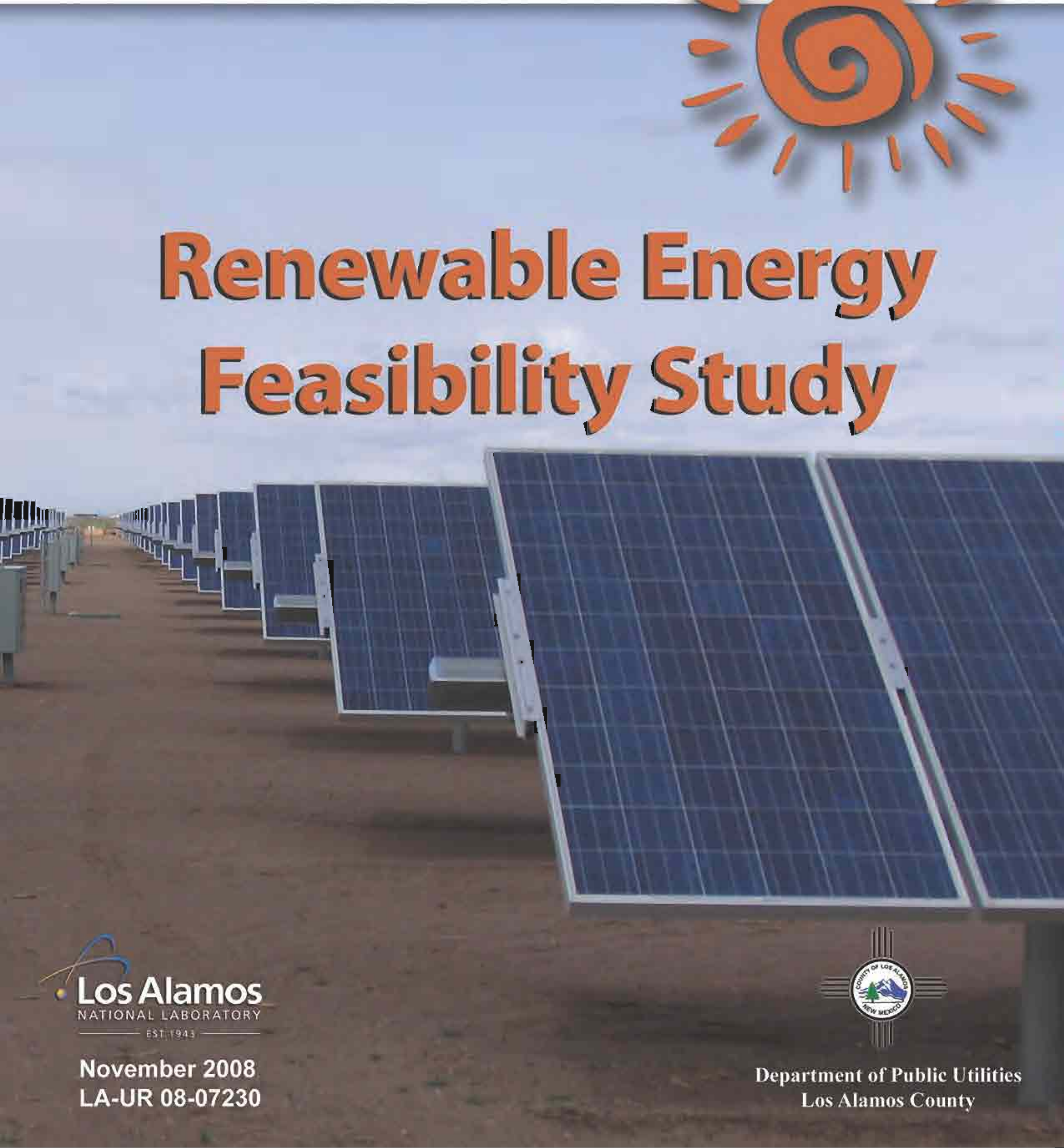
Los Alamos National Laboratory

Los Alamos County



Renewable Energy Feasibility Study

November 2008
LA-UR 08-07230

Department of Public Utilities
Los Alamos County

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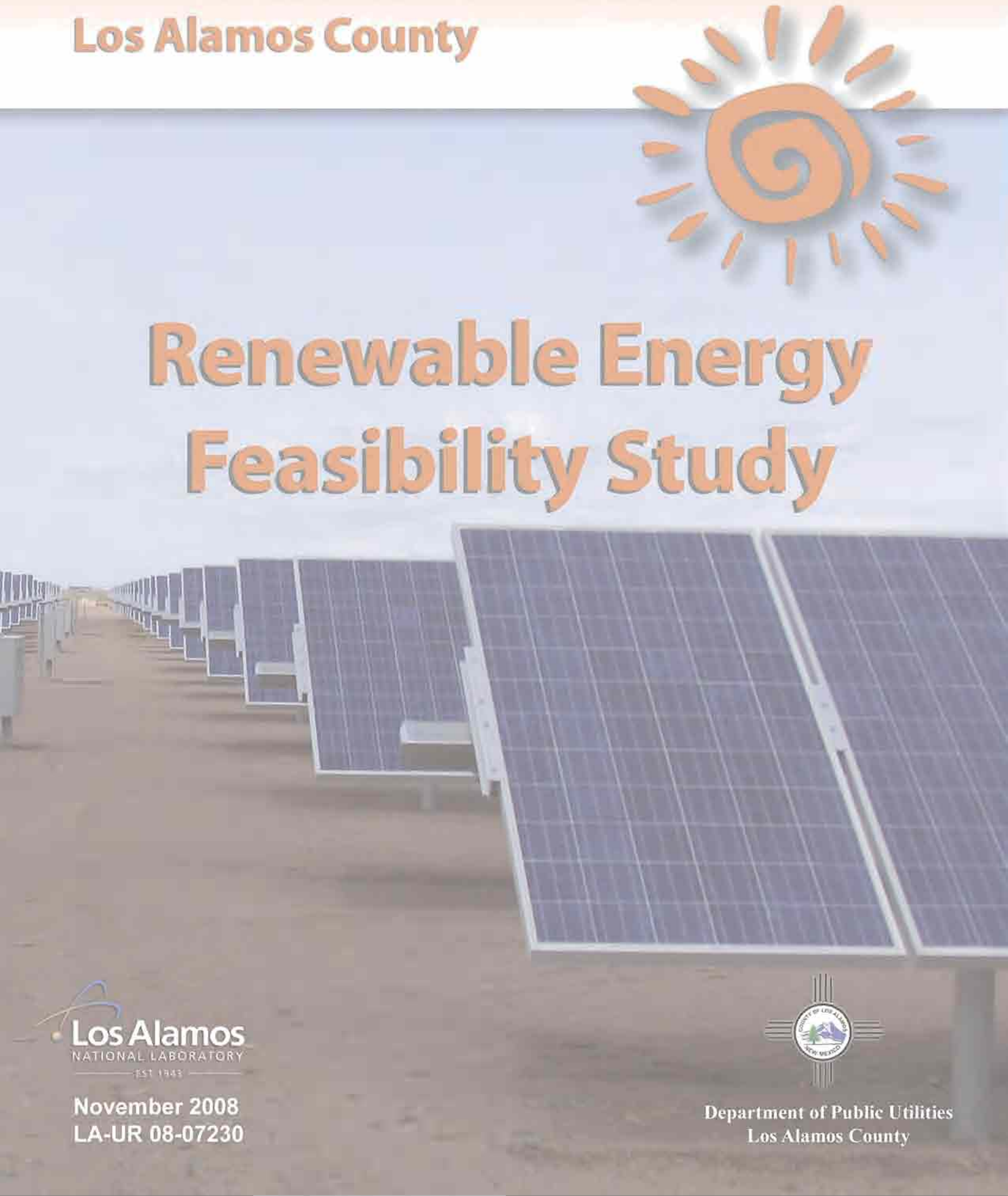

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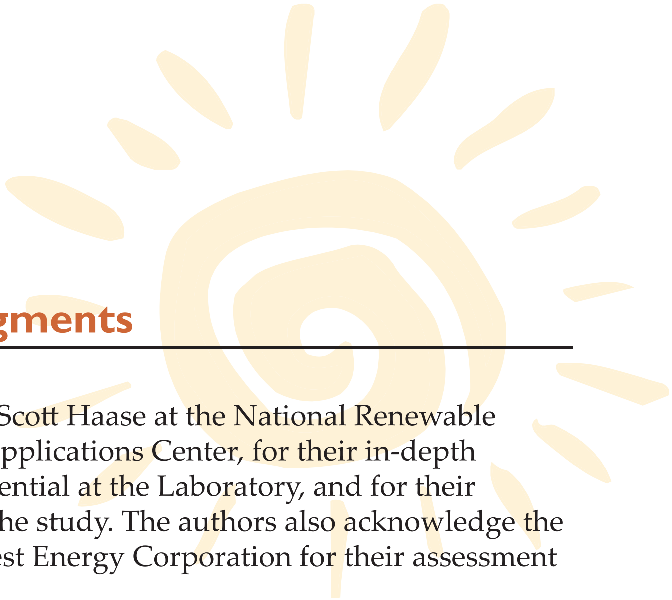

Acknowledgments

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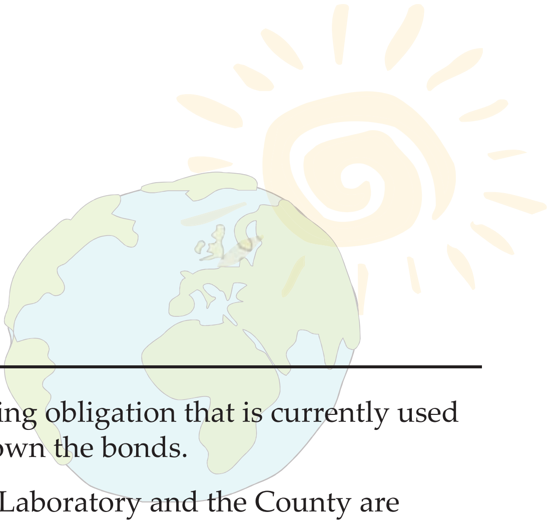

Executive Summary

Since 1985, Los Alamos County and the Los Alamos National Laboratory have benefited from reliable and cost competitive electrical power. These benefits are the direct result of a unique power pooling arrangement created between the two parties in 1985 – the Los Alamos Power Pool. The contract that governs the Power Pool's cost sharing, management, and operations, *the Los Alamos County/Department of Energy, Electric Energy and Power Coordination Agreement (ECA)*, enabled Los Alamos County to purchase fossil-fueled and hydroelectric generation capacity in the mid-1980s through the sale of tax-exempt municipal revenue bonds, which retire in 2015. For the last twenty-three years, the County's ownership of a portfolio of generation assets has sheltered the County and the Laboratory from much of the inherent market risks associated with the wholesale power market.

The power pooling agreement was amended in 2006 with the option for additional extensions in rolling five-year terms. Each five-year extension must be negotiated five years in advance. The next notice period occurs in 2010 for the five-year extension beginning in 2015.

The upcoming renegotiation and likely extension of the ECA provides an opportunity to incorporate new renewable energy sources (renewables) into the Power Pool's portfolio of energy supplies. This can be accomplished at zero net impact to the DOE's current cost of electricity (CoE) by funding the acquisition of renewables with that portion of the DOE's cost sharing obligation that is currently used to pay down the bonds.

Both the Laboratory and the County are under increasing pressure to add renewables to its supply portfolio. In 2007, the Los Alamos County Utility Board mandated that the Los Alamos County Department of Public Utilities seek opportunities to "go green." In early 2008 the DOE issued an Order[1] (DOE O 430.2B) requiring all of its sites to install on-site renewable generation. At present, the only renewable energy source planned for the Power Pool is the County's installation of a third unit at Abiquiu Dam in FY09. This study explores the practicality of renewable energy for the Power Pool, beyond the addition of the Abiquiu hydroelectric project, in order to meet both the DOE and County requirements; ensure that the costs of production for renewables remain competitive with the current costs of production in the Power Pool (the majority of which are fossil fueled); and stabilize the future cost of energy for the County and the Laboratory. This study considers three questions.

1. How much on-site renewable energy is realistic considering:
    - commercially available renewable generation technologies,
    - existing power system capacity and constraints,
    - forecasted demand for energy at the Laboratory, and

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[1] U.S. DOE, *Departmental Energy, Renewable Energy and Transportation Management* (DOE 430.2B), Washington, D.C. (February 2008).

  - capital costs per megawatt (MW) for renewable generation typically exceed fossil based generation?
2. How can the Laboratory meet its TEAM[2] Initiative goal of supplying 7.5% of its energy needs from renewable resources?
3. Can a Laboratory/ County ECA extension be tailored in a manner that:
   - keeps renewable energy costs lower than either party could obtain individually, and
   - integrates renewables without an increase in the effective rate for the Power Pool?

Approach

To answer these questions, both baseload ("round-the-clock" continuous demand) and intermittent loads were analyzed to determine where renewable power might fit within the portfolio of the Power Pool's generation sources.

Ten-year load growth forecasts were analyzed ranging from minimum growth to implementation of all of the Laboratory's and County's currently proposed projects reflecting a variety of potential future programmatic configurations for the Laboratory.

Hourly power demand from the past four years was compared with estimated hourly energy generation from possible solar photovoltaic (PV) arrays to identify opportunities to displace high priced peaking power purchased on the wholesale market.

The Study measures the amount of renewable energy that will be needed to fill the gap between the current generation and transmission capacity of the Power Pool and forecasted Laboratory load growth to 2016.

Geothermal, wind, fuel cells, biomass, hydroelectric, and solar power production were evaluated to assess their feasibility for supplementing generation resources for the Power Pool.

Findings

The Study found that currently there are no renewable generation technologies feasible for installation on the Laboratory campus to supply baseload power. Additionally, the Study determined:

- The 115 kilovolt (kV) transmission infrastructure currently has sufficient capacity to import an additional 25 to 30 MW of renewable (or non-renewable) power to serve baseload requirements for the Laboratory and the County. However, significant new power demand resulting from new supercomputing or other planned programmatic changes could increase the Laboratory's load to the point where it would exceed the current 110 MW import capacity of the two existing lines. Above 110 MW, a fully redundant transmission system no longer exists and a third transmission line is required to restore redundancy. The construction of a third 115 kV transmission line from Public Service of New Mexico's (PNM) Norton Station to the Laboratory's Southern Technical Area (STA) Substation must be timed to serve any incremental system loads above 110 MW. In addition, if a large water diversion project planned for 2011 by the City of Santa Fe is completed, steps must be taken by DOE to assure that PNM augments infrastructure such that the 110 MW import capacity to the STA substation is maintained.
- On-site renewable generation from solar PV arrays for daily peak shaving

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[2] Department of Energy Secretary's Transformational Energy Action Management (TEAM) Initiative (August 2007). The TEAM Initiative established the goal that at least 7.5% of the annual amount of energy consumed at each DOE site should be supplied from on-site renewable sources. To meet the Laboratory's TEAM goal it would have to provide approximately 17 MW of renewable power; however, if power generation is sited on federal property, it counts double towards satisfying the goal. In this case the Laboratory would only be required to provide 8.5 MW of renewable energy.

Fixed-axis photovoltaic panels at the Alamosa photovoltaic power plant near the New Mexico border (NREL).

is technically attractive, commercially available and might be economic, despite the fact that there are very few state incentives. Adequate sites exist to conservatively support up to 10 MW of solar PV.

- Generating electricity with local wind resources at a Laboratory (or anywhere within the County) is not feasible due to insufficient wind resources. However, purchasing and importing wind-generated power could become an option for supplying a portion of the Laboratory's baseload energy requirements. Further study of how this option might be implemented, especially how firm blocks of power would be contracted within the grid, are recommended.
- Molten carbonate fuel cells (MCFC) are a moderately attractive source of supplemental energy at the Laboratory because of their ability to supply steam, premium quality, and reliable power. However, fuel cells were not recommended as an immediate supply option. The Laboratory would be required to use natural gas as the fuel due to the unavailability of a local supply of a renewable fuel; and the maintenance and installation costs for an on-campus facility could be prohibitive.
- Biomass steam production presents a unique opportunity to use local wood wastes, forest thinnings, and downfall, to fire a boiler and supplant a portion of the steam plant capacity provided by the existing natural gas boilers. Further analysis is recommended to explore the adoption of biomass technologies.
- Geothermal hot rock steam generation is attractive, but the technology required to tap this resource, available in close proximity to the laboratory, is not commercially proven. It is recommended

that the DOE consider collaborating with private firms to demonstrate and prove the commercial viability of geothermal power production at the Laboratory.

- Concentrating solar power was found to be too much of a technical challenge to install at the Laboratory due to the hilly terrain and limited acreage. There are concentrating solar technologies in the early stages of development that do not have similar space or grade constraints, and may become options in the future. However, concentrating solar power could be immediately attractive as a renewable source of baseload power if it were generated at, and imported from, a remote location.

Incentives

Federal and state incentives, as well as the sale of carbon credits and Renewable Energy Certificates (REC), are available to lower the cost of renewable energy production. Eligibility for incentives differs according to ownership structure: private firms enjoy a variety of tax and production incentives; while public entities, such as the County, can tap federal low interest, tax-exempt bonds to fund construction. Project structures that maximize the use of private and public incentives are described later in the Study.

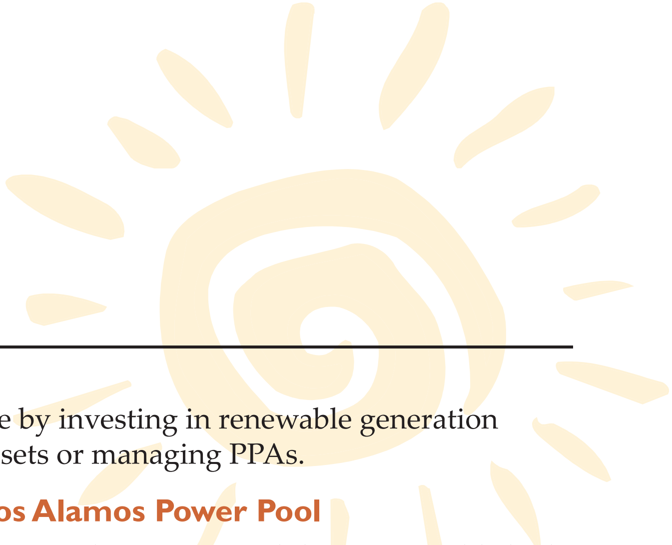
FY09 Action Items

In addition to the County completing its plans for constructing an additional hydro unit at Abiquiu Dam as an approved Power Pool resource, the study recommends that the following activities be pursued in FY09 to facilitate the use of the ECA as a vehicle to introduce renewable energy into the Power Pool portfolio:

- Satisfy the TEAM goal through the installation of 8.5 MW of PV at TA-36 and TA-61.
- Request a modification to the TA-61 landfill permit from the New Mexico Environmental Department (NMED) to allow installation of a PV array.
- Initiate a Laboratory PR-ID process and siting analysis to evaluate a parcel at TA-36 as a potential site for the installation of a PV array.
- Evaluate issuing a special use permit to the Los Alamos County Department of Public Utilities for a PV installation at TA-36.
- Issue a Los Alamos County Department of Public Utilities request for Power Purchase Agreement (PPA) proposals from renewable energy developers for 8.5 MW of PV to be installed on the TA-36 and the TA-61 parcels.
- Initiate an in-depth study to determine whether wind-generated energy could be imported to satisfy a portion of the Laboratory's baseload electricity requirements.
- Continue the evaluation of supplanting steam capacity at the TA-3 Steam Plant or other distributed boiler locations with biomass boilers.
- Evaluate the potential impact of the County aggregating customer-owned renewable generation for the purpose of counting it as a Power Pool resource.

There is a broad potential range of load growth forecasts for the Laboratory that are dependent on its future configuration. Neither the County nor the Laboratory is interested in overbuilding its electrical or steam capacity. None of these recommendations would put either party in that position. In fact, given the modular nature of most renewables, should any of the currently unattractive options become viable, they can be installed "just in time" to meet new electrical loads as they materialize.

By pursuing the FY09 recommended activities, the County, DOE and the Laboratory will have made significant progress to ensure that affordable renewable energy becomes an integral part of the County's and the Laboratory's energy portfolio meeting current needs and future growth.



Chapter 1. Introduction

In July 2007, the Los Alamos County Department of Public Utilities approached the Los Alamos National Laboratory Infrastructure Planning Office (IP) with the idea of adding renewables to the present mix of electrical generation assets owned by the County[1] and the DOE.[2] The parties agreed to investigate options for adding renewables to their energy supply portfolio. Subsequently, a concept paper[3] was prepared that explored the idea of using the County as the funding mechanism to increase the availability of renewables to the County and the Laboratory.

In late 2007, the concept paper[3] was presented to Laboratory management, the Department of Energy's National Nuclear Security Administration (NNSA) Los Alamos Site Office, and the County. During the presentations, the authors recommended and received approval to proceed with a joint Laboratory/County renewable generation feasibility study. The Infrastructure Planning Office was chartered to lead the study.

For renewable generation to be attractive it must provide value to both the Laboratory and the County. The Laboratory is motivated to find a supply of renewable energy to meet the goals of DOE Order 430.2B, the County is enthusiastic about adding renewables to its portfolio provided it can receive a reasonable fee by investing in renewable generation assets or managing PPAs.

Los Alamos Power Pool

In 1985, the County and the DOE established the Los Alamos Power Pool, as a means to pool their generation and transmission assets. The CoE delivered by the Power Pool, as well as its management and operation, are governed by terms set by the Los Alamos County/Department of Energy Electric Energy and Power Coordination Agreement.

The current agreement expires June 30, 2015. Because of low cost resources and efficiencies, the Pool has enabled both the County and DOE to acquire reliable and economical power by making use of County tax-exempt bonds to fund acquisitions. As a result, there has been no investment in renewable power resources to date. However, the County intends to add a third hydroelectric unit at Abiquiu Dam in FY09. In order for renewables to be introduced into the Power Pool, either through the funding of physical generation assets or through PPAs, both parties must concur. The Power Pool's existing generation and transmission resources are described in Appendix A.

In 1985, the County issued tax-exempt revenue bonds and funded a $110 million acquisition of generation assets for the benefit

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[1] The "County" is used interchangeably to refer to Los Alamos County and the Los Alamos County Department of Public Utilities.

[2] The Department of Energy contracts for energy at each of its sites. The site management and operations contractor pays for the energy consumed through its operating budget.

[3] Los Alamos National Laboratory, William H. Jones, Alfred J. Unione, and John E. Arrowsmith, *Improved Energy Management at Los Alamos National Laboratory and Los Alamos County Using Renewable Energy Generation*, October 2007.

of the Power Pool. The ECA requires the DOE to pay approximately 80% of the $8.8M annual debt service on the bonds. The bonds will be fully amortized and retired on June 30, 2015.

The County is no longer eligible to use tax-exempt bonds for this purpose.[4] However, the Energy Policy Act of 2005[5] created a new Federal Bond program, the Clean Renewable Energy Bonds (CREB), which is available to the County as a source of capital to purchase new renewable generation assets. The County could also purchase power from a renewables developer, using New Mexico Energy Acquisition Authority (NMEAA) debt to prepay the developer.

Retirement of the existing debt will reduce the cost of delivered power from the Power Pool's already low cost resources. This study recommends that, rather than reducing the overall shared cost of power after the bonds are retired, renewable power sources are acquired at a total cost not to exceed the savings. In this manner, renewables can be added with no net change in the effective power rates of either party.

Renewable Energy Options

Solar, wind, biomass, geothermal, and fuels cells are evaluated for commercial availability, economic feasibility, siting potential, and climatic resource.

Solar Electricity

PV received considerable attention, given the exceptional solar resource available at the Laboratory. It appears that PV alone could meet the Laboratory's current TEAM Initiative goal of approximately 8.5 MW of renewables. The TEAM goal is based on annual energy consumption at the Laboratory and adjusted each year. Supplying 8.5 MW[6] of renewables to the Laboratory satisfies the 7.5% TEAM initiative goal based on the Laboratory's current level of consumption, but does not accommodate future growth.

An analysis of potential local solar applications conducted earlier this year by the National Renewable Energy Laboratory (The NREL Study)[7] concluded that PV installations of up to 10 MW on Laboratory property are feasible.

Biomass Energy

Energy production (steam and power) from biofuels was evaluated with considerable scrutiny. The County is located adjacent to the Santa Fe National Forest, which undergoes selected forest thinning annually. Harvesting and transporting a reliable and sustainable quantity of biomass fuel was analyzed for two cases. The scenarios considered different biomass applications and the quantity of biofuel needed to supply only (1) heating steam, and (2) heating steam plus 5 MW of electrical generation.

Fuel Cells

Fuel cells were evaluated to access their potential to supply high quality and reliable power to the TA-3 data center distribution feeders with the intent of using waste heat to replace (or augment) steam production at TA-3. The high installation and maintenance costs at the Laboratory pose a challenge for an on-site installation of fuel cells. Economic applications of fuel cells using renewable fuels typically use a waste gas produced in waste water treatment facilities or landfills. These renewable fuel sources are not

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[4] The County is restricted from issuing its own tax exempt revenue bonds to purchase assets when a single customer, such as the Laboratory, constitutes over ten percent of the total utility load.

[5] Energy Policy Act of 2005 (Pub.L. 109-58).

[6] In 2006, the Laboratory consumed 443 gigawatt-hours (GWh) of electricity. Satisfying the 7.5% goal would require nearly 17 MW) Under the TEAM goal rules, however, if the renewable source is sited on government property, it is double counted, resulting in a Laboratory requirement of approximately 8.5 MW.

[7] National Renewable Energy Laboratory, *DOE Los Alamos National Laboratory – PV Feasibility Assessment – NREL Final Report* (January 2008).

currently available at the Laboratory or the County. An evaluation using natural gas as a fuel source is included in the study.

Wind and Geothermal

Wind and geothermal energy production technologies are discussed, but are not evaluated in depth because wind resources at the Laboratory are insufficient to support economic power production. However, there are areas in New Mexico, Colorado, and Texas where power is produced at wind farms and exported to the wholesale electricity market. Remotely generated wind energy may provide an immediate source of renewable power into the Power Pool depending on how procurement is tailored and accomplished.

Geothermal (hot rock) power production was successfully tested near Fenton Hill in the 1970's. Large scale hot rock geothermal technologies are still in the early stages of development. Over time, this technology is likely to advance and may become feasible in the future.

Business Structures and Incentives

The economic feasibility of renewable power projects is entirely dependent upon the business structure of the project and available government incentives. Several proven business arrangements, either to support the construction of facilities on or near the Laboratory, or to support the use of PPA's, are discussed and recommended as a model for the Power Pool to pursue in FY09.

Study Approach

This study considers three questions

1. How much on-site renewable energy is realistic considering:
    - Commercially available renewable generation technologies,
    - Existing power system capacity and constraints,
    - Forecasted demand for energy at the Laboratory, and
    - Capital costs per MW for renewable generation, which typically exceed fossil based generation?
2. How can the Laboratory meet its TEAM Initiative goal of supplying 7.5% of its energy needs from renewable resources?
3. Can a Laboratory/ County ECA extension be tailored in a manner that:
    - Keeps renewable energy cost lower than either party could obtain individually, and
    - Integrates renewables without an increase in the effective rate for the power pool?

Chapter 2, Los Alamos Power Pool Projected Electric Load Growth, begins with an overview of energy consumption at the Laboratory and the County, and forecasts anticipated future increases and decreases in energy use that may result from programmatic changes or future capital projects.

Chapter 3, Daily Load Characteristics and Peak Shaving Opportunities, analyzes the hourly load profiles of the County and the Laboratory and evaluates PV applications as a possible means to offset the amount of electricity purchased outside the Power Pool.

State and Federal incentives for generating power from renewable energy are presented in Chapter 4, and provides examples of typical business structures for renewable energy development projects.

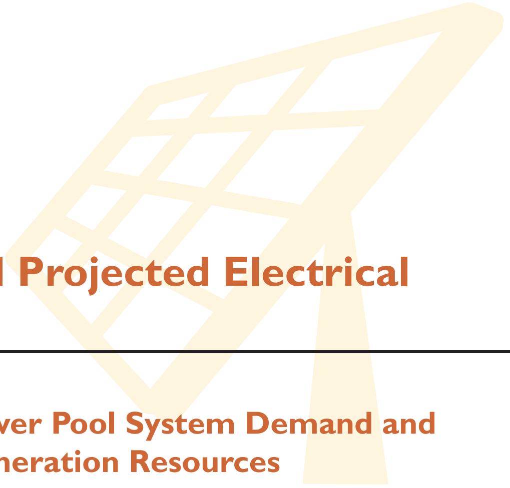
Chapter 5 discusses several renewable technologies and describes how they may or may not be appropriate for the Laboratory or the County.

Chapter 6, Power Purchase Options, describes opportunities for purchasing remotely generated renewable power.

The appendices provide greater detail on the source data and methodology used to prepare the load growth scenarios and technology assessments; background information on generation and transmission resources;

renewable technologies; descriptions of State and Federal Incentives; a sample Request for Proposal (RFP) for solar project development, and proposed modifications to the ECA that will accommodate the introduction of renewable energy into the Power Pool.

This study concludes with recommendations that will promote renewables as a component of future energy supplies for the County and the Laboratory and set the stage for a successful renegotiation of the ECA in FY10.



Chapter 2. Los Alamos Power Pool Projected Electrical Load Growth

Understanding the Laboratory's and the County's future electric load growth is the first step in any analysis of possible renewable power options that could serve that load. Recent load growth at the Laboratory has been relatively flat and therefore predictable. However, the Preferred Alternative of the NNSA Final Complex Transformation Supplemental Programmatic Environmental Impact Statement[1] designates the Laboratory as the host site for supercomputing. Planned supercomputing systems could potentially double system demand of the Power Pool. Although this magnitude of demand growth within the next ten years seems extreme, even a much smaller growth rate has the potential to render the existing utility system less reliable.

This chapter measures (1) the gap between the current power demand of the Power Pool and its generation capacity; and (2) the forecasted range of electrical load growth to 2018, which are based on potential future configurations for the Laboratory. The forecasts identify incremental loads that may exceed the Power Pool's current 115 kV transmission system's ability to maintain full redundancy. This capacity is approximately 110 MW.

The amount of additional system capacity that will be necessary, if any, to satisfy future loads could be provided by on or off-site generation, an increased ability to import power, or a combination of the two.

Power Pool System Demand and Generation Resources

Before exploring future load growth, it is important to understand the difference between the Power Pool's generation capacity and the load on its system. The Power Pool's generation capacity (assuming all assets are on-line) is approximately 85.5 MW in the summer and 66.5 MW in the winter. The difference between summer and winter is attributed to a seasonal supply of hydroelectric power. For several years, the Power Pool's generation capacity of its owned assets has not been able to meet the combined load of the Laboratory and the County. The amount of energy purchased outside the Power Pool to meet system requirements is detailed in Chapter 3, Daily Load Characteristics and Peak Shaving Opportunities for the Los Alamos Power Pool, Figures 3-1 and 3-2.

Vulnerabilities and Risks Posed by New Loads at the Laboratory

The Power Pool's transmission infrastructure includes two redundant 115 kV transmission lines that connect to the Public Service Company of New Mexico (PNM) 115 kV system (see Figure 2-1). Although the two incoming lines, the Reeves line (RL) and the Norton line (NL), are adequate and provide full redundancy, if one of the lines is out of service there may be circumstances in the near future that will require the existing system to shed load. This condition would result in blackout or brownout periods

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[1] U. S. Department of Energy, Final Complex Transformation Supplemental Programmatic Environmental Impact Statement (Complex Transformation SPEIS), DOE/EIS-0236-S4 (October 2008).

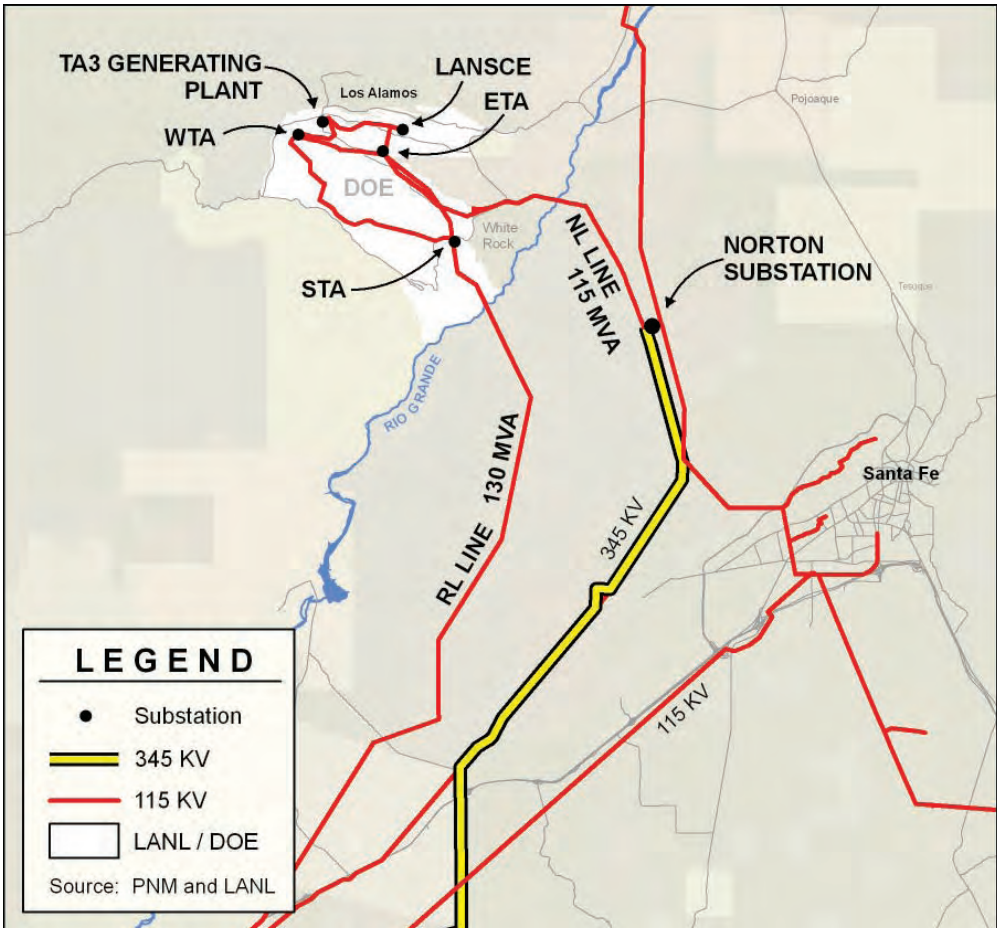

Figure 2-1. Los Alamos Power Pool and Public Service Company of New Mexico electrical transmission infrastructure (Public Service Company of New Mexico).

at certain facilities or substations. In the long term, there is no question that if the incremental projected supercomputing loads materialize, the existing transmission infrastructure will not have the capacity to meet power demands and baseload on-site power generation will have to be installed or the transmission system expanded.

The Power Pool has explored the need for a third 115 kV transmission line to wheel additional power to satisfy future load growth on several occasions since the late 1990s. The most logical route for a new line is from the PNM Norton Station, through the Santa Fe National Forest and across the Rio Grande (see Figure 2-1). At a minimum, approval of a new line will require absolute assurance that the new demand will actually materialize.

While the traditional response to future increases in electrical demand would be to reinforce and upgrade the transmission infrastructure, the inherent difficulty of permitting an additional line requires consideration of on-site generation options, especially from renewable fuels.

Load Growth Forecasts

Growth in the Power Pool's demand is almost entirely driven by incremental changes to Laboratory programs and the construction of new facilities. The majority of new projects require line-item funding and are subject to the appropriations process. As a result, there is considerable uncertainty about exactly which projects will come to fruition. The data presented in this study considers these uncertainties by conducting separate load analyses for a subset of proposed line-item projects, potential programmatic changes, and other Laboratory activities that may influence power consumption.

Previously Projected Ten-Year Demand and Energy Consumption Growth (2008–2018)

In 2007, Keres Consulting, Inc., prepared a ten-year load growth forecast (Keres). The Keres forecast included the Power Pool's historical growth since 1991 and forecasted future growth through 2016 (see Table 2-1 and Figures 2-2 and 2-3).The Keres Study[2] adopted an average annual forecasting technique and included the set of proposed line-item projects that existed at the time. However, the current set of proposed line-items has expanded considerably in the last year. The Keres study is summarized in the next section, followed by a discussion of four additional load growth scenarios that are driven by the current set of proposed line-items and possible future programmatic changes at the Laboratory. This information was unavailable to Keres.

Keres Forecast

Keres predicted that the combined Laboratory and County demand would increase at an average rate of 1.5 percent per year. Keres predicted that combined coincidental peak demand would grow by approximately 13 MW from 2007 to 2016. It attributed approximately 8 MW of the growth to the Laboratory, and approximately 5 MW to the County. According to Keres, the County's demand has the potential to grow from 18 to 23 MW, a 28% increase, while the Laboratory's demand could grow from 69 MW to 77 MW or 12% (see Figure 2-2) and that the Power Pool's consumption would reach 660 GWh in 2016 (see Figure 2-3).

Keres forecasted significant energy consumption growth in 2009 (5%) and 2011 (nearly 2%), and predicted that in the remaining years the Power Pool would experience an annual growth rate of nearly 1%. Of the overall 8.5% increase in Power Pool growth, 4.7% was attributed to the Laboratory and 3.8% to the County (see Figure 2-4).

Keres considered previous predictions of planned increases in computing resources at the Laboratory's Nicholas C. Metropolis Center for Modeling and Simulation (Metropolis Center) and increased power requirements at the Los Alamos Neutron Science Center (LANSCE). The Chemistry Metallurgy Research Replacement (CMRR) project was not considered. The Keres study

Table 2-1. Keres Estimated Laboratory, County, and Power Pool Peak Demand (MW) and Power Consumption (GWh); Historical to 2007, Forecasted 2008–2016 (Keres, 2007)

	Coincidental Peak Demand (MW)			Power Consumption (GWh)		
Fiscal Year	Laboratory	County	Power Pool	Laboratory	County	Power Pool
2007	69	18	87	440	135	575
2008	73	19	92	439	137	577
2009	74	19	93	468	141	608
2010	74	20	94	470	144	614
2011	75	20	95	473	154	626
2012	75	21	96	475	158	633
2013	76	21	97	478	162	640
2014	76	22	98	482	165	647
2015	77	22	99	484	169	653
2016	77	23	100	487	173	660

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[2] Los Alamos Power Pool Power Supply Study, Keres Consulting, Inc., March 2007, NNSA Contract No. DE-AC52-05NA26690.

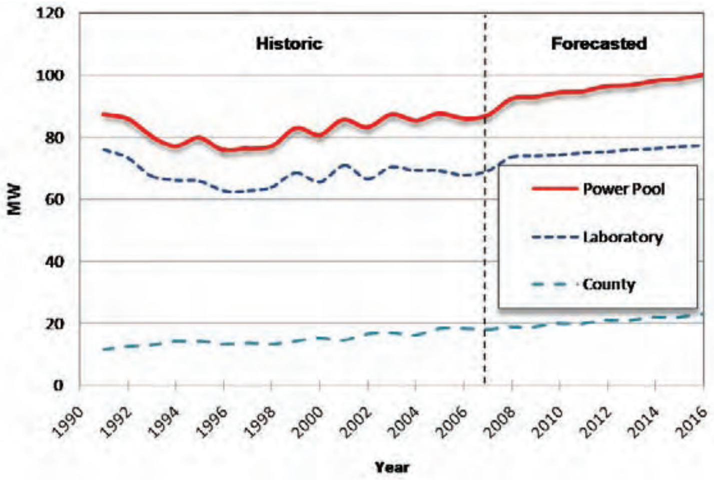


Figure 2-2. Keres analysis of the Laboratory, County, and Power Pool peak demand (MW) historical to 2007, forecasted 2008–2016 (Keres, 2007).

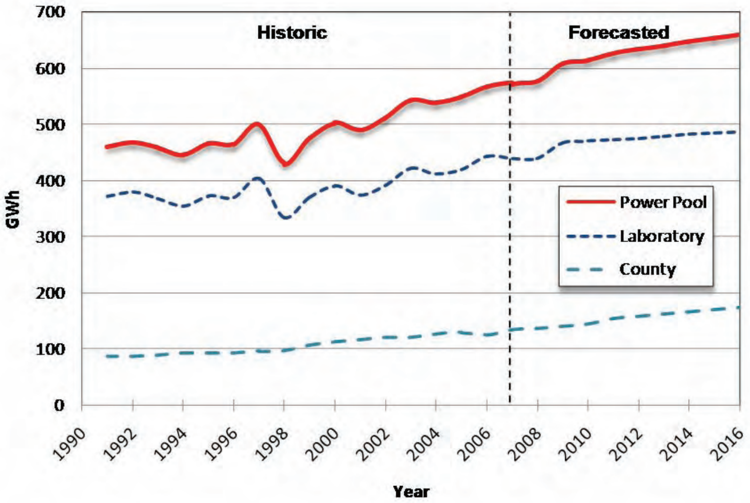


Figure 2-3. Keres analysis of the Laboratory, County, and Power Pool consumption (GWh) historical to 2007, forecasted 2008–2016 (Keres, 2007).

