and 2007[9].

The City has purchased the water infrastructure, but that resulted in the opposite of the intended effect: a rate increase instead of a decrease. This drastic increase in water bills for residents was to pay for the loans that made the purchase possible. There are no full maps of the City's electrical infrastructure available to this project group to allow for a full assessment of the value of the power infrastructure. The main unresolved issue with the purchase of the electric grid is whether or not it

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[7] (*Current and historical monthly retail sales, revenues and average revenue per kilowatthour by state and by sector (form EIA-826).*)
[8] (City Clerk - 2009 Ordinances - 2009-047, 2009)
[9] (*Farmington electric utility history.*2007)

would be cost effective to do so. The corollary to that is the method of how the City would pay for the purchase.

Our project's goals are straight forward: first, to determine if it is cost effective for the city of Santa Fe to purchase their electrical infrastructure; second, if it is how they might pay for it. Our research will gather numbers such as operating costs, maintenance costs, age, and several other factors. After we know the purchase price and value, we can figure out what methods of financing the city could use after undertaking such a large financial burden. The financing will require the team to conduct in-depth research of how the city could potentially raise the amount of money required to purchase the infrastructure. Finally, the team will study available renewable resources and determine potential power generation capabilities and the costs associated with the construction of such power stations. By performing each of these objectives, we will be able to help the City of Santa Fe determine if the possibility of purchasing the electrical infrastructure is a worthwhile endeavor for them to undertake.

2 Background

2.1 Overview of the Electric Infrastructure

The electric infrastructure consists of an assortment of parts such as the power station, the substations, the utility poles, the transformers, the power lines and the electricity meters.

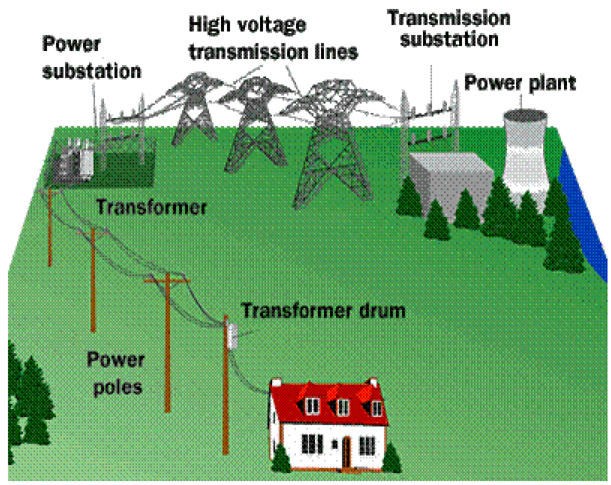

Figure 1 Power Infrastructure[10]

2.2 Elements of the Electric Infrastructure

2.2.1 Power Stations

There are a wide variety of power stations that are used, but all still supply the electricity that powers the electric infrastructure. Power stations can be categorized by two main elements: fuel, and method of power generation. The types of fuel are:

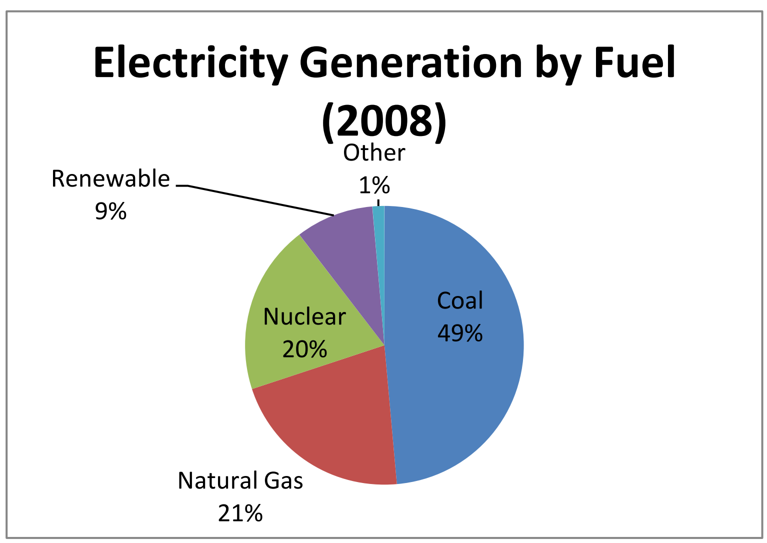

Figure 2 Electricity Generation by Fuel[11]

[10] (Brain)

[11] (*Net generation by energy source: Total (all sectors).*2010)

nuclear, fossil fuel (including coal and natural gas), geothermal, waste heat, solar thermal and renewable energy. The methods of power generation are: steam turbine, gas turbine, combined cycle, and internal combustion engines.