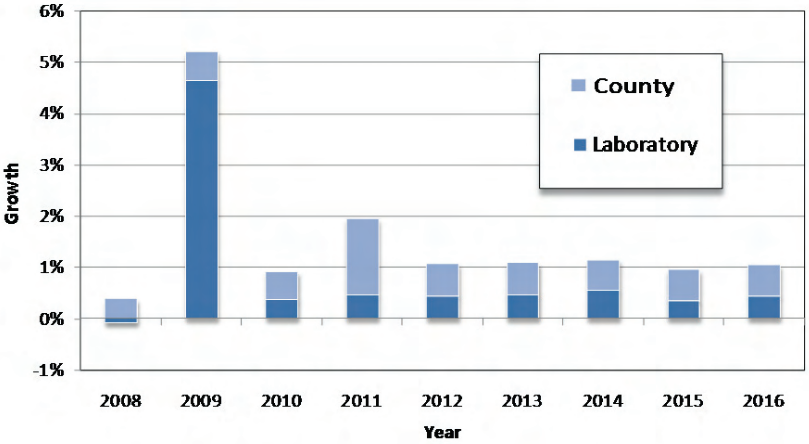


Figure 2-4. Keres forecasted percentage growth in Power Pool consumption attributed to the Laboratory and the County, 2007–2016 (Keres, 2007).

preceded, and therefore did not include the predicted decrease in consumption resulting from the current initiative to reduce Laboratory footprint by 2 million gross square feet (gsf), and the DOE mandated energy conservation initiative currently in progress under an NNSA contract with NORESCO.

New Demand Forecasts Based on Current Information

This section provides an expanded analysis of the Power Pool's load growth and provides scenario driven growth forecasts incorporating data from the following activities:

- Potential programmatic missions at the Laboratory
- Facility dispositions captured within the Laboratory footprint reduction initiative
- Potential energy savings from the NORESCO conservation project
- Current Los Alamos County demand forecasts

The data were collected from interviews with Laboratory subject matter experts (SME) familiar with existing facilities. Each SME provided the estimated power demand range of new and disposed loads over the next 10–15 years associated with their facilities (see Table 2-2). Where possible, the analysis includes the year in which the expected load change is predicted to occur.

Figure 2-5 graphs the impact of each load on overall Laboratory power demand. The methodology and assumptions used to develop the load estimates are provided in Appendix H, Major Programmatic Impacts on Future Electricity Demand. The primary facilities (or initiatives) considered in the forecasts include the following:

1. Computer Centers
    - The Metropolis Center
    - Laboratory Data Communications Center (LDCC)
    - Central Computing Facility (CCF)
    - Advanced Computing Laboratory (ACL)

Table 2-2. Estimated Increase or Decrease in Power Demand Attributed to Laboratory Projects and Initiatives in the Year they are Anticipated to Occur (reductions are shown in parenthesis)

Project	Range of Incremental Demand Change (MW)											
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Future
Metropolis	4.6–10.4		8.3–12.4				41.4–69.5					
LDCC	1.5–2.0	0.6–1.3			(2.0)							
CMRR-RLUOB					2.5–3.0			0.6–0.8				
CMRR-NF								3.5–4.0				
LANSCE-R								4.0–4.5				
MTS										0.5–1.0		
SPEF											1.0	
LEDA (FEL)							5–6					
Science Complex Facility					5.6–7.4							
Science Complex Computer					20							
MaRIE												3.0–10.0
2M FRI						(1.0)						(1.0–2.0)
NORESCO				(0.5–1.0)								

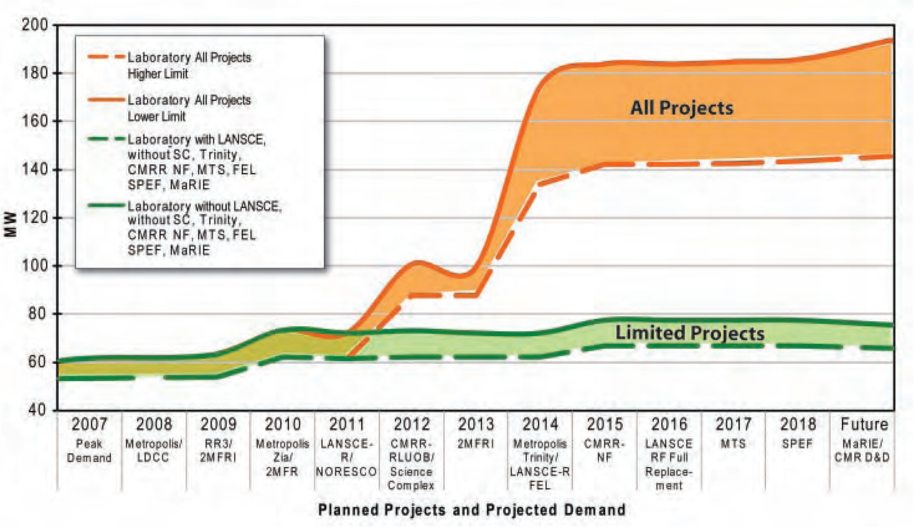


Figure 2-5. Range of forecasted Laboratory demand (MW) if all proposed projects and initiatives are implemented on schedule (orange). Range in forecasted demand with major projects delayed beyond 2018 (green).

2. CMRR
   - Radiological Laboratory Utility Office Building (CMRR-RLUOB)
   - Nuclear Facility (CMRR-NF)
3. LANSCE
   - LANSCE Refurbishment (LANSCE-R)
   - Material Test Station (MTS)
   - Short Pulse Experimental Facility (SPEF)
   - Free Electron Laser (FEL) at the Low Energy Demonstration Accelerator (LEDA) Facility
4. Matter-Radiation Interactions in Extremes (MaRIE)
5. Science Complex (SC)
6. Two Million gsf Footprint Reduction Initiative (2M FRI)
7. Energy Savings Performance Contract (NORESCO)

Scenario Driven Laboratory Load Growth Forecasts

The Laboratory's projected demand growth through 2018 is dependent on the future configuration and programmatic missions of the Laboratory. In 2007, the peak demand at the Laboratory was approximately 65 MW when LANSCE was operating. Two cases show projected demand to 2018, "All Projects" and "Limited Projects," both illustrated in Figure 2-5.

The "All Projects" case assumes that between now and 2018 all proposed projects will take place, and that by 2018 the demand will be in the range of 147–194 MW. A sharp increase is predicted to occur in 2014 due to the addition of the Trinity computer. The Trinity computer alone could add approximately 30–50 MW of demand for the computer and the cooling.

The "Limited Projects" case assumes that SC, Trinity computer, Chemistry Metallurgy Research Replacement-Nuclear Facility (CMRR-NF), MTS, FEL, SPEF, and MaRIE projects are delayed beyond 2018. This limited case projects the demand to range between 67 MW and 75 MW.

Los Alamos County Demand Forecast Based on Current Information

The County prepared a ten year power and demand projection in January 2008. An interesting observation is that the County system peaks in December. December data is always used in the "Maximum" case shown in Figure 2-6. The median of the remaining eleven months was used as a baseline and considered comparable to the minimum growth, shown as the ”Minimum” case on the Figure 2-6. The County’s forecast of the monthly demand in 2018 indicates a range of between 20 and 26 MW (from today’s demand of approximately 18 MW).

Los Alamos Power Pool Updated Demand Forecast

The Laboratory’s (Figure 2-5) and the County’s (Figure 2-6) load growth cases were combined to predict the Power Pool’s demand shown in Figure 2-7. Four scenarios were evaluated:

Scenario 1: Minimum growth

Scenario 1 combines the lower range of the County forecast with the lowest growth case for the Laboratory, the low end of “Limited Projects” with large projects deferred beyond 2018.

The 2007 average peak demand for the Power Pool is approximately 65 MW. Under the most conservative forecast of “Minimum” growth, as illustrated in Figure 2-7, the 21 MW of new load can be accommodated within the existing transmission infrastructure.

Scenario 2: Moderate-Low growth

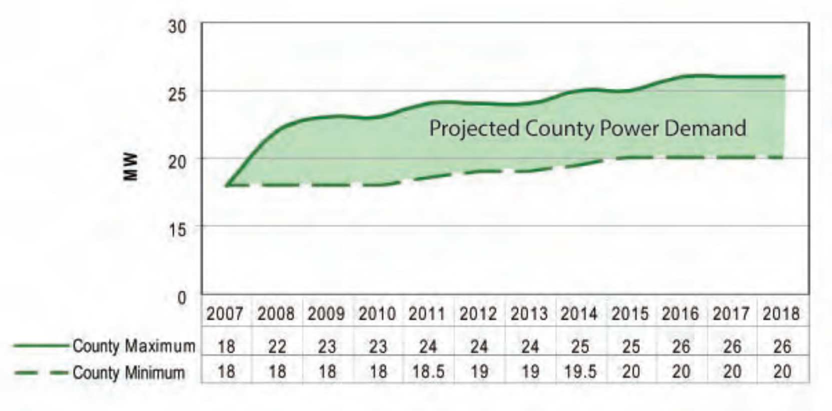
The “Moderate-Low” growth scenario uses the same assumptions for the County as Scenario 1, but uses the high end of the Laboratory “Limited Projects” case.

Under the scenario “Moderate-Low” growth, the power demand on the 115 kV NL line would be approaching its rating by 2015.[3]

Scenario 3: Moderate-High growth

“Moderate-High” growth assumes the lowest range in estimated growth for the County and that all planned Laboratory projects are completed on schedule but operate at the lower range of estimated demand (the lower end of the “All Projects” case).

The “Moderate-High” growth, scenario portrays a smaller Trinity supercomputing demand and smaller incremental increases in new science and weapons mission loads.



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
County Maximum	18	22	23	23	24	24	24	25	25	26	26	26
County Minimum	18	18	18	18	18.5	19	19	19.5	20	20	20	20

Figure 2-6. Los Alamos County range of power demand (MW) historical to 2007, forecasted 2008–2018.

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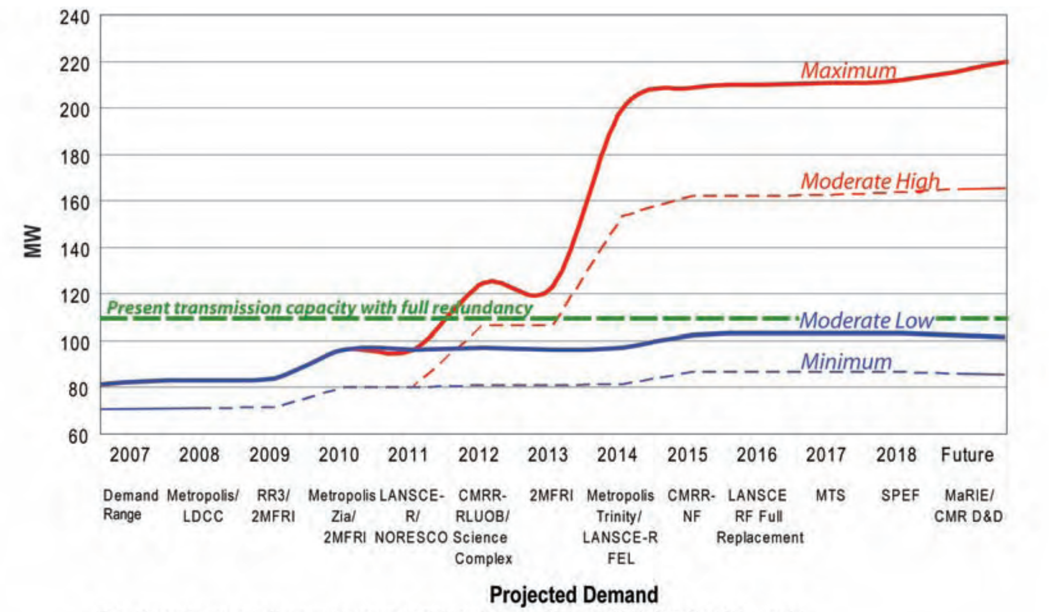
[3] The MW capacity is dependent on power factor. If the power factor is 1.0, the power rating is 115 MW. Re-conductoring the NL line to match the RL line’s 130 MVA rating is an alternative that would defer the need for a third transmission line, or on site generation, under this scenario. Presently the City and County of Santa Fe are installing a water diversion project which will draw power from the NL line tapped at the Buckman substation. If the existing infrastructure is not augmented, this project could reduce the import capacity of the NL line to the Laboratory by as much as 7 MW. Telecons with PNM disclosed that the existing Buckman power tap is being expanded to install a 22.5 MVA substation to serve the existing Buckman wells, the planned water diversion pumps and potentially supply future loads. It is important that DOE begin discussions to gain assurances from PNM that the Laboratory’s current 110 MW of import capacity be maintained, regardless of the water diversion project or other PNM customer loads.



Note: Moderate Low and Minimum do not include Science Complex, Trinity, CMRR-NF, MTS, FEL, SPEF, or MaRIE

Figure 2-7. Power Pool maximum transmission capacity and forecasted demand, 2007–2018 (MW) for four project-dependent scenarios.

Under these circumstances, minimum demand in 2014 could be 154 MW and by 2018, 167 MW. An additional 115 kV transmission line, and/or on-site generation will be required.

Scenario 4: Maximum growth

The "Maximum" growth scenario depicts future increases in demand resulting from a fully implemented supercomputing mission and maximum incremental increases in new science and weapons mission loads. In this scenario, incremental demand could be as high as 200 MW in 2014, driving the need for a third transmission line, or significant round-the-clock generation at the Laboratory.

Addressing Load Growth

All four Power Pool scenarios suggest that decisions regarding on-site generation and planning for an additional transmission line might best be phased. Although different in magnitude depending on the scenario, three discreet increments of increases in load occur, and are dependent on when and which of the proposed projects are implemented; 2010, 2012, and 2014 (see Figure 2-7). The magnitude of these increments is uncertain. On the other hand, if the 2014 "Maximum" growth scenario occurs, approximately 5 years of lead time, starting in 2009, will be necessary to engineer, permit, and construct the third transmission line.

It is likely that the demand curves in Figures 2-5 and 2-7 will shift to the right as proposed projects may be delayed or cancelled. This, in turn, will delay the urgent need for a third line, estimated to cost approximately $15 million, and take approximately 5 years to complete. It is imperative that the Power Pool remain aware of the power transmission constraints, and begin planning a new line in conjunction with the power requirements for any funded capital projects.

Regardless of load growth, the Power Pool often experiences a shortfall in generation on a typical day. This energy is purchased outside of the Power Pool at relatively high prices. Renewable power wheeled to the Laboratory from off-site sources could fill this gap, contribute to TEAM goals, and possibly reduce costs. Chapter 6 provides a detailed discussion of the current circumstances and describes potential options for meeting this shortfall in supply.

Chapter 3. Daily Load Characteristics and Peak Shaving Opportunities for the Los Alamos Power Pool

Purchased Power and Hourly Demand

Solar electric power provides the most power at peak sunlight, which is normally coincident with peak electric load on most utility systems. The sources of power for these peaks is always the highest cost, whether from "peaking" units owned by the utility, or through the purchase of imported power. The Power Pool does not have sufficient generation sources to fully serve its load. As a consequence, it purchases power to fill the gap, whether on or off peak. This chapter analyzes historical daily Power Pool hourly demand and then quantifies the amount of peak demand that can be reduced ("peak shaving") by various sizes of solar electricity generators.

Figures 3-1 and 3-2 show the Power Pool's net on-peak and off-peak monthly energy purchases from 2005–2008 (the Power Pool makes sales to, as well as purchases from the grid). Ignoring the huge off peak purchases in November 2007, the Power Pool's average monthly total net off-peak purchase was 2,300 megawatt hours (MWh).[1] Assuming a unity load factor[2] for this off-peak purchase, nearly 6.4 MW of generation capacity would be required somewhere in the utility system to feed the Power Pool's load.

Figure 3-3 illustrates the hourly changes in energy demand during a typical workday in July. The figure shows the load shape for the average hourly loads in 2006 and 2007 for the Power Pool, the Laboratory, and the County. Weekday hourly demand for the Power Pool follows the pattern of the population being at work between 08:00 and 17:00, then in residence between 18:00 and 23:00. Two daily workday peaks occur: a mid-afternoon peak approximately 14:00, primarily due to Laboratory operations and a later, minor peak due to County residential loads between 21:00 and 22:00. While average hourly demand varies from season to season, the daily load shapes are virtually identical. Preliminary data suggests that the 2008 average hourly demand will be consistent with the July 2007 data.

Figure 3-4 shows the Power Pool seasonal average hourly demand, 2004–2007. The daily demand pattern is similar for all seasons, and demand peaks in the summer between 12:00 and 18:00.

Photovoltaic Array Scenarios

Los Alamos is located in the US region with the highest amount of average solar radiation (See Figure 3-5).

NREL assisted the Laboratory in early FY08 with an analysis of potential sites for roof-mounted and ground mounted PV arrays. Excerpts from NREL's report are attached

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[1] Both San Juan Unit 3 and San Juan Unit 4 were down for unplanned maintenance during this period. Although Los Alamos County owns 36.5 MW in San Juan Unit 4, it has a hazard sharing agreement where 18.25 MW is available from Unit 3, when Unit 4 is down. Since both units were down, it had to replace 36.5 MW with power purchases.

[2] Load factor is a measure of energy consumption relative to the energy consumption that would occur operating at the rated capacity of the serving equipment. Load factor equals the MWh in a billing cycle divided by the peak MW demand that has been multiplied by the number of hours in the billing cycle.

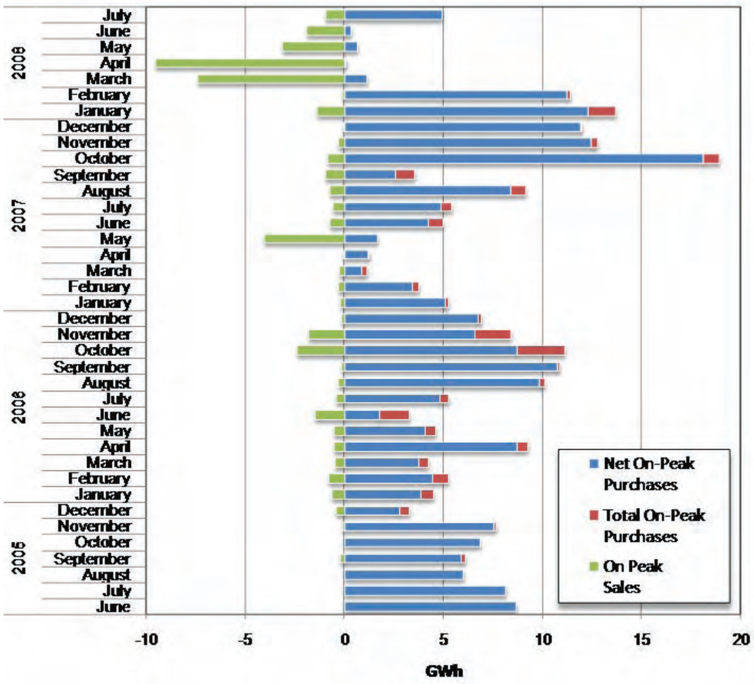

Figure 3-1. Power Pool on-peak power purchases and sales, 2005–2008 (Los Alamos County).

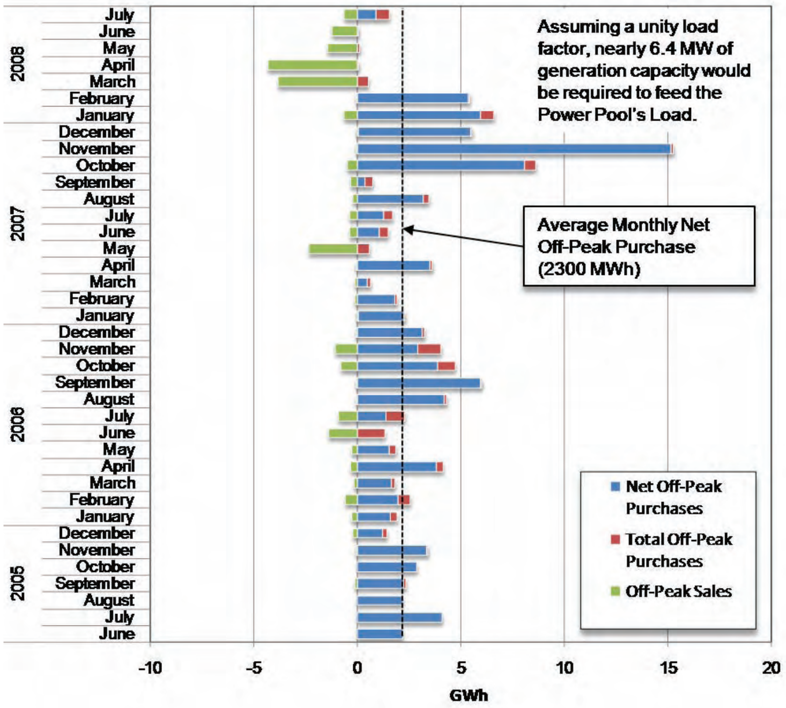

Figure 3-2. Power Pool off-peak power purchases and sales, 2005–2008) (Los Alamos County).

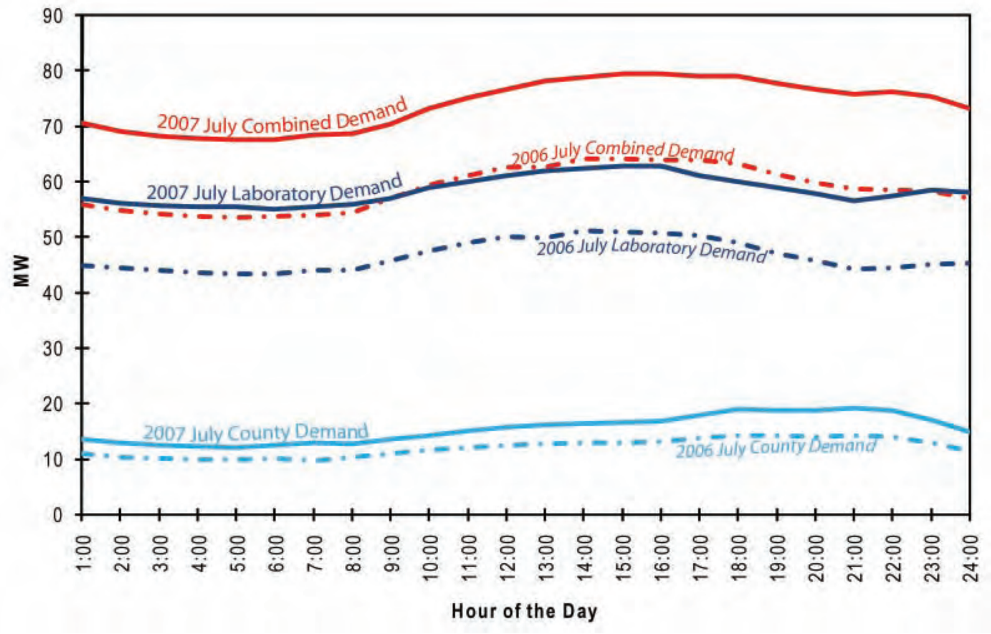

Figure 3-3. Average hourly weekday demand for the County, the Laboratory and the Power Pool for July 2006 and July 2007.

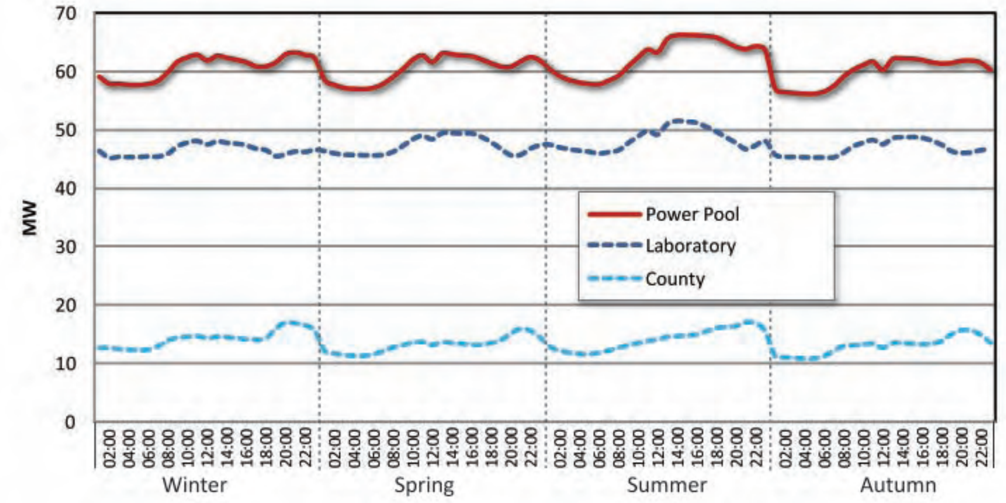

Figure 3-4. Power Pool average hourly demand by season (MW), 2004–2007.

as Appendix B. Although roof-mounted PV systems are technically feasible, they represent a number of difficulties with regard to installation and access within secure areas due to the Laboratory's stringent construction and security requirements. Roof mounted systems are not considered in this study.

Three types of ground mounted systems were considered; fixed installation (or "fixed tilt") panels that track the sun on one axis ("one" or "single axis tracking"), and systems that track the sun on two axes ("two" or "double axis tracking"). A pictorial representation of each is shown in Figure 3-6. Figure 3-7 shows the hourly output of each system type for a 10 MW system. As can be seen in the figure, for all practical purposes, the output of single and double axis systems are virtually

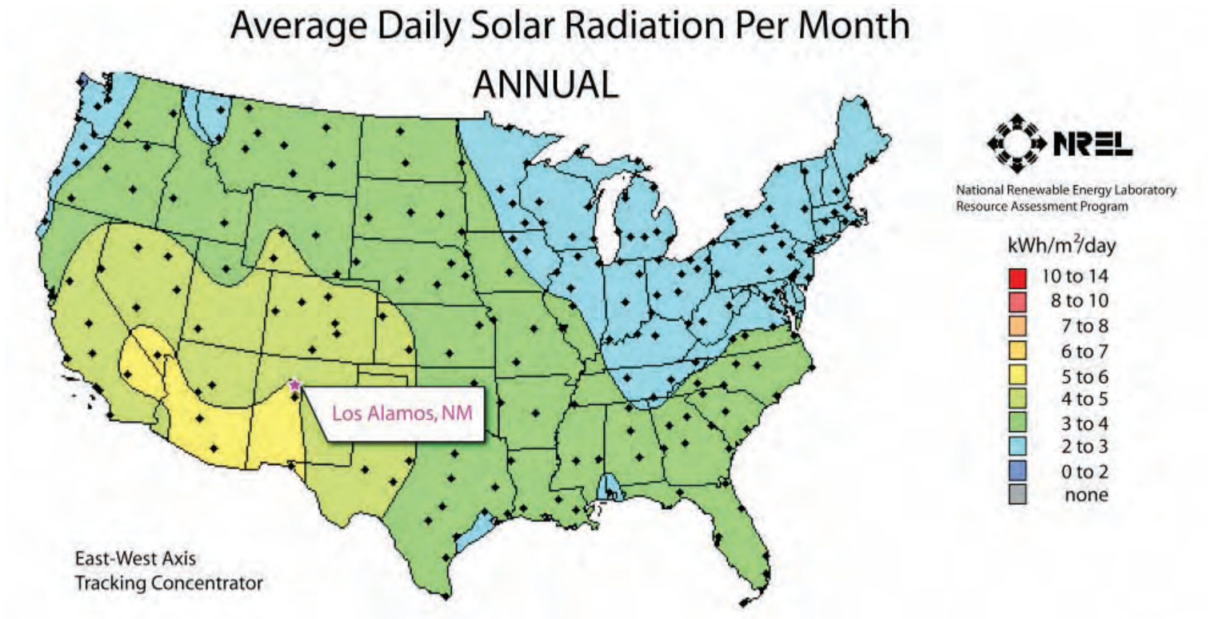

Figure 3-5. U.S. annual average daily solar radiation per month (kWh/m^2/day) (NREL).

identical in the Los Alamos region. Since the added expense of double axis systems does not materially increase output, only single axis systems are considered later in this study.

The NREL PVWatts™ calculator was used to determine the energy production of each option. The calculator uses typical meteorological weather data for the area and then determines the solar radiation incident on the PV array along with the PV cell temperature for each hour of the year. The PV array specifications used for these analyses are provided in Appendix B, PV Array Specifications. Average daily PV array power generation was calculated and is shown as a supply that reduces the summer hourly demand in Figures 3-8 and 3-9.[3]

Both 5 MW and 10 MW systems were assessed. The 5 MW single axis system (Figure 3-8) during the summer could allow the Power Pool to sell approximately 2 MW below the baseline demand of power during the hours of 5:00 am to 9:00 am.[4] At its peak, the system could displace 4 MW of power during the day, reducing the Power Pool's dependence on remote sources.

A 10 MW single axis system (Figure 3-8) during the summer could allow the Power Pool to sell up to 5 MW below the baseline summer demand during the hours of 05:00 to 12:30. It is estimated that the PV supply could reduce the off-site dependence by as much as 8 MW between the hours of 13:00 and 19:00.

Further analysis concludes that a 10 MW PV double axis array could shave as much as 10% of the Power Pool's afternoon peaking load. A 5 MW single axis PV array could shave as much as 5% of the Power Pool's afternoon peak load.

Chapter 5.1 and Appendix B provide a detailed discussion of PV technology, economics and recommendations for its use at the Laboratory, including likely sites for installation. In general, using PV for peak shaving could be quite economic and increasingly so as the average on-peak cost of purchased power escalates. Figure 3-10

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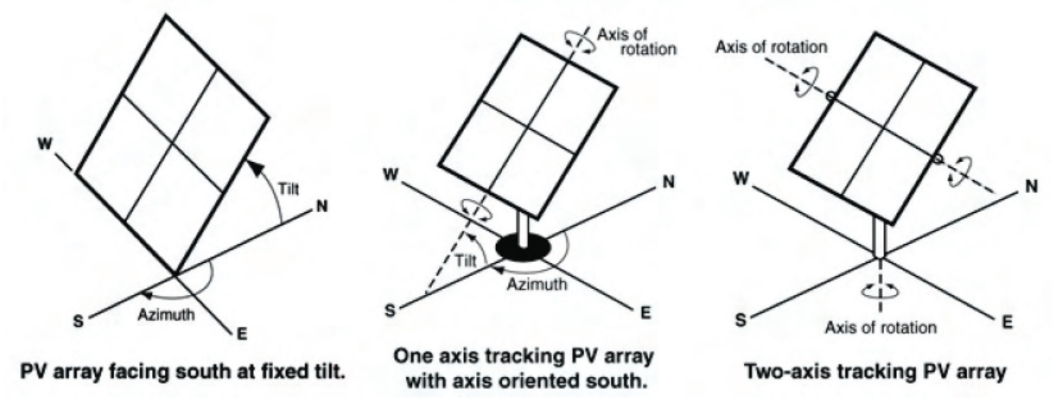
[3] July 2007 hourly peak demand was used for illustrative purposes.

[4] This analysis is hypothetical for illustrative purposes. The County would determine whether to sell or consume the energy based on its mix of on-line generation resources and purchased power contract commitments.



PV array facing south at fixed tilt.

One axis tracking PV array with axis oriented south.

Two-axis tracking PV array

Figure 3-6. Fixed, single-, and double-axis tracking ground mounted photovoltaic systems.

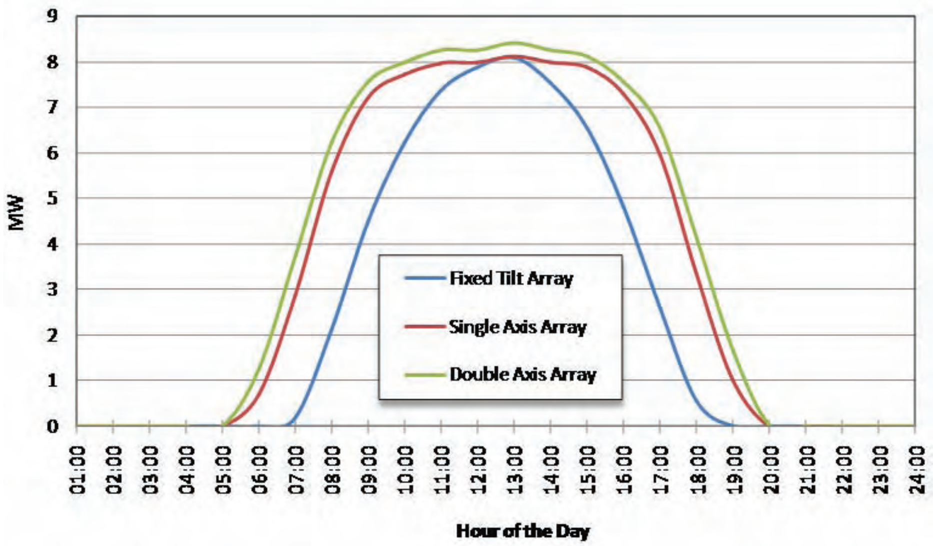


Figure 3-7. Annual average hourly power output of a 10 MW PV array for three system types for Albuquerque, NM (NREL PVWatts™).

presents the high, low, and average daily price paid by the Power Pool for delivered energy in 2008, compared with a likely range of costs of electricity from on-site PV.

The power prices represent the sum of the 4 Corners wholesale costs and a $3/MWh wheeling charge, adjusted for 3% line losses.

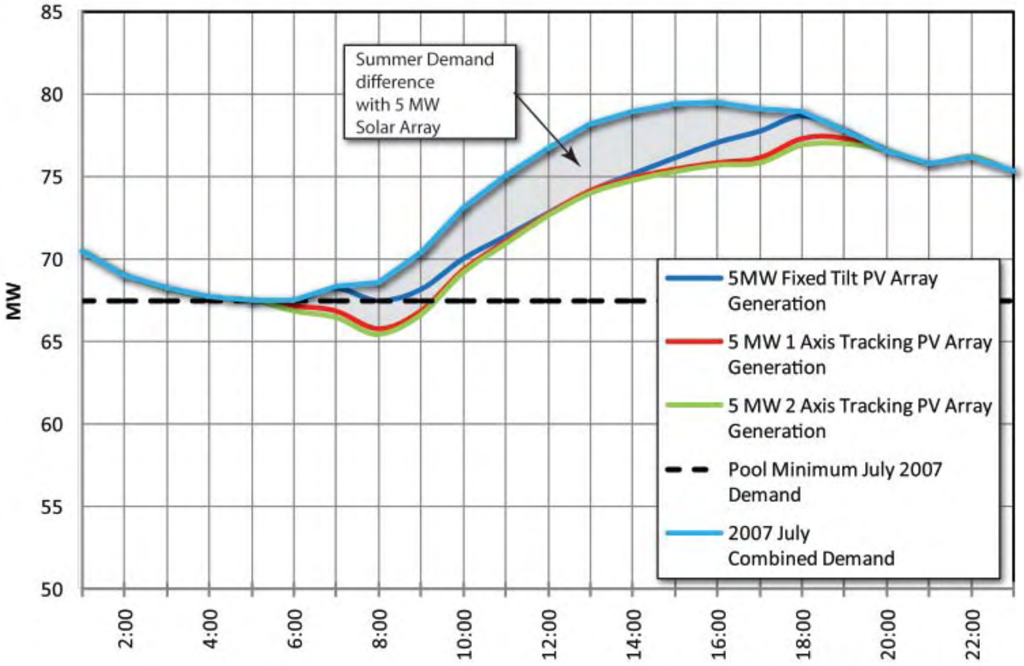


Figure 3-8. Power Pool average hourly peak demand for July 2007 and the potential peak demand reduction from a 5 MW PV system (Los Alamos County and NREL).

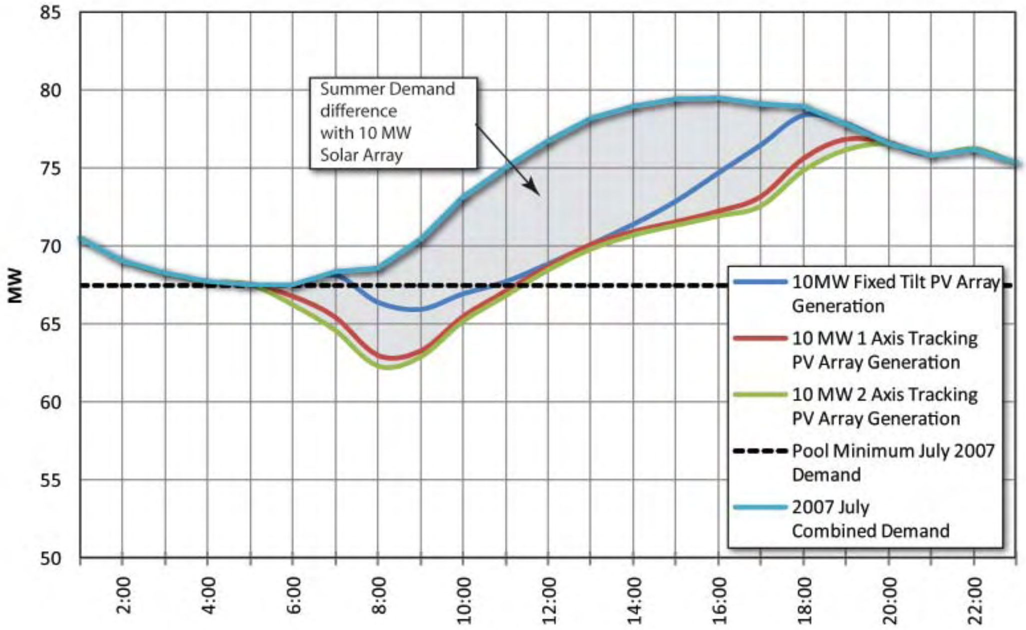


Figure 3-9. Power Pool average hourly peak demand for July 2007 and the potential peak demand reduction from a 10 MW PV system (Los Alamos County and NREL).

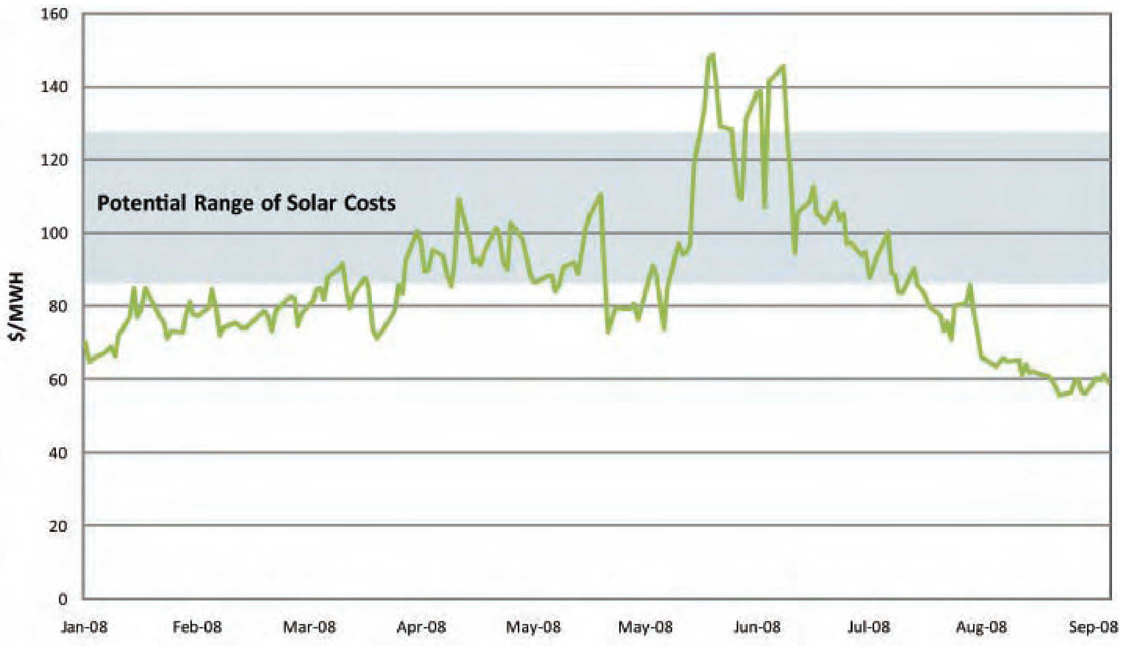


Figure 3-10. Peak wholesale price at Four Corners delivery point[4] purchased and delivered to the Power Pool to satisfy peak power requirements (Intercontinental Exchange, Inc. and U.S. Energy Information Administration).

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[4] Price adjusted for 3% line losses and $3/MWh transmission fee.

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Chapter 4. State and Federal Incentives, and Business Structures for Renewable Energy Projects

Legislation at both the state and federal level has resulted in a wide variety of incentives to stimulate the development of renewable energy projects. These incentives, along with opportunities to reduce costs through grants and the sale of RECs and Carbon Credits, can significantly reduce the effective cost of renewable generation. Appendix F contains a detailed description of Federal and State incentives, as well as how the REC markets operate.

The business structure of the developer has a significant impact on the ultimate cost of renewable generation. Incentives available to any particular project vary, depending on the organizational structure of the developer/owner. While some incentives apply to all projects, others are dependent on whether or not the project is public or private.

Incentives and Business Structures

The value of incentives depends upon whether or not they can be used by the developer. For example, accelerated depreciation may be of little value to a government entity but of considerable value to a commercial firm.

For simplicity, two business structures, public and private, are presented. The impact of incentives on each is described for a solar installation.

The Business Structures

The following sections describe commercial and municipal structures: they illustrate relative differences between ownership options, with or without incentives, and should not be construed as forecasts of actual installation costs.

Sale Lease-Back by Commercial Entity through the County

A common cost effective business structure for a commercial entity would be a sale lease-back case. The process, as it would apply to the Laboratory and the County, is as follows:

1. The DOE, through the County, grants the use of its property to a commercial entity.
2. The commercial entity constructs the facility.
3. The County, using Tax-Exempt CREBs, buys the installation from the commercial entity, leases it back to the same entity at the preferential interest rate obtained through the CREB program; and executes a PPA with the commercial entity.
4. The County and the DOE agree on how the renewable generation is credited towards Laboratory goals for renewable supplies and how the costs are factored into the ECA (see Figure 4-1).

In this arrangement, the commercial entity can include all of the construction tax credits and incentives in the proposed price in the PPA, allowing much of the benefits to flow back to the Power Pool (i.e., the lease rate will reflect the tax-exempt benefit). The combination of commercial and public incentives would maximize all available incentives into the ultimate CoE.