2.2.2 Power Substations

Figure 3 Power Substation[12]

A substation is used to either step up the voltage of the electricity or to step down the voltage of the electricity. To do so the substation uses transformers.

[12] (*Illustrated glossary: Substations.*)

2.2.3 Transformers

Transformers are the actual mechanism by which any changes in voltages are enacted. The equation that governs the relationship between the primary voltage (V_P), the secondary voltage (V_S), the number of primary turns (N_P) and the number of secondary turns (N_S) is:

Equation 1 Transformer Equation[14]

$$\frac{V_S}{V_P} = \frac{N_S}{N_p}$$

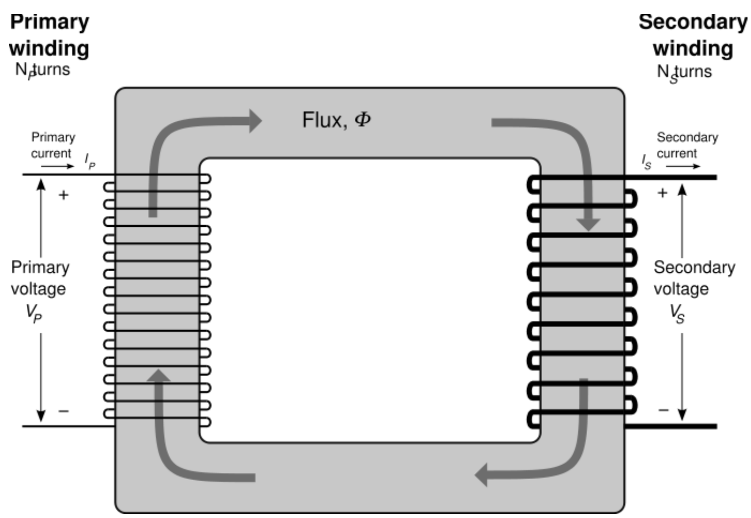

Figure 4 Transformer Circuit[13]

Figure 5 Single Phase Transformer[15]

A picture of an idealized transformer circuit can be seen above; however, in a real transformer both the primary and secondary windings are on top of each other in order to minimize leakage flux[16].

2.2.4 Utility Pole

One of the connections on a utility pole is for the electric lines which carry electricity. In general, poles are about 35 feet tall and are buried 6 feet into the ground; however, the poles can range in height from 20 feet to 100 feet tall. Utility poles can be made out of concrete,

13 (*Single phase transformer.*)
14 (*Transformer.*2010)
15 (Glogger, 2004)
16 (Calvert, 2006)

steel, fiberglass, or wood, but wood remains the most common and popular type of material[17].

2.2.5 Power Lines

Power lines carry the electricity from the power station to the substation to the transformer to the meter to your house. They are usually made out of aluminum or an alloy of aluminum although in some cases copper is used.

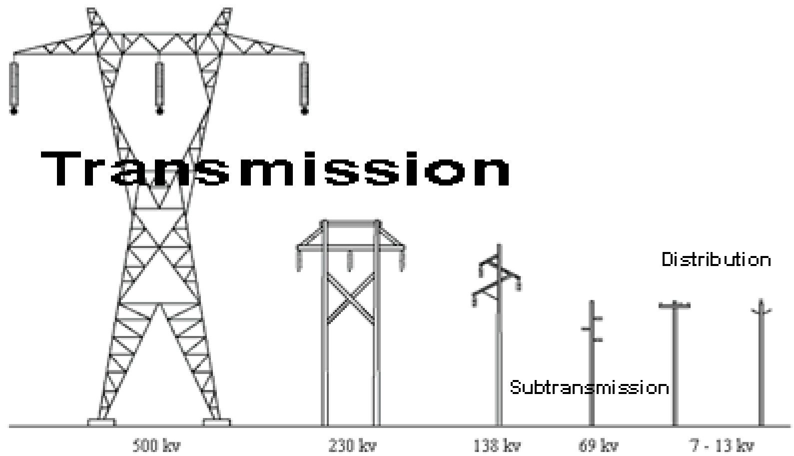

Figure 6 Utility Pole[18]

2.2.6 Meter

Most electricity meters are electromechanical in nature. They utilize an induction motor which is connected to a wheel that is attached to a gear that will turn the dial on your meter. The speed at which the induction motor turns is directly proportional to the voltage and current of the electricity that enters your house[19]. However, more recently smart meters have begun to penetrate the markets. Smart meters have several more features and functions compared to traditional meters in addition to simply monitoring electricity usage. Smart meters will theoretically have the ability to monitor electricity usage by time so that peak hour usage can be determined and by appliance assuming the appliances have the capability to be connected to the network. Furthermore, smart meters will have the ability to turn off

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17 (State of Florida, 2010)
18 (*Illustrated glossary: Transmission lines.*)
19 (Bureau of Reclamation, 2000)

electricity to the house during peak hours for example, lowering the total price the consumer has to pay[20]. While smart meters are part of the smart grid, they are not the whole of the smart grid.