For realism, the sale price of the electricity is determined by establishing a kilowatt hour (kWh) charge that results in the private

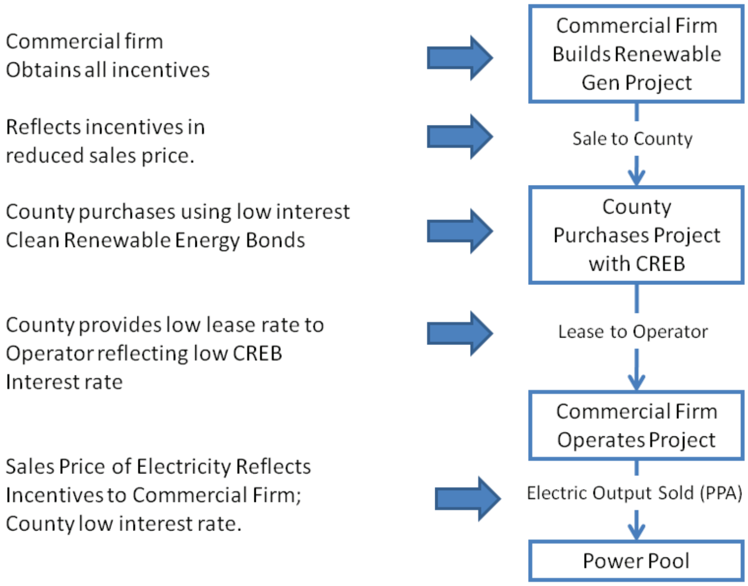

Figure 4-1. Sale - Lease-Back project structure process and benefits.

entity obtaining a 10% margin on its cost of generation. The next section evaluates two different capital structures: a 65% debt case and a no debt case.

Ownership by the County

Under this scenario, renewable generation is located on the DOE property, but owned and operated by the County. This analysis assumes that the County sells this electricity at cost.

Scenarios assume that the County finances 100% of its capital costs using bonds at government rates. The County is presumed to utilize RECs and Carbon Credits.

Incentives Available to an Installation at the Laboratory

Table 4-1 summarizes the potential incentives and cost reduction programs that are currently available to an installation at the Laboratory.

Incentive and Cost Reduction Impacts to Business Structure

The NREL Study provided a number of case studies describing the impact of incentives on business structure. Table 4-2 summarizes a portion of the analysis from the NREL Study. The full analysis is included in Appendix B.

While the assumed value for RECs in the NREL study is now regarded as overly optimistic, it is apparent from Table 4-2 that a private installation benefits the most from available incentives.

REC and Carbon Credit Sales

REC and Carbon Credit sales are available to both a commercial or County project. RECs generated at the Laboratory, but not sold to PNM, could be sold to a number of resellers or brokers (See Appendix F). While the County does not have to meet Renewable Portfolio Standards (RPS) requirements, it does purchase RECs on behalf of its customers who want to buy “green” power.

The County has been able to buy these “non-compliance” RECs at approximately a half cent/kWh. When the Abiquiu Dam project begins operation, the County will be able to sell RECs from that project (existing hydroelectric power is not eligible for RECs in New Mexico and most other states). The DOE also buys RECs to meet its renewable energy goals and through an RFP process, has procured non-compliance RECs for

Table 4-1. Current Incentives and Cost Reduction Programs Available to Commercial Owned, County Owned and Federally Owned Projects

	Project Ownership/Structure		
Cost Reduction Programs	**Commercial Bidders to County**	**County Owned**	**Federal**
Modified Accelerated Depreciation	X		
Investment Tax Credit (30%)	X		
Renewable Energy Production Incentive (1.5 cents/kWh)		X	
Clean Renewable Energy Bond Program	X	X	
NM Production Tax Credit (2.7 cents/kWh 10 years)	X		
NM Bond Financing		X	
Sale of Renewable Energy Certificates	X	X	X
Sale of Carbon Credits	X	X	X
Renewable Electricity Production Tax Credit (1-2 cents, solar excluded)	X		

Table 4-2. Cost of Electricity (cents/kWh) for Public and Private Entities for a Sample Solar Installation (NREL 2008)

	Public Entity (Cents/kWh)	Private Entity (Cents/kWh)
No Incentives	23.8	
All State and Federal Incentives		12.7
State and Federal Incentives plus sale of RECs		7.4

1.5 cents/kWh (this price will increase in 2010). Compliance RECs bought by entities that have RPS obligations are worth more. In this Study, RECs are valued at 2 to 10 cents/kWh.

In addition, projects that can be certified to displace carbon that would otherwise be emitted to the atmosphere can sell credits, usually priced on a $ per metric tonne of carbon offset. In the case of PV at Los Alamos, it was assumed that each MWh of electricity produced for the grid emits 3,000 lbs., or 1.5 tons of carbon. A 10 MW PV array producing approximately 22,600 MWh per year could sell $203,400 of carbon credits at $6/ton of carbon displaced.

It is noteworthy that despite the rather significant solar resource in the State of New Mexico, state incentives are paltry in comparison with other states. Regardless of whether the owner is a federal agency, municipality, or corporation, the representative rates do indicate that with some level of incentives, renewable generation options might be economic.

The most optimum scenario is likely to be the sale lease-back case where the final sale price of the electricity reflects all available incentives, both those that a private entity can obtain (tax incentives, production credits, etc.), as well as the low interest rates available from bonds issued by the County.

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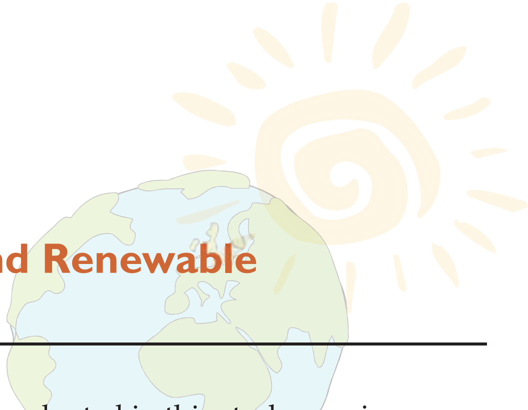


Chapter 5. Distributed Generation and Renewable Technologies

Distributed Generation

Early in the last century, electricity was generated in city centers and delivered to nearby buildings. Waste heat was recycled to make steam to heat these same buildings. Over time, it became economic to build large, centralized power plants located far from load centers with transmission wires carrying the electricity many miles to end-users. Industrialization and urbanization eventually led to the widespread implementation of a transmission and distribution infrastructure. Centralized systems became the dominant design paradigm. The systems delivered affordable, reliable power. Central power systems are encumbered by a number of large, built-in inefficiencies, including energy loss during transmission, distribution, and wasted heat. Aging infrastructure and accelerated growth in some regions have caused reliability problems.

All forms of on-site renewable energy discussed in this report can be considered distributed generation (DG). DG is a term for a generation source located close to where the power is required. However, all of the on-site systems evaluated in this study require grid interconnections through the electrical distribution system. They will not reliably operate as islands, unless interruptable power is acceptable or energy storage devices are packaged with the system. DG need not be renewable, and in fact, many combustion turbines fall into this category.

This decentralized distribution system has the advantage of capturing the waste heat from generation, offsetting the energy requirements of other end-uses, and potentially lowering the total energy requirements (i.e., the combined requirements for electricity, steam, cooling, space heating, and water heating). Very often, the waste heat in the centralized generation facility is emitted directly into the biosphere. Utilizing the heat that is otherwise wasted, DG has the additional benefit of avoiding the transmission and distribution losses associated with centralized generation and, possibly, the need to upgrade transmission and distribution grids.

DG can provide the end user a degree of self reliance and flexibility because of its modularity and proximity to demand.

5.1 Solar Photovoltaic Power

Solar PV cells are semiconductor devices that convert energy directly into electricity. In approximate numbers, in locations where the sun's rays are the most intense, solar energy has the potential to generate 1 kW per square meter.

Nearly 95% of the PV cells sold today are made of crystalline silicon. Crystalline PV cells come in several varieties: Figure 5.1-1 provides a schematic of a crystalline silicon cell.

N-type silicon is silicon that has been doped with phosphorus gas to turn it into a material that contains extra electrons that it will release easily. P-type silicon is doped with boron gas to turn it into a material that contains holes that accept a free electron easily. Although "n" and "p" imply negative and positive, n-type and p-type silicon are in an "in-between" stage that has the inclination to readily become more negative and positive. A p-n junction is a junction formed by combining P-type and N-type semiconductors together in very close contact. The most common type of solar cell is basically a large p-n junction; the free carrier pairs created by light energy are separated by the junction and contribute to current.

The balance of the market is served by an assortment of thin film technologies. Both technologies produce DC electricity. Appendix B provides considerable detail on the various PV technologies, applications, systems, mounting options and output considerations.

Photovoltaic Impact on Peak Demand

PV is highly valued for its ability to reduce or "shave" peak demand, making it a useful application for the Laboratory and the County. Chapter 3 contains an analysis of Power Pool demand patterns and presents a quantification of the impact of 5 MW and 10 MW PV systems (see Figures 3-8 and 3-9).

A hypothetical 10 MW system could reduce the County off-site purchase power requirements by as much as 8 MW between the hours of 13:00 and 19:00.

Photovoltaic Economics

The NREL Feasibility Study provided an economic analysis of several PV ground mounted single-axis tracking systems. Some very simple conclusions can be drawn from their analysis:

- The economics of PV is entirely a function of incentives: with no incentives it is clearly not viable; with incentives it could be;

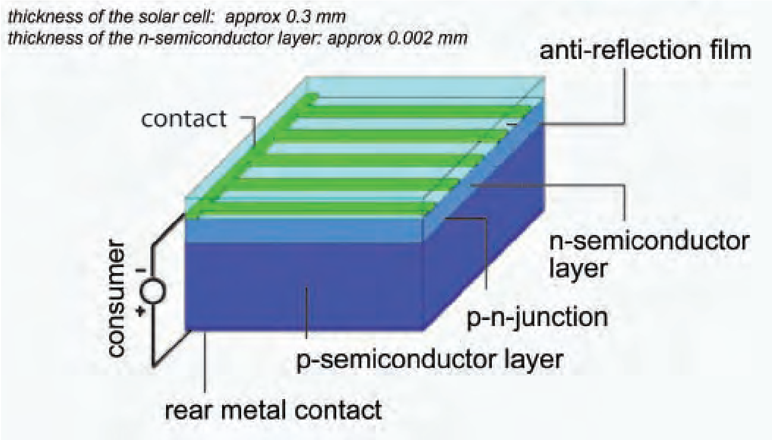


Figure 5.1-1. Crystalline PV cell schematic (Solarserver).

- The CoE from a PV system constructed and operated by a commercial entity is much less than a public entity due to the way incentives are structured;
- A ground mounted single axis-tracking system under a commercial business structure taking advantage of RECs should be able to produce power at approximately 7 cents/kWh.

Recommended Locations for PV Installations at the Laboratory

While the Laboratory could support a number of roof mounted PV installations, this report only considered ground installations as the most practical, as discussed in Chapter 3.

Appendix B presents excerpts from the NREL Feasibility Study where potential sites were discussed and evaluated. Figure 5.1-2 shows a map of potential Greenfield and Brownfield locations for a photovoltaic array. NREL identified two promising locations: Option B, the southeast portion of the DOE property (TA-36); and Option F, the former County landfill (TA-61). These array options combined could easily support between 6–10 MW capacity, depending upon site and land considerations.

The east portion of TA-36, a Greenfield site near the eastern boundary of the Laboratory along State Road 4, shown in Figure 5.1-3, has up to 118 acres potentially available straddling a 13.2 kV distribution line. This attractive site could be released to a developer in phases for PV arrays, as new loads are installed that require daytime peaking power.

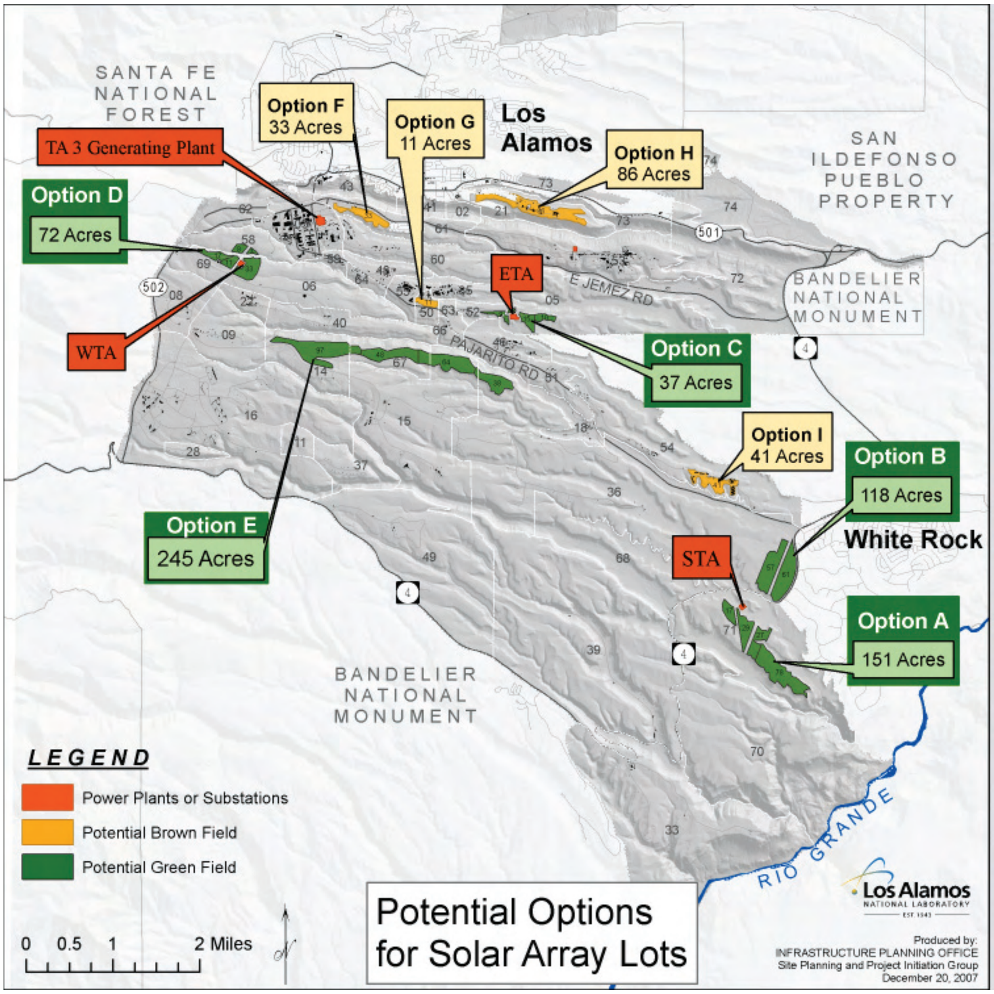


Figure 5.1-2. Various NREL-identified locations for ground mounted photovoltaic arrays for Los Alamos National Laboratory.

Figure 5.1-3. Greenfield site at the southeastern boundary of the Laboratory (TA-36)

The former County landfill, a Brownfield site, has approximately 18 acres of capped landfill that could be used for a PV array shown in Figure 5.1-4. This site is near the TA-3 electrical substation. Using the six acres per MW as a rule of thumb for single-axis tracking arrays, up to 3 MW could potentially be installed at the County Landfill. A modification to the closure permit with NMED would be required for a new use.

Los Alamos County Roof-Top Photovoltaic Promotions

The County currently offers "net metering" (net metering allows the electric meter to literally runs backwards, subtracting the excess generation from use when the amount of solar electricity exceeds the facility demand) to retail customers who construct qualifying renewable generation sources on their properties. The plan provides credit at the retail rate for all generation up to the amount consumed on an annual basis and credit at the County's wholesale cost for generation in excess of consumption. Only two customers are currently enrolled in this program. A group of customers and other interested parties have approached the Board of the County DPU encouraging them to adopt a more generous program.

Figure 5.1-4. Brownfield site at the capped County landfill (TA-61)

The Pool should evaluate the economics and practicality of the County aggregating customer-owned renewable generation as an additional Pool resource.

The Purchase Power Option

In lieu of County or DOE ownership of a PV array, two variants using the RFP process should be considered. In one case, the RFP would be issued by the County and would simply request proposals for on-peak power sales for 5–10 MW of solar generated electricity. The developer could respond by proposing sales from a project located on Laboratory property with output sold to the County. An alternative response would allow the developer to install PV arrays off-site where the power would be delivered to the grid, and contracted to the County. Appendix E provides a sample RFP, based on one used in Colorado.

Recommendations

The hypothetical 10 MW system as modeled would allow the County to reduce its off-site purchase power requirements by as much as 5 MW in the morning and 8 MW in the afternoon. It could potentially shave 12% of the daily peaking summer load and reduce the daily morning baseline load by as much as 8.6%. The CoE for this system or the purchase price from a PPA will depend upon business structure and available incentives.

It is recommended that steps be taken to secure at least 8.5 MW of solar and evaluate the aggregation of County customer-owned renewables as a Pool resource.

5.2 Concentrating Solar Power

Ultimately, all centralized large scale electricity generation employs the same process: heat water to boiling, and create steam to power a turbine generator. This same process applies to concentrating solar thermal power; generate electricity by concentrating the sun's rays to heat a fluid, create steam, and spin a turbine.

There are four primary methods to concentrate the sun's light and create heat: parabolic troughs; linear Fresnel (or other concentrator) collectors; dish reflectors; and the "power tower" where separate mirrors focus on a single location (see Figure 5.2-1).

Four Technologies and their Characteristics

All of the technologies in Figure 5.2-1 generate baseload power in the hundreds of MW range. The system operates 24 hours a day by storing some of the daytime heat for use at night.

Figure 5.2-2 provides a schematic of a thermal system with heat storage:

Dish Sterling

The Dish Sterling system utilizes a dish or array of mirrors to concentrate the sun's energy on the heater head of a sterling cycle engine, which in turn generates electricity. Although regarded as developmental, the

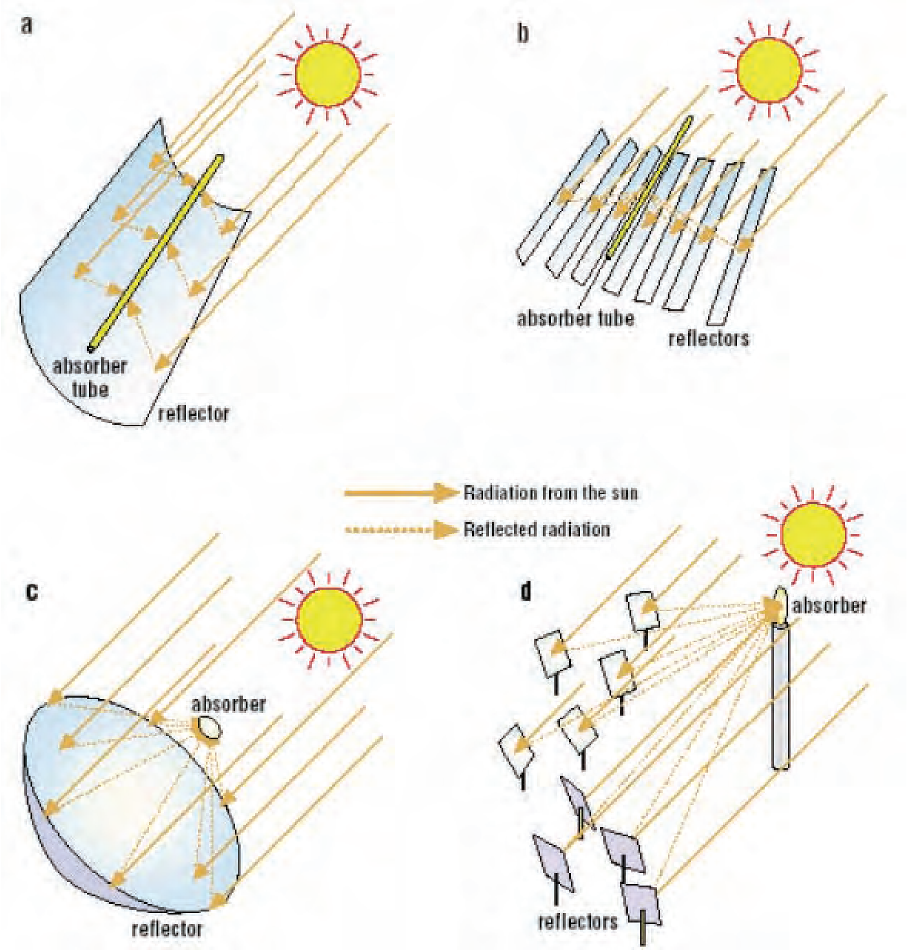


Figure 5.2-1. Four approaches for solar thermal power production. a: parabolic trough; b: linear Fresnel; c: dish reflector; d: power tower (Volker-Quashning).

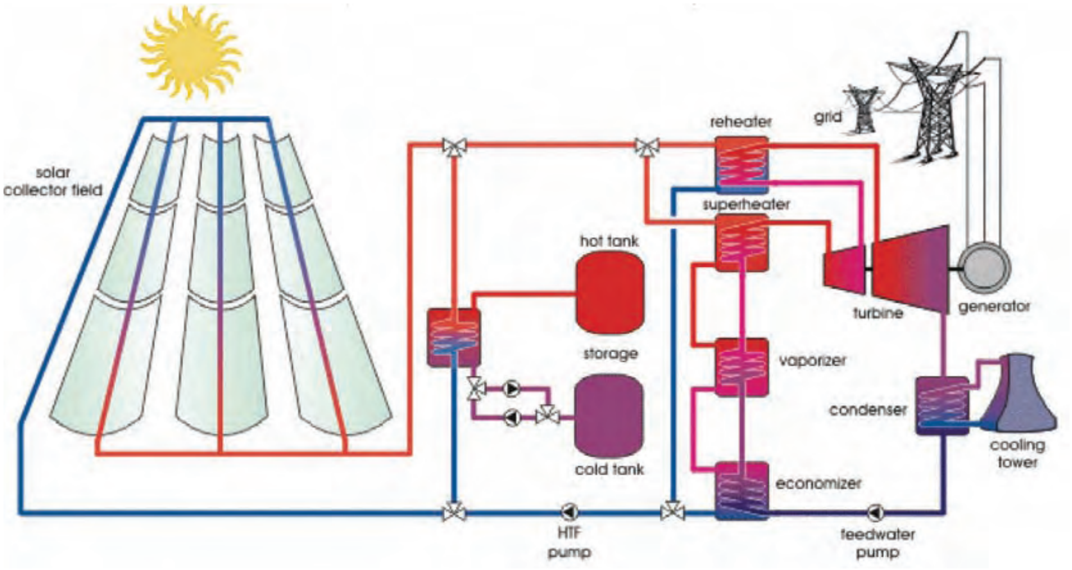


Figure 5.2-2. Solar thermal power plant with storage (http://www.volker-quaschning.de/articles/fundamentals2/index_e.html) July 2008.

Sterling Energy Systems (SES) company appears to be on the verge of large scale deployment. At the end of June 2008, SES filed applications to certify a 750 MW dish sterling solar thermal system in southern California. SES has a PPA with San Diego Gas & Electric (SDG&E) for 600 MW. The PPA is expandable to 900 MW, of which 750 MW will be constructed on the current parcel. SES also has a PPA with SDG&E for 850 MW from a similar plant in the Mojave Desert. These plants are constructed from thousands of the SES basic building block, a 25 kW dish/engine system (see Figure 5.2-3).

Figure 5.2-3. Sterling Energy Systems' 25 kW dish sterling unit.

Power Tower Systems

Power tower systems, also called central receivers, use many large, flat heliostats (mirrors) to track the sun and focus its rays onto a receiver. The receiver sits on top of a tall tower and concentrated sunlight heats a fluid, such as molten salt, to as high as 1,050°F. The hot fluid is utilized immediately to make steam for electricity generation or stored for later use. Molten salt retains heat efficiently, so it can be stored for days before conversion into electricity. That means electricity production can continue on cloudy days, or even several hours after sunset. There are no commercial power tower plants in operation. The 10 MW Solar One plant near Barstow, California, operated from 1982 to 1988 and produced over 38 GWh of electricity.

Linear Systems

Both parabolic trough and Fresnel concentrators are linear systems. Considerably more refinement has gone into parabolic trough and: it is regarded as the only truly commercial solar thermal system available (although that status may change with the deployment of dish sterling systems). Fresnel concentrators are still in the prototype stage. Figure 5.2-4 illustrates the differences between the two methods.

Parabolic Trough Systems

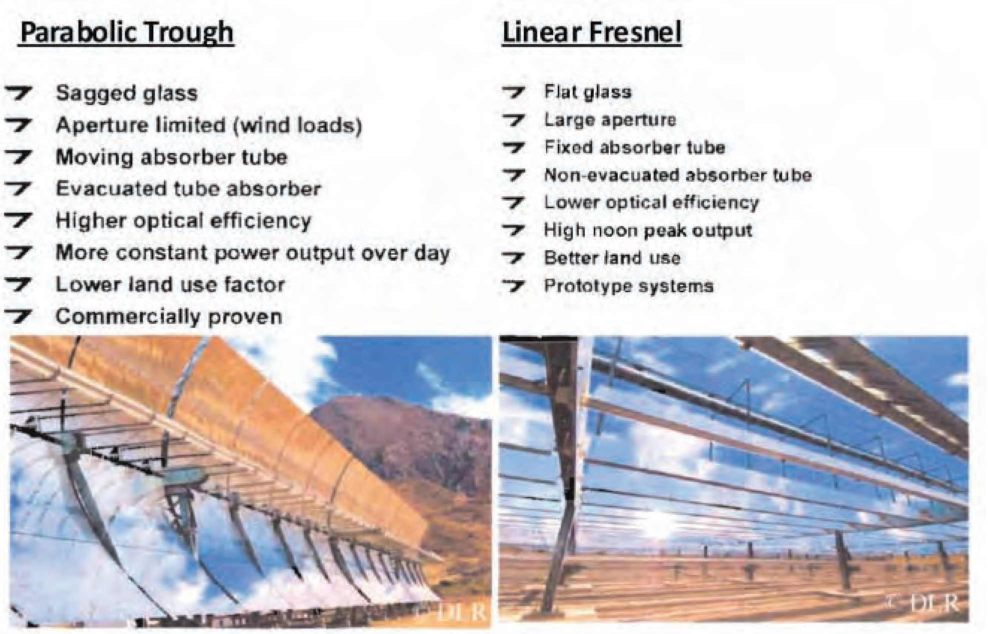
While solar thermal power plants have been operating for the past 15 years, the parabolic trough is the only truly commercialized system (see Figure 5.2-5). Table 5.2-1 describes the current fleet of parabolic trough power plants in the U.S.

District Heating and Cooling

Although outside of this study's scope, parabolic trough systems can be roof mounted. In this configuration, rooftop systems could provide steam for building district heating and cooling in an area where a number of buildings or facilities are concentrated.

Recommendation

Further consideration of concentrating solar is not recommended. Commercially proven systems require considerable land with less than a 1% slope. A 25 MW unit, for example, would require at least 200 flat acres. Thus even if a Laboratory installation was theoretically economic – and studies indicate the CoE from a system in northern New Mexico would be at least 15 cents/kWh – there are no 200 acre flat sites to support even a 25 MW unit.



Parabolic Trough

- Sagged glass
- Aperture limited (wind loads)
- Moving absorber tube
- Evacuated tube absorber
- Higher optical efficiency
- More constant power output over day
- Lower land use factor
- Commercially proven

Linear Fresnel

- Flat glass
- Large aperture
- Fixed absorber tube
- Non-evacuated absorber tube
- Lower optical efficiency
- High noon peak output
- Better land use
- Prototype systems

Figure 5.2-4. Differences between parabolic trough and Fresnel concentrator systems (Deutsch-Zentrum für Luft-und Raumfahrt e.V.).

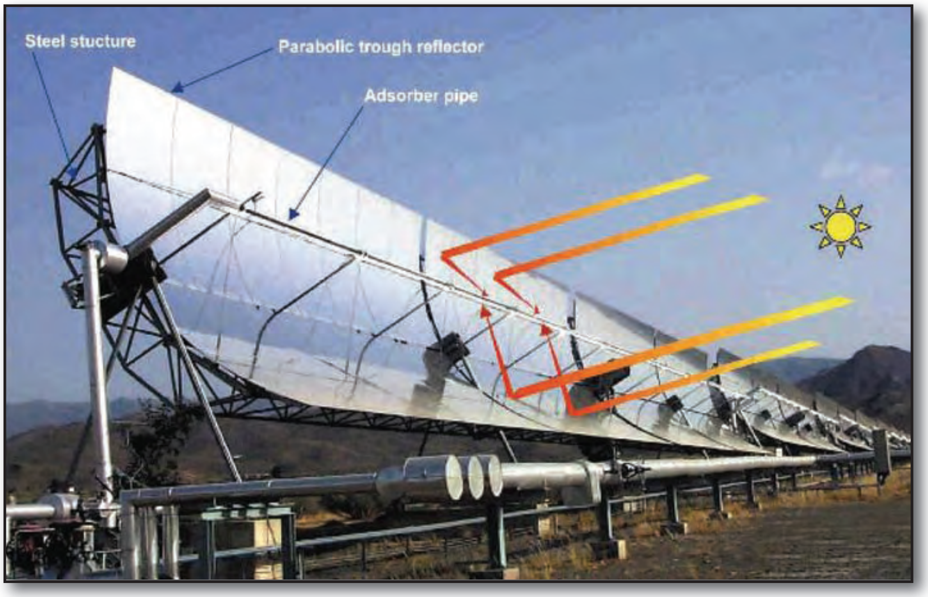


Figure 5.2-5. Parabolic trough system components (NREL).

Table 5.2-1. U.S. Commercial Solar Thermal Power Plants (NREL)

Plant Name	Location	First Year of Operation	Net Output (megawatt electric)	Solar Field (m^2)	Turbine Efficiency (%)
Nevada Solar One	Boulder City, NV	2007	64	357,200	37
APS Saguaro	Tucson, AZ	2006	1	10,340	21
SEGS IX	Harper Lake, CA	1991	80	483,960	38
SEGS VIII	Harper Lake, CA	1990	80	464,340	38
SEGS VI	Kramer Junction, CA	1989	30	188,000	37
SEGS VII	Kramer Junction, CA	1989	30	194,280	37
SEGS V	Kramer Junction, CA	1988	30	250,500	31
SEGS III	Kramer Junction, CA	1987	30	230,300	31
SEGS IV	Kramer Junction, CA	1987	30	230,300	31
SEGS II	Daggett, CA	1986	30	190,338	29
SEGS I	Daggett, CA	1985	14	82,960	31

5.3 Fuel Cells

Fuel cell technology could theoretically provide the Laboratory premium quality electricity and process heat on a continuous basis, easily sited at the point of use and enhancing the reliability of the Laboratory's overall electricity service.

Fuel cells are energy conversion devices that, for all practical purposes, are continuously fueled batteries. The term "fuel cells" applies to a whole collection of technologies, each with unique characteristics and designed for applications as diverse as replacement batteries for notebook computers to multi-megawatt combined heat and power (CHP) applications. Appendix C provides an overview of the various technologies, their applications, state of development and primary manufacturers and developers.

Fuel cells are only as "green" as their fuel source. While many fuel cell types can be fueled with renewably derived fuels, the types most suited to this feasibility study are designed to consume natural gas or methane. Fuel cells emit carbon dioxide, but at much lower levels than fossil fuels. Fuel cell installations are eligible for carbon credits and can generate RECs, if renewably fueled in New Mexico.

Fuel Cell Installations for the Laboratory

Based on the load growth projections in Chapter 2, and given the nature of the Laboratory's missions and geographical location, and the need to focus on economic and commercially available options, only large (hundreds of kW to multi-MW) stationary fuel cells were considered. These fuel cells operate at medium to high temperatures and are capable of producing water at a minimum temperature of 140°F and some can produce steam.

Fuel Supply

All fuel cells that might fulfill the baseload power requirements of computing centers, especially those that produce heat, for all practical purposes, would require natural gas as their fuel. Natural gas procurement for the Laboratory is the responsibility of the Defense Energy Support Center. At present, there is a 2 year contract with the price of gas based on a monthly index developed by the pipeline owner, PNM. This index has shown considerable volatility. For planning purposes, current guidance recommends that the price of gas be assumed to be $11/MMBtu (million British thermal units). While not curtailable, the contract has a not-to-exceed value of 12,000 MMBtu per day. Normal gas consumption during the heating season rarely exceeds 8,000 MMBtu. The Laboratory has not approached the not-to exceed value in the last 20 years.

Should a fuel cell option be exercised, and assuming an installation in the 2 to 3 MW range (the recommended capacity – see below), natural gas supply does not appear to be a limiting factor.

Products that Could Serve the Laboratory

Currently there are only two manufacturers of large stationary fuel cells that could be applied at the Laboratory: UTC Power, a subsidiary of United Technologies; and FuelCell Energy (FCE), the developer of the molten carbonate fuel cell (MCFC) (see Appendix C).

UTC Power

The UTC Power 400 kW fuel cell is described for completeness, but is not yet in production. UTC recently announced that this new 400 kW unit will be available in 2009 at an approximate price of $3,000/kW. UTC has stopped producing its 200 kW unit (a very successful unit with an operating fleet of over 260 installations).

The UTC unit, while having attractive attributes, needs to remain in the "under development" category until production actually begins. Details regarding this unit are provided in Appendix C.

Fuel Cell Energy

FCE collaborates with CFC Solutions (formerly RWE MTU in Germany). CFC Solutions produces fuel cell stacks designed by FCE and FCE provides the balance of plant. FCE offers four products, all of which are baseload applications, and ideally, at installations that utilize the waste heat. The 300, 1500 and 3000 products all operate at 47% electrical efficiency.

- DFC300 - 300 kW; 480,000 Btu/hr at 250°F
- DFC1500 – 1.2 MW; 1,900,000 Btu/hr at 250°F
- DFC3000 - 2.4 MW 3,800,000 Btu/hr at 250°F

The DFC3000 is shown in Figure 5.3-1. It has a footprint of approximately 55 feet on a side.

Scalable up to 50 MW, the DFC 3000 system was designed for applications with larger load requirements such as hospitals, universities, manufacturing facilities, wastewater treatment plants, and utility/grid support. Unit specifications include:

- Heat Rate, 7,260 BTU/kWh
- Water Consumption 7 gpm
- Water Discharge 3.5 gpm

Pollutant Emissions

• NO_x	0.01 lb/MWh
• SO_x	0.0001 lb/MWh
• PM10	0.00002 lb/MWh

Greenhouse Gas Emissions

- CO_2 980 lb/MWh
- CO_2 (with waste heat recovery) 520-680 lb/MWh

Electrical Output

2.4 MW, 13.8 kVAC

2,700 kVA, 50 or 60 Hz

Potential Fuel Cell Installations at the Laboratory

Given the nature of the majority of the Laboratory's potential new loads, the deployment of large fuel cells would be an obvious choice under most circumstances. The FCE units are sufficiently large and, when co-located with the load, provide much higher reliability and power quality than grid-supplied, grid-distributed electricity, and do not consume transmission capacity. Fuel cells would be an improvement over existing or new on-site natural gas fired generation, with much higher efficiencies and a lower carbon footprint. In any analysis where the

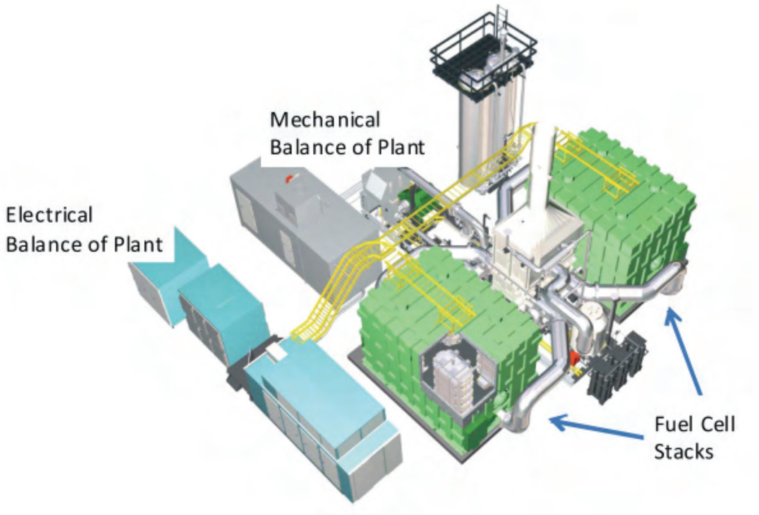


Figure 5.3-1. FuelCell Energy DFC 3000 fuel cell schematic. Overall system dimensions are 55 by 50 ft (FuelCell Energy).

sole metric is the price of currently delivered retail electricity, however, they cannot compete. This is exacerbated by the unique and exceptional O&M costs attributed both to their installation and operation. Construction in secure areas as well as 24 hour operations in the Laboratory environment will only add to their cost. As an example, the typical estimate of installation costs for a 2.4 MW unit is approximately $900 per kW, or $2.2 million. A Laboratory installation could cost much more. Even a doubling of installation costs will yield a delivered CoE over 10 cents/kWh, taking advantage of all incentives.

Recommendation

There are no fuel cells on the market today that can deliver power at a cost that is competitive with energy delivered to the Laboratory, unless there is a change in the available incentives. Additionally, there are no local sources of renewable fuels to power the fuel cell.

5.4 Biomass

Biomass energy is normally released through the combustion of plants and plant-based materials. Wood burning was the world's primary energy source for many centuries, until it was replaced by coal. Wood is still the largest source of biofuel today, although there are many other options.

Biomass energy is a renewable because the plant matter it consumes can be continuously grown. When biofuels burn, they release the carbon dioxide and solar energy absorbed during the growth stage, functioning as a natural solar energy storage system. Biomass combustion is regarded as "carbon neutral" because the amount of carbon dioxide emitted during combustion is equal to the carbon it absorbed during growth.

There are several developing technologies that convert biomass into energy without combustion; however, none are commercial nor described in this Study. Biomass combustion could be an option for the Laboratory as a source of heat to generate either steam, hot water, or electricity. Wood waste (from forest downfall, thinnings, and waste from commercial operations) would be the likely fuel source for a plant located near or at the Laboratory. It is unknown whether or not collecting and transporting this biomass to a proximate location is economic or whether a biomass steam plant could be permitted, but further study is warranted.

Sources of Wood Fuel

Forest Energy Systems (Forest) completed a feasibility study for a thermal (steam) and combined electric and thermal power plant fueled by chipped wood and wood pellets. The full report is provided in Appendix D. The report provided an analysis of the available wood resources in Northern New Mexico to determine the availability of a sufficient and reliable fuel supply for a biomass heating system located in Los Alamos. The initial analysis identified the following potential sources of supply:

- Over 190,000 dry tons of biomass (less than 10" in diameter) from timber and slash exist within a 50 mile radius on portions of the Santa Fe National Forest, Carson National Forest, the Valles Caldera, and the Santa Clara Pueblo.
- Within a 100 mile radius, the sources include the majority of the Santa Fe National Forest, additional Carson National Forest resources, and both private and reservation lands, increasing the supply to over 270,000 dry tons.

Figure 5.4-1 shows the two radii on a map of the region. The rule of thumb governing the adequacy of biomass resources requires an availability of fuel at least three times demand. The three options evaluated would require 30,000, 50,000, and 130,000 tons of biomass per year, respectively. The fuel requirements of Option 3 (130,000 tons) cannot be met within the 100 mile radius. There is an adequate fuel supply inside the 50 mile radius for the other two options, provided there is no competition.

Laboratory Steam Requirements

Figure 5.4-2 shows the monthly boiler loads for campus steam production from 2004 to 2007 at the TA-3 Steam Plant.

Generation Options

The Forest Study (Appendix D) outlines three generation scenarios:

- Option 1 provides baseload operations (operating at or near capacity for 12 months) using a smaller boiler than Options 2 and 3: approximately 19 MMBtu (million British thermal units) fueled with pellets or 24 MMBtu fueled with chips. The biomass boiler would provide 100% of the daytime requirements for the summer months; the existing natural gas boilers would supplement night time loads and winter operation. Wood chip fuel delivery for this option would result in new traffic at the rate of 6 trucks per day (assuming 22 tons per load). Pellet fuel delivery would be 2 trucks per day.

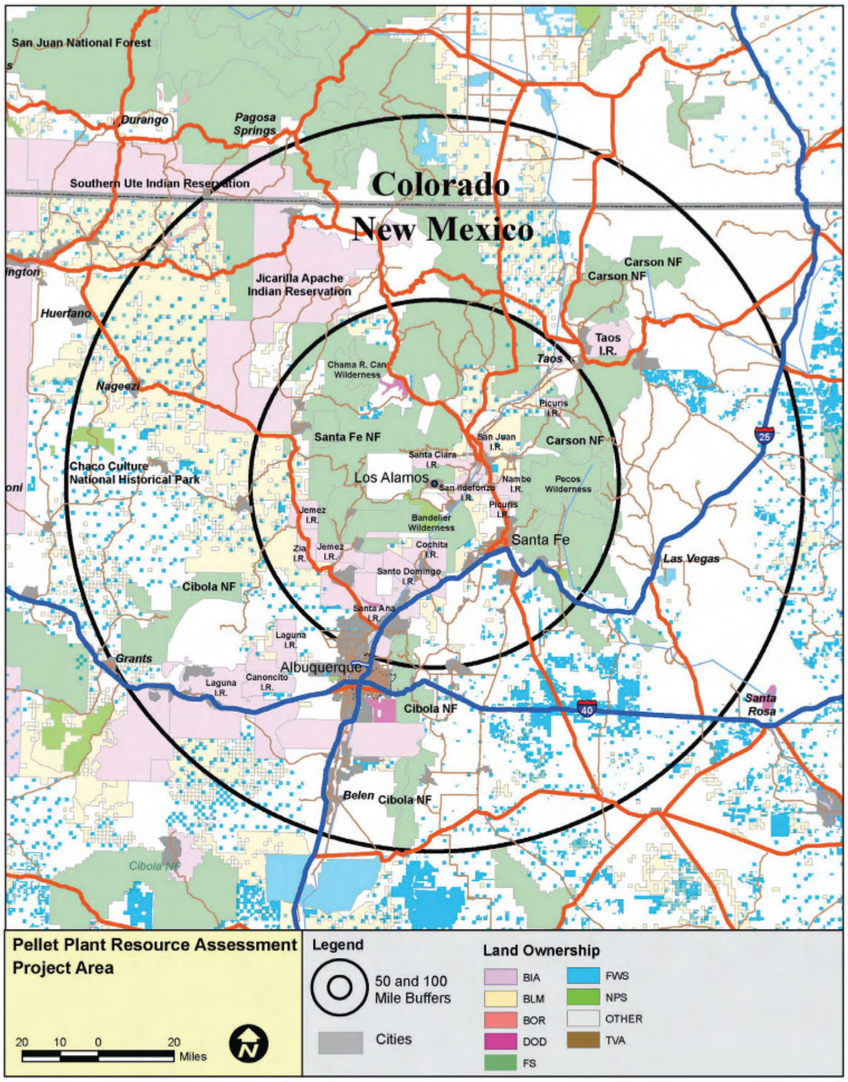


Figure 5.4-1. 50 and 100 mile radii from Los Alamos.

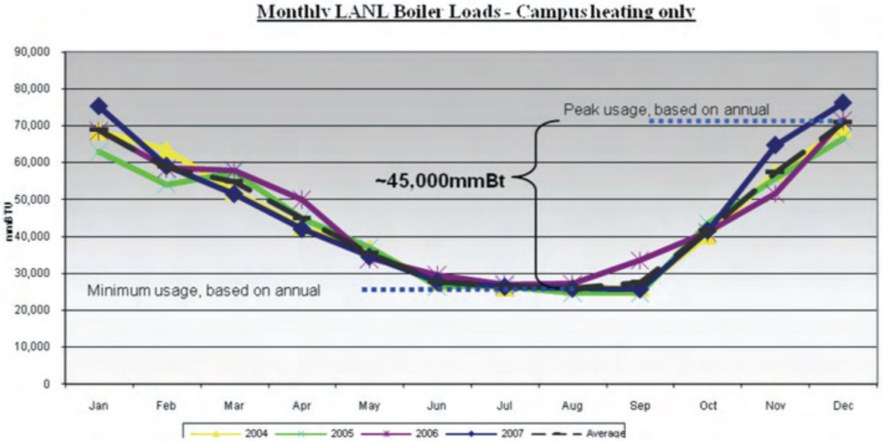


Figure 5.4-2. Monthly boiler loads for campus steam production at the TA-3 Steam Plant, 2004–2007 (MMBtu) (Forest Energy Systems) 2008.

- Option 2 provides baseload operations plus 50% of peak demand, using a larger boiler, 38 MMBtu pellet or 48 MMBtu chips. This boiler serves the majority of the Laboratory heat load, supplemented by natural gas for periods of peak demand that are above the capacity of the biomass plant. One natural gas boiler would be removed to make space for this unit. Wood chip fuel delivery for this option would result in new traffic at the rate of 9–12 trucks per day depending on the season (assuming 22 tons per load). Pellet fuel delivery would be 4 trucks per day.
- Option 3 is a CHP application. The biomass installation provides 5 MW of electricity and utilizes the waste heat to provide steam to the campus heating system. Wood chip fuel delivery for this option would result in 26 trucks per day of additional traffic (assuming 22 tons per load). Pellet fuel delivery would be 5–9 trucks per day.

A typical 38 MMBtu boiler is pictured in Figure 5.4-3.

Siting Options

The Forest Study identified four potential sites:

- A boiler collocated with the existing Power Plant (assumes one of the existing natural gas boilers is removed).
- A boiler and fuel storage located at the County Landfill, adjacent to the existing Power Plant site.
- A boiler located on DOE property and fuel storage at the County Landfill.
- Both the boiler and fuel storage located on a secure Laboratory site adjacent to the Power Plant.

Each site has advantages and disadvantages. Until details regarding economics, supply, and permitting are known, an ideal site cannot be determined.

Figure 5.4-3. Typical 38 MMBtu biomass boiler.

Two of the four sites would have fuel storage at a different location than the boiler. In round numbers, should either of the separate storage options be considered, the aforementioned truck volume estimates effectively double: one trip to the storage location and another to the boiler. Under these circumstances, daily truck volume for Option 1 increases the number of trucks to 12; Option 2, 18–24; and Option 3 to 52 trucks.

It may be difficult to use of the landfill site for both fuel storage and a solar PV installation.

Waste Disposal, Permitting, and Emissions

Neither this Study, nor Forest's, evaluated potential problems associated with emissions and waste disposal (principally ash), or the likelihood of successfully permitting the plant. The Forest Study provided comparisons of biomass steam plant emissions to other forms of power generation.

All boilers under consideration have a multi-cyclone system to remove particulates from the exhaust. All plant emissions would be below emissions standards set by the New Mexico Air Quality Bureau (NMAQB), and the Federal Government. The NMAQB will evaluate the quantity of emissions that would result from the system operating at peak load, 24 hours per day, 12 months per year, with the emission-control system bypassed.

Figure 5.4-4 compares the emissions profile of a pellet-type wood burning source versus other common fuel types.

Therefore, the plant should be able to secure an emission permit although all permitting issues merit further exploration.

Economics

In the case of Options 1 (Baseloaded operations, smaller boilers) and 2 (Base plus 50% of peak demand, larger boilers), the primary economic benefit of biomass is fuel cost savings. The Forest Study assumed the Laboratory natural gas cost is $11/MMBTU in 2008, escalating at 5% per year. Wood chips are assumed to cost $7/MMBTU and wood pellets $9/MMBTU (including delivery), both escalating at 2% per year. While cost recovery is necessary for capital, operations, and maintenance expenses, the overwhelming determinant of an economic biomass project is fuel cost savings. The Forest Study does not adequately support its assumed delivered prices for the fuel, or the escalation rates for biomass or natural gas. Therefore, while Table 5.4-1 presents Forest's conclusions, these conclusions have not been verified and should not be used for decision making.

The efficiency of a pellet boiler is 90%, and the efficiency of a wood boiler is 70%. However, the cost of wood chips is on average 20% to 30% less than wood pellets. Even though a pellet boiler is more efficient, the net operating cost per MMBtu is lower for wood chips, and the Laboratory would not be dependent on pellet suppliers.

In addition to the fact that there does not appear to be an adequate supply of fuel within a 100 mile radius to support Option 3 (CHP), it is simply too expensive. The CoE produced, even if fuel were available at the prices cited, is several multiples more than the rate paid by the Laboratory. The Forest Study assumes that the Power Pool's retail electricity rates will be in the range of 5 to 6.2 cents/kWh through 2018.[1]

Biomass has the potential to augment the Laboratory's steam plant but does not appear to be an economic form of electricity generation, relative to the power purchase options.

There are two benefits of producing steam from biomass at the Laboratory:

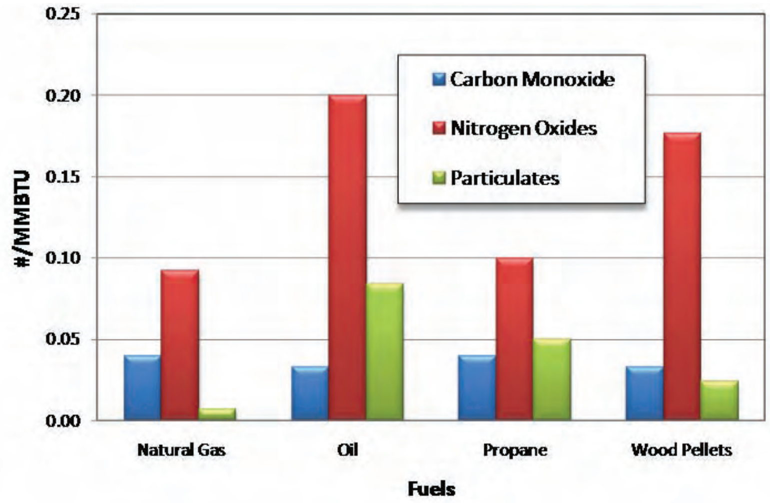


Figure 5.4-4. Wood pellet emissions compared with other fuel types, pellet data from actual test of Binder 150 kW boiler (Forest Energy Systems).

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[1] Department of Energy / Los Alamos County Resource Pool Fiscal Years 2009 thru 2018 Budget, Los Alamos County, New Mexico.

Table 5.4-1. Biomass Thermal Fuel Cost Savings and Payback (Forest Energy Systems, 2008)

	10 Year Fuel Cost Savings ($M)	Payback (Yrs)
Option 1 – Baseloaded operations, smaller boilers		
Pellets	6.6	3.5
Chips	12.9	2.8
Option 2 – Base plus 50% of peak demand, larger boilers		
Pellets	13.1	3.4
Chips	23.9	2.4

- A biomass plant would displace a portion of the Laboratory's fossil fuel consumption (natural gas) with a less expensive, renewable and sustainable fuel.
- The amount of energy derived from the biomass fuel would result in carbon neutral emissions, as opposed to the direct emissions from the existing steam plant.

Options 1 (Baseload) and 2 (Base Plus 50% Peak) are worthy of further exploration due to their potential economic benefits. However, it is important to stress that the feasibility of biomass is entirely dependent on fuel cost differentials: small changes in either the long term price forecast for natural gas or the biofuel, or the escalation assumptions for the fuels, will significantly alter the conclusions.

Recommendation

If either option is considered, the following analyses and engineering studies must be completed:

- Meet with U.S. Forest Service to evaluate current thinning plans for local forests and to determine the terms of the 10 year Forest Service stewardship contract
- Conduct a more detailed evaluation of the Laboratory's steam loads
- Confirm the actual delivered cost of each fuel, potential providers, and the terms of a fuel supply contract
- Evaluate plant configurations for other small pilot projects such as TA-16
- Evaluate land use and fuel storage requirements
- Evaluate potential sites for the plant and for storage, if not co-located
- Assess transport routes and the impacts of truck traffic volumes
- Assess how wastes, particularly ash, will be disposed from the plant
- Resolve all State and Local permitting requirements and assess the ability to operate a plant within these constraints
- Perform on-site inspections of operating boilers at other DOE laboratories and industrial sites

5.5 Wind

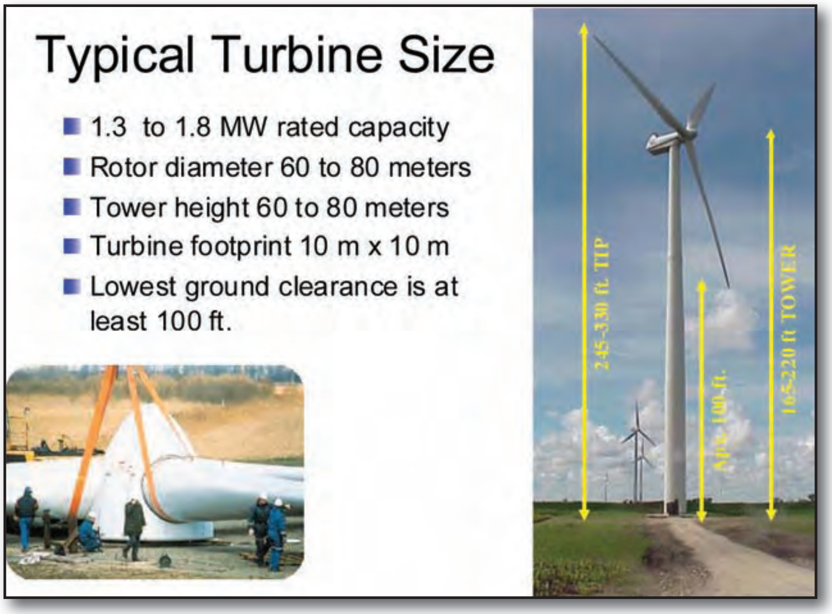
Wind power is a form of renewable energy – energy that is replenished daily by the sun. As portions of the earth are heated, air rushes to fill areas of low pressure, creating wind that can be harnessed for power production.

Wind power is converted to electricity by a wind turbine. In a typical wind turbine, moving air is converted to rotational motion by the rotor – typically a three-bladed assembly at the front of the wind turbine. The rotor turns a slowly rotating shaft that enters a gearbox in the nacelle (the large housing at the top of a wind turbine tower). The gearbox significantly increases the shaft speed. The high-speed output shaft connects to a generator producing electricity at a few hundred volts. The voltage is boosted and fed into the grid at a distribution substation.

Wind turbines come in a variety of sizes, depending upon the end use of the electricity. A large, utility-scale turbine may have blades over 40 meters long, mounted on towers 80 meters tall (one blade would extend approximately halfway down the tower), and produce up to 1.8 MW. Turbines of up to 7 MW are being built for offshore applications in Europe. Figure 5.5-1 provides characteristics of several wind turbines.

Wind Projects Structure

Utility scale wind projects typically require multiple MW sized units and involve many players. A typical arrangement includes a landowner, a developer, and an energy buyer. The developer negotiates with the landowner for the right to "harvest the wind" above the land, the price of the lease for use of the land, and to place the turbine on a small plot of land. Typically less than 1 acre is removed from normal use for each 50 acres of wind resource captured because turbines must be spaced apart a certain minimum distance to avoid "shadowing" each other and reducing power output. The developer must secure financing for the purchase, installation, and operation of the equipment, and contract with a utility to buy the output.



Typical Turbine Size

- 1.3 to 1.8 MW rated capacity
- Rotor diameter 60 to 80 meters
- Tower height 60 to 80 meters
- Turbine footprint 10 m x 10 m
- Lowest ground clearance is at least 100 ft.

Figure 5.5-1. Typical characteristics of large wind generators (Nelson, R. *Wind Energy: Resource, Advantages, and Constraints*).

The Business of Wind Energy

Where appropriate wind resources exist, wind generated energy has become a stable, commercial business, generating economic power in many parts of the U.S., including New Mexico.

U.S. wind energy capacity increased by 5.2 GW in 2007, representing a 45% increase in one year and an investment of $9 billion.

The U.S. wind power fleet now numbers 16.8 GW in 34 states, generating just over 1% of U.S. electricity supply (Figure 5.5-2).

The American Wind Energy Association estimates that the total amount of newly installed wind production capacity for 2008 could equal the new capacity realized in 2007. This explosive growth is illustrated in Figure 5.5-3.

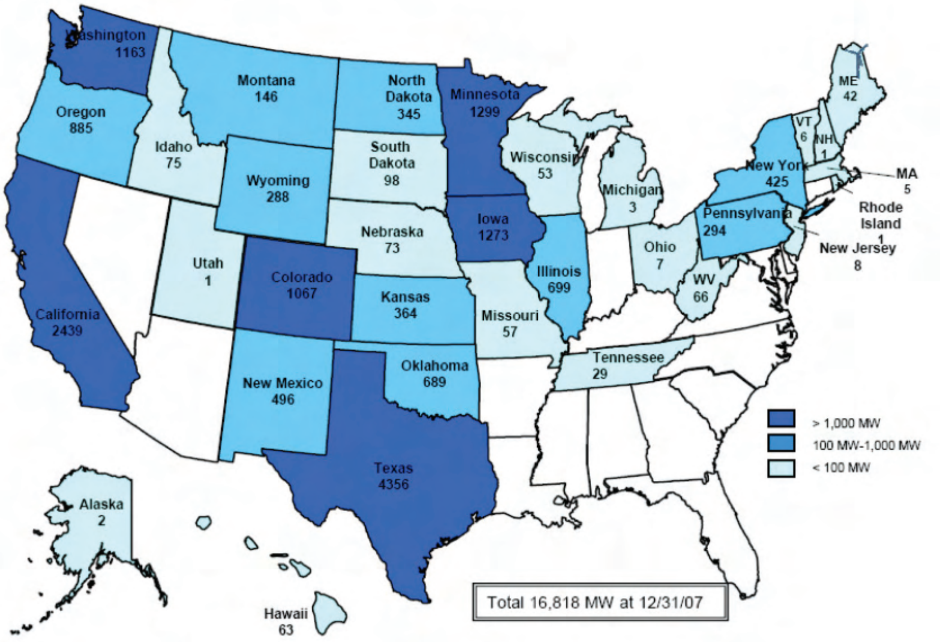


Figure 5.5-2. Installed utility-scale wind power as of December 31, 2007 (MW) (American Wind Energy Association).

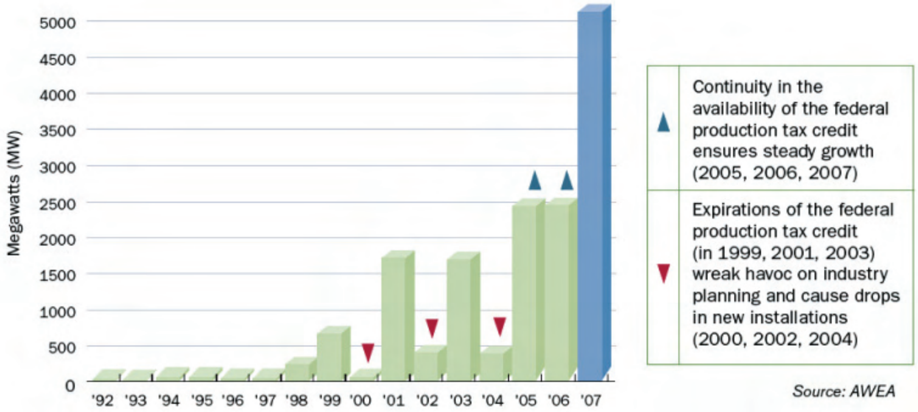


Figure 5.5-3. U.S. wind power capacity growth (MW) (American Wind Energy Association).

Local Wind Energy Resources

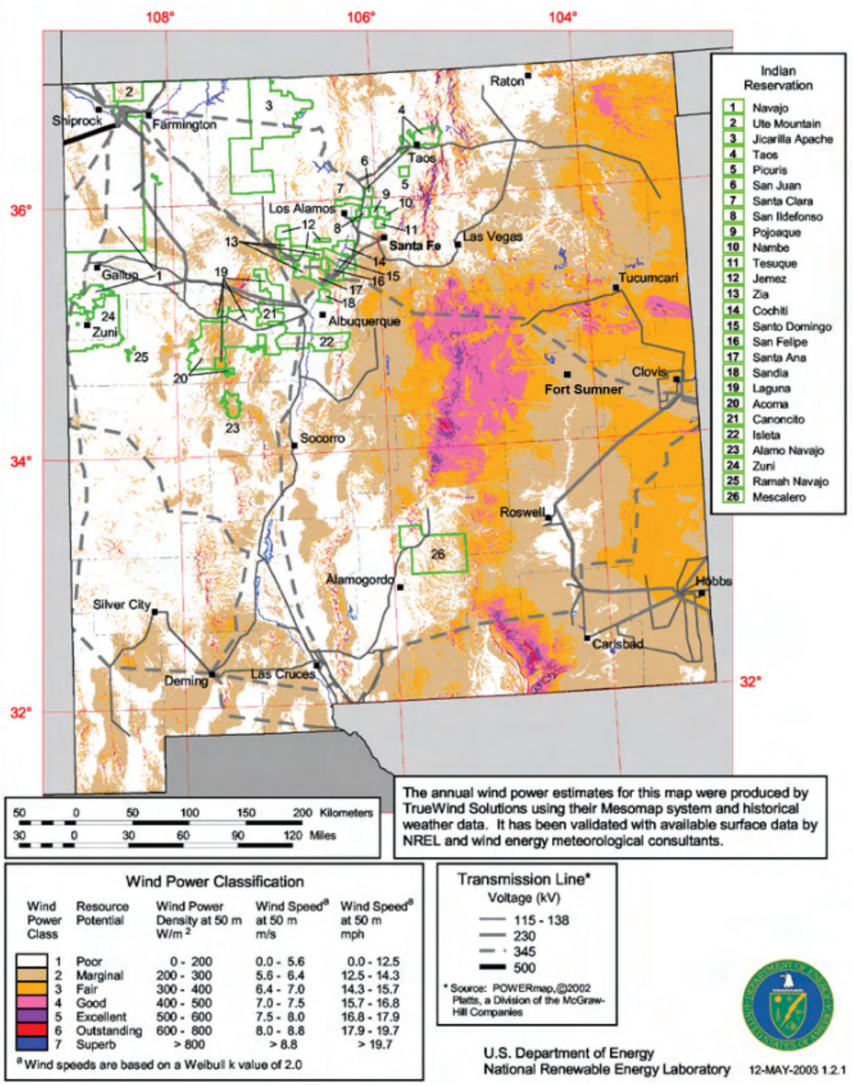
Figure 5.5-4 displays the wind resources throughout the state of New Mexico.

In fact, the nation's seventh largest wind project, the New Mexico Wind Energy Center, began producing electricity on October 1, 2003. Located 170 miles southeast of Albuquerque and 20 miles northeast of Fort Sumner, the Wind Center consists of 136 turbines, each standing 210 feet high. The plant can produce up to 200 MW of power, or enough electricity to power 94,000 average-sized New Mexico homes. Florida-based FPL Energy owns and manages the plant, and PNM purchases all of its output.

Recommendation

As can be seen in Figure 5.5-4, the Laboratory lies in the "Poor" category on the statewide wind resources map.

Generating electricity from wind on a Laboratory site (or anywhere within the County) is not feasible due to the local patterns of wind velocity and direction.



Indian Reservation

1	Navajo
2	Ute Mountain
3	Jicarilla Apache
4	Taos
5	Picuris
6	San Juan
7	Santa Clara
8	San Ildefonso
9	Pojoaque
10	Nambe
11	Tesuque
12	Jemez
13	Zia
14	Cochiti
15	Santo Domingo
16	San Felipe
17	Santa Ana
18	Sandia
19	Laguna
20	Acoma
21	Canoncito
22	Isleta
23	Alamo Navajo
24	Zuni
25	Ramah Navajo
26	Mescalero

The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

Wind Power Classification

	Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m ^{2}	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
☐	1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
■	2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
■	3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
■	4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
🟪	5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
🟥	6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
🟦	7	Superb	> 800	> 8.8	> 19.7

[a] Wind speeds are based on a Weibull k value of 2.0

* Source: POWERmap,©2002 Platts, a Division of the McGraw-Hill Companies

Figure 5.5-4. New Mexico – wind resource at 50 meters (NREL).

However, purchasing remotely generated wind power could be an attractive option for supplying a portion of the Laboratory's baseload energy requirements. Additional studies will be required to determine how such purchases would be best accomplished, including the means by which the Power Pool could contract for firm power supplies that would counter the intermittent qualities of wind generation. Chapter 6, Purchased Power Options, provides a more detailed discussion of this option.

5.6 Geothermal Energy

Geothermal energy is a statute-recognized renewable energy resource. The U.S. is the world's largest producer of geothermal electricity. The first U.S. geothermal plant, which opened in 1960 (The Geysers in California) continues to operate. In 2007, and excluding conventional hydroelectric power, geothermal power generation nearly equaled wind (see Figure 5.6-1). Of the total peak US demand in 2007 of 1,000 GW, geothermal production accounted for 2.3 GW or 0.23%.

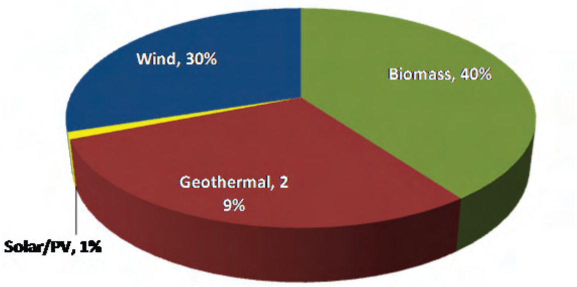


Figure 5.6-1. 2007 U.S. renewable electricity generation by source (electricity sales to the public; excluding hydropower) (U.S. Energy Information Administration).

Types of Geothermal Plants

There are two primary types of geothermal power plants: steam and binary cycle. Steam plants generate electricity with steam that is more than 300°F (149°C). The steam either comes directly from the thermal resource (referred to as a "dry steam" plant), or the steam is generated by flashing geothermal fluids, usually at temperatures greater than 350°F. In both cases, steam powers a turbine, which drives generators to produce electricity. The only significant emission from these plants is water vapor. Minute amounts of carbon dioxide, nitric oxide, and sulfur are emitted, but at rates of almost 50 times less than traditional, fossil-fuel power plants.

Binary cycle power plants use hot water (100°F–300°F) as the heat source. The hot water passes through a heat exchanger with a secondary fluid that has a lower boiling point (usually a hydrocarbon such as isobutane or isopentane). The secondary fluid vaporizes, turns the turbines, and drives a generator. The remaining secondary fluid is recycled through a heat exchanger. The geothermal fluid is condensed and returned to the reservoir. Because binary plants use a self-contained cycle, there are no emissions. Power produced by binary plants currently costs between 5 to 8 cents/kWh.

Geothermal power has a number of positive attributes:

- Reliability–Normally operated in baseload or intermediate mode, and is dispatchable
- Sustainability–Geothermal resources are sustainable because available heat does not diminish over time
- Low to Zero Emissions–Significant reduction over fossil sources in the case of steam geothermal; zero emissions for binary cycle plants
- Additional Products–Extraction of minerals from geothermal fluids is showing great promise: this extraction avoids mining and its impacts and provides an additional revenue stream to reduce the effective cost of power
- Minimal Land Use

Geothermal Resources in New Mexico

According to the Western Governors Association[1] (WGA), in the near term there are sufficient economic geothermal resources to support as much as 80 MW in New Mexico (compared with 5,508 MW in the 10 other western states). These resources are located mostly in southwest part of the State, stretching from the Arizona border to Las Cruces. Figure 5.6-2 displays the areas of geothermal potential and highlights the area around the Laboratory. Red dots indicate wells with temperatures less than 50°C; blue dots represent wells between 30°C and 50°C.

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[1] Western Governors Association, *Geothermal Task Force Report*.

The area considered to have the greatest potential for power production in New Mexico was omitted from the WGA Report: The Valles Caldera.[2] The Caldera is 15 miles wide, covering approximately 125 square miles in north-central New Mexico. In 1978, when the U.S. Geological Survey (USGS) released USGS Circular 790,[3] the Valles Caldera was identified as the only high-temperature geothermal resource in the state. A 50 MW power plant was proposed in 1977 after confirmation drilling took place. The proposed plant, a joint venture between the USDOE, PNM, and UNOCAL Geothermal, would have utilized an air-cooled condenser, a technology never demonstrated on a large scale. Drilling continued until January 1982 when the project terminated due to a myriad of complications, including the fact that only 20 MW could be produced with the existing technology.

Advanced Geothermal Technology

Although considerable geothermal resources exist in New Mexico, utilization of these resources is highly dependent on local conditions. While geothermal resources exist at Fenton Hill (see next section) and the Valles Caldera, each site will require the deployment of advanced geothermal technologies, uniquely oriented to very deep, very hot dry resources (HDR).

Tapping HDR at Fenton Hill will require Enhanced Geothermal Systems (EGS) technology (see Figure 5.6-3). EGS converts any geothermal resource requiring artificial stimulation. This includes resources that produce sub-standard hydrothermal fluid. Although EGS technology is still immature and in many aspects remains unproven, several projects are underway. If EGS technology proves commercially successful,

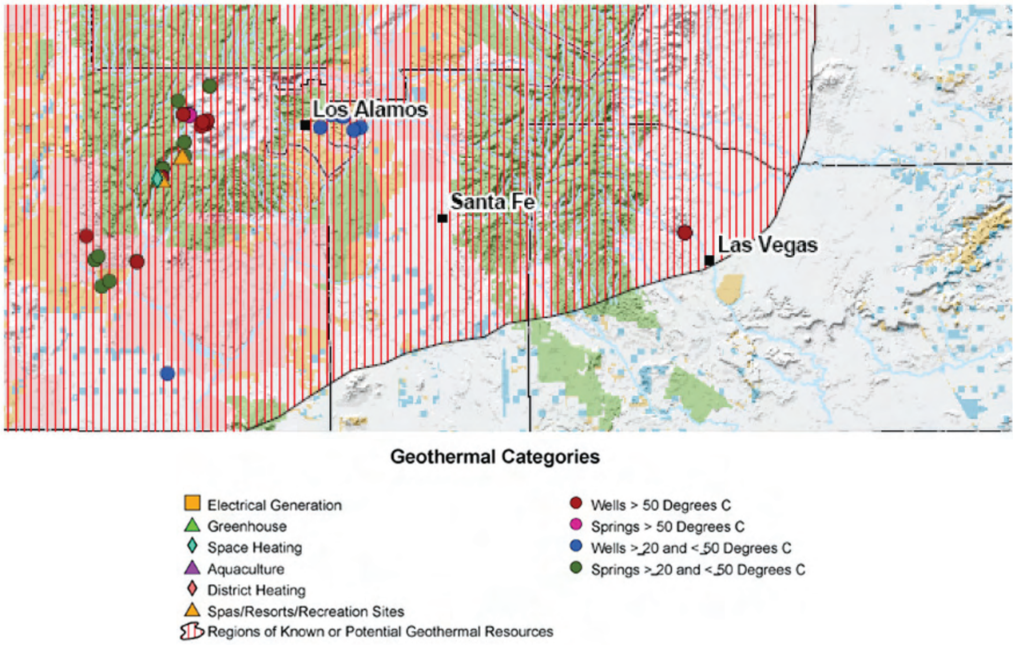

Figure 5.6-2. Geothermal resources, State of New Mexico (Pub. No. – INEEL/MISC-2002-395, Rev. 1, November 2003).

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[2] Fleischmann, D., *Geothermal Resource Development Needs in New Mexico.* .

[3] The U.S. Geological Survey, in its circular 790, estimates a hydrothermal resource base of between 95,000 and 150,000 MWe. Hydrothermal resources are those that support power in the U.S. today and are one of several parts of the total geothermal resource base. http://pubs.er.usgs.gov/usgspubs/cir/cir790#viewdoc.

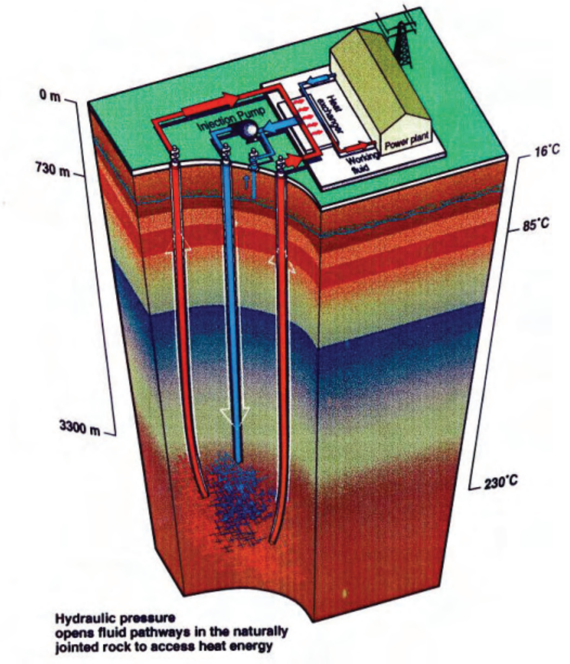

Figure 5.6-3. Schematic of an enhanced geothermal system power plant (Don Brown, Los Alamos National Laboratory).

it may significantly increase the extension of and production from existing fields, as well as tap geothermal resources that were previously unsuited for power production.

Fenton Hill

Fenton Hill was the site of one of the earliest geothermal research projects in the U.S. The project, referred to as the Fenton Hill Hot Dry Rock project, spanned from the mid 1970's to the early 1990's. The Fenton Hill project stimulated other research projects in Japan, Europe, and Australia.

The Fenton Hill HDR project took an ambitious approach at the time by attempting to mine sub-surface thermal resources. Rather than relying on high-grade thermal sources limited by geology, the system used several deep wells to reach heat bearing rock. It manipulated the rock's fractured structure to circulate water and extract heat to power steam generators. The Fenton Hill project demonstrated the scientific validity of deep wellbore drilling into geo-thermally productive rock structures. The project concluded in the late 1990s.[4]

Recommendation

This Study was purposely limited to the consideration of commercially available technologies for the Power Pool. An EGS geothermal project is not recommended for immediate consideration because the technology is immature.

The Fenton Hill site does represent favorable conditions for a 5 MW power plant but capacity may be restricted to 3 MW due to the size of the existing electrical distribution line.[5] It is recommended that a follow-on study be conducted that would evaluate the possibility of reactivating the existing Fenton Hill infrastructure and determine the ability of the existing electrical distribution infrastructure to wheel the power. The interest in geothermal technology within the Federal research agenda has increased. Federal funding might provide support for a follow-on study.

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[4] Los Alamos National Laboratory, Duchane, David V., Progress in Making Hot Dry Rock Geothermal Energy a Viable Renewable Energy Resource for America in the 21st Century (1996).

[5] The 14.4 kV, 3 phase distribution line running along Jemez Creek is rated at 4 MW up to Jemez Springs, and 3 MW from Jemez Springs to Fenton Hill, as discussed with the Jemez Electrical CO-OP in a telephone conversation. The exact rating of this line still needs to be verified.

5.7 Los Alamos County Department of Public Utilities Hydroelectric Opportunities

The Los Alamos County Department of Public Utilities has considered several new hydroelectric opportunities including a third unit (3 MW) at the existing Abiquiu plant, a small unit at the outlet of the San Juan-Chama water diversion project, and a plant at the existing Cochiti Dam and Reservoir. Of these, the Abiquiu project has the best economics.

The Abiquiu project was put out for bid and awarded in 2005, but the project was never initiated because of problems during subsequent negotiations. The project is included in the FY09 budget and the staff has been meeting with potential bidders.

Recommendation

The County should complete the installation of the third unit at Abiquiu Dam.

Figure 5.7-1. Abiquiu Dam hydroelectric plant (Los Alamos County Department of Public Utilities).

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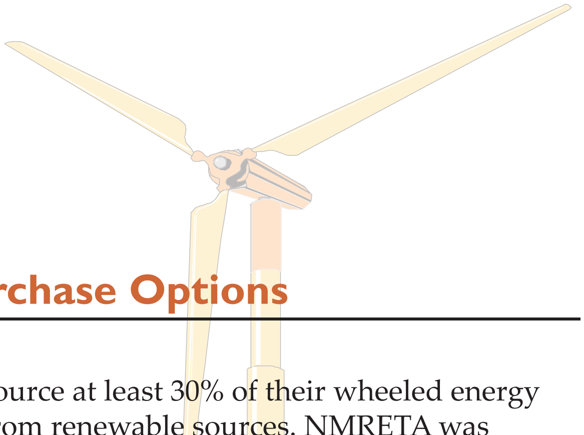

Chapter 6. Renewable Power Purchase Options

The bulk of this study focuses on the identification of renewable energy sources that could be developed within or adjacent to the Laboratory. Another option, however, would be the simple purchase of renewable generation produced within proximity such that the energy costs when combined with transmission fees ("wheeling" charges) results in an economic purchase of renewable energy. For example, wind power is not feasible at the Laboratory, but there are numerous sites and numerous developers in New Mexico and Colorado where the resource is plentiful. The County could enter into PPAs with specific developers to offset power that would otherwise be purchased from the grid. Although certainly more difficult to achieve, the County and the Laboratory could also cooperate in the encouragement of local generation, especially that involving the Native American community. In addition to the incentives summarized in Chapter 4, tribes have access to a broad portfolio of grant programs. Teamed with the right technology partner, and perhaps with County participation, new renewable generation projects could be facilitated.

NM Renewable Transmission Authority

Arranging for renewable power purchase contract paths through the existing grid can be challenging, since generation is dispersed and intermittent and existing transmission lines might not be convenient. Recognizing these difficulties, the New Mexico legislature created the New Mexico Renewable Energy Transmission Authority (NMRETA) in 2007. NMRETA provides planning services and financing for new transmission lines that source at least 30% of their wheeled energy from renewable sources. NMRETA was organized to develop a renewable energy generation and export industry in New Mexico, increase in-state electric system infrastructure reliability, and proactively pursue statewide electric transmission and distribution capital improvement planning and implementation. It is also charged with orchestrating multistate, multi-electric utility negotiations to facilitate the development of NM transmission and distribution infrastructure for renewable energy development and export. Figure 6-1 shows a schematic of the NMRETA activities and responsibility with regard to imports and exports of electricity to the state of California.

In addition to promoting the import and export of power, the NMRETA will enhance the ability to do PPAs within the state.

NMRETA and the Los Alamos Power Pool

This feasibility study discusses the full realm of reasonably commercial renewable energy supply options. NMRETA could be an important component within a renewable energy portfolio for the Power Pool by creating the opportunity for the Power Pool to enter into direct PPAs with renewable power projects that might otherwise not be feasible for siting in Los Alamos.

Agreements could be negotiated to secure the full output of specific large projects, such as a wind farm or a solar thermal plant, and utilize NMRETA to assure sufficient transmission capacity to move the power. A PPA is an essential ingredient to securing

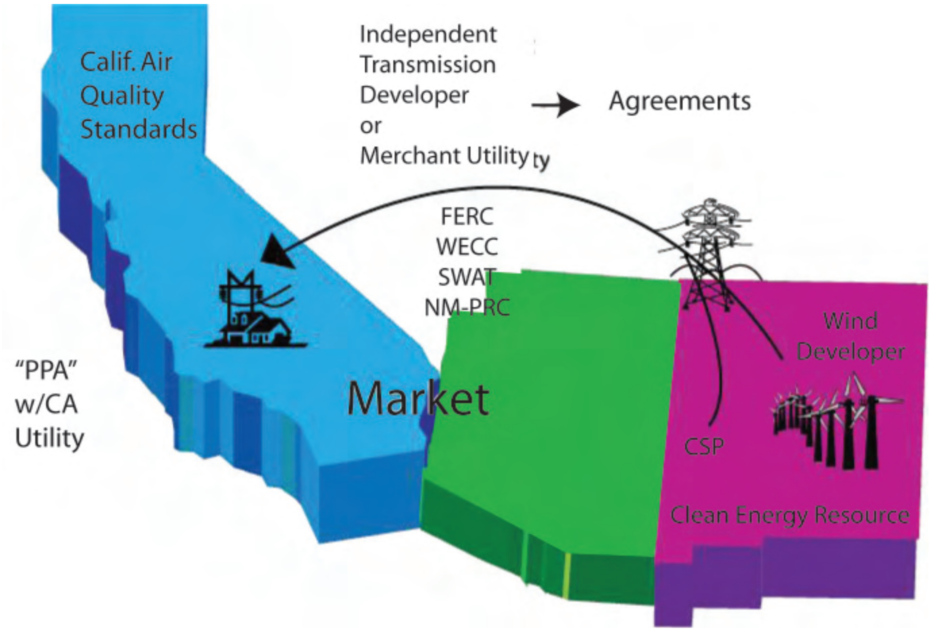

Figure 6-1. Interstate power flows and New Mexico Renewable Energy Transmission Authority (Enabling Legislation Fact Sheet, HB188, March 2007).

project financing. The commitment of the Power Pool to fully purchase all output of a project could be the deciding factor for a project to actually be built.

Wind

The following wind projects are in operation or have been announced. The developers might be interested in responding to a County RFP:

- The New Mexico Wind Energy Center is the seventh-largest wind generation project in the United States. The wind center consists of 136 turbines, each standing 210 feet high. The facility can produce up to 200 MW of power, or enough electricity to power 94,000 average-sized New Mexico homes. Florida-based FPL Energy owns and manages the facility, while PNM purchases all of its output.
- Llano Estacado Wind Ranch, Texico, NM, 2 MW.
- Caprock Wind Ranch, Quay County, NM, 80 MW.
- Gerhardt Wind Project, Guadalupe County, by GreenHunter Energy. Two hundred turbines developing 300 MW. Land is leased, but the wind project is not yet constructed.
- Argonne Mesa II Babcock & Brown Wind Project, west of Tucumcari and South of Santa Rosa, NM: 120 MW (planned).
- Owaissa Wind Project, North of Tucumcari, near Clayton, NM, 120 MW (planned).
- High Lonesome Wind Ranch, Willard, NM, 100 MW (planned).

There are a number of important details that would need to be considered in such a purchase, such as the intermittent nature of wind generation. Unlike solar power, where maximum generation normally occurs during maximum demand, wind tends to be the opposite, generating power off peak. In order to import predictable blocks of power that can be used for baseloaded operations, the wind power's intermittent quality needs to be balanced with other generation sources. This bundling can sometimes be done by the transmitting utility, such as PNM, but needs to be considered as a component of the PPA.

The ownership of the wind resource can make a difference as well. For example, tribal entities have access to greater incentives than other firms.

Recommendation

The Power Pool should incorporate the possibility of renewable PPAs as an important element of its purchased power options, however considerable exploration and further analysis is required. Exploration could include researching existing or planned projects or the facilitation of a tribal owned generation source by using a purchase power agreement to assist the financing package. Where baseload requirements are to be met with PPAs, means by which intermittent renewable energy purchases are bundled to create reliable blocks of power should be evaluated before a recommendation can be made as to the type and amount of renewable PPAs.

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Chapter 7. Conclusions and Recommendations

County and Laboratory Electrical Load Growth

The Laboratory and the County currently have a peak demand of approximately 80 MW when LANSCE is operating. The County is forecasted to add as much as 8 MW of new load (for a total load of 26 MW) through 2018. Depending on the Laboratory's programmatic configuration, the Laboratory forecasts between 20 MW to as much as 145 MW new demand. Five facilities, some still under consideration, contribute to the majority of the Laboratory's forecast:

- Computer Centers (Metropolis and LDCC)
- Chemistry Metallurgy Research Replacement projects (RLUOB and NF)
- Los Alamos Neutron Science Center projects (LANSCE-R, SPEF, and FEL)
- Matter-Radiation Interactions in Extremes facility
- The SC and its associated computing center

The overwhelming majority of the Laboratory's projected growth (nearly 77%) is from computing facilities. For all practical purposes, it is the Laboratory's electrical demand growth that will drive the future direction of electrical generation and transmission projects. In the absence of load growth at the Laboratory, if the County's growth materializes, it could be accommodated by renewable power generation and the existing transmission and distribution infrastructure.