Figure 7 Smart Meter and Mechanical Meter[21+22]

2.3 History of the Grid

The power grid had very humble beginnings. In 1882, when electricity was first starting to enter households and businesses, it was provided by small generators that were always close by to where the power used and was always transmitted by DC, or direct current. By 1886 AC, alternating current, generators were starting to appear and in 1888 the universal system was developed. This system used transformers to up the voltage as it was put into the power lines and then drop it back down as it entered homes and buildings. The increased voltage allowed the electricity to travel much longer distances in the power lines without being depleted by the time it got to its destination. This ability to transmit electricity over long distances lowered costs and for generation plants to produce enough energy to power far larger areas than ever before.

As with most things, technology improved over time and the grid was made more efficient. Although the basic concept of the grid has changed very little since the inception of the universal

[20] (CBC News Online, 2005)
[21] (EVB Energy Ltd, 2008)
[22] (*Electric meter front.*)

system, now the nation is broken down into three main grids; The Western Interconnect; The Eastern Interconnect and the Electric Reliability Council of Texas. The way these grids function allows for a generator plant in one area of the grid to go down and have the other plants within that grid to, for the most part, cover the area in which the downed plant no longer can. This also allows power lines to break and have something similar happen, although the power in the immediate area around the downed line will be temporarily out of service.

2.3.1 Public Service Utility of New Mexico (PNM)

PNM is the current supplier of electricity to Santa Fe. Two of PNM's coal-firing plants near Farmington, NM provide 62 percent of Santa Fe's electricity while a nuclear power plant near Phoenix provides another 19 percent. Natural gas, wind, solar, and third party providers supply the rest of Santa Fe's energy. By 2020, PNM must meet a state mandate of providing 20% of its energy from renewable resources. With their current renewable energy plan PNM provides 6% of its energy from solar power, and pays 26 cents per kWhr for solar energy sourced from customer sites.

One of the benefits of a municipal-owned power infrastructure is the ability to keep electricity costs down for residents. Profit margin is no longer a concern when the infrastructure owns the power lines. The city can install solar farms if the citizens decide to pursue renewable energy. Although initial costs would be high, the energy independence would help sustain Santa Fe. The county of Los Alamos currently supplies electricity on its municipality-owned power lines to 9,000 customers who pay a little more than the PNM rate, but they pay one service charge and no surcharge that PNM customers do pay.

The control of the power infrastructure has been a topic of debate in recent events. In November 2009, PNM complained to the New Mexico's Public Regulation Commission about Santa Fe's intent to contract Maryland-Based SunEdison to install solar arrays on government buildings to reduce municipal energy consumption. The electricity would be purchased from SunEdison, not PNM, and tax credits would also be given to SunEdison. PNM declared that all power in Santa Fe should be regulated by PNM itself.

2.4 Alternative Renewable Energy Resources

The team will be exploring the feasibility of using renewable energy sources to help power the city of Santa Fe. Using renewable energy could potentially allow the city to generate part or all of their energy needs for cheaper. The carbon dioxide emissions are another area of concern that renewable resources could help to reduce.

2.4.1 Solar Power

One of the most feasible forms of renewable energy production in Santa Fe is solar power due to the geographical location of the city. Solar power captures energy from the Sun using photovoltaic cells and turns it into usable electricity.

The basic components involved in the production, storage, and usage of electricity from solar power is outlined in the figure below. The solar panel is composed of an array of a number of solar cells that combine to generate energy from sunlight. Through the photovoltaic effect, solar cells work by using semiconducting materials to absorb photons from sunlight, causing the electrons in the material to flow, thus creating electricity which can be used. Depending on how much power you want to generate, creating a large array of solar cells that can produce the desired amount of energy.[23] The electricity produced by the solar panel is then sent through a charge controller that can send some of the energy directly to DC devices because the electricity produced is in DC (direct current). The rest of the energy is sent to batteries for storage, and then before it can be used the same way as any other power source for the home, it must first go through a power inverter to make it AC(alternating current).