General Assumptions and Considerations

The construction of new Laboratory facilities is subject to a number of variables, particularly the adequacy of funding from federal appropriations. Given the current climate of declining budgets, the probability of implementing all of the proposed projects on the preferred schedule is low. Nonetheless, the potential range of load growth forecasts over the next 10 years is significant. Due to the uncertainty of the future configuration of the Laboratory, the study considered the following:

- Assume actual growth will likely fall somewhere in between the minimum and maximum estimates of electrical load growth.
- Emphasize strategies that minimized the need to purchase expensive on-peak power by considering peak shaving.
- Identify renewable technologies that could supply a portion of the Laboratory's base load power requirements.

Conclusions

Despite the fact that New Mexico State incentives are minimal, the study makes the following observations regarding renewable energy options that can and should be pursued immediately:

- Currently, the 115 kV transmission infrastructure has sufficient capacity to import an additional 25 to 30 MW of renewable (or non-renewable) electricity to serve baseload requirements for the Laboratory and the County. However, significant new electrical demand resulting from new supercomputing or other planned programmatic changes could increase the Laboratory's load to the point where it would exceed the current 110 MW import capacity of the two existing lines. Above 110 MW, a fully redundant transmission system no longer exists and a third transmission line is needed to restore redundancy. The construction of a third 115 kV transmission line from PNM's Norton Station to the Laboratory's STAStation must be timed to serve any incremental system load above 110 MW. In addition, if a large water diversion project planned by the City of Santa Fe Water Division is installed, steps must be taken by DOE to ensure that PNM augments infrastructure such that the 110 MW import capacity to the STA substation be maintained.

- On-site renewable generation from solar PV arrays for daily peak shaving is technically attractive. Solar PV technology is commercially available and potentially economically feasible as a source of renewable electricity. Adequate sites exist to conservatively support up to 10 MW of solar PV.
- Generating electricity with local wind resources at a Laboratory site (or anywhere within the County) is not feasible due to insufficient wind resources. However, purchasing and importing remotely generated electricity produced from wind could become an option for supplying a portion of the Laboratory's baseload energy requirements.
- MCFC are a moderately attractive source of supplemental energy at the Laboratory because of their ability to supply steam, premium quality and reliable power for computing facilities. However, fuel cells are not recommended as a supply option; the Laboratory would be required to use natural gas as the fuel due to the unavailability of a local supply of a renewable fuel; and the maintenance and installation costs for an on-campus facility would be prohibitive.
- Biomass energy production might present a unique opportunity to use wood wastes and forest thinnings and downfall to fire a boiler and supplement heating steam. Further conceptual analysis is recommended to adopt biomass technologies to supplant a portion of the steam capacity provided by the existing natural gas boilers at TA-3 or another site.
- Geothermal hot rock steam generation is attractive, but the technology required to harness this resource is not commercially proven. It is recommended that DOE consider partnering with private firms to demonstrate and prove the commercial viability of geothermal hot rock steam generation for the Laboratory before the Power Pool considers applying this technology.
- Concentrating solar power was found to be too much of a technical challenge to install near the TA-3 Steam Plant due to the hilly terrain and limited acreage. There are concentrating solar technologies that are in the early stages of development that do not have similar space or grade constraints, and may become options in the future. However, concentrating solar power could be immediately attractive as a renewable source of baseload electricity for the Power Pool if it were generated at, and imported from a remote location.
- Federal and state incentives, as well as the sale of carbon offset credits and RECs can be used to lower the cost of producing renewable energy. The incentives available to a renewable developer differ depending on ownership structures: private firms enjoy a variety of tax and production incentives; while public entities, such as the County, can tap federal low interest, tax exempt bonds to fund construction. Project structures are available and described in the study that maximize the use of private and public incentives.

New Mexico Wind Energy Center located 20 miles northeast of Ft. Sumner, New Mexico (Public Service Company of New Mexico).

At present, the only renewable energy source planned for the Power Pool is the County's installation of a third hydro unit at Abiquiu Dam (for installation in FY09). Additional on-site renewable energy generation was evaluated to displace the power currently purchased outside the Power Pool needed to satisfy the Laboratory's baseload energy requirements, and to increase energy supplies to satisfy future electrical load growth. On-site generation could also relieve the constraints posed by the 115 kV transmission system import capability. The study found that there are currently no renewable energy generation technologies that could be sited in Los Alamos that are feasible for supplying baseload power to the Laboratory.

FY09 Action Items

In addition to the County completing its plans for constructing an additional hydro unit at Abiquiu Dam as an approved Power Pool resource, the study recommends that the following activities be pursued in FY09 that facilitates the successful renegotiation of the ECA in FY10. The recommended revisions to ECA language are provided in Appendix G.

- Draft revisions to the Electrical Coordination Agreement to extend the agreement and allow for the introduction of additional renewable energy supplies (beyond hydroelectric) into the Power Pool's generation portfolio, at a cost not to exceed the savings resulting from the retirement of debt in 2015.
- Evaluate the TA-36 parcel for a special use permit (similar to the TA-61 Landfill special use permit) by the LADPU for the exclusive use of a PV array.
- Initiate a Laboratory "Permits and Requirements Identification" (PR-ID) process and siting analysis to evaluate a parcel at TA-36 as a potential site for the installation of a PV array.
- Issue a County request for PPA proposals from renewable energy developers to use the TA-36 and the TA-61 landfill parcel for the installation (and operation) of at least 8.5 MW of PV arrays. If these proposals

are economic, such an installation would satisfy the Laboratory's TEAM Initiative goal for renewable energy sources at DOE facilities.

- Request a modification to the TA-61 landfill permit from the NMED to allow a PV array to be installed on the capped site.
- Initiate an in-depth study to determine the best business approach to employ wind powered energy to satisfy a portion of the Laboratory's baseloaded electricity requirements.
- Continue the evaluation of supplanting steam capacity at the TA-3 Steam Plant or other distributed boiler locations with biomass boilers.

By pursuing the FY09 recommended activities, the County, DOE and the Laboratory will have made significant progress to ensure that affordable renewable energy becomes an integral part of the County's and the Laboratory's energy portfolio meeting current needs and future growth.

Appendix A. Los Alamos Power Pool Generation and Transmission Resources

1985 Pooled Generation and Transmission Resources

Prior to 1985, DOE purchased power for the Laboratory through purchase agreements with PNM and the DOE's Western Area Power Administration (Western). Forming the Power Pool agreement enabled DOE and the County to better control future power and energy costs through County ownership of generation, transmission, and distribution resources. The pooling concept has proven to be an excellent collaborative vehicle to provide an industrially competitive CoE for the Laboratory.

The initial $110 M bond issue enabled the County to acquire a 36 MW ownership in San Juan Unit 4 and to construct the 14 MW Abiquiu and the 8 MW El Vado hydroelectric plants. The San Juan plant is the largest generation asset in the approved set of pooled resources. In addition to the resources purchased with bonds, the County included in the pool a life-of-the-plant entitlement for 10 MW of power from Laramie River Station in Wheatland, Wyoming, and a small 1.4 MW Western allocation that is currently limited to approximately 1.0 MW.[1]

Figure A-1. El Vado Hydroelectric (Los Alamos Department of Public Utilities).

DOE initially contributed its 22.5 MW gas/oil fired generator at the TA-3 power plant, and a 34 MW Western allocation that is currently limited to approximately 18 MW[2] to the Power Pool. DOE also provided its Eastern Technical Area (ETA) Switching Station, its on-site 115 kV transmission lines, and its 115 kV ETA to the Norton transmission line, as well as the TA-3 transformer facilities, capacitor banks, and related facilities. In 1997, DOE added the ETA Switching Station static VAR compensator to the Pool and in return received a credit of 10 MW of free transmission from PNM.

The Power Pool recognizes the 24 MW combustion turbine that DOE installed at TA-3 in 2007 as a special purpose approved resource (SPAR), since it was installed to meet reliability requirements for the Laboratory. When the combustion turbine is operating for the purposes of the Power Pool, its operating costs are recoverable in accordance with agreed upon guidelines.

Generation Resources in 2007

Table A-1 provides a summary of Los Alamos Power Pool generation resources. Summer

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[1] Summer allocations are slightly lower than winter allocations.

[2] Summer allocations are slightly lower than winter allocations.

Table A-1. Los Alamos Power Pool Generation Resources

Resource	Net Installed Capacity (MW) Summer	Net Installed Capacity (MW) Winter
San Juan Unit 4	36.50	36.50
El Vado Hydroelectric	8.00	0.00
Abiquiu Hydroelectric	12.60	0.00
Western Allocation	0.98	1.46
Laramie River Station[3]	10.00	10.00
Total Installed Capacity	68.08	47.96
DOE Western Firm Entitlement	17.44	18.60
DOE Gas-Fired Steam Turbine Generators	20.50	20.50
DOE Gas-Fired Combustion Turbine[4]	20.00	20.00
DOE Quick-Start Diesel Generators[5]	2.50	2.50
Total DOE Resources	60.44	61.60

Figure A-2. San Juan Unit 4 (Los Alamos Department of Public Utilities).

and winter figures are provided to show the impact of the hydroelectric plants and the Western allocation.[6]

The DOE Western allocation is typically the sole DOE generation contribution to the Power Pool. The three DOE gas-fired steam turbine generators, the combustion turbine, and the quick start diesel generators have a combined rated capacity of approximately 45 MW; but are operated only for emergency backup in the event of a power supply shortage or a problem in the transmission system. Therefore, the Power Pool provides a maximum of 85.5 MW on a typical summer day, and 66.5 MW on a typical winter day (see Table A-1).

The 85.5 MW summer rating and a 66.5 MW winter rating were used as a basis for determining the current gap between the Power Pool's recent demand and its available generation capacity (see Chapter 3). The gap is currently filled with spot-market purchased power contracts that could be replaced with renewable on-site generation (or off-site renewable generation through PPAs).

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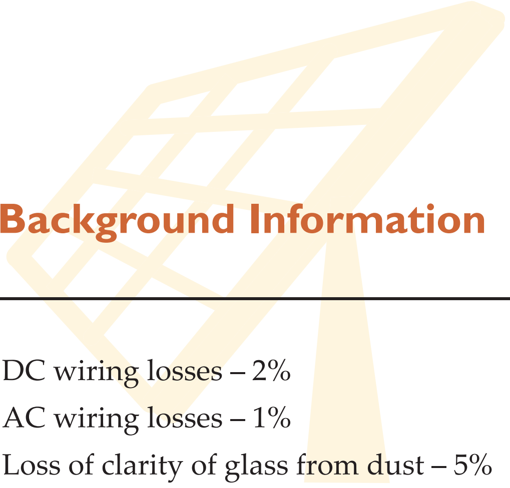
[3] The Laramie River Station (life-of-project entitlement) is part of the Lincoln Electric System.

[4] The combustion turbine is a special purpose approved resource included in the ECA.

[5] Two 1.25 MW quick start diesel engine generators are special purpose approved resources for contingency reserve included in Operating Agreement B-12.

[6] The hydroelectric units are typically available from April to July depending on spring runoff and lake level.



Appendix B. Photovoltaic Systems Background Information and Data

Appendix B supports Chapter 3, Peak Shaving Opportunities for the Laboratory, and Chapter 5, Distributed Generation and Renewable Technologies. The economic analysis and siting recommendations are excerpted directly from the NREL Report.[1]

PV Array Specifications

This section provides the data and assumptions[2] for the analysis of potential peak shaving opportunities (see Chapter 3). The NREL PVWatts™ calculator was used to determine the energy production of a 4 kW grid-connected PV array for three tracking options: fixed-mount, single-axis and double-axis. Each 4 kW array takes up approximately 35 m^2 (377 ft^2) of ground area (cell only, not for a complete PV system). The analysis uses typical meteorological data for Albuquerque, NM (the NREL standard for an analysis of Los Alamos) to model the solar radiation incident[3] of the PV array and the PV cell temperature for each hour of the year.[4] The rated output for the array was reduced by 23%, based on the following losses:

- PV module nameplate DC rating – 5%
- Inverter and transformer losses – 8 %
- Mismatch of wiring – 2%
- Diodes and connection losses – 0.5%
- DC wiring losses – 2%
- AC wiring losses – 1%
- Loss of clarity of glass from dust – 5%
- System availability – 2% loss

The 4 kW model was then expanded to model the 1, 5, and 10 MW PV systems. The peak power output and land area required for these systems is presented in Table B-1, Figure B-1, and Figure B-2.

Single and double-axis tracking systems rotate to follow the early morning and late afternoon sun and are therefore more efficient then the fixed-tilt arrays (see Figure 3-5). In Albuquerque, a double-axis tracking system's peak power production is 4% more than a fixed-tilt system while it can produce 48% more energy during the day. The single-axis system's peak power is 1% more than the fixed-tilt system, but can produce up to 42% more energy during the day.

Figure B-1 presents the annual average power output of a 1 MW system (requiring 8,750 m^2 or 2 acres) for each system type over a 24 hour period. Peak power output is similar for all tracks and approaches 0.8 MW.

Figure B-2 illustrates the annual average hourly power output of a 5 MW system

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[1] National Renewable Energy Laboratory, DOE Los Alamos National Laboratory – PV Feasibility Assessment – NREL Final Report (January 2008).

[2] The data, assumptions, and descriptions in this appendix are excerpted substantially from the National Renewable Energy Laboratory's, *NREL PVWatts™ Calculator* website (http://rredc.nrel.gov/solar/codes_algs/PVWATTS/system.html).

[3] The amount of solar radiation striking a surface per unit of time and area.

[4] The PV array specifications used system specifications of a tilt angle equal to the latitude of 35.05, longitude of 106.62 degrees, and an azimuth angle of heading south at 180 degrees.

Table B-1. Comparison of the Power Output between the Three Scenarios for the Three Tracking Systems[5] (NREL PVWatts™)

Monthly Average of the Maximum AC Power Output								
1 MW Peak Power			5 MW Peak Power			10 MW Peak Power		
8,750 m² PV (2 acres+)[3]			43,750 m² PV (10 acres+)			87,500 m² PV (21 acres+)		
Fixed Tilt Array	1 Axis Tracking Array	2 Axis Tracking Array	Fixed Tilt Array	1 Axis Tracking Array	2 Axis Tracking Array	Fixed Tilt Array	1 Axis Tracking Array	2 Axis Tracking Array
0.81 MW	0.81 MW	0.84 MW	4.04 MW	4.06 MW	4.20 MW	8.08 MW	8.13 MW	8.41 MW

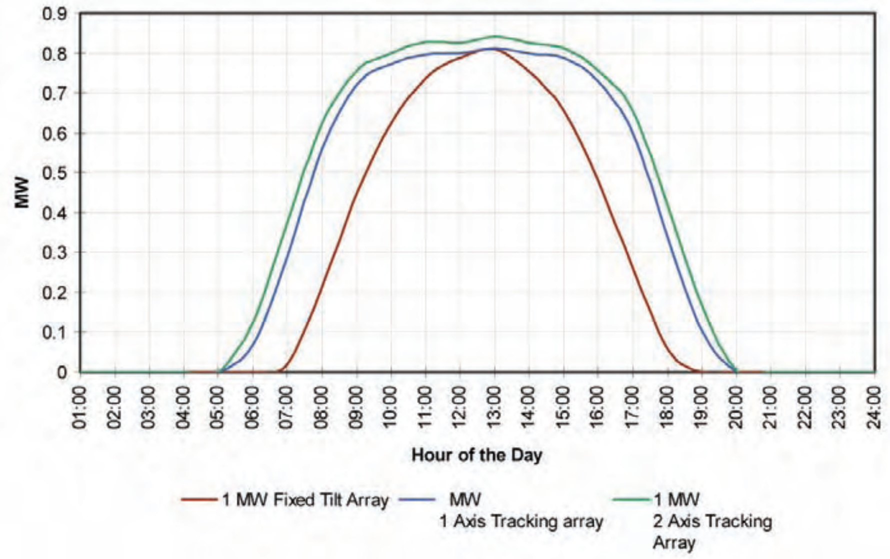

Figure B-1. Annual average hourly power output of a 1 MW PV array (NREL PVWatts™).

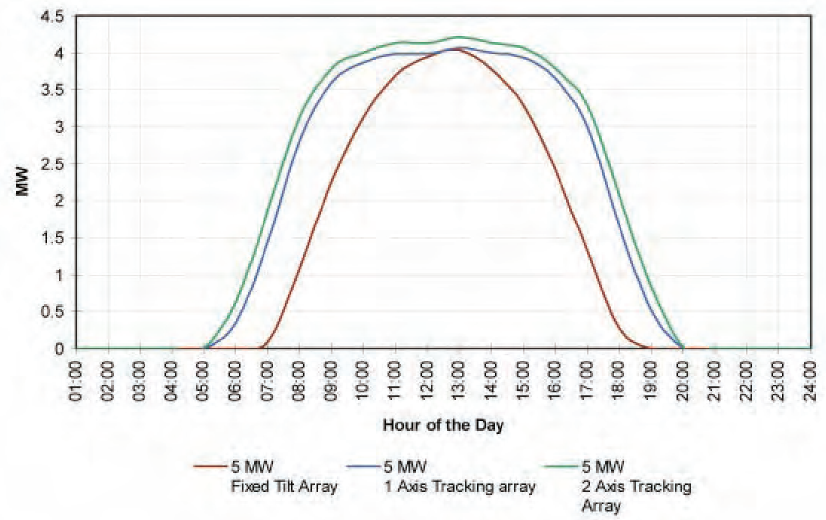

Figure B-2. Annual average hourly power output of a 5 MW PV array (NREL PVWatts™).

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[5] Acreage only accounts for PV cell area.

requiring 43,750 m^2 (10.8 acres+) of cell surface area. A double-axis system has the potential to generate 4.2 MW at its peak (13:00) and the potential to sustain nearly 4 MW for approximately 5 hours between 11:00 and 15:00.

Figure B-3 models a 10 MW system (87,500 m^2 or 21.6 acres+). The double-axis tracking system can potentially generate up to 8.4 MW.

Economics of a PV installation at Los Alamos National Laboratory – The NREL Report

The following text was excerpted from the Executive Summary of the NREL report.

"The Solar Advisor Model™ (SAM)[6] *was used for this analysis. A variety of cost scenarios were calculated for each potential system: no incentives or REC sales included; all applicable federal, state and local incentives included but no renewable energy certificate (REC) sales included; and all federal, state and local incentives as well as assumed REC sales of $0.10/kWh included. The sales of RECs are annual income streams. For this analysis, these benefits were analyzed for 20 years. This was done by discounting the total value of these benefits over the timeframe in consideration, and then deducting this value from the initial capital cost of the system. These different cost scenarios are used to calculate economic parameters such as simple payback period and levelized cost energy. It is apparent from this analysis that the cost-effectiveness of PV installations at this facility will largely depend on incentives and REC sales. The table below details the economic findings for each of the three cost scenarios considered.*

It is recommended that LANL and Los Alamos County plan for large ground mounted single axis tracking PV system. The LCOE of this type of system could become very reasonable when the anticipated REC market develops. NEPA work should begin as soon as possible for selected sites."

Introduction to PV Technologies and Applications

There are a number of technologies used to manufacture PV cells: some are regarded as commercial, others are still in development. The primary technologies and their characteristics are shown in Table B-3.

Applications

PV installations can be sized to meet very small loads (to trickle charge battery storage systems), intermediate loads (individual

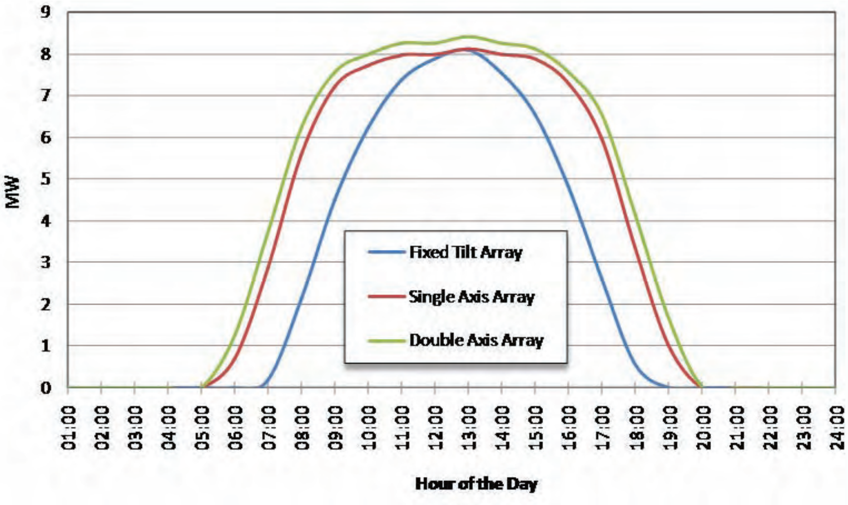

Figure B-3. Annual average hourly power output of a 10 MW PV array (NREL PVWatts™).

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[6] The NREL, in conjunction with Sandia National Laboratory and in partnership with the DOE Solar Energy Technologies Program, developed the Solar Advisor Model™ (SAM) in 2006.

Table B-2. Summary Findings, NREL Study, pp. 4–5

	Incentive Scenario	System Cost[7] ($M)	Annual Energy (kWh)	Payback Period (years)	Levelized Cost of Electricity Produced by PV ($/kWh)
Roof Mounted[8]	No Incentives	6.9		76	0.36
20 Year Analysis Period for Production Incentives and $0.10/kWh REC Sales	Federal, State, and Local Incentives	6.9		42	0.16
	Federal, State, and Local Incentives & REC Sales	6.9		15	0.13
Ground Mounted Single-Axis[9]	No Incentives	6.9		56	0.24
20 Year Analysis Period for Production Incentives and $0.10/kWh REC Sales	Federal, State, and Local Incentives	6.9		31	0.13
	Federal, State, and Local Incentives & REC Sales	6.9		11	0.07

facilities) up to, and including large-scale central generation.

They can be deployed as remote power sources or connected to the utility grid. With additional equipment, DC power output can be inverted to AC power; and, when included in the system battery storage or a backup generator, can provide uninterrupted power.

The most appropriate application of PV would be to use it to offset peak power demand. Offsetting Laboratory peak demand would reduce the amount of power purchased on the wholesale market during the hours when it is most expensive. Los Alamos is an ideal location for PV systems, having an average annual solar resource that is among the best in the lower 48 states.

Efficiency

A key consideration in the deployment of PV is cell efficiency. The more efficient the cell, the less area of PV cells will be required for a given output, and therefore, less land required.

Although the full amount of solar energy delivered to the earth is as much as a kW/m^2, each of the technologies noted in Table B-3 has effective limits for output and efficiency. The maximum for crystalline silicon is approximately 28%. Gallium arsenide thin film approaches 30%, while amorphous silicon thin film efficiency is approximately 24%. As a practical matter, while in the laboratory the efficiency of PV has approached the theoretical maximums the final product is likely to achieve far less in the field.

In the final analysis, there is a tradeoff between efficiency, installed cost and land area requirements. As a result, crystalline with its high efficiencies is not always the best choice.

Systems

In many small scale applications where there is a need for intermittent DC power, the PV cell can be directly connected to a load. A PV system that produces AC power can be connected to internal loads and the grid. Figure B-4 shows the system components required to connect the PV array to the grid.

Many of these components are "off the shelf." The inverter, however, must be carefully considered. Current inverter technology provides true sine wave power that is often

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[7] All PV and inverter cost data from personal communication with Jesse Dean, NREL.

[8] Payback periods assume $0.06/kWh.

[9] Payback periods assume $0.06/kWh.

Table B-3. Photovoltaic Technologies and Attributes (pvresources.com)

Technologies	Efficiency	Features
Crystalline	9.5%–18%	93% Market Share. Greater efficiency (least space per peak watt produced), established manufacturing technology. Most expensive. Further R&D not likely to improve cost and efficiency.
Monocrystalline		
Silicon	15%–18%	Best researched solar cell material – highest power/area ratio.
Dendritic Web Silicon	13%	Limited use of this production procedure, no wafer sawing, and production in form of band possible.
Polycrystalline		
Silicon	13%–15%	Wafer sawing necessary. Most important production procedure at least for the next ten years.
Transparent Silicon	10%	Lower efficiency than monocrystalline solar cells.
EFG	14%	Limited use of this production procedure Very fast crystal growth, no wafer sawing necessary.
Ribbon Silicon	12%	Decrease in production costs expected in the future.
Apex Silicon	9.5%	Significant decrease in production costs expected in the future.
Thin Film	5%–9.5%	7% Market Share. Relatively inexpensive manufacturing; further R&D very likely to improve cost and efficiency. Lower efficiency than crystalline.
Amorphous Silicon	5%–8%	Lower efficiency.
Cadmium Telluride	6%–9%	Poisonous raw materials, significant decrease in production costs expected in the future.
Copper-Indium-Diselenide	7.5%–9.5%	Limited Indium supply in nature. Significant decrease in production costs possible in the future.
Spherical	11.7%	Beginning production. Spherical silicon suspended on a variety of highly moldable substrates. One fifth silicon required, expect to be half cost of crystalline by 2010.
Concentrators (with tracking)	Various	Developmental. Potentially lower materials and manufacturing costs. Still very costly; tracking systems add cost and complexity.
Electrochemical	7% in lab	Developmental. Potentially lower materials and manufacturing costs. Still in laboratory.
Hybrid Silicon Solar Cell	18%	Developmental. Limited use of this production procedure, higher efficiency, better temperature coefficient and lower thickness.

purer than the power distributed on the utility grid.

Inverters are available that include most or all of the control systems required for operation including some metering and data-logging capability. They must be appropriately sized to handle peak output from the PV arrays. Inverters, like PV technologies, are available in a variety of efficiencies. The higher the efficiency, the higher the cost of the unit. Efficiency of the inverter is important to the overall efficiency of the system (see Output Considerations).

Mounting

PV arrays can be installed in many different ways: directly on roof tops, in fixed positions in open areas and on systems that track the sun's intensity. PV can also be mounted as a shading structure, such as over a parking lot. In addition, a few manufacturers offer PV cells integrated into commercial roofing membranes, roofing tiles and building exterior components. Figure B-5 shows a PV integrated membrane roof recently installed on the Frederick C. Murphy Federal Center in Waltham, MA, the Northeast headquarters for the National Archives and Records Administration.

Figure B-6 illustrates a ground mounted system in Nevada.

Figure B-7 illustrates a roof mounted system (non-integrated with the roofing material), installed at a manufacturing plant of Shisheido America.

Output Considerations

A number of factors have a dramatic influence on PV array output and require careful consideration in any installation. Rated output is quoted at a number of ideal (and rarely experienced) factors, referred to as Standard Test Conditions: 25°C; 1,000 watts/square meter of sun intensity; and a light spectrum assuming filtering of 1.5 atmosphere thicknesses. A typical rule of thumb is that, at a maximum, a system will operate at 90% of its nameplate rating. Output is also influenced by temperature (reduced at higher temperatures), air quality and dust, and wiring losses.

The overall system efficiency is the product of all of the system components, especially the inverter. If standard test conditions exist, a thin film module rated at 100 watts and a 92% efficient inverter, will have a maximum output of 74 kWh when the inverter and cell efficiency are coupled with wiring losses.

Siting Analysis and Recommendations Excerpted from the NREL Report

Figure B-8 illustrates potential PV array sites that were evaluated. The most promising sites recommended by NREL are Option B at TA-36 and and Option F at TA-61. See Table B-4 for a description of all sites considered in the NREL study.

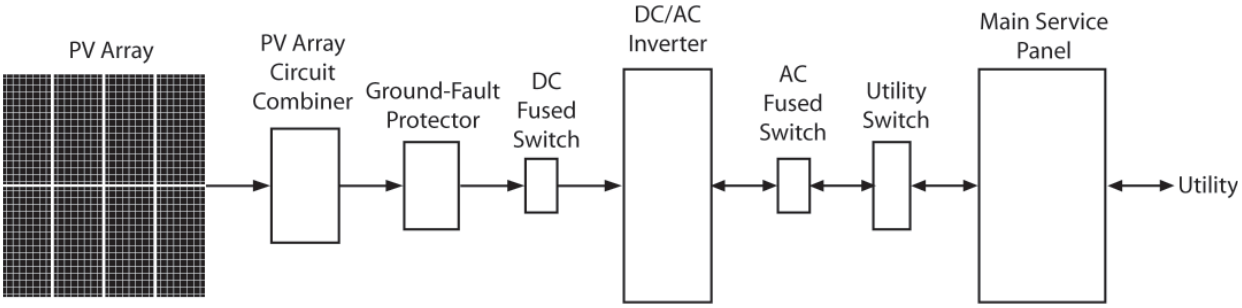


Figure B-4. Components of a grid-connected PV without battery storage (California Energy Commission).

"The entire campus was considered in this analysis, and many potential system locations were identified: 9 different ground mount locations with total available land up to 1000 acres, however the identified locations have constraints. As a result, 500 usable acres is assumed. The installed capacity could be as large as 83 MW."

Figure B-5. PV integrated roof installation (Silka Sarnafil, Inc. and Solar Integrated Technologies).

Figure B-6. Ground mounted PV system, Ronzone Reservoir, Nevada (Sunpower Corporation).

Figure B-7. Roof mounted 700 kW PV system, Shisheido America HQ (Sunpower Corporation).

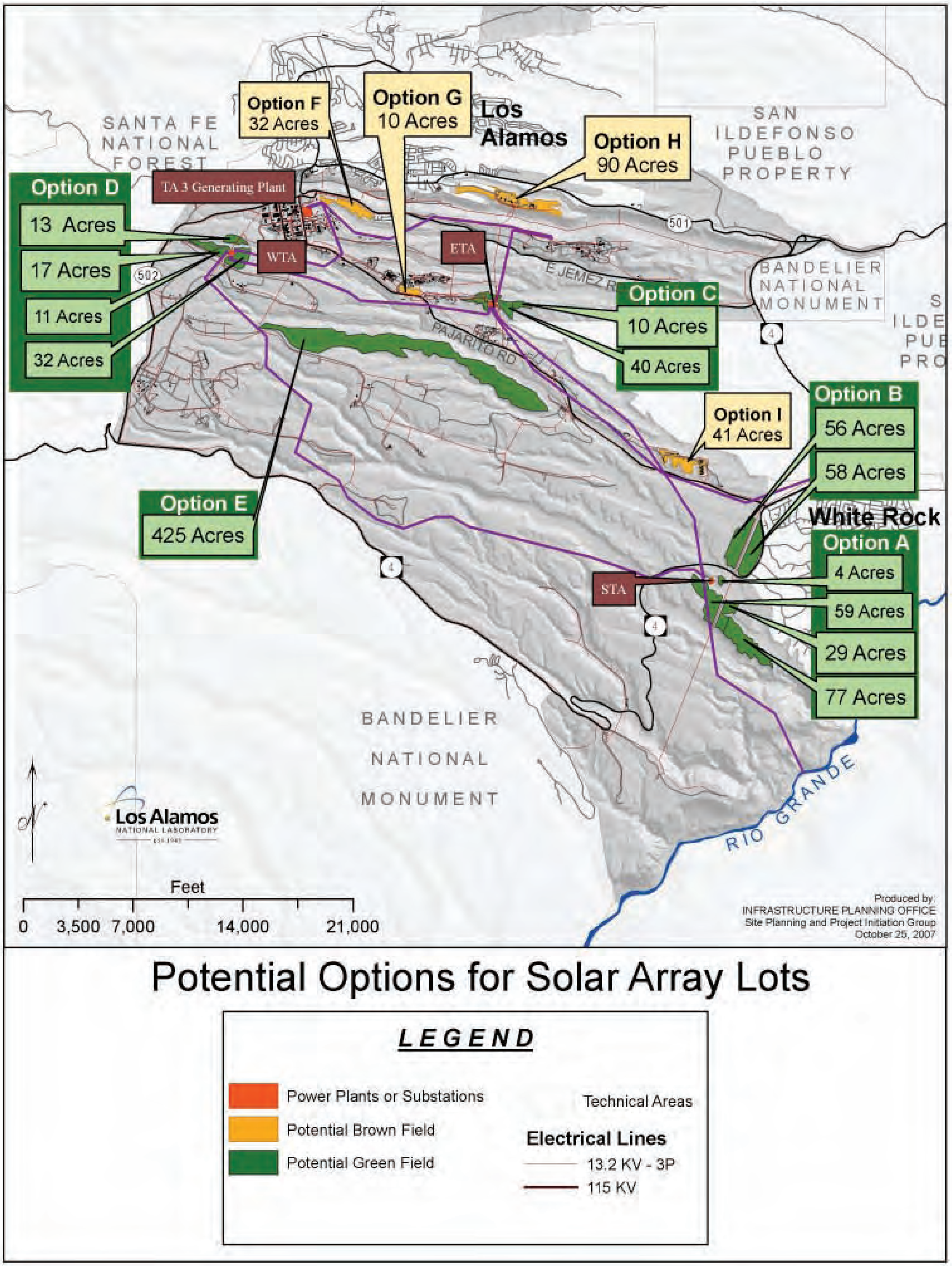


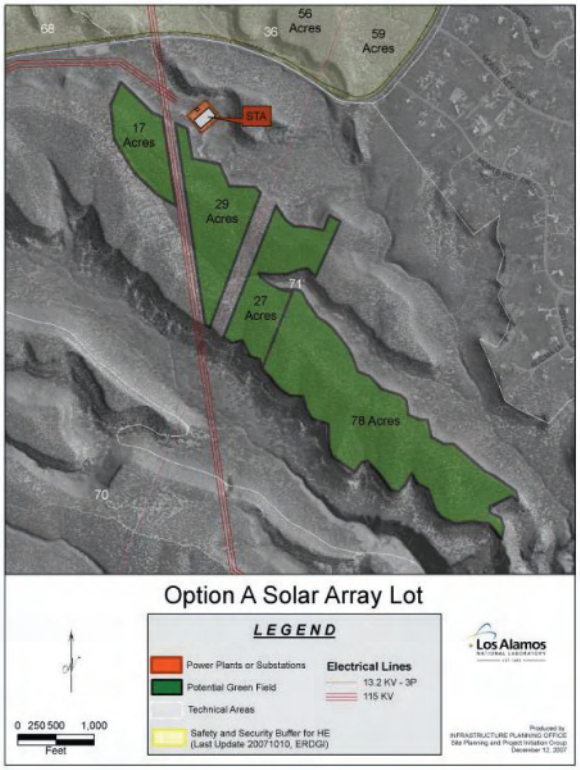
Figure B-8. Potential locations for ground mounted photovoltaic arrays at Los Alamos National Laboratory (NREL).

Table B-4. Synopsis of Sites for Ground Mounted Photovoltaic Arrays Considered in the NREL Study (NREL)

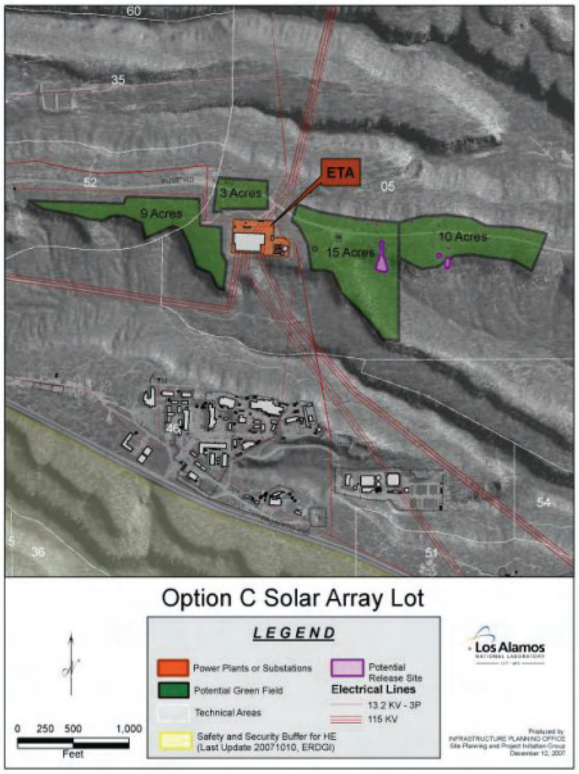
Potential Options for Solar Array Lots				
Option	**Site Area (acres)**	**Site Description**	**Distance to the Power Grid**	**Other Information**
A	169	Green field made up of 4 available sublots: 4 acres may be used as a sample site. 59 acres lie northwest of the power line. 29 acres lie southeast of the power line. 77 acres lie southeast of the 29 acre lot. These sublots sit on top of a mesa with sparse vegetation. They are located in a property protection area of the Laboratory in TA-71.	All sublots are within 100 feet of the 13.2 kV 3P power line with the exception of the 77 acre lot. Its northwest end is 825 feet from the power line, which extends through the 29 acre lot. All lots located near Substation STA.	Partial public view. Located near State Road 4.
B	114	Green field made up of 2 available sublots. A 56 acre lot to the northwest side of the power line and a 58 acre lot to the southwest of the power line. These lots are located just east of White Rock and are readily seen by the public. They are also located to the west of New Mexico State Road 4. Vegetation is pinion-juniper. Archeological sites are present on these sublots. These lots lie with the property protection area of the Laboratory in TA-36.	Both sublots are within 100 feet of a 13.2 kV 3P power line.	Public view. Located near State Road 4.
C	50	Green field made up of two sublots, one is 10 acres, the other is 40 acres. These lots are located within the security perimeter of the Laboratory. Vegetation is ponderosa pine, pinon, juniper, and scrub oak. Location surrounds Substation ETA. These sublots are located in TA-5 and TA-52.	Within 100 feet of a 13.2 kV 3P power line and Substation ETA.	May interfere with the proposed RLWCS project. No public view.
D	73	Green field made up of 4 sublots: a 13 acre lot; a 17 acre lot; an 11 acre lot; and a 32 acre lot. The 13 acre lot is across a small narrow canyon from the other sub lots. Located on the northwest end of the Laboratory and is currently in a property protected area. Vegetation is ponderosa pine which has been thinned for wildfire control. These sublots are located in TA-6, TA-58, and TA-69.	Surrounds substation Western Technical Area (WTA) and is within 100 feet of a 13.2 kV 3P power line.	Partial public view. Located near State Highway 501.

Table B-4. Synopsis of Sites for Ground Mounted Photovoltaic Arrays Considered in the NREL Study (NREL) (continued)

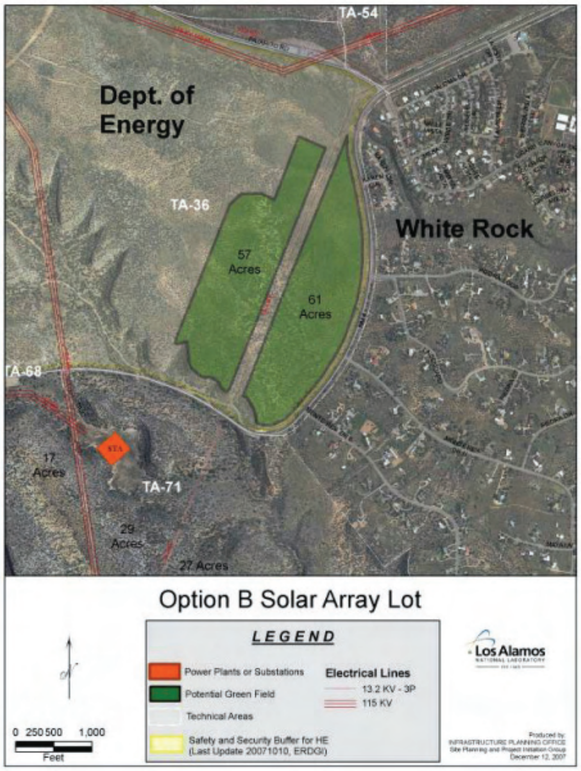
Potential Options for Solar Array Lots				
Option	**Site Area (acres)**	**Site Description**	**Distance to the Power Grid**	**Other Information**
E	425	Option E is a 425 acre green field that sits on top of a mesa inside a limited security area. Only the farthest west point of the lot is within 100 feet of a 13.2 kV power line. Other power lines surround the lot but are at least 1000 feet away and across a canyon. Vegetation consists of ponderosa pine, juniper, and pinon. The lot contains archeological sites. This lot is sprawled across TA-14, TA-15, TA-16, and TA-67.	Within 100 feet of a 13.2 kV 3P power line on the west side of the lot, otherwise more than 1000 feet from power lines.	Remote mesa with dirt road. Access is within a limited security area. No public view.
F	32	Brown field of 32 acres. Previously a county landfill, currently a stransfer station with capped landfill. Located in a property protection area along a State Road 4. Located within TA-61. Current usable area is about 18 acres, large enough for a 2-3 MW tracking PV system.	Within 100 feet of a 13.2 kV 3P power line and 1000 feet of the generating plant at TA-3.	Public view. Located near State Road 4.
G	10	Brown field on 10 acres. Currently identified as a material disposal area. Located at TA-50.	Within 100 feet of a 13.2 kV 3P power line.	No public view.
H	90	Brown field on 90 acres. Currently identified as a potential release site. Located at TA-21.	Within 100 feet of a 13.2 kV 3P power line.	Public view.
I	41	Brown field on 41 acres. Currently a low level radiation waste storage site. Located at TA-54.	Within 100 feet of a 13.2 kV 3P power line.	No public view.



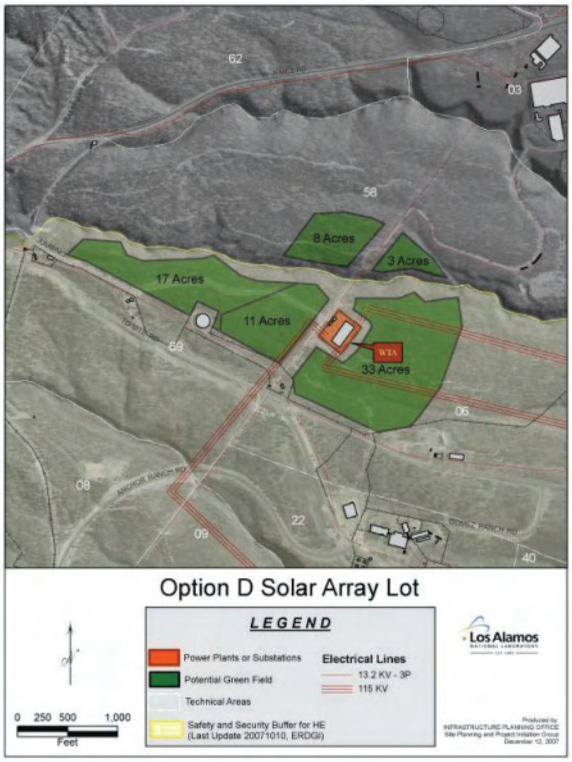
TA-71



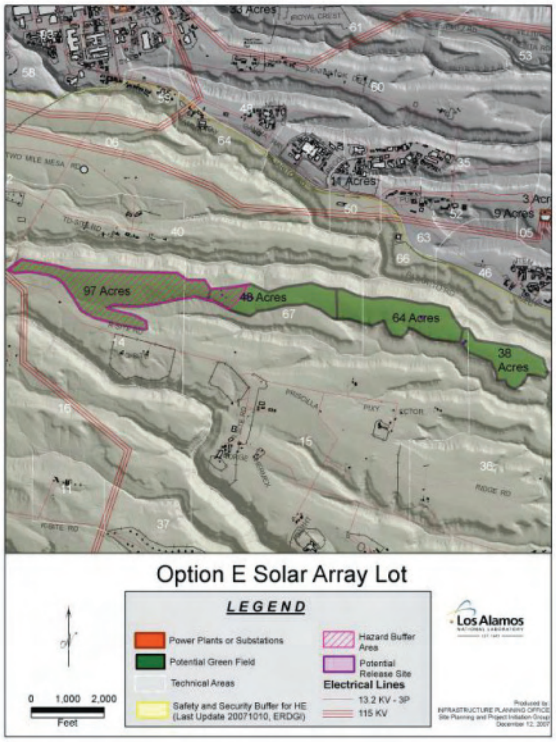
TA-52, TA-5



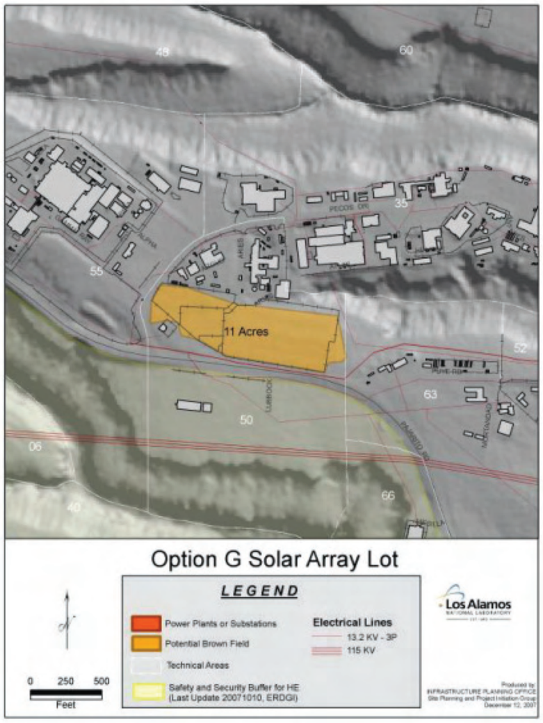
TA-36



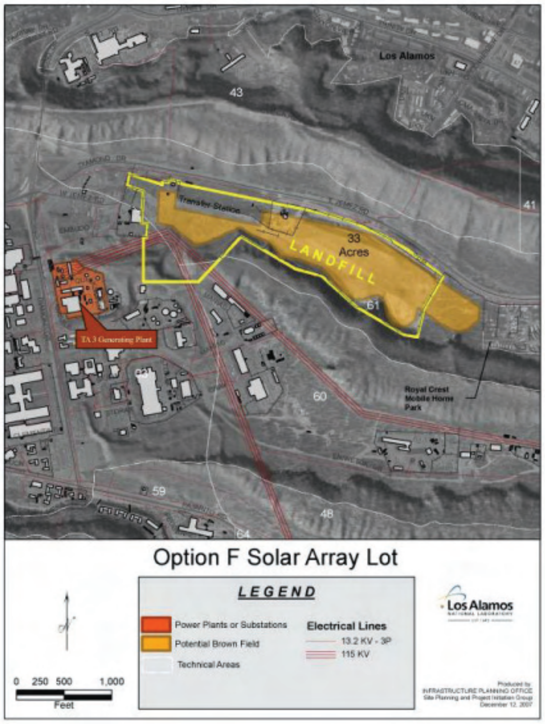
TA-58



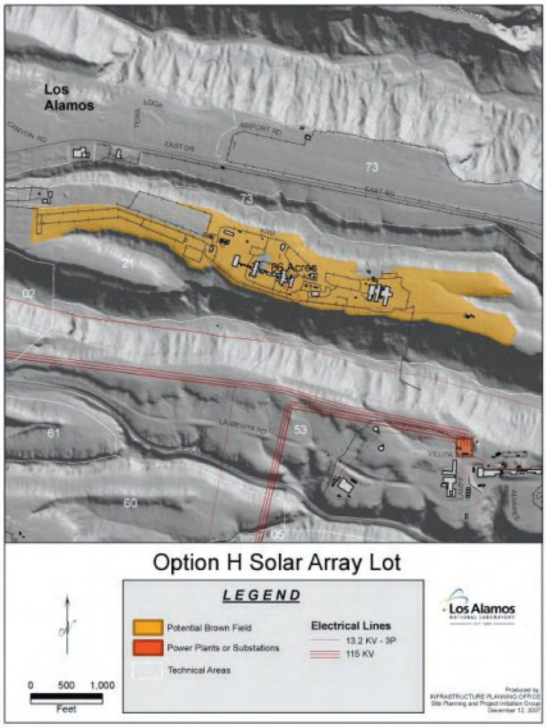
TA-14, TA-67, TA-36



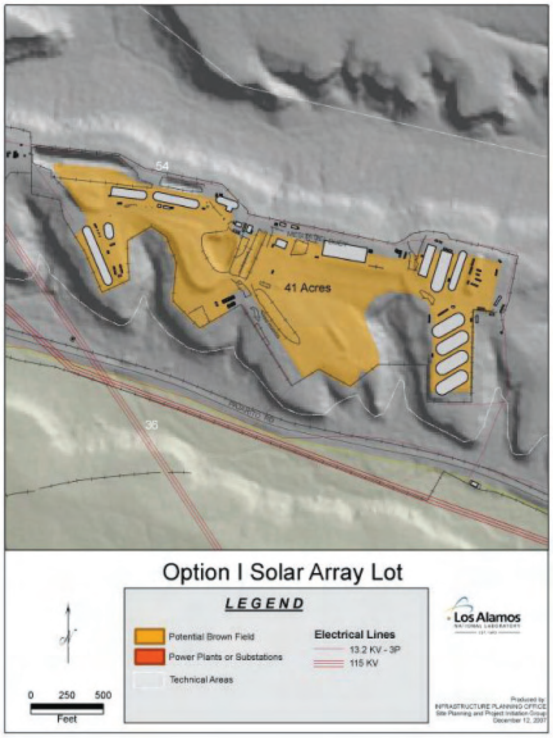
TA-50



TA-61



TA-21


54
41 Acres
36
Option I Solar Array Lot
LEGEND
Potential Brown Field
Power Plants or Substations
Technical Areas
Electrical Lines
13.2 KV - 3P
115 KV
N
0 250 500
Feet
Los Alamos NATIONAL LABORATORY
Produced by:
INFRASTRUCTURE PLANNING OFFICE
Site Planning and Project Initiation Group
December 12, 2007

TA-54

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Appendix C. Fuel Cell Systems

Basic Technology

Fuel cells, for all practical purposes, are continuously fueled batteries. Each cell consists of a cathode, anode and an electrolyte. Unlike a battery, however, a fuel cell is not an energy storage device, consuming the stored energy until it runs out. Rather, a fuel cell continuously converts the chemical energy of its fuel and oxidant into electrical energy. Fuel cells, regardless of type, all operate using the same basic chemical reaction:

$$2H_2 + O_2 \rightarrow \text{heat} + 2H_2O + \text{current}$$

Figure C-1 illustrates this process; hydrogen fuel, introduced on the anode side of the fuel cell, exchanges an ion with oxygen introduced on the cathode side, in the presence of an electrolyte and a catalyst. The ion exchanges result in current flow, with two byproducts: heat and water.

Fuel Cell Stacks and Systems

A fuel cell is a single cell (see Figure C-2). In virtually all applications, the power output of a single cell is insufficient: fuel cells are therefore "bundled" into a fuel cell "stack."

A fuel cell stack is fueled with pure hydrogen and produces DC current. In many applications, more common fuels and AC output are desired. In addition, depending on the type of fuel cell stack involved (see Types of Fuel Cells), there may be additional modules that extract the useful heat in the forms of warm or hot water or steam. Figure C-3 is an example of a fuel cell system where the input fuel (converted to hydrogen) is natural gas and the desired output is AC power and heat. Some portion of the heat produced by the stack (the power section in Figure C-3) is recycled and used in the fuel processor.

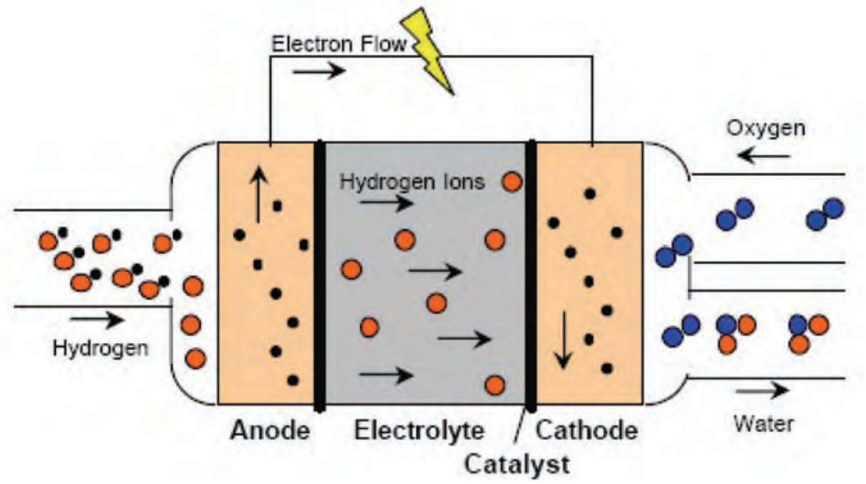


Figure C-1. Fuel cell schematic.

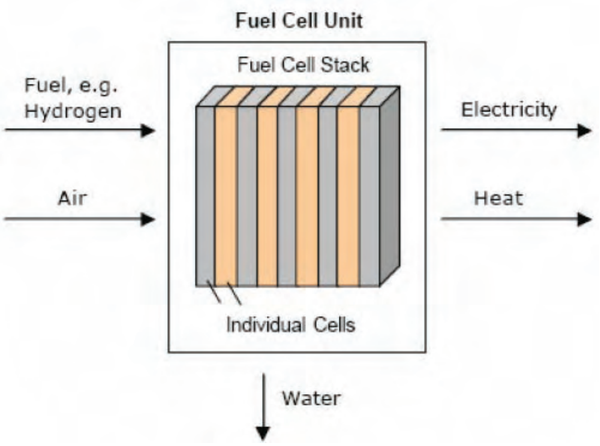


Figure C-2. Fuel cell stack.

Types of Fuel Cells

Fuel cells are classified by their electrolyte, which in turn, defines the basic materials, operating characteristics, operating temperature and ultimately, ideal applications. While this is not an exhaustive list, the following types of fuel cells are in common use and/or development today.

Alkaline

The Alkaline fuel cell (AFC) uses an alkaline electrolyte such as potassium hydroxide. AFCs became famous for their use in early NASA space missions, including Apollo. They remain in use in all space shuttles. The Russian Army uses AFCs as a robust power source that could handle severe weather conditions.

Advantages

AFCs can use a variety of alkaline catalysts and have high reliability.

Disadvantages

The AFC is sensitive to fuel impurities. Both hydrogen and ambient air introduced into the cells need to be carbon monoxide and carbon dioxide free. This added level of fuel processing (and air intake filtering) complicates the economics of the AFC.

Proton Exchange Membrane

The Proton Exchange Membrane (PEMFC) fuel cell uses a polymer (plastic) membrane as the electrolyte, with platinum electrodes. The PEM fuel cell is also sometimes called a polymer electrolyte fuel cell (PEFC). PEMFC have a very short start up period, can respond instantly to changes in load and are very light weight.

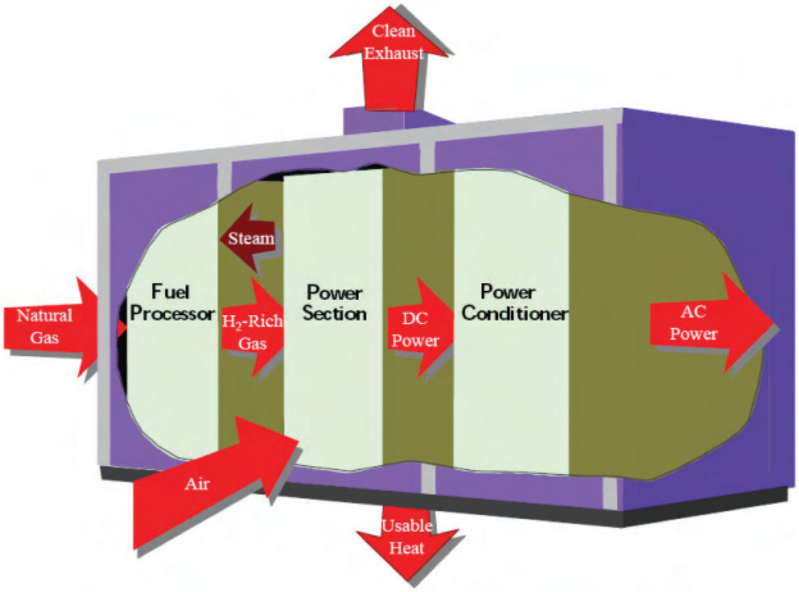


Figure C-3. Natural gas-fueled fuel cell system.

Advantages

The PEMFCs operating characteristics lend themselves to three key applications: transportation as a replacement for internal combustion engines, and in small, remote applications where pure hydrogen fuel is available, and for back up power.

Disadvantages

High quality hydrogen fuel is necessary – PEMFCs are very sensitive to fuel impurities and contaminants. The Platinum catalyst and electrode represent a major economic hurdle for mass market applications.

Direct Methanol

Direct Methanol fuel cells (DMFC) are essentially a PEMFC where methanol is introduced directly into the fuel cell on the anode side with specialized catalysts that extract the hydrogen. The DMFC is therefore a liquid fueled fuel cell and is ideal as a battery substitute in portable devices. Several companies are working on battery replacements where the device's normal battery space is replaced with a DMFC. Methanol cartridges are then used to supply the fuel, resulting in much longer operating periods and higher power densities than current batteries. Typical applications include notebook PCs and commercial quality video cameras.

Phosphoric Acid

A Phosphoric Acid fuel cell (PAFC) consists of carbon plates that hold liquid phosphoric acid and a platinum catalyst. Over three hundred 200 kW PAFC units are operating worldwide, produced by United Technologies or their licensees. They have a history of proven reliability.

Advantages

PAFCs are much less sensitive to the quality of hydrogen and can operate on hydrogen extracted from other sources, such as natural gas or methane (from waste digesters or landfills). In addition, they can deliver hot water at a temperature that results in high electric and thermal efficiency.

Disadvantages

PAFCs also require platinum, and the nature of phosphoric acid demands the use of expensive and exotic materials to prevent corrosion.

Molten Carbonate

The MCFC uses a molten carbonate salt as the electrolyte. The MCFC operates at 650°C, allowing for the production of steam as well as electricity. There is a growing fleet of MCFC units with a history of reliability.

Advantages

No expensive catalysts are required. The process heat is high quality, resulting in a combined thermal and electrical efficiency in the 60 percent range. MCFCs have shown themselves to be reliable cogeneration units that can operate on a variety of fuels with little pre-processing, including natural gas, methane, synthetic gases from gasification systems, and landfills.

Disadvantages

MCFCs have a relatively long start up period and are not suited for load following applications.

Solid Oxide

Solid Oxide fuel cells (SOFC) operate at higher temperatures than molten carbonate cells, in the range of 800°C to 1,000°C. They use a solid ceramic electrolyte and can reach electrical efficiencies of approximately 50%. Because of their ability to produce pressurized steam, SOFCs can be linked with a steam turbine for combined cycle operation. Under these circumstances, electrical efficiencies in the 70 percent range are achievable. Development efforts are focused at the 10 kW size (primarily for auxiliary power for large vehicles), or in very large commercial and industrial applications requiring more than 5 MW.

Advantages

Materials cost for the SOFC are relatively low compared with other fuel cell types. Electrolytes are solid, eliminating corrosion problems. Its potential as a cogenerator is quite valuable.

Disadvantages

SOFC high temperature operation creates a number of economic and engineering challenges that have not yet been overcome: the various materials internal to the fuel cell have different expansion characteristics at high temperature; simple heat management, including insulation, has ramifications for the balance of plant equipment; and like the MCFC, the SOFC has a long start up time as well as poor load following characteristics. Table C-1 summarizes the primary characteristics of each of these fuel cell types.

Information in the table is ranked by operating temperatures. The low temperature fuel cells offer simple materials construction, light weight and durability. While not identified on the table, they typically also offer quick startup periods and the ability to "cycle" – accommodate to rapid and large changes in load.

The high temperature fuel cells are normally used in much larger applications, in part because the equipment necessary to contain the high heat of operation adds weight. These units offer much higher electrical efficiencies than the low temperature units and the added benefit of high quality process heat. Both SOFCs and MCFCs have been deployed in a combined cycle system, where the high pressure steam output of the unit drives a steam turbine, extracting considerably higher electrical efficiencies.

Fuel Sources

All fuel cell types ultimately require pure hydrogen as the fuel source. The hydrogen must be provided as pure to the fuel cell unit, or the unit must take a hydrogen containing material and process it to extract the hydrogen. Today, virtually all commercial hydrogen is extracted from natural gas and most fuel cell developers include a fuel processing module to allow for fossil fuels

Table C-1. Fuel Cell Types and Characteristics (Fuel Cell Handbook)

Type	Electrolyte	Temp of Operation	Catalyst	Uses	Benefits
Alkaline	Potassium Hydroxide	60°–90°C	Platinum	Spacecraft (used on Apollo and Shuttles); submarines	Produces potable water and heat; highly reliable
Proton Exchange Membrane	Ion Exchange Membrane (plastic)	80°C	Platinum	Vehicles and portable power; portable appliances	Fast startup; lightweight; small
Direct Methanol	Polymer Membrane	60°–130°C	Platinum	Portable applications; small battery replacement	Lightweight; small
Phosphoric Acid	Liquid Phosphoric Acid	200°C	Platinum	Stationary power at medium to large commercial size, limited useful heat	Reliable operation; substantial operating history and global commercial fleet
Molten Carbonate	Liquid Molten Carbonate	–650°C	Nickel Oxide	Stationary power in large commercial, small to medium industrial applications; steam quality heat but low heat to power ratio	Electricity efficiency in mid 50s; ~70% including thermal optimum in base loaded application
Solid Oxide	Cermics	800°–1,000°C	Ceramic-metals	Very broad range of stationary power; high quality heat; combined cycle operations; auxiliary power for vehicles	Electricity efficiency 50%–60%, up to 80% in conbined cycle operation; over 85% continued cycle and thermal; fuel flexibility

to be used. Ideally, however, hydrogen should come from renewable and sustainable sources. This can be accomplished by using solar or wind generated electricity to operate an electrolyzer, which splits water into hydrogen and oxygen. Renewable systems are not yet fully economic, especially if the resultant hydrogen must be transported, rather than used where generated. As a result, early stage development of fuel cells will require the use of extraction systems so that natural gas, methanol, gasoline or ethanol can be the source of fuel. These extraction systems are called reformers.

Reformer Systems

Generally, there are two different kinds of reforming: external reforming, which is carried out before the fuel reaches the fuel cell, and internal reforming, which takes place within the fuel cell stack.

External reforming is carried out at a refinery or chemical plant and the hydrogen delivered by pipeline to filling stations. For automotive uses, on-board reformers may be used so that vehicles can use liquid fuels which are converted to hydrogen in a processor attached to the fuel cell structure. This option will of course add to the cost and complexity of the vehicle's power system. The use of hydrogen onboard reformers would allow for a less complex fuel cell system but would necessitate the introduction of hydrogen storage facilities.

For high temperature systems, such as molten carbonate and solid oxide cells, internal reforming is possible. The high temperature allows this stage to take place within the fuel cell structure. In practice, some preliminary reforming will probably be carried out. The exception to this is for DMFC that are being developed to run on methanol without reforming.

Reforming Technologies

Steam Reforming

In steam reforming, fuel is mixed with steam in the presence of a base metal catalyst to produce hydrogen and carbon monoxide. This method is the most highly developed and cost effective method for generating hydrogen and is also the most efficient, giving conversion rates of 70% to 80% on a large scale.

Partial Oxidation Reforming

Partial oxidation can be used for converting methane and higher hydrocarbons but is rarely used for alcohols. This method involves the reaction of the hydrocarbon with oxygen to liberate hydrogen, and produces less hydrogen for the same amount of fuel than steam reforming. The reaction is, however, exothermic and therefore generates heat. This means that the reaction can be initiated by a simple combustion process leading to quick start up. Once the system is running it then requires little external heating.

Autothermal Reforming

Autothermal reforming combines the endothermic steam reforming process with the exothermic partial oxidation reaction, therefore balancing heat flow into and out of the reactor. These systems can be very productive, fast starting and compact and have been demonstrated with methanol, gasoline and natural gas. A number of auto and oil companies are also working on proprietary versions of this technology.

Fuel Cell Applications

Large Stationary

More than 2500 fuel cell systems have been installed all over the world – in hospitals, nursing homes, hotels, office buildings, schools, utility power plants - either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines.

Fuel cell power generation systems in operation today achieve nearly 40 percent fuel-to-electricity efficiency utilizing hydrocarbon fuels. Since fuel cells operate silently, they reduce noise pollution as well as air pollution and when the fuel cell is sited near the point of use, its waste heat can be captured for beneficial purposes (cogeneration). In large-scale building systems, these fuel cell cogeneration systems can reduce energy costs by 20% to 40% over conventional energy service and increase overall efficiency to 85 percent.

So far fuel cell manufacturers have focused on non-residential applications. UTC Fuel Cells, for instance, has installed over 300 PAFCs at a range of sites, including schools, office blocks and banking facilities. In the future, high temperature fuel cells, such as MCFCs and SOFCs, may be adapted for larger industrial applications. With operating temperatures between 600°C–1100°C these high temperature cells can tolerate a contaminated source of hydrogen and hence can use unreformed natural gas, diesel or gasoline. Furthermore, the heat generated can be used to produce electricity by driving steam turbines.

Fuel cells currently operate at landfills and wastewater treatment plants across the country, proving themselves as a valid technology for reducing emissions and generating power from the methane gas they produce. They are also installed at several breweries – Sierra Nevada, Kirin, Asahi, and Sapporo. Untreated brewery effluent can undergo anaerobic digestion, which breaks down organic compounds to generate methane, a hydrogen rich fuel.

Small Stationary

There is significant potential for small stationary units (which we have defined as anything with a power output below 10kW). In this field the heat and power requirements of private households or small businesses could be met by low temperature PEMs or SOFCs. Units could power individual houses or groups of homes and could be designed to meet all of the energy requirements of the inhabitants, or only the base load, with peak demands covered in another way. Initially at least, in most cases natural gas will provide a source of hydrogen fuel. As well as residential applications small stationary fuel cells could also be used to power remote sites, or as premium power supplies. In these areas, the fuel could be hydrogen.

Telecommunications

Communication networks and systems require a degree of power reliability that is not available in many electrical grids. Fuel cells have proven to be up to 99.999% (five nines), and sometimes as much as seven nines reliable. Fuel cells can also replace battery backup systems for cell tower and telecom sites. Such systems are used to provide primary or backup power for telecom switch nodes, cell towers, and other electronic systems that would benefit from on-site, direct DC power supply.

Portable/Micro

Fuel cells can provide low emissions power where no electric grid is available. Portable fuel cells are also being used in emergency backup power situations and military applications. They are much lighter than batteries and last a lot longer, especially important to soldiers carrying heavy equipment in the field.

Fuel cells are already having an impact in consumer electronics and are being used to power cellular phones, laptops and video cameras hours longer than batteries. Companies have already demonstrated fuel cells that can power cell phones for 30 days without recharging and laptops for 20 hours. Other applications for micro fuel cells include pagers, video recorders, portable power tools, and low power remote devices such as hearing aids, smoke detectors, burglar alarms, hotel locks and meter readers. These miniature fuel cells generally run on methanol.

Military

Military applications are expected to remain a significant niche market for fuel cell technology. Their efficiency, versatility, extended running time and quiet operation make fuel cells extremely well suited for the power needs of military services. In various forms, fuel cells could provide power for the majority of military equipment from portable handheld devices used in the field to land and sea transportation.

Transportation

All the major automotive manufacturers have a fuel cell vehicle either in development or in testing and several have begun leasing and testing in larger quantities. More than 50 fuel cell buses have been demonstrated in North and South America, Europe, Asia and Australia. Because the fuel cell system is so much quieter than a diesel engine, fuel cell buses significantly reduce noise pollution as well.

A major new market niche for fuel cells is in materials handling. Electric forklifts are currently being retrofitted with fuel cell units. The retrofitted units require significantly less maintenance than electric forklifts, whose batteries must be periodically charged, refilled with water, and replaced.

Today's heavy-duty trucks are equipped with a large number of electrical appliances–from heaters and air conditioners to computers, televisions, stereos, even refrigerators and microwaves. To power these devices while the truck is parked, drivers often must idle the engine. Fuel cell auxiliary power units that could operate directly on diesel fuel would significantly reduce maintenance and the emissions that result from the idling. Several SOFC manufacturers are focused on this market.

Fuel Cell Developers and Manufacturers

Table C-2 lists the primary fuel cell manufacturers and developers – there are over 1,000 companies that claim to be working in this business sector.

UTC Power PureCell™ 400 kW Product

Figure C-4 provides UTC's picture of this product.

The PureCell™ offers:

- Grid connected or independent operation. Operational modes (of interest to the Laboratory):
- Grid-connected/grid-independent
- Grid-connected/grid-independent parallel

Table C-2. Primary Fuel Cell Developers and Manufacturers

AFC	PEMFC	DMFC	PAFC	MCFC	SOFC
Appollo Energy Systems Astris Energi Inc. UTC Fuel Cells ZeTek Power Plc UK	Anuvu Inc. Avista Labs Ballard Power Systems General Hydrogen General Motors IdaTech Intelligent Energy Novars GmbH Nuvera Fuel Cells Plug Power Proton Energy Systems, Inc. (Distributed Energy Systems Corp.) Protonex ReLion UTC Fuel Cells	DTI Energy, Inc. MTI Micro Medis Technologies NaVant Systems Smart Fuel Cell GmbH	Electrochem, Inc. HydroGen, LLC Toshiba UTC Fuel Cells	Fuel Cell Energy, Inc. MTU GmbH	Acumentrics CFCL, Ltd. Honeywell McDermott NexTech Rolls Royce Siemens Sulzer Hexis Versa Power Systems Ztek Corporation

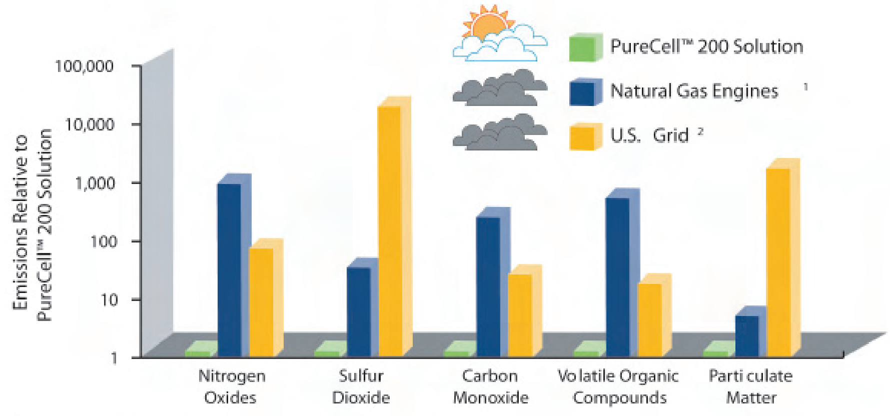
Figure C-4. UTC Power's PureCell™ Model 400 (UTC Power).

- Superior load following capabilities
- Ultra low emissions (better than CARB 07)
- Low sound profile (60 dBA at 30 ft) Electrical efficiency 40%
- 683,000 BTU/hr heat output at 250°F
- Powered by natural gas or synthetic natural gas/methane

While not "pristine," the UTC unit offers significant emission reductions over the alternative of fossil-fired power transmitted to Los Alamos. Figure C-5 presents these reductions for the 200 kW units. The reductions in the figure would double for the 400 kW units.

A recent example of a UTC Power installation that would have similar characteristics to a Laboratory application is a facility at a Verizon call center in Garden City, NY. Seven units are operated in parallel to generate 1.4 MW of electricity. The units are part of an intricate backup power system designed to run in parallel with the grid under normal circumstances, and independent of the grid in the event of a power failure or natural disaster. Under an agreement with the Long Island Power Authority, the fuel cells also run continuously during periods of peak demand, providing additional cost savings to Verizon. Waste heat from the fuel cells is captured and used to provide a portion of the energy for two absorption chillers for cooling in the summer and to supplement the heating system in the winter, resulting in an overall efficiency for the system of approximately 90%. The installation is powered by natural gas.

PURECELL™ 200 SOLUTION EMISSIONS VS. U.S. GRID AND NATURAL GAS ENGINES

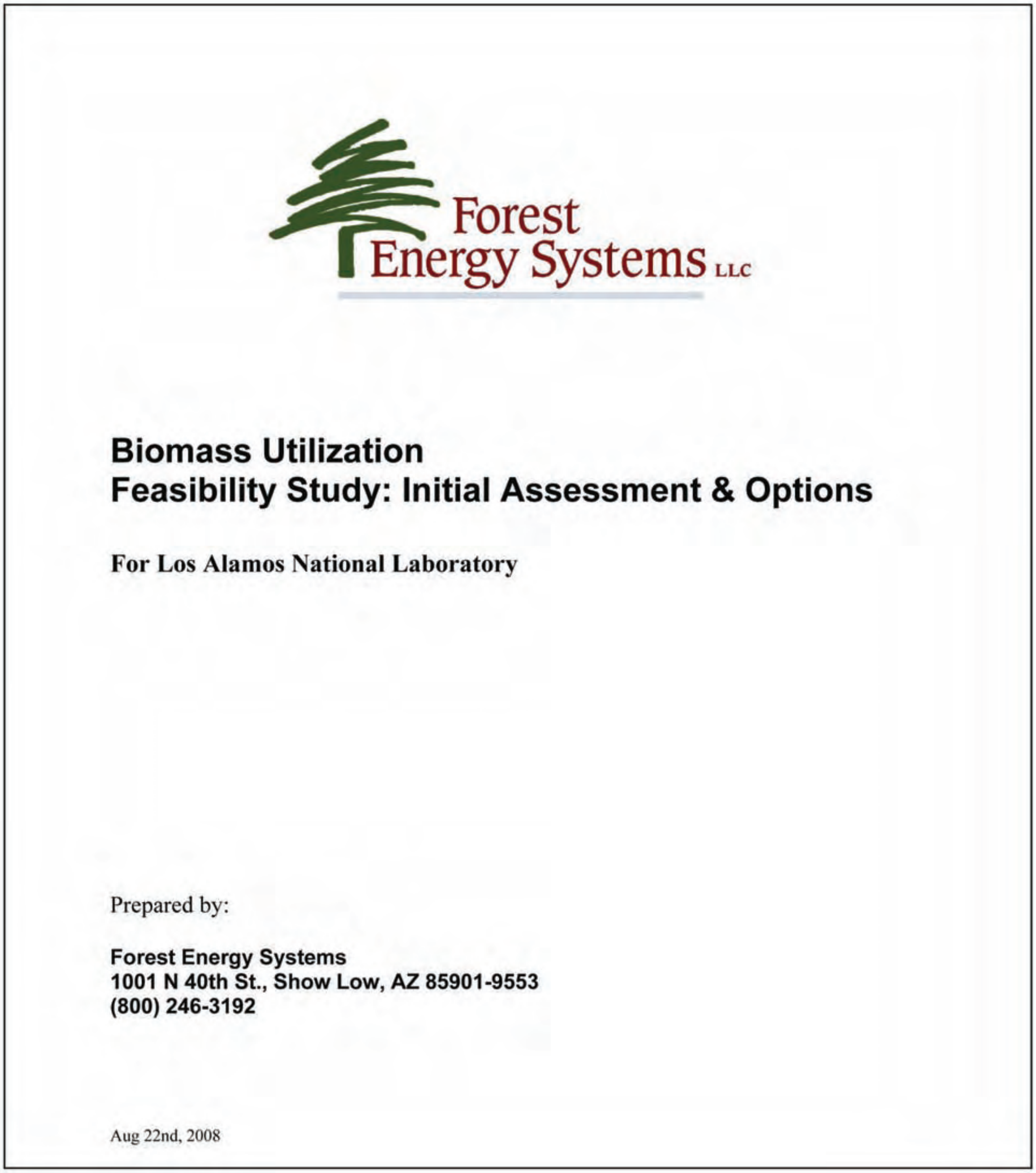


[1] Based on U.S. EPA AP-42 emissions factors (Ref: U.S. EPA, AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors)

[2] Based on average U.S. power plant emissions (Ref: 2002 data, U.S. EPA, DOE/Energy Information Administration)

Figure C-5. UTC Power 200 kW unit relative emissions profile comparison (UTC Power); U.S. EPA AP-42 emissions factors (U.S. EPA); Average U.S. power plant emissions (U.S. EPA, DOE Energy Information Administration).

Appendix D. Biomass Utilization Feasibility Study



Forest Energy Systems LLC

Biomass Utilization
Feasibility Study: Initial Assessment & Options

For Los Alamos National Laboratory

Prepared by:

Forest Energy Systems
1001 N 40th St., Show Low, AZ 85901-9553
(800) 246-3192

Aug 22nd, 2008

Introduction

The Los Alamos National Laboratory (LANL) is attempting to meet a portion of its steam heat requirements with renewable energy sources and has entered into a contract with Forest Energy to complete a feasibility study on utilizing biomass to fire steam boilers to displace natural gas.

Forest Energy Corporation

Forest Energy Corporation was founded in 1991 to procure wood residues and produce densified pellet fuel is Show Low, AZ. Forest Energy Systems a subsidiary of FEC has been providing biomass heating systems for four years. They have installed systems that are currently operating in Arizona and continue to provide this service in AZ, NM, and CO.

Scope of Work

LANL has contracted with Forest Energy Systems to:

1. Evaluate long-term biomass supply near LANL. Determine the volumes, sources, approximate distances and delivered costs of available biomass that could provide a long-term supply for the facility.
2. In conjunction with LANL, determine their thermal energy requirements based upon an historical load analysis.
3. Evaluate and recommend appropriate biomass alternatives.
4. Perform a preliminary feasibility study and impacts of converting to biomass to include:
    a. Trucking delivery impacts on Town of Los Alamos
    b. Fuel storage requirements
    c. Ash waste analysis
    d. Biomass emissions facts data
    e. Evaluate feasibility for Biomass boiler infrastructure and fuel pricing estimates.

Forest Energy will not include the following in their scope of work:

1. An evaluation of replacing the existing heat distribution system
2. Analysis of interconnect requirements or costs for power or thermal
3. Analysis of land or land preparation costs or any system engineering

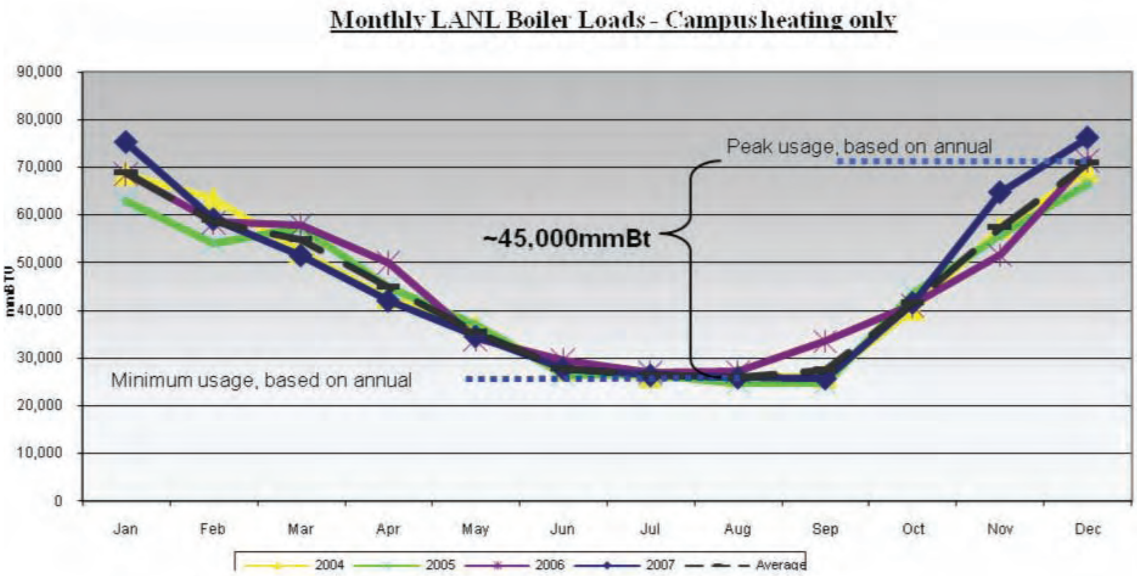
Methodology & Findings

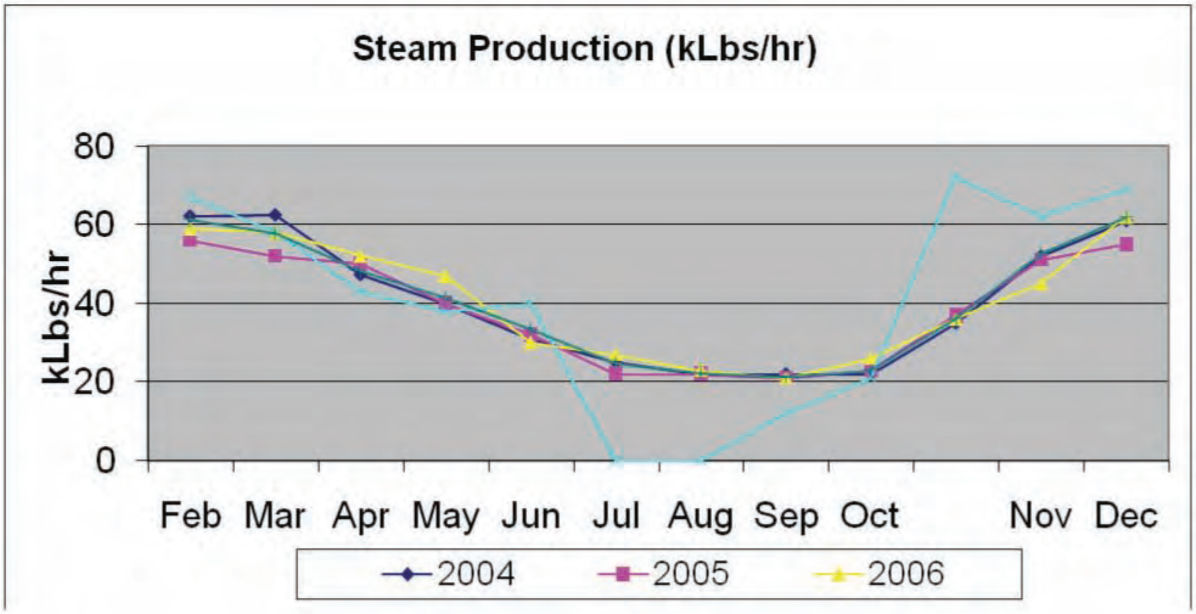
Los Alamos National Laboratory supplied Forest Energy with 7 years of historical fuel consumption and cost data. The total natural gas consumption of the campus including peak and minimum demand were used to determine biomass boiler sizing options and the amount of biomass fuel needed to supply heat to the campus environment. Based upon subsequent discussions, LANL has stated that existing equipment may be retired if the biomass solution dictates. It is assumed that all remaining equipment can be utilized as back up and to supplement peak loads. LANL informed Forest Energy that the existing natural gas boiler system can be completely shut down if the biomass solution handles the entire campus heat load. For the purpose of this paper natural gas boiler efficiency given by LANL is approximately 82%. The assumed biomass boiler efficiency is 70% for wood chip fuel and 90% for wood pellet fuel.

Based upon the meeting held on June 3rd between members of LANL and Forest Energy, the steam turbines used to generate power have not been in production for nearly 4 years and combined heat and power was ruled out of this analysis. However, based on ensuing discussions and the potential for sufficient supplies of biomass fuels, LANL requested that a combined heat and power analysis be completed. LANL provided Forest Energy the operating specifications of the turbines for this analysis. LANL has informed Forest Energy that the time and cost to convert the existing steam heat infrastructure to a hot water system would be prohibitive to the completion of the project. Therefore, no consideration of a hot water system has been completed and this document will focus solely on steam generation.