[23] (*Solar explained where solar is found.*2009)

The biggest factor that will make or break solar power in a certain location is the amount of sunlight that will hit the solar panel since without sunlight no energy can be produced. The Southwestern United States has both long days and direct sunlight for most of the year. The ideal location for solar panels is usually in a desert due to the strength of the sunlight in those

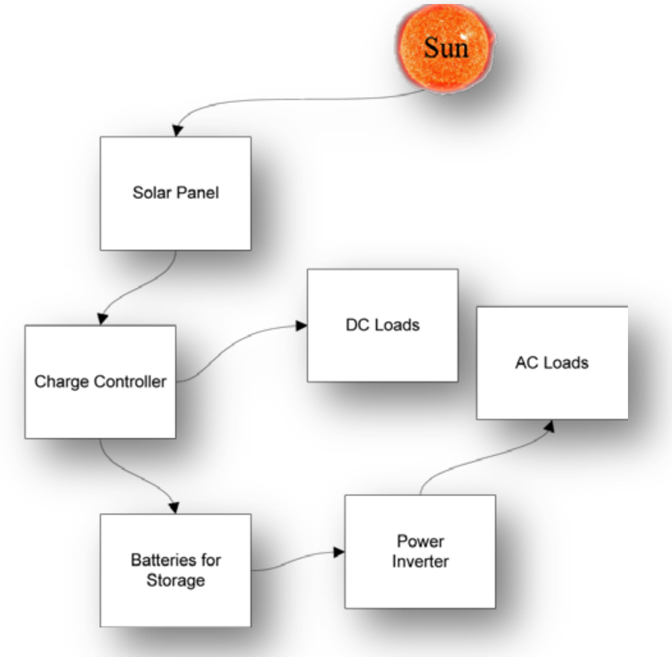

Figure 9 How Solar Panels Work

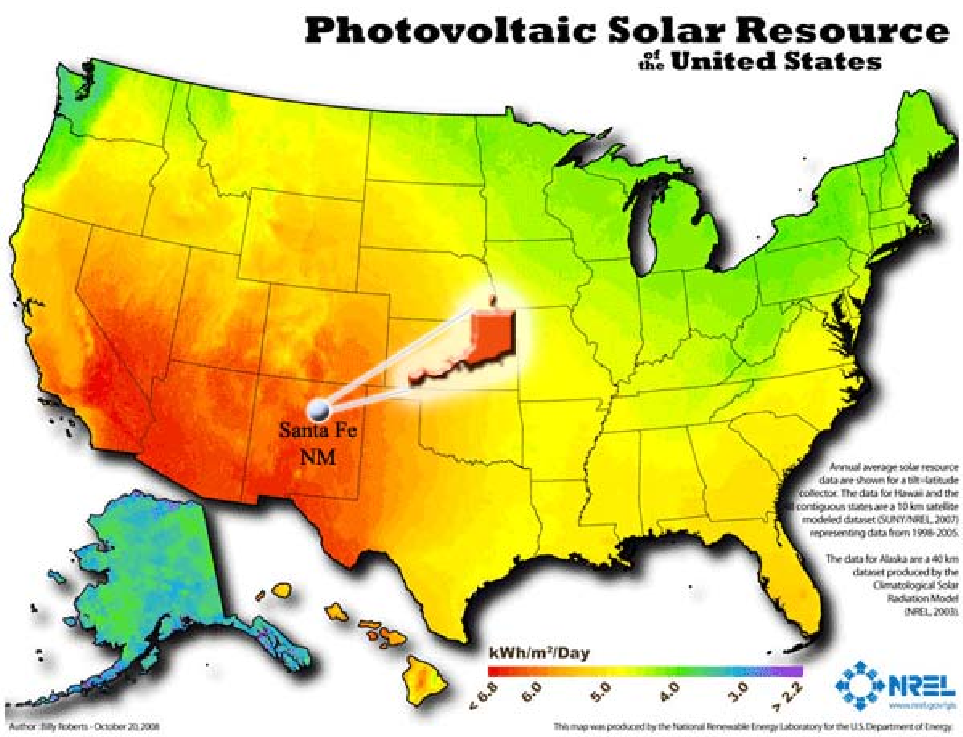

Figure 8 - Solar Levels Map of U.S.[24]

24 (*Photovoltaic solar resource map.*)

locations as well as the large amount of empty and undesirable real estate. The higher the altitude the solar panel is at also allows more energy to reach the panel because less energy is lost as the light passes through the atmosphere. The City of Santa Fe is in a desert, as well as the highest capital city in the United States. Due to both of these attributes, Santa Fe meets many of the ideal conditions for producing large amounts of energy from the sun. The solar resource map below shows us the potential the Southwestern US has for producing solar power.

Most modern solar panels that are in development today have an efficiency rate of approximately 20%. For example, The SunPower™ 315 Solar Panel has an efficiency of 19.3% and a peak production of 18 Watts per square foot.[25] As production costs and efficiencies continue to improve, the ability of the world to make the switch to renewable resources an ever-growing reality.

Figure 10 Nevada Solar One[26]

By creating large solar plants similar to the one shown above in Nevada, Santa Fe may be able to achieve their goal of reaching lower carbon dioxide emission levels.

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[25] (*SUNPOWER 315 solar panel.*2009)

[26] (Wald, 2008)

2.4.2 Geothermal

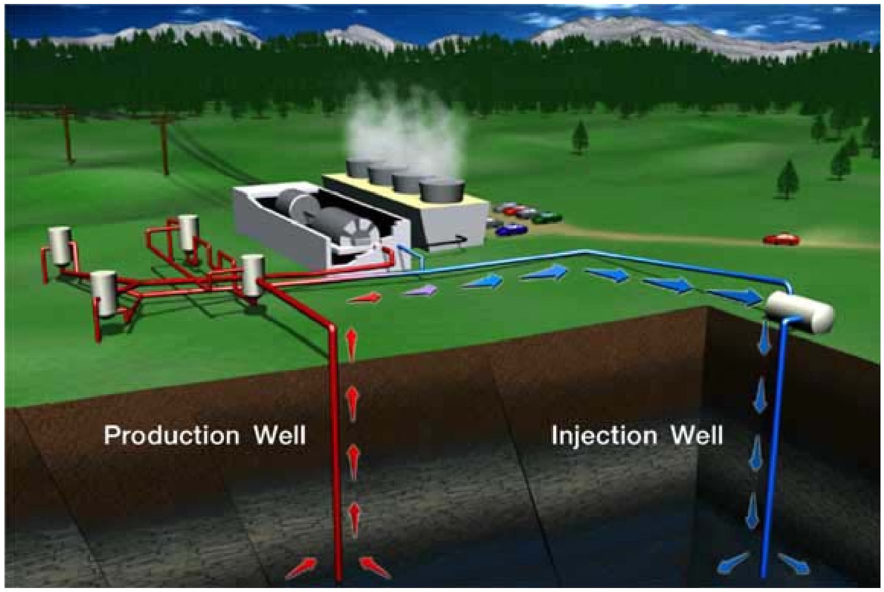

Figure 11 - Geothermal Energy Plant[27]

As the name suggests, geothermal energy comes from heat that is stored in the Earth and is used as a source of heat for several applications. This heat can be used directly to heat a home or business, or used to generate energy through various means. In order to use the heat from the earth, we must first drill deep into the Earth's crust. The depth we must drill depends entirely on how thick the crust is at the location of drilling, or if there are any hot spots near the surface that could be used as a heat source. The figure above shows how a standard geothermal power plant works: the plant taps into a reservoir deep in the crust where it is very hot, and injects cold water into the reservoir; next that cold water is heated by the rocks in the Earth, and once it is heated up enough, convection currents cause it to rise up a pipe that takes it into the power plant. Once the hot water has reached the power plant, it is used to turn turbines using convection currents and steam to produce energy.[28]

[27] (Heidtken, 2003)
[28] (Dickson & Fanelli, 2004)

2.5 Smart Grid

In development and in partial deployment in the US, in such cities such as Boulder, Colorado, is the smart grid. The smart grid will reduce the duration of power outages; allow the grid to demand additional energy from other resources to balance the flow of electricity through the grid. Additionally, the ability the smart grid will have the ability to monitor the status of components allowing their replacement before their failure improving the reliability of the grid[29]. The smart grid will also be able to handle non-constant power generation such as that produced by solar, or wind power; furthermore, the smart grid will be able to handle a more decentralized power production, allowing the construction and contribution of a number of small solar panels or other power plants. Currently, if any electricity is produced in excess of need, there is nowhere for it to go, so it travels the power lines until the energy is lost, however, part of the smart grid will involve the construction of large storage facilities for energy that was produced, but not needed at that point[30].