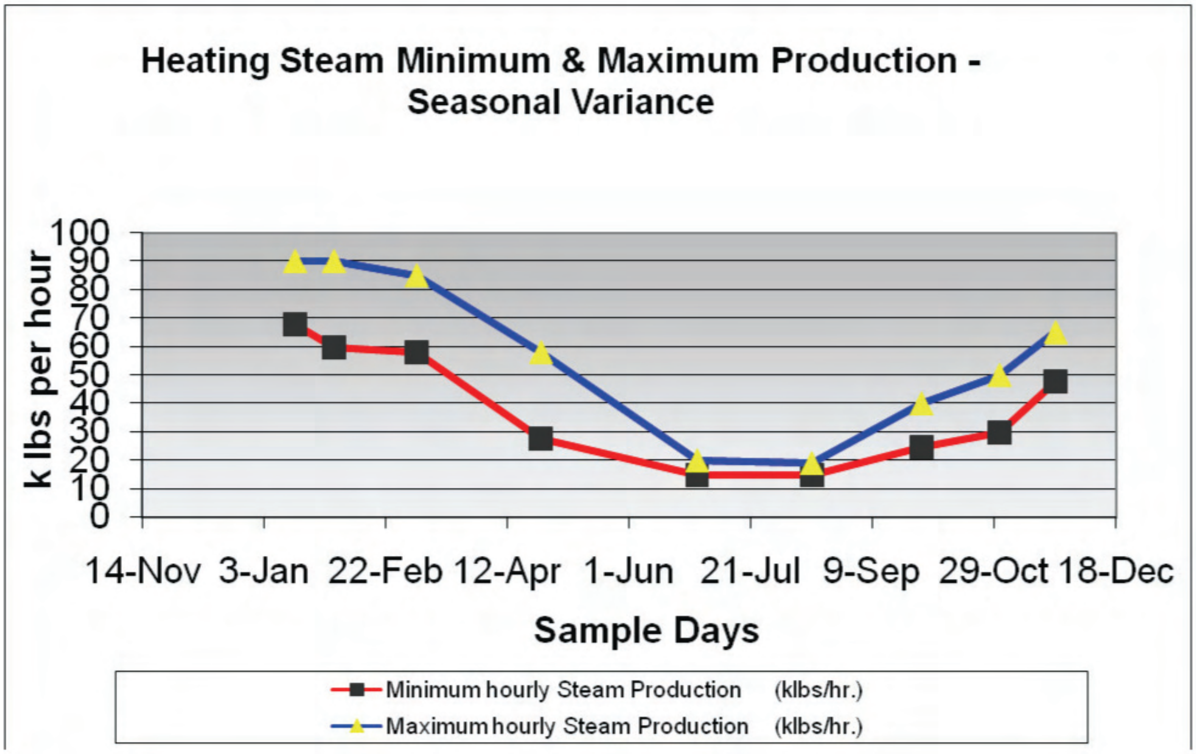
LANL Boiler Load Requirements

The following graphs depict the historical natural gas usage at the central plant. See appendix for additional table data.


Monthly LANL Boiler Loads - Campus heating only


Steam Production (kLbs/hr)

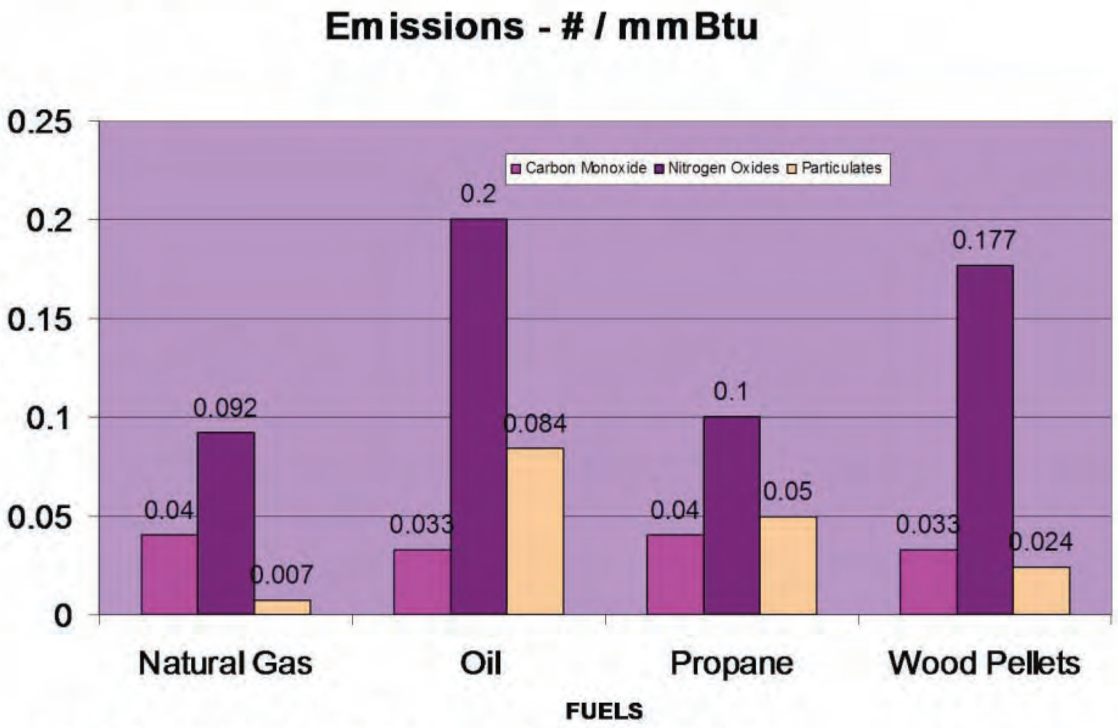
LANL provided Forest Energy with 5 sample days of data indicating the minimum and maximum production of steam throughout those days. The following graph is a curve fit depicting the given minimum and maximums throughout the year. See appendix for additional table data.



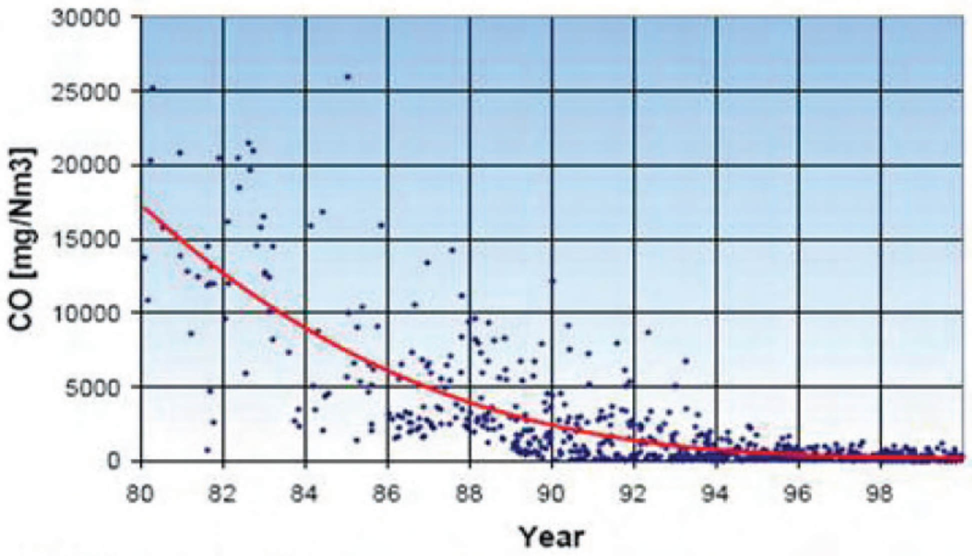
Biomass Emissions & Efficiency Overview

Air Emissions from the Biomass Heating System

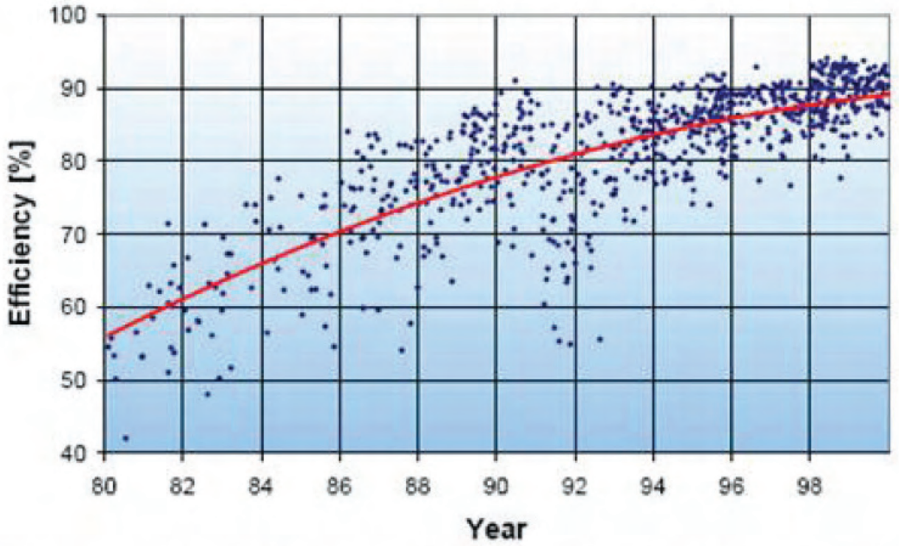
All boilers would have a multi-cyclone system for removing particulate emissions from the exhaust. With an Electrostatic Precipitator (ESP), emissions from any system will be well below the level set by the New Mexico Air Quality Bureau (NMAQB), and the federal government. The NMAQB bases their requirements on the emissions that would result if the system were operated at peak load, 24 hours per day year-round with the emission-control system bypassed.



Source for natural gas & oil data: EIA - Natural Gas Issues and Trends 1998
Pellet data from Actual test of Binder 150kw boiler & http://www.energytech.at/pdf/task28_5_1_Pellets_Boiler.pdf



Units: PPM = mg/Nm^3 * 0.8345
Source: "Heating Large Buildings with Wood Fuels" SWS Group, www.bioheat.info



Reference: Quality Marking and Environmental Testing of Small-Scale Biomass Boilers in Austria, 1999. Federal Institute of Agricultural Engineering (BLT), Wieselburg

Fuel Options & Comparisons

Technology Options:

Pellets vs. Chips

- Fuel:
- Advantages of Pellets
  - Uniform processed fuel - consistent burn properties
  - Solid Pellet easily transported via pneumatic delivery or transport auger
  - Condensed Pellet requires less storage space
  - Few potential contaminants
  - Less Ash
  - Less frequent deliveries - Fewer deliveries per day and traffic to site
- Advantages of Chips
  - Cost is substantially lower than pellets
  - Simpler transport – walking floor trailers vs. pneumatic delivery

- Boilers:
- Advantage of Pellet Boilers
  - Higher efficiency
  - Less fuel storage required
  - Smaller physical size plant
  - Less Maintenance
- Advantages of Chip Boilers
  - Less expensive fuel

Fuel Availability Estimates: 20 year outlook

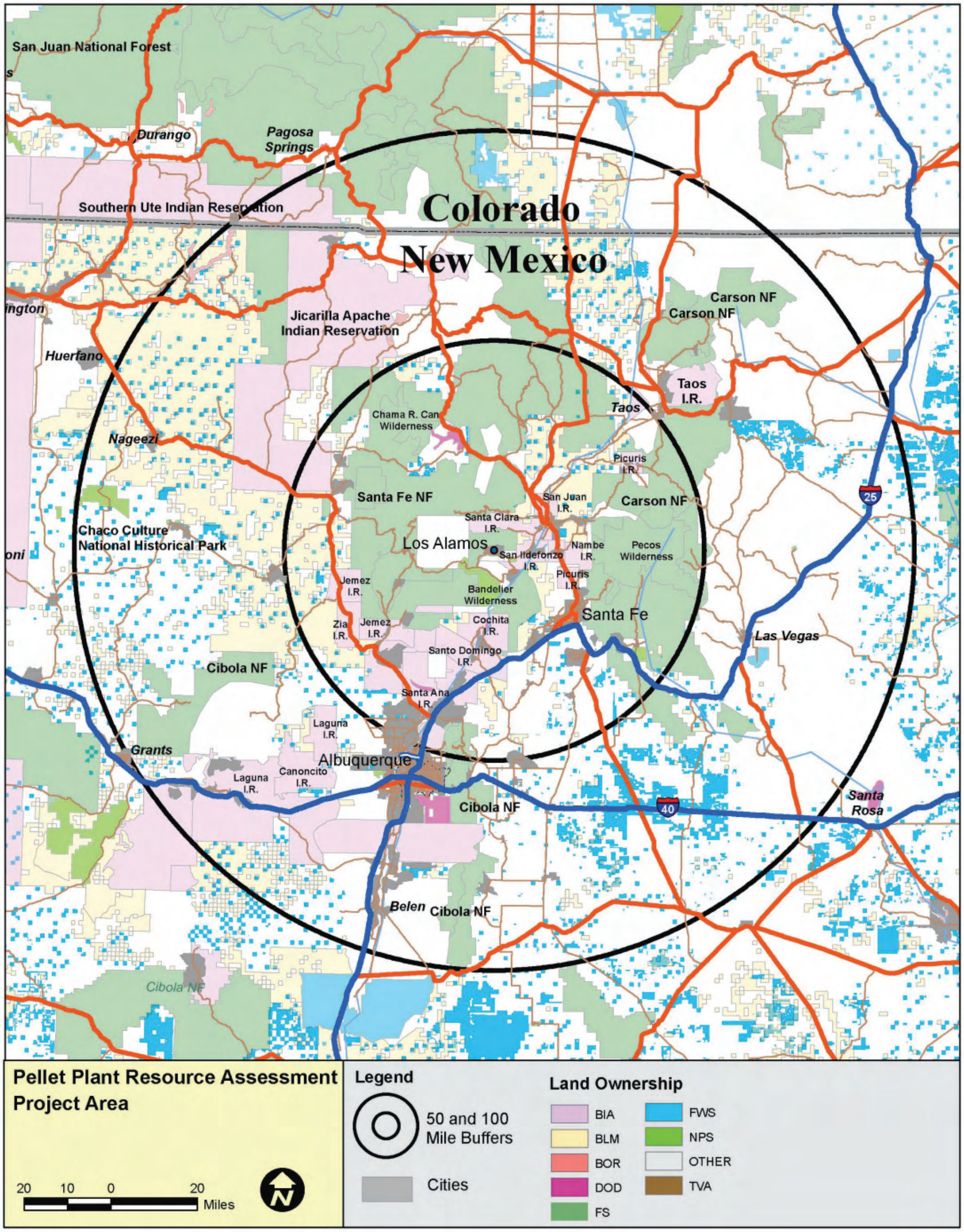
An analysis of the available wood resource in Northern New Mexico was undertaken to determine the certainty of supplying for a biomass heating system in Los Alamos, NM. This Resource Evaluation gives an up-to-date, accurate tally of the quantity of forest products available. The map below displays the geographic region. Within a 50 mile radius, sources of wood are currently 193,726 dry ton from timber (< than 10") and slash on a portion of the Santa Fe National Forest, Carson National Forest, the Valles Caldera Trust, and Santa Clara Pueblo. Within a 100 mile radius of Los Alamos the sources of wood expand to include nearly the majority of the Santa Fe National Forest except for the far east side, additional Carson NF resource and additional private and reservation lands. The 100 mile radius increases the supply of wood available in the immediate future, to an estimated 272,388 dry tons. The supply of wood in the immediate future is not reflective of what will be sustained annually over decades to come. The current production has been severely curtailed due to lack of market for the materials from the forest. As additional markets develop for the various materials, the plans will increase to reach these available volumes.

It is anticipated that any wood chip fuel for the boilers will be treated in some manner. A uniform size, (1.5" or smaller) and a reduced moisture content will be advantageous to the performance of the boiler system. In order to achieve this, it is expected that a collection/processing yard or perhaps two will be necessary to store and process material for the boiler. This process could be as simple as grinding and screening or continuing the process and producing pellets. Ideally a collection yard on the west and on the east of Los Alamos would be established to assure a consistent supply during seasons when active forest harvesting is not possible. This will impact the cost of an assured supply.

Currently pellets are not economically available for the project. There are two plants within 100 miles that are both scheduled to be on line within the next one to two years, either which would have adequate capacity to supply up to 35,000 tons.

Resource volumes in the forest that are planned to be treated are significantly larger than this boiler requirement. This boiler would help to stimulate the performance of the plans, yet still not consume a high percentage of the resource.

(See attached WoodResourceLANL.doc)


San Juan National Forest
Durango
Pagosa Springs
Southern Ute Indian Reservation
Colorado
New Mexico
ington
Jicarilla Apache Indian Reservation
Carson NF
Carson NF
Huerfano
Taos I.R.
Taos
Chama R. Can Wilderness
Nageezi
Picuris I.R.
Santa Fe NF
San Juan I.R.
Carson NF
25
Santa Clara I.R.
Chaco Culture National Historical Park
Los Alamos
San Ildefonzo I.R.
Nambe I.R.
Pecos Wilderness
oni
Picuris I.R.
Jemez I.R.
Bandelier Wilderness
Santa Fe
Zia I.R.
Jemez I.R.
Cochita I.R.
Las Vegas
Santo Domingo I.R.
Cibola NF
Santa Ana I.R.
Laguna I.R.
Grants
Albuquerque
Laguna I.R.
Canoncito I.R.
Santa Rosa
40
Cibola NF
Belen
Cibola NF
Cibola NF
Pellet Plant Resource Assessment Project Area
20 10 0 20 Miles
N
Legend
50 and 100 Mile Buffers
Cities
Land Ownership
BIA
BLM
BOR
DOD
FS
FWS
NPS
OTHER
TVA

Boiler & Fuel Logistics

Delivery and Handling:

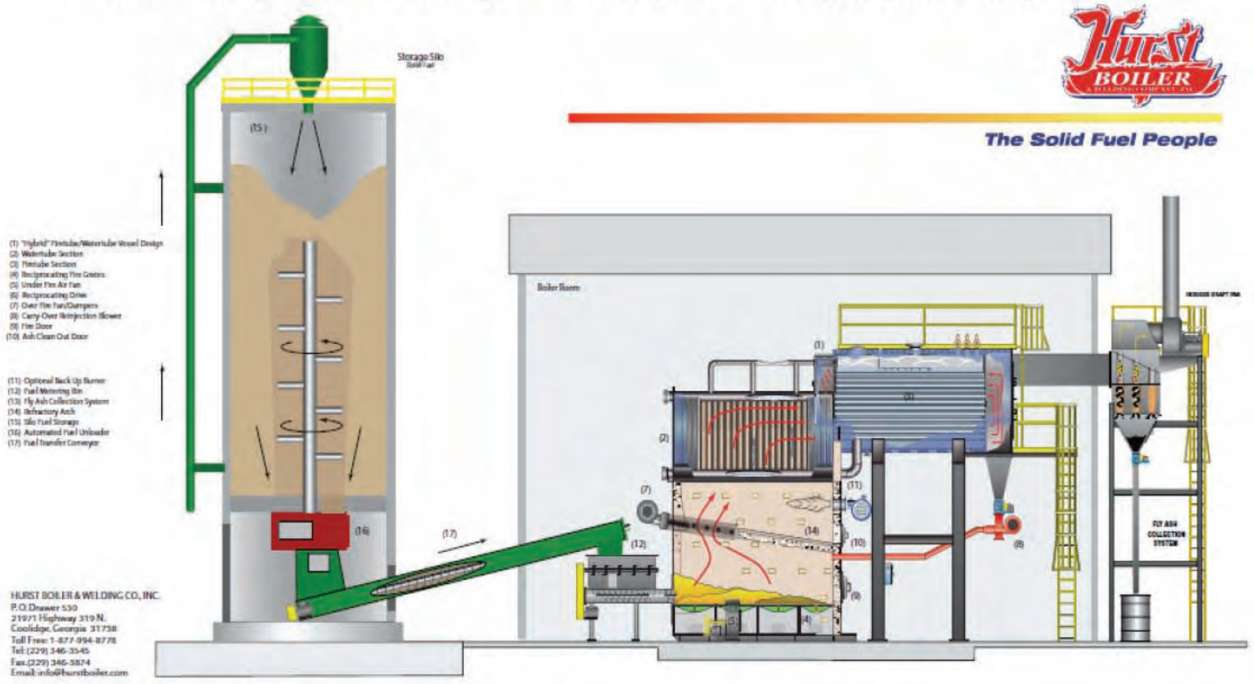
1. It is advised that all deliveries be routed via Highway 4 to avoid traffic issues within the downtown area.
2. Live floor trucks and live floor bunkers will be utilized for wood chip options to eliminate the need for front end loaders on site.
3. Pellet delivery trucks will be equipped with pneumatic transport or auger systems to load the silos

Operations Examples:

Pictured below are examples of biomass boilers, schematics, and physical plant operations which display the size and scale of typical operations.

Picture 1: Typical 38 mmBtu boiler

Picture 2: Example of a Hurst Boiler system schematic, overview of a typical pellet boiler operation



Picture 3: 5.3 Megawatt wood fired Combined Heat and Power plant

Location Options:

The location for the biomass boiler and fuel storage presents several challenges. The first issue concerns available space on or near the existing power plant. It was stated during the onsite meeting that LANL does not intend to retire any existing equipment if a biomass option is pursued. Subsequent discussions modified that requirement and the retirement of existing equipment is a possibility. The second issue concerns security. Access to the existing power plant requires two security clearances; the first is the general, drive through security accessing the campus and the second is the power plant specific access point. Any biomass option will require multiple daily trips by both employees and fuel trucks (chips or pellets). Ideally both the biomass boiler and fuel storage would be located offsite from the Los Alamos National Laboratory secured site.

1. Boiler collocated within existing power plant. This assumes one of the existing natural gas boilers is retired.
    - i. Advantages
        1. No new building construction required
        2. Managed by same boiler operations team
        3. Permitting & construction fees should be significantly lower.
    - ii. Disadvantages
        1. Option will not work with combined heat and power option as biomass system size is prohibitive.
        2. Existing boiler plant operations would be greatly impacted.
2. Boiler and Fuel storage located on County landfill site adjacent to existing power site. Steam would be created and piped to the power plant.
    - i. Advantages
        1. Eliminate security clearances for fuel and operations traffic
        2. County landfill is closing and traffic related to biomass operations would offset previous landfill traffic
        3. Access off highway is already established and AC/DC lanes exist.
    - ii. Disadvantages
        1. County landfill is due to be closed however, exact date is unknown.
        2. Use of the site for this purpose has not been approved.
        3. Suitability of site for this purpose is unknown.
        4. Security issues involving adding a high pressure steam pipe from unsecured County site to secured power plant would need to be addressed.
3. Boiler located adjacent to existing power plant on LANL secured site with fuel storage on County landfill site.
    - i. Advantages
        1. The Boiler and its operation are in secure and controlled environment only accessible by authorized individuals.
        2. Proximity of biomass boiler to existing power plant would reduce steam transport loss.
        3. Security concerns for the majority of traffic, including fuel delivery is eliminated by locating storage on County landfill
        4. A potential boiler site in close proximity to power plant exists adjacent to the “radio building”.
        5. County landfill infrastructure could still be utilized for majority of trips
    - ii. Disadvantages
        1. Security issue as fuel transport conveyor would need to cross from unsecured County site to secure LANL site.
        2. Usability of this site has not been approved.
    - b. Boiler and Fuel Storage located on secured LANL site adjacent to power plant.
        - i. Advantages
            1. All biomass operations within a secure, controlled environment
            2. Proximity of biomass boiler to existing power plant would reduce steam transport loss.
        - ii. Disadvantages
            1. Required land may not be available.
            2. All trips both employee and fuel delivery must pass through one or more security sites.

Biomass Boiler Options

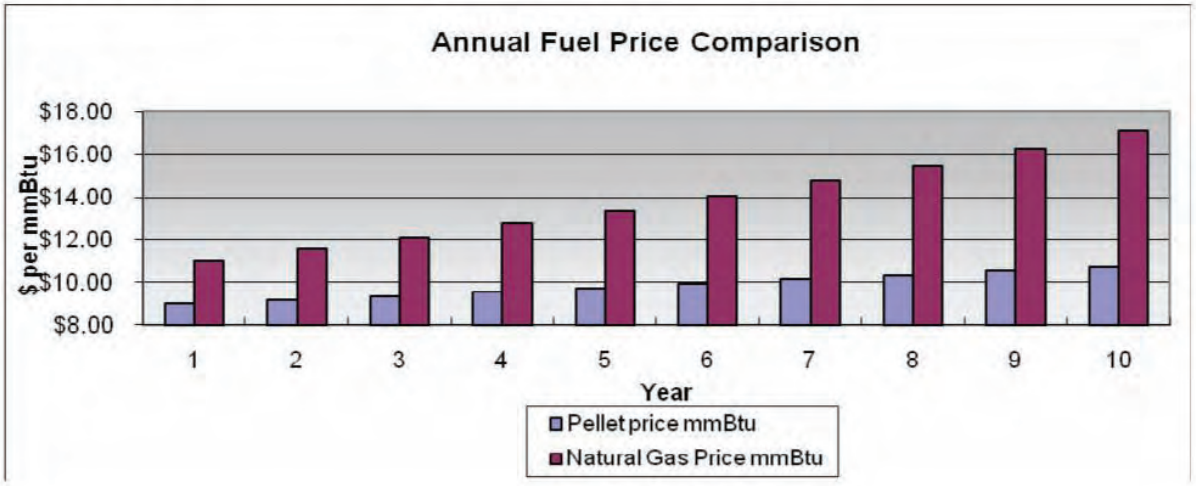
Forest Energy has included three potential biomass options for the LANL Campus. Each option is considered utilizing pellet or wood chip fuel. The options comprise of: 1. A baseload scenario where the biomass boiler would operate at or near capacity for all 12 months to heat to meet the baseload throughout the year. 2. A 50% of peak demand scenario designed to handle the majority of the LANL campus heat load, but keeping natural gas for peak demand and as back up. 3. A combined heat and power scenario designed to provide 5MW of electricity plus utilize the waste heat to provide steam to the campus heating system.

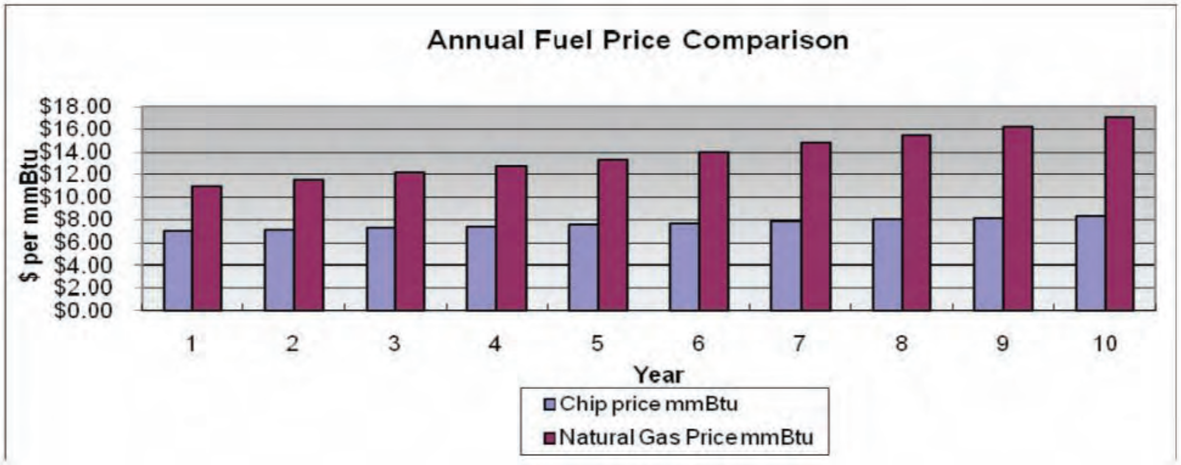
Each option will be analyzed to include:

- Heat/Power steam production profile
- Fuel volumes and delivery requirements
- Fuel storage and ash disposal requirements
- Preliminary Economics
    - Annual Fuel Cost Comparisons
    - Boiler Costs & Breakeven Analysis

Annual Fuel Price Estimates

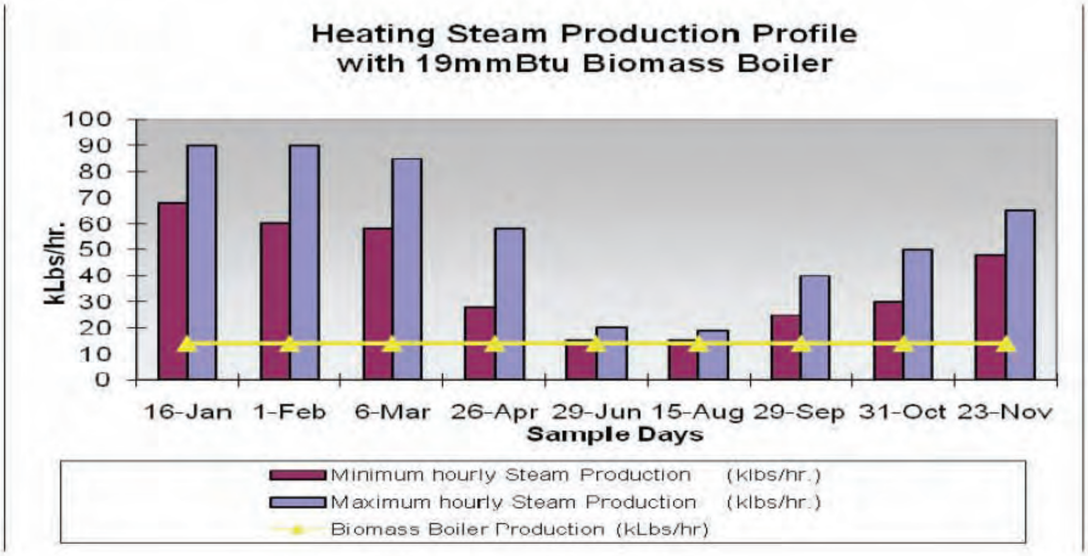
All biomass costs are assumed to include transportation, fieldwork, i.e. logging & transport to a processing yard and processing of material. The graphs illustrated below reflect a current natural gas rate of $11per mmBtu with an increase of 5% annually. Pellets are priced at $9 mmBtu and wood chips are $7 mmBtu both increasing at 2% annually.





- **OPTION 1**: Baseload - LANL could meet the minimum summer baseload with one 19mmBtu pellet or 24 mmBtu chip biomass boiler. The boiler would run year round at full capacity. The full time operation would meet approximately 30% of the annual load currently served. From mid June through mid August it could handle 100% of the daily minimum load based on the 24 hour profile of historical usage. In essence, the biomass boiler operating full time could handle 100% of the daytime requirements for the summer months but gas would be required to supplement night time needs.

Steam Production Profile



Fuel Volumes & Delivery Requirements:

Biomass Boiler Fuel Requirements
Baseload Production (19 & 24 mmBtu Boilers)

Wood Chip Fuel:		-			-
Wood chip boiler efficiency:			70%		
Heating values: (Wood chips @ 50% Moisture content)			7	mmBtu	
Max Daily Wood Chip Volume			82	ton	
	Average Steam Usage based upon calendar days per month (mmBtu)	**Wood Chip Volumes based on steam usage & Boiler Efficiency (tons)**	**Truck Loads per month 22 tons per load**	**Truck loads per day**	**Operational Days per month**
Jan	68,872	2,551	116	6	31
Feb	58,801	2,304	105	5	28
Mar	54,790	2,551	116	6	31
Apr	44,874	2,469	112	6	30
May	35,528	2,551	116	6	31
Jun	27,852	2,469	112	6	30
Jul	26,457	2,551	116	6	31
Aug	26,014	2,551	116	6	31
Sep	27,523	2,469	112	6	30
Oct	41,655	2,551	116	6	31
Nov	57,387	2,469	112	6	30
Dec	70,925	2,551	116	6	31
Annual Total	**540,677**	**30,034**	**1,365**		

Pellet Fuel:

Pellet boiler efficiency:	90%	
Heating values:	16	mmBtu
Max Daily Pellet Volume	28	ton

	Average Steam Usage based upon calendar days per month (mmBtu)	Pellet Volumes based on Steam usage & Boiler Efficiency (tons)	Truck Loads per month 22 tons per load	Truck loads per day	Operational Days per month
Jan	68,872	862	39	2	31
Feb	58,801	779	35	2	28
Mar	54,790	862	39	2	31
Apr	44,874	834	38	2	30
May	35,528	862	39	2	31
Jun	27,852	834	38	2	30
Jul	26,457	862	39	2	31
Aug	26,014	862	39	2	31
Sep	27,523	834	38	2	30
Oct	41,655	862	39	2	31
Nov	57,387	834	38	2	30
Dec	70,925	862	39	2	31
Annual Total	**540,677**	**10,149**	**461**		

Truck loads per day assumes Monday - Friday delivery only

Fuel Storage & Ash Disposal Requirements:

Fuel Storage Capacities for Biomass Boilers
Baseload Production (19 & 24 mmBtu Boilers)

Wood Chip Storage:

Days of Storage Required:	7	days
Storage Pile Height	15	ft
Wood Chip Density:	19	lbs./cu.ft.
Max Tons Required per day	82	ton

Wood Storage Capacities:

	7	Days of Storage Required
X	82	Max Tons Required per day
	576	**Ton storage capacity**
	576	Ton storage capacity
X	2,000	lbs./ton
/	19	lbs./cu.ft.
	60,632	**cu.ft. required**
	60,632	cu.ft.
/	15	Storage Pile Height
	4,042	**sq. ft. required**

Pellet Storage:

Days of Storage Required:	7	days
Silo Storage Capacity	150	tons
Storage Pile Height	15	ft
Pellet Density:	40	lbs./cu.ft.
Max Tons Required per day	28	tons

Pellet Storage Capacities:

	7	Days of Storage Required
X	28	Max Tons Required per day
	195	**Required Storage/Tons**

Silo Storage

	195	Required Storage/Tons
/	150	Silo Storage Capacity
	1	Equivalent Silos Required

Bin Storage

	195	Ton storage capacity
X	2000	lbs./ton
/	40	lbs./cu.ft.
	9,732	**cu.ft. required**
	9,732	cu.ft.
/	15	Storage Pile Height
	649	**sq. ft. required**

Ash Disposal Volumes:	Chips		Pellets
Ash Percent by weight:	1.5%		1.0%
Roll-off dumpster capacity	30.0	cu.yd.	
Ash Density*	47.5	lbs/cu.ft.	
	1282.5	lbs/cu.yd.	

Chips

	30,034	Annual Fuel Tons
X	1.5%	Ash Percent by weight:
	451	Annual Ash produced / tons
/	12	Months
	38	Tons/month average

Ash Volume

	38	Tons/month average
X	2000	lbs./ton
/	1282.5	lbs./cu.yd.
	59	**cu.yd/month avg.**
/	30.0	Roll-off capacity
	2	**Roll-offs/month average**

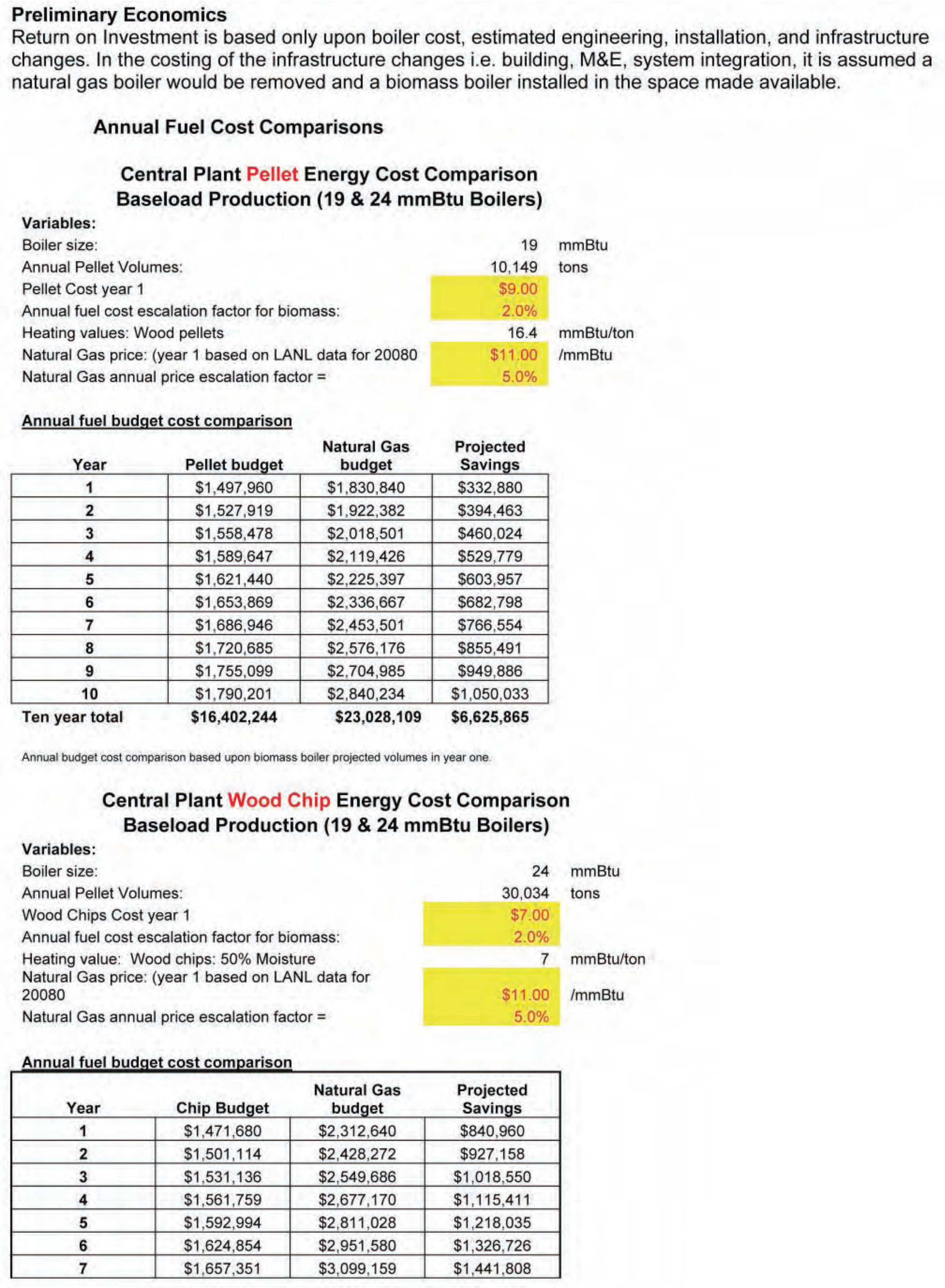
Pellets

	10,149	Annual Fuel Tons
X	1.0%	Ash Percent by weight:
	101	Annual Ash produced / tons
/	12	Months
	8	Tons/month average

Ash Volume

	8	Tons/month average
X	2000	lbs./ton
/	1282.5	lbs./cu.yd.
	13	**cu.yd/month avg.**
/	30.0	Roll-off capacity
	1	**Roll-offs/month average**

*Ash Density: Journal of Practices and Technologies Characteristics of Wood Ash



Preliminary Economics

Return on Investment is based only upon boiler cost, estimated engineering, installation, and infrastructure changes. In the costing of the infrastructure changes i.e. building, M&E, system integration, it is assumed a natural gas boiler would be removed and a biomass boiler installed in the space made available.

Annual Fuel Cost Comparisons

Central Plant Pellet Energy Cost Comparison
Baseload Production (19 & 24 mmBtu Boilers)

Variables:

Boiler size:	19	mmBtu
Annual Pellet Volumes:	10,149	tons
Pellet Cost year 1	$9.00	
Annual fuel cost escalation factor for biomass:	2.0%	
Heating values: Wood pellets	16.4	mmBtu/ton
Natural Gas price: (year 1 based on LANL data for 20080	$11.00	/mmBtu
Natural Gas annual price escalation factor =	5.0%	

Annual fuel budget cost comparison

Year	Pellet budget	Natural Gas budget	Projected Savings
1	$1,497,960	$1,830,840	$332,880
2	$1,527,919	$1,922,382	$394,463
3	$1,558,478	$2,018,501	$460,024
4	$1,589,647	$2,119,426	$529,779
5	$1,621,440	$2,225,397	$603,957
6	$1,653,869	$2,336,667	$682,798
7	$1,686,946	$2,453,501	$766,554
8	$1,720,685	$2,576,176	$855,491
9	$1,755,099	$2,704,985	$949,886
10	$1,790,201	$2,840,234	$1,050,033
Ten year total	**$16,402,244**	**$23,028,109**	**$6,625,865**

Annual budget cost comparison based upon biomass boiler projected volumes in year one.