2.5.1 Boulder, Colorado and SmartGridCity

SmartGridCity is the name of the new grid system implemented in Boulder, Colorado. It is owned by Xcel Energy, the company supplying most of Boulder's Energy, although the City does operate 8 hydroelectric plants that produce electricity that is sold directly to Xcel for distribution. The Boulder plants generate enough energy for 18% of the residential sector in Boulder while, at the same time, depressurizing the water supply for the City[31]. SmartGridCity is the world's first implementation of a "smart grid", that is, an electrical infrastructure monitored and controlled by computers. The current abilities of the smart grid allow remote monitoring total electricity usage, voltage fluctuations in the line, as well as the ability to balance loads from different energy sources by way of remote shut-off. SmartGridCity reduces blackouts by finding voltage fluctuations and reacting to them, and it improves

[29] (*The smart grid: An introduction*2008b)
[30] (*The smart grid: An introduction*2008a)
[31] (*Boulder's municipal hydroelectric system.*)

financial efficiency by making obsolete the old way of finding electricity usage with a physical reading of meters. Electrical efficiency is improved with the ability to balance loads, since it decreases the likelihood of power plants being forced to operate beyond their efficiency range during peak or low usage periods[32].

2.6 Municipal Energy Trends

In current events, it is more likely that a municipality will keep its utility assets rather than selling it to a company. This represents a shift from the days when electricity use was law and energy production was cheap. The rationale for keeping electricity distribution and production government-owned and operated is the awareness of environmental effects and the increasing use of electricity in general. In Sweden, municipalities play a large role in the distribution of electricity. Since the late 1970's, Swedish Energy policy consists of four major themes: reduction of oil usage, phasing out nuclear power, improvement of municipal energy efficiency, and incorporation of renewable resources. Likewise, in Canada, a community-derived energy policy is favored. Motivations for this include the desire to reduce greenhouse gas emissions, to limit exposure to rising prices for centrally generated electricity, or to shift to a more self-sufficient energy system[33].

2.6.1 Farmington Electrical Utility Company

The City of Farmington operates an electric utility company that provides power for the entire San Juan County and a portion of the Rio Arriba County. The city has owned the electric utility since 1944. In 1982, FEUS purchased an 8.745% (42,000 kW) share in the PNM-owned San Juan Generation plant and, in 1995; FEUS completed the construction of its Animas Combined-Cycle (25,600kW) Plant to cope with increasing electrical demand. In 1999 FEUS installed meters that allow remote metering of

[32] (*Xcel energy SmartGridCity™ benefits hypothesis summary.*2008)
[33] (Nilsson & Martensson, 2003)

power consumption. Despite all the growth that FEUS experienced, the electric utility rate did not increase between 1982 and 2007 and FEUS has remained out of debt[34].

2.7 Historical Example: Santa Fe Water Utility Purchase

In November of 2009, the City of Santa Fe issued bonds for the sum of $61 million for the acquisition and maintenance of its water utility, as well as the sourcing of funds for the Buckman Direct Diversion program. The raising of funds is in response to the water supply and the quality of water in Santa Fe. Acquiring the water utility allows plans pertaining to the Buckman program, an effort to reduce the City's dependence on ground water, to proceed

Table 1 Bond Maturation and Yield, A-Type (Top) and B-Type (Bottom)[35]

Amounts Maturing	Interest Rate (Per Annum)	Year Maturing
$150,000	2.000%	2010
695,000	2.000%	2011
710,000	2.000%	2012
725,000	2.250%	2013
740,000	2.500%	2014
760,000	3.000%	2015
780,000	3.000%	2016
805,000	3.250%	2017
830,000	3.500%	2018
860,000	4.000%	2019
895,000	4.000%	2020
930,000	5.000%	2021
975,000	5.000%	2022
1,025,000	5.000%	2023
1,075,000	5.000%	2024
1,130,000	5.000%	2025
2,435,000	5.000%	2026
2,560,000	5.000%	2027

4,975,000*	**6.000%**	**2029**
36,915,000*	6.200%	2039

***Term Bonds, subject to mandatory sinking fund redemption**

[34] (*Farmington electric utility history.*2007)
[35] (City Clerk - 2009 Ordinances - 2009-047, 2009)

without the impedance of a private owner. Also, the city of Santa Fe will be able to cooperate with the Los Alamos National Laboratory to reduce water supply contamination[36].

2.7.1 Government Bonds and Santa Fe

The conventional way that municipalities raise money for services (such as building schools, or buying city utilities) is through the sale of bonds. A government bond is a loan to the government that yields interest over time, eventually reaching maturity at some point determined by the seller of bonds (usually the city). Selling bonds starts with the issuance of bonds by the government entity that needs them. The issuer works with a municipal bond dealer, usually a bank or financial firm that takes on government dealings, to set interest rates and maturation dates. Once the bonds are approved, they are sold to private investors, banks, insurance companies, or any other entity that can produce the funds.

In this way, Santa Fe raised the necessary money to purchase its water and sewage system. It appears that bonds can have different maturation dates and different yields. For example, the first year of maturation in the chart above shows that the total amount of bond value maturing this year (2010) is 150,000 and the interest yield is 2% annually. The bonds maturing this year are comparatively low in value and yield when regarding the other values in the chart. This is probably to give the city of Santa Fe headroom to cover costs during its “start-up” year. The chart also shows A and B-type bonds, the latter meant for long term investing[37].

[36] (City Clerk - 2009 Ordinances - 2009-047, 2009)
[37] (City Clerk - 2009 Ordinances - 2009-047, 2009)

2.7.2 Increase in Water Utility Rates

To pay for the bonds that made the purchase possible, Santa Fe has adopted a plan that

Summary of Financial Plan for Fiscal Year 2007-08 through FY 20015-16
($ in millions)

Description	FY 2008-09	FY 2009-10	FY 2010-11	FY 2011-12	FY 2012-13	FY 2013-14	FY 2014-15	FY 2015-16	FY 2016-17
User Charge Revenue Requirement	$27.59	$30.25	$33.13	$35.59	$38.98	$41.06	$41.68	$42.31	$42.94
Percent Revenue Increase Needed	8.20%	8.20%	8.20%	8.20%	8.20%	0.00%	0.00%	0.00%	0.00%
Bonds Issued	$0.00	$34.50	$0.00	$0.00	$20.60	$0.00	$0.00	$0.00	$0.00
Fund Balance	$41.82	$28.58	$20.00	$11.57	$19.96	$21.75	$15.50	$14.83	$12.92
Debt Service Coverage (1.25=min. req., 1.40=recommended min)	2.9	2.1	1.5	1.6	1.7	1.8	1.8	1.8	1.7

Figure 12: Water Bond Repayment Financial Plan[38]

progressively increases the water billing rate 8.2% per year for 5 years, which started in 2008. Spreading out the increase over 5 years "allows for better planning and helps avoid large, single-year corrections to the rates," according to Santa Fe Water Utility webpage[40]. From a consumer standpoint, this translates to a less drastic adaptation to household spending. By spreading out the increase, time is given for

Table 2 Estimated Monthly Water Bill Over the Next 5 Years for a Household[39]

Average Residential Water Bill Estimates	
Existing	31.5
1st Year (2009)	34.1
2nd Year (2010)	36.9
3rd Year (2011)	39.9
4th Year (2012)	43.2
5th Year (2013)	46.7

38 (Gallaher & Aranda, 2009)
39 (*8.2% for a safe and sustainable water future.*2009)
40 (*8.2% for a safe and sustainable water future.*2009)

household incomes to adapt which places less strain on citizens. This is especially important for the low-come sector of Santa Fe.

Before preparing a bond plan, the city's electrical infrastructure must be assessed for value to account for depreciation and inefficiencies in the system. It would be reasonable to add renovation of the power system in Santa Fe to the total cost of the purchase, since making the infrastructure more efficient would reduce operating costs and lessen payback time. Investing in solar energy may also be a consideration at the planning stages. Doing so will be conducive to helping the city achieve its renewable energy and carbon reduction quotas.

The following are preliminary calculations based on power system component values and statistics from a study performed by Worcester Polytechnic Institute of Boylston Electric System:

Table 3 Preliminary Cost Estimate

Unit	Number of Units	Cost per unit	Cost (millions)
Wire	159.86 mi	9820.8	1.57
Poles	8438	155	1.31
Transformers	2134	1100	2.35
Meters	32815	120	3.94
		TOTAL	9.16

The preceding calculations form a rough estimate of the value of what the city would be purchasing. There are other small components, such as hand holes, that have not been accounted for.

3 Methodology

This project will assess the feasibility of having the City of Santa Fe purchasing their electric infrastructure, and if possible determine how the City will pay for the purchase with the end goal of allowing the City to add renewable sources of electricity to the grid without interference from PNM.

The project will occur between March 14, 2010 and May 2, 2010, however, even if the purchase is found to be feasible, it is unlikely that it will occur during that time frame due to practical restrictions.

We plan to fulfill our goal by performing the following steps:

1. Inventory the current electrical infrastructure of the City of Santa Fe
2. Determine the current value and operating costs of the infrastructure
3. Determine the financing options available to the City
4. Explore the feasibility of integrating renewable energy sources into the infrastructure

3.1 Inventory Electric Infrastructure

Before we make a recommendation to the City of Santa Fe about purchasing their infrastructure, first we must discover what said infrastructure consists of. Ideally, we will have access to complete GIS layers of the electric infrastructure and will be able to determine the numbers of each part of the infrastructure (meter, poles, miles of lines, etc) easily. However, since the GIS layers of the infrastructure are owned by PNM, they are unlikely to become available to us, since they are not otherwise publicly available. Therefore we shall use alternative layers including sewer lines/roads, building footprints, zoning areas, and city limits to substitute. Using the sewer lines/road layers and the average distance between poles we will be able to determine the number of poles. Using a combination of the zoning and building footprint layers, we will be able to determine the number of meters and number of transformers. The layer of the city limits will provide a boundary for other layers making sure we only calculate the elements of the infrastructure in the city. The location and number of the substations and power plants will be determined either through zoning/building footprint layers or via interviews with city members.

Once we have this estimate, we will then use a second method to compare our estimates and make sure we have reasonable precise estimate. An alternative method to determining the number of components is to visually identify the numbers of each component in a section of the city and multiply that area by whatever ratio it is of the total city area. The area chosen to count in would have to be a representative sample of the city including the proper number of commercial, industrial and residential buildings.

3.2 Determine current value and operating costs

The next step in giving a recommendation to the City of Santa Fe is determining the value of the infrastructure. Ideally, PNM would tell us when we ask them, however, as it is possible that they either will not tell use or do not know themselves, we might be required to determine the value ourselves. Using the data gathered in inventorying the infrastructure, we will have the numbers of each component, and will use the replacement costs of each component as determined by a study conducted by Worcester Polytechnic Institute in Boylston, MA, therefore we shall be able to put an upper limit on the value of the infrastructure. Furthermore, we shall attempt to determine the age of each component and with that data factor in depreciation due to time into the value estimates; however, that might prove to be impossible to do.

Next, in order to find the operating costs, we shall again ask PNM for the data; however, as they will most likely not provide us with that data, we shall have to use other means to compensate. In this case, we shall find the operating costs of another publicly owned power utility such as the one in

Boulder, Colorado or in Farmington, New Mexico and compare the area of that city to the area of Santa Fe in order to scale for the size difference. This will not necessarily be an accurate assessment due to differences in location, size and the fact that the scaling mechanism is not a perfect correlation.

3.3 Determine the finance options

Now that we have the value of the infrastructure we can determine how the City will pay for it. While completing our project, we will attempt to come up with alternative ways for the City to pay for the purchase, but we will assume that they will pay via bonds.

First, we will find interest rates that the City will charge on any bonds that they might issue. Next, we will verify how much the City can pay with upfront with their current budget constraints so to minimize the amount of bonds that they must sell and/or rate increases. We will develop several financing options that will each have a varying amount of bonds sold and rate increase to the consumer, in order to provide the City with the consequence of each method of financing.

An additional part of the finance options will be accounting for the electricity requirements of Santa Fe, that is either the cost of a power plant sufficient for the generation needs, or purchasing the power from PNM directly or purchasing a part of one of PNM’s power plants. An alternative method to provide the electrical generation necessary for the City would be to construct a power plant utilizing renewable sources of energy such as solar, wind or geothermal. If such a power plant was constructed certain incentives at the Federal or state level would ease the cost of construction and allow the plant to sell energy back to the grid generating profit to further offset the cost of construction. Additional financial options would also become possible, such as selling carbon credits and selling on the carbon futures market.

3.4 Explore the feasibility of Renewable Energy

As the final component of our project, we will determine if it would be possible for renewable sources of energy such as solar, wind or geothermal to be integrated into the electric infrastructure of Santa Fe which will include accounting for land area and minimal upgrades to the infrastructure. First, we shall gather solar radiation, wind speed, and geothermal maps of the Santa Fe area. Next, we will find the amount of land that the City has by using the zoning/building footprint layers provided. Next, we will find the size and efficiency of each source, that is to say, find a solar panel, a wind turbine and a geothermal plant that is the best currently available in their respective fields. Using their size and cost we will be able to ascertain the cost of the power plant versus its power generation capabilities.

Additionally, we shall learn what the voltages of the power lines near each plot of land in order to determine suitability of each area to the creation of a power plant. The issue is that if the power lines are too low in voltage, they will not be capable of handling the loads a power plant would place on them, thus requiring the construction of higher voltage power lines adding to the cost of a power plant which must be accounted for in the finance options.

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