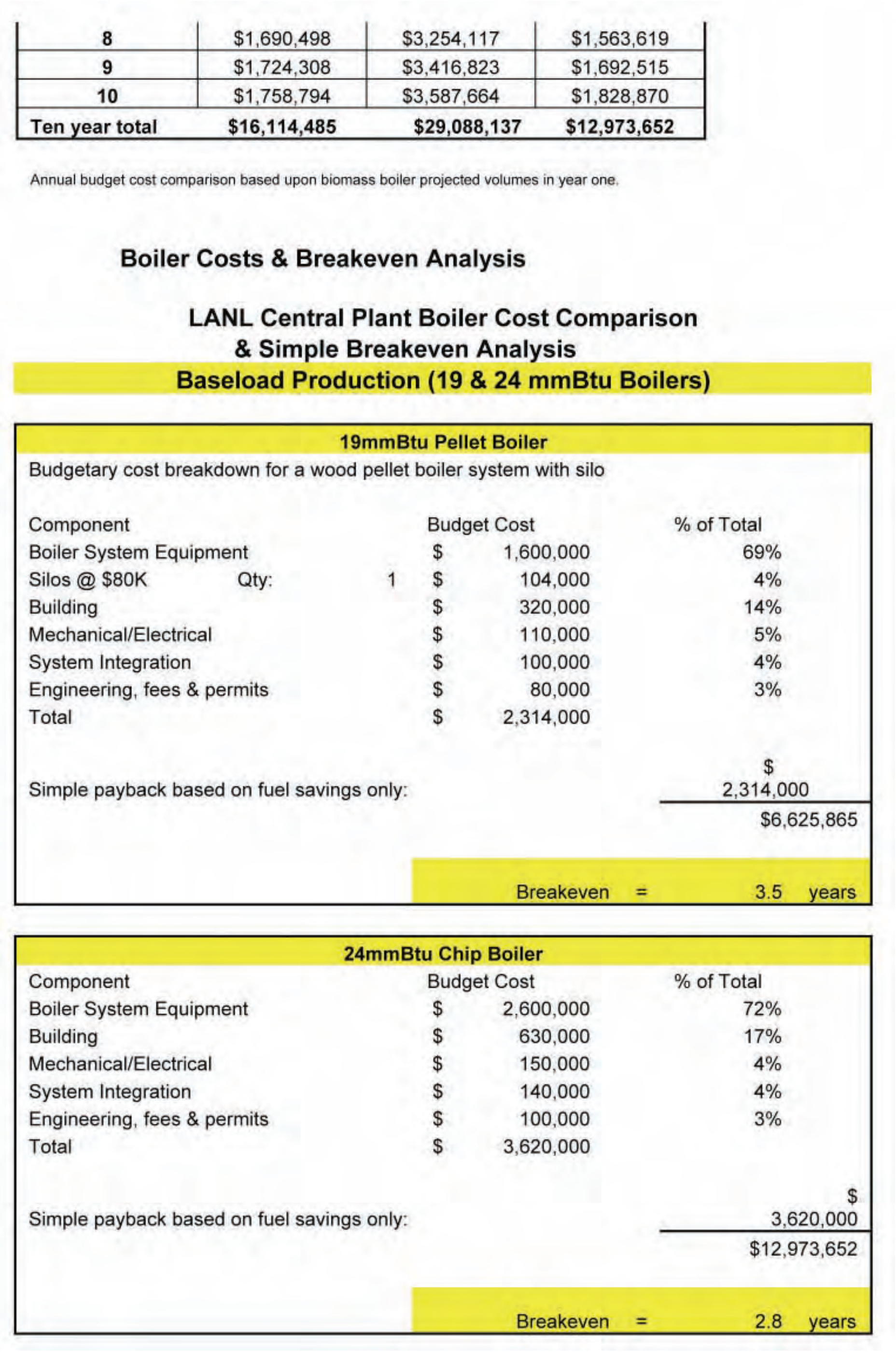
Central Plant Wood Chip Energy Cost Comparison
Baseload Production (19 & 24 mmBtu Boilers)

Variables:

Boiler size:	24	mmBtu
Annual Pellet Volumes:	30,034	tons
Wood Chips Cost year 1	$7.00	
Annual fuel cost escalation factor for biomass:	2.0%	
Heating value: Wood chips: 50% Moisture	7	mmBtu/ton
Natural Gas price: (year 1 based on LANL data for 20080	$11.00	/mmBtu
Natural Gas annual price escalation factor =	5.0%	

Annual fuel budget cost comparison

Year	Chip Budget	Natural Gas budget	Projected Savings
1	$1,471,680	$2,312,640	$840,960
2	$1,501,114	$2,428,272	$927,158
3	$1,531,136	$2,549,686	$1,018,550
4	$1,561,759	$2,677,170	$1,115,411
5	$1,592,994	$2,811,028	$1,218,035
6	$1,624,854	$2,951,580	$1,326,726
7	$1,657,351	$3,099,159	$1,441,808



8	$1,690,498	$3,254,117	$1,563,619
9	$1,724,308	$3,416,823	$1,692,515
10	$1,758,794	$3,587,664	$1,828,870
Ten year total	**$16,114,485**	**$29,088,137**	**$12,973,652**

Annual budget cost comparison based upon biomass boiler projected volumes in year one.

Boiler Costs & Breakeven Analysis

LANL Central Plant Boiler Cost Comparison & Simple Breakeven Analysis

Baseload Production (19 & 24 mmBtu Boilers)

19mmBtu Pellet Boiler

Budgetary cost breakdown for a wood pellet boiler system with silo

Component			Budget Cost	% of Total
Boiler System Equipment			$ 1,600,000	69%
Silos @ $80K	Qty:	1	$ 104,000	4%
Building			$ 320,000	14%
Mechanical/Electrical			$ 110,000	5%
System Integration			$ 100,000	4%
Engineering, fees & permits			$ 80,000	3%
Total			$ 2,314,000	

Simple payback based on fuel savings only: $ 2,314,000 / $6,625,865

Breakeven = 3.5 years

24mmBtu Chip Boiler

Component	Budget Cost	% of Total
Boiler System Equipment	$ 2,600,000	72%
Building	$ 630,000	17%
Mechanical/Electrical	$ 150,000	4%
System Integration	$ 140,000	4%
Engineering, fees & permits	$ 100,000	3%
Total	$ 3,620,000	

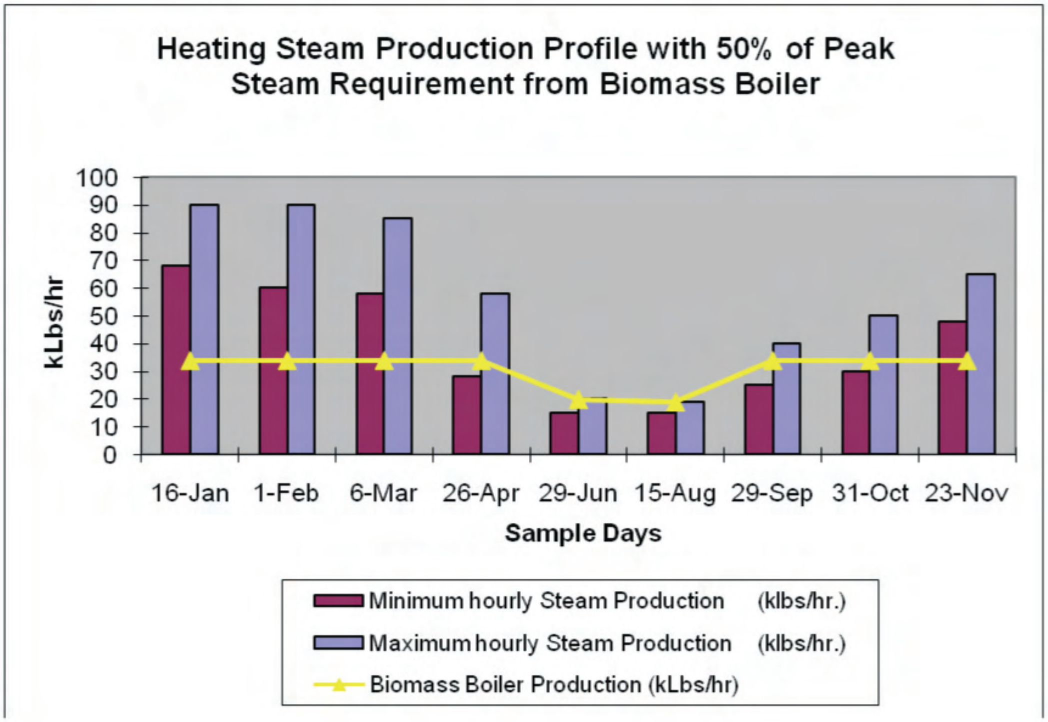
Simple payback based on fuel savings only: $ 3,620,000 / $12,973,652

Breakeven = 2.8 years

OPTION 2: 50% of Peak – By sizing a boiler to meet 50% of the peak demand, LANL could meet up to 90% of its annual load. This equate to a 38mmBtu pellet or 48mmBtu chip biomass boiler. In the costing of the infrastructure changes i.e. building, M&E, system integration, it is assumed a natural gas boiler would be removed and a biomass boiler installed in the space made available.

> "Systems sized to meet 50% of the peak load should be capable of meeting about 90% of the actual annual load. The existing natural gas boiler is kept in place to meet the remainder of the peak load and as back-up."
> Final Report: Biomass Boiler Market Assessment, October 5, 2006, Submitted by
> CTA Architects and Engineers, Christopher Allen + Associates, Montana Community Development Corp., Geodata Services, Inc.

Steam Production Profile



Fuel Volumes & Delivery Requirements:

Biomass Boiler Fuel Requirements

50% of Peak Production

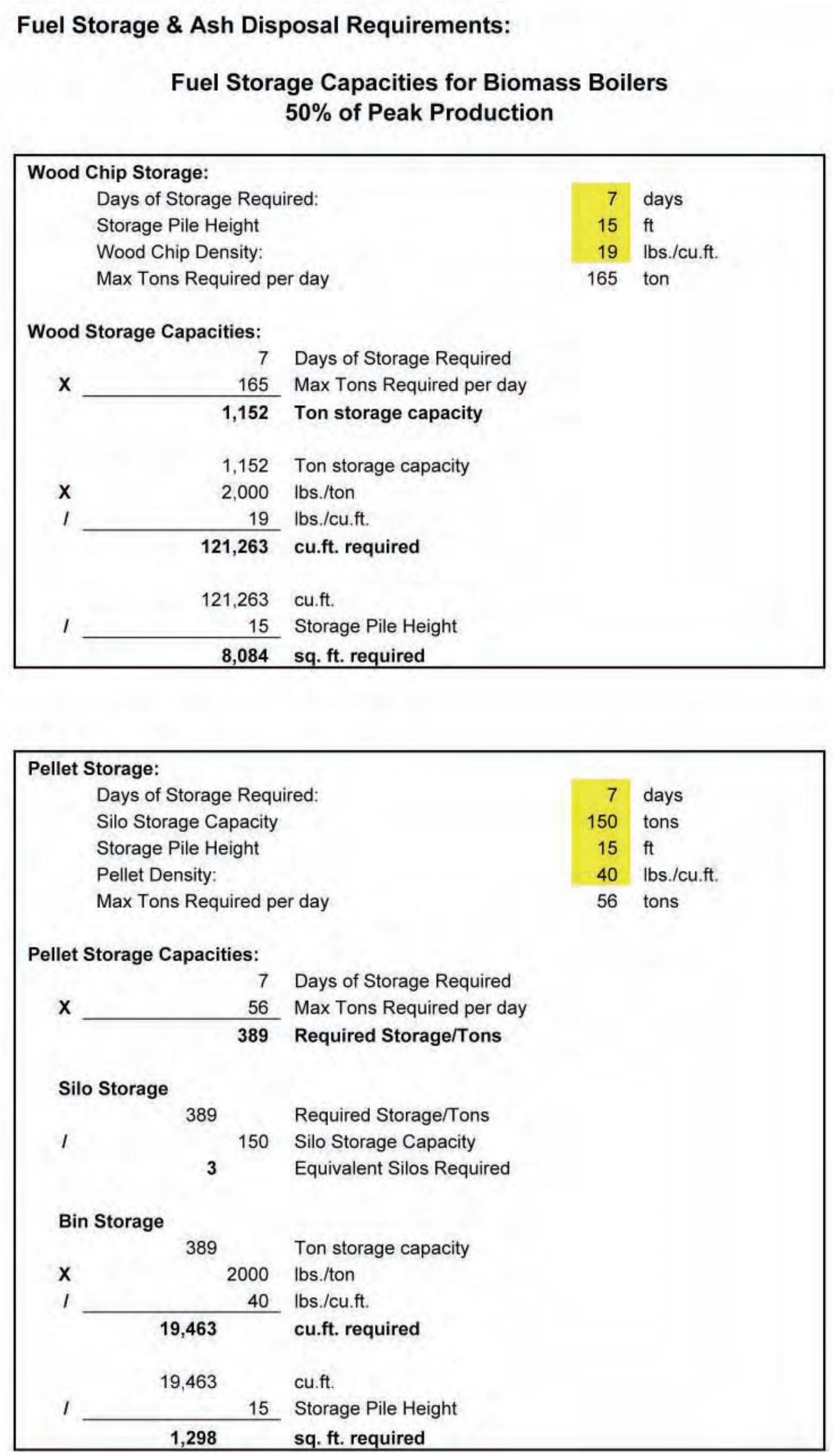
Wood Chip Fuel:	-		-
Wood chip boiler efficiency:	70%		
Heating values: (Wood chips @ 50% Moisture content)	7	mmBtu	
Max Daily Wood Chip Volume	165	ton	

	Average Steam Usage based upon calendar days per month (mmBtu)	**Wood Chip Volumes based on steam usage & Boiler Efficiency (tons)**	**Truck Loads per month 22 tons per load**	**Truck loads per day**	**Operational Days per month**
Jan	68,872	5,102	232	12	31
Feb	58,801	4,608	209	10	28
Mar	54,790	5,102	232	12	31
Apr	44,874	4,937	224	11	30
May	35,528	5,075	231	12	31
Jun	27,852	3,979	181	9	30
Jul	26,457	3,780	172	9	31
Aug	26,014	3,716	169	8	31
Sep	27,523	3,932	179	9	30
Oct	41,655	5,102	232	12	31
Nov	57,387	4,937	224	11	30
Dec	70,925	5,102	232	12	31
Annual Total	**540,677**	**55,371**	**2,517**		

Pellet Fuel:		
Pellet boiler efficiency:	90%	
Heating values:	16	mmBtu
Max Daily Pellet Volume	56	ton

	Average Steam Usage based upon calendar days per month (mmBtu)	**Pellet Volumes based on Steam usage & Boiler Efficiency (tons)**	**Truck Loads per month 22 tons per load**	**Truck loads per day**	**Operational Days per month**
Jan	68,872	1,724	78	4	31
Feb	58,801	1,557	71	4	28
Mar	54,790	1,724	78	4	31
Apr	44,874	1,668	76	4	30
May	35,528	1,724	78	4	31
Jun	27,852	1,668	76	4	30
Jul	26,457	1,613	73	4	31
Aug	26,014	1,586	72	4	31
Sep	27,523	1,668	76	4	30
Oct	41,655	1,724	78	4	31
Nov	57,387	1,668	76	4	30
Dec	70,925	1,724	78	4	31
Annual Total	**540,677**	**20,049**	**911**		

Truck loads per day assumes Monday - Friday delivery only



Fuel Storage & Ash Disposal Requirements:

Fuel Storage Capacities for Biomass Boilers
50% of Peak Production

Wood Chip Storage:

Days of Storage Required:	7	days
Storage Pile Height	15	ft
Wood Chip Density:	19	lbs./cu.ft.
Max Tons Required per day	165	ton

Wood Storage Capacities:

	7	Days of Storage Required
X	165	Max Tons Required per day
	1,152	**Ton storage capacity**
	1,152	Ton storage capacity
X	2,000	lbs./ton
/	19	lbs./cu.ft.
	121,263	**cu.ft. required**
	121,263	cu.ft.
/	15	Storage Pile Height
	8,084	**sq. ft. required**

Pellet Storage:

Days of Storage Required:	7	days
Silo Storage Capacity	150	tons
Storage Pile Height	15	ft
Pellet Density:	40	lbs./cu.ft.
Max Tons Required per day	56	tons

Pellet Storage Capacities:

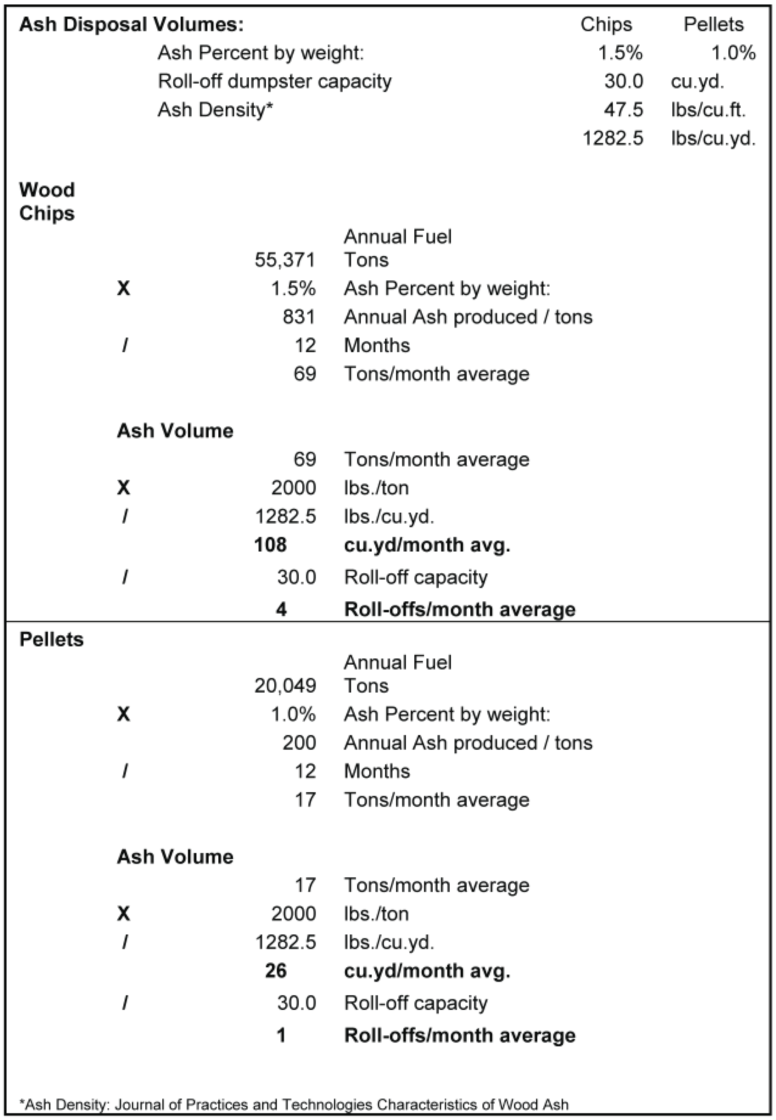
	7	Days of Storage Required
X	56	Max Tons Required per day
	389	**Required Storage/Tons**

Silo Storage

	389	Required Storage/Tons
/	150	Silo Storage Capacity
	3	Equivalent Silos Required

Bin Storage

	389	Ton storage capacity
X	2000	lbs./ton
/	40	lbs./cu.ft.
	19,463	**cu.ft. required**
	19,463	cu.ft.
/	15	Storage Pile Height
	1,298	**sq. ft. required**



Ash Disposal Volumes:	Chips	Pellets
Ash Percent by weight:	1.5%	1.0%
Roll-off dumpster capacity	30.0	cu.yd.
Ash Density*	47.5	lbs/cu.ft.
	1282.5	lbs/cu.yd.

Wood Chips

	55,371	Annual Fuel Tons
X	1.5%	Ash Percent by weight:
	831	Annual Ash produced / tons
/	12	Months
	69	Tons/month average

Ash Volume

	69	Tons/month average
X	2000	lbs./ton
/	1282.5	lbs./cu.yd.
	108	**cu.yd/month avg.**
/	30.0	Roll-off capacity
	4	**Roll-offs/month average**

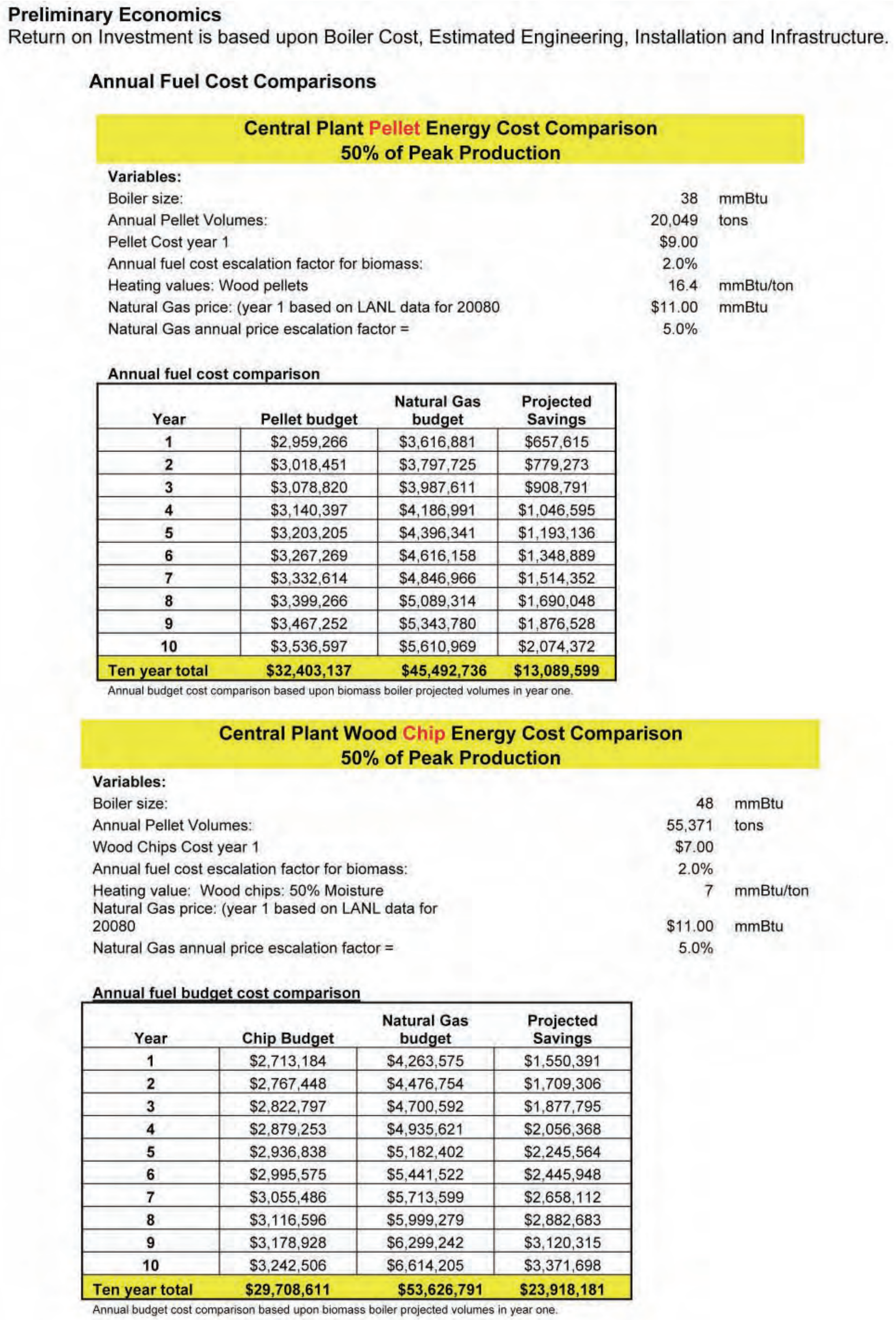
Pellets

	20,049	Annual Fuel Tons
X	1.0%	Ash Percent by weight:
	200	Annual Ash produced / tons
/	12	Months
	17	Tons/month average

Ash Volume

	17	Tons/month average
X	2000	lbs./ton
/	1282.5	lbs./cu.yd.
	26	**cu.yd/month avg.**
/	30.0	Roll-off capacity
	1	**Roll-offs/month average**

*Ash Density: Journal of Practices and Technologies Characteristics of Wood Ash



Preliminary Economics

Return on Investment is based upon Boiler Cost, Estimated Engineering, Installation and Infrastructure.

Annual Fuel Cost Comparisons

Central Plant Pellet Energy Cost Comparison
50% of Peak Production

Variables:

Boiler size:	38	mmBtu
Annual Pellet Volumes:	20,049	tons
Pellet Cost year 1	$9.00	
Annual fuel cost escalation factor for biomass:	2.0%	
Heating values: Wood pellets	16.4	mmBtu/ton
Natural Gas price: (year 1 based on LANL data for 20080	$11.00	mmBtu
Natural Gas annual price escalation factor =	5.0%	

Annual fuel cost comparison

Year	Pellet budget	Natural Gas budget	Projected Savings
1	$2,959,266	$3,616,881	$657,615
2	$3,018,451	$3,797,725	$779,273
3	$3,078,820	$3,987,611	$908,791
4	$3,140,397	$4,186,991	$1,046,595
5	$3,203,205	$4,396,341	$1,193,136
6	$3,267,269	$4,616,158	$1,348,889
7	$3,332,614	$4,846,966	$1,514,352
8	$3,399,266	$5,089,314	$1,690,048
9	$3,467,252	$5,343,780	$1,876,528
10	$3,536,597	$5,610,969	$2,074,372
Ten year total	**$32,403,137**	**$45,492,736**	**$13,089,599**

Annual budget cost comparison based upon biomass boiler projected volumes in year one.

Central Plant Wood Chip Energy Cost Comparison
50% of Peak Production

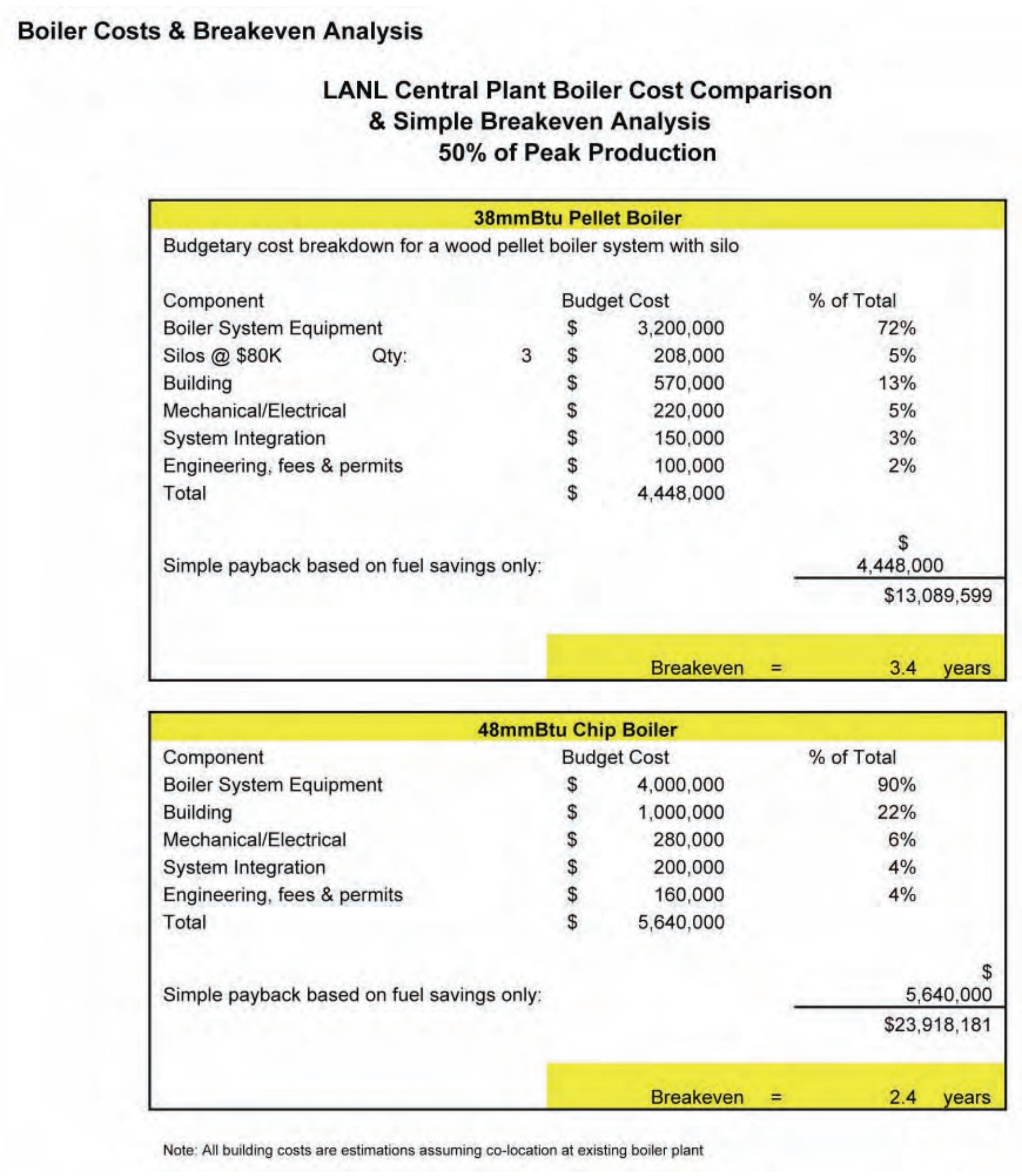
Variables:

Boiler size:	48	mmBtu
Annual Pellet Volumes:	55,371	tons
Wood Chips Cost year 1	$7.00	
Annual fuel cost escalation factor for biomass:	2.0%	
Heating value: Wood chips: 50% Moisture	7	mmBtu/ton
Natural Gas price: (year 1 based on LANL data for 20080	$11.00	mmBtu
Natural Gas annual price escalation factor =	5.0%	

Annual fuel budget cost comparison

Year	Chip Budget	Natural Gas budget	Projected Savings
1	$2,713,184	$4,263,575	$1,550,391
2	$2,767,448	$4,476,754	$1,709,306
3	$2,822,797	$4,700,592	$1,877,795
4	$2,879,253	$4,935,621	$2,056,368
5	$2,936,838	$5,182,402	$2,245,564
6	$2,995,575	$5,441,522	$2,445,948
7	$3,055,486	$5,713,599	$2,658,112
8	$3,116,596	$5,999,279	$2,882,683
9	$3,178,928	$6,299,242	$3,120,315
10	$3,242,506	$6,614,205	$3,371,698
Ten year total	**$29,708,611**	**$53,626,791**	**$23,918,181**

Annual budget cost comparison based upon biomass boiler projected volumes in year one.



Boiler Costs & Breakeven Analysis

LANL Central Plant Boiler Cost Comparison
& Simple Breakeven Analysis
50% of Peak Production

38mmBtu Pellet Boiler

Budgetary cost breakdown for a wood pellet boiler system with silo

Component			Budget Cost	% of Total
Boiler System Equipment			$ 3,200,000	72%
Silos @ $80K	Qty:	3	$ 208,000	5%
Building			$ 570,000	13%
Mechanical/Electrical			$ 220,000	5%
System Integration			$ 150,000	3%
Engineering, fees & permits			$ 100,000	2%
Total			$ 4,448,000	

Simple payback based on fuel savings only: $ 4,448,000 / $13,089,599

Breakeven = 3.4 years

48mmBtu Chip Boiler

Component	Budget Cost	% of Total
Boiler System Equipment	$ 4,000,000	90%
Building	$ 1,000,000	22%
Mechanical/Electrical	$ 280,000	6%
System Integration	$ 200,000	4%
Engineering, fees & permits	$ 160,000	4%
Total	$ 5,640,000	

Simple payback based on fuel savings only: $ 5,640,000 / $23,918,181

Breakeven = 2.4 years

Note: All building costs are estimations assuming co-location at existing boiler plant

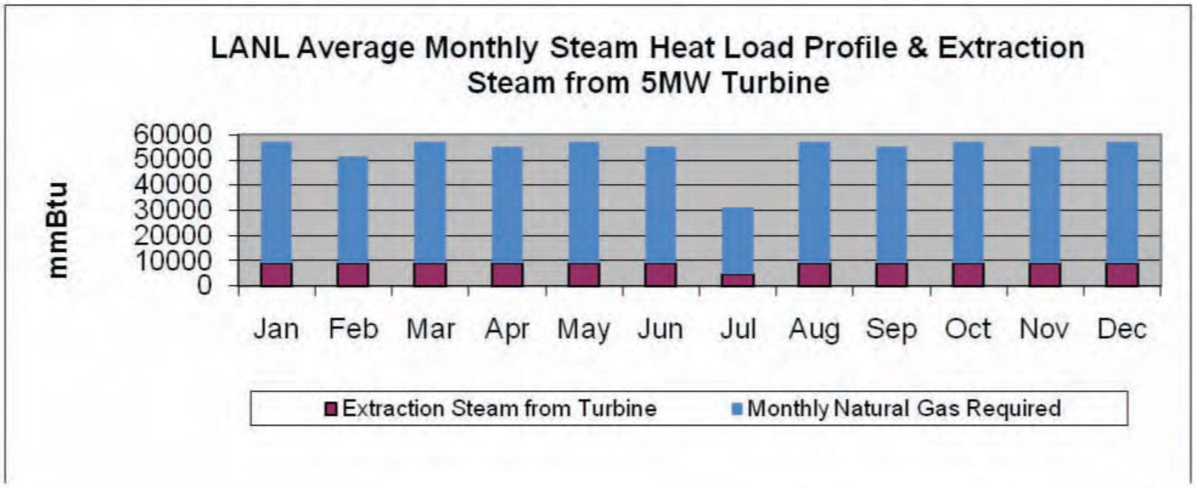
- **OPTION 3:** 5 Megawatt Combined Heat and Power

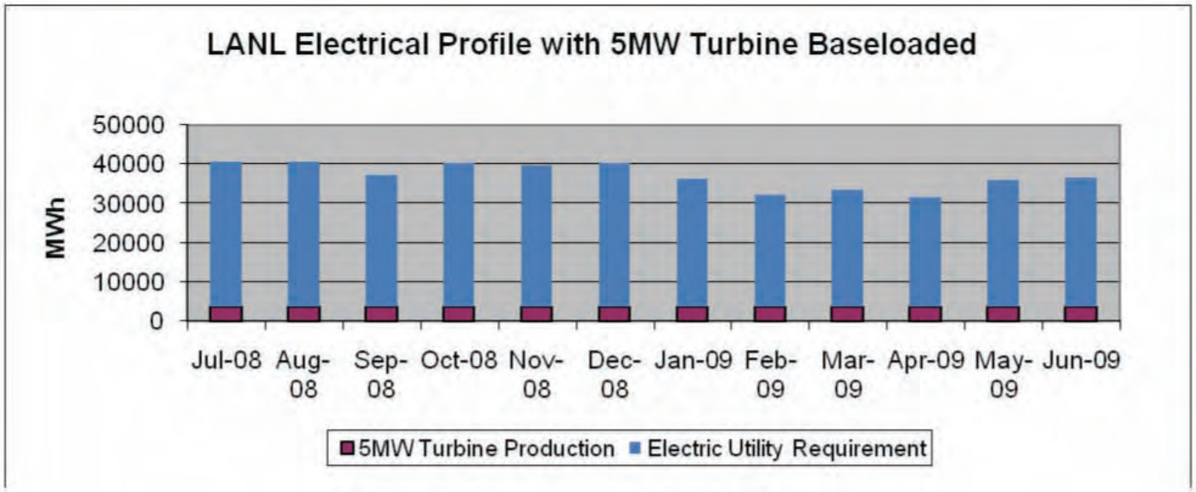
The existing combined heat and power central plant was built in the late 1940s. The plant has operated as a boiler plant only for supplying steam to the LANL campus for at least the last eight years. The low cost of purchased power and the rise in natural gas costs combined make the operation of the plant as a combined heat and power facility uneconomical.

The alternative of removing one natural gas boiler and replacing it with a biomass boiler capable of supplying 55,000 lbs/hr of steam to run the turbine generator and generate power while recovering a percentage of steam for campus heating is the focus of this analysis.

The percentage of steam available from the turbine is approximately 15% of the campus steam requirement. The 5MW electrical generator is capable of supplying approximately 10% of the electrical requirement of the campus.

Steam Production Profile





Fuel Volumes & Delivery Requirements:

Biomass Boiler Fuel Requirements
5MW Combined Heat & Power production

Wood Chip Fuel:		-			-
Wood chip boiler efficiency:				70%	
Heating values: (Wood chips @ 50% Moisture content)				7	mmBtu/ton
Average Daily Steam Boiler Output Required :				1,835	mmBtu
Average Daily Wood Chip Volume				374.4	ton

	Average Steam Usage based upon calendar days per month (mmBtu)	Wood Chip Volumes based on steam usage & Boiler Efficiency (tons)	Truck Loads per month 22 tons per load	Truck loads per day	Operational Days per month
Jan	56,879	11,608	528	26	31
Feb	51,374	10,485	477	24	28
Mar	56,879	11,608	528	26	31
Apr	55,044	11,233	511	26	30
May	56,879	11,608	528	26	31
Jun	55,044	11,233	511	26	30
Jul	31,192	6,366	289	14	17
Aug	56,879	11,608	528	26	31
Sep	55,044	11,233	511	26	30
Oct	56,879	11,608	528	26	31
Nov	55,044	11,233	511	26	30
Dec	56,879	11,608	528	26	31
Annual Total	**644,015**	**131,432**	**5,974**		**351**

Pellet Fuel:	-	-			-
Pellet boiler efficiency:				90%	
Heating values:				16.4	mmBtu/ton
Average Daily Steam Boiler Output Required :				1,835	mmBtu
Average Daily Pellets Volume				124.3	ton

	Average Steam Usage based upon calendar days per month (mmBtu)	Pellet Volumes based on Steam usage & Boiler Efficiency (tons)	Truck Loads per month 22 tons per load	Truck loads per day	Operational Days per month
Jan	56,879	3,854	175	9	31
Feb	51,374	3,481	158	8	28
Mar	56,879	3,854	175	9	31
Apr	55,044	3,729	170	8	30
May	56,879	3,854	175	9	31
Jun	55,044	3,729	170	8	30
Jul	31,192	2,113	96	5	17
Aug	56,879	3,854	175	9	31
Sep	55,044	3,729	170	8	30
Oct	56,879	3,854	175	9	31
Nov	55,044	3,729	170	8	30
Dec	56,879	3,854	175	9	31
Annual Total	**644,015**	**43,632**	**1,983**		**351**

Truck loads per day assumes Monday - Friday delivery only

Fuel Storage & Ash Disposal Requirements:

Fuel Storage Capacities for Biomass Boilers
5 MW Combined Heat & Power Production

Wood Chip Storage:

Days of Storage Required:	7	days
Storage Pile Height	15	ft.
Wood Chip Density:	19	lbs./cu.ft.
Tons required per Day	374	ton

Wood Storage Capacities:

	7	Days of Storage Required
X	374	Tons required per Day
	2,621	**Ton storage capacity**

	2,621	Ton storage capacity
X	2000	lbs./ton
/	19	lbs./cu.ft.
	275,910	**cu.ft. required**

	275,910	cu.ft.
/	15	Storage Pile Height
	18,394	**sq. ft. required**

Pellet Storage:

Days of Storage Required:	7	days
Silo Storage Capacity	150	ton
Storage Pile Height	15	ft
Pellet Density:	40	lbs./cu.ft.
Tons required per Day	124.3089	ton

Pellet Capacities:

	7	Days of Storage Required
X	124	Tons required per Day
	870	**Required Storage/Tons**

Silo Storage

	870	Ton storage capacity
/	150	Silo Storage Capacity
	6	Equivalent Silos Required

Bin Storage

	870	Ton storage capacity
X	2000	lbs./ton
/	40	Pellet Density
	43,508	**cu.ft. required**

	43,508	cu.ft.
/	15	Storage Pile Height
	2,901	**sq. ft. required**

Ash Disposal Volumes:	Chips	Pellets
Ash Percent by weight:	1.5%	1.0%
Roll-off dumpster capacity	30.0	cu.yd.
Ash Density*	47.5	lbs/cu.ft.
	1282.5	lbs/cu.yd.

Wood Chips

	131,432	Annual Fuel Tons
X	1.5%	Ash Percent by weight:
	1971	Annual Ash produced / tons
/	12	Months
	164	Tons/month average

Ash Volume

	164	Tons/month average
X	2000	lbs./ton
/	1282.5	lbs./cu.yd.
	256	**cu.yd/month avg.**
/	30.0	Roll-off capacity
	9	**Roll-offs/month average**

Pellets

	43,632	Annual Fuel Tons
X	1.0%	Ash Percent by weight:
	436	Annual Ash produced / tons
/	12	Months
	36	Tons/month average

Ash Volume

	36	Tons/month average
X	2000	lbs./ton
/	1282.5	lbs./cu.yd.
	57	**cu.yd/month avg.**
/	30.0	Roll-off capacity
	2	**Roll-offs/month average**

*Ash Density: Journal of Practices and Technologies Characteristics of Wood Ash

Preliminary Economics

Return on Investment is based upon Boiler Cost, Estimated Engineering, Installation, and Infrastructure.

The following tables compare the annual cost to generate turbine steam and power the existing 5MW turbine generator using wood chips to the budgeted cost of 5MW of electric power and displacing the coupled natural gas costs. The electric cost analysis was based upon data supplied by Los Alamos County[1].

Los Alamos County and LANL share in an electric power pool, which supplies both entities with electric service. The average electric cost per MWh between 2008 and 2018, calculated from the forecast is $54.76 or 5.5 cents/kWh. This value is inclusive of the usage and demand charges and based upon Los Alamos County's forecast labeled "Net Adjusted Costs due to Los Alamos." Of significant note is the 18% rate decrease in year 7(2015) due to the pay-off of debt service on three power projects that the power pool invested in, San Juan, El Vado and Abiquiu. These savings approximate $92 thousand dollars a year.

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[1] Department of Energy / Los Alamos County Resource Pool Fiscal Years 2009 thru 2018 Budget", Los Alamos County, New Mexico.

The annual fuel costs for wood chips was based upon the calculated tonnage required, the heating value of wood chips at 50% moisture content and the cost per mmBtu for chips. The cost of wood chips is on average 20-30% less than wood pellets and even though a pellet boiler is more efficient, the net operating cost per mmBtu is lower for wood chips.

As a first test of economic feasibility, the calculation considers only fuel costs without regard to capital or operating costs of the boiler and turbine. The table evaluates the fuel and power costs over 10 years including the natural gas displaced by the extraction of steam from the turbine operation for campus heating. The maximum amount of steam that can be extracted from the turbine operating at the full capacity of 5MW was supplied to Forest Energy by LANL. With the turbine operating at 5MW, the maximum steam flow available for campus heating is 10,000pph. This amount of steam is approximately one-third of the minimum monthly summer production requirement of 35,000pph. The 10,000pph on an annual basis amounts to approximately 16% of the total natural gas usage.

Annual Fuel Cost Comparisons

Central Plant Energy Cost Comparison
5 MW Combined Heat & Power Production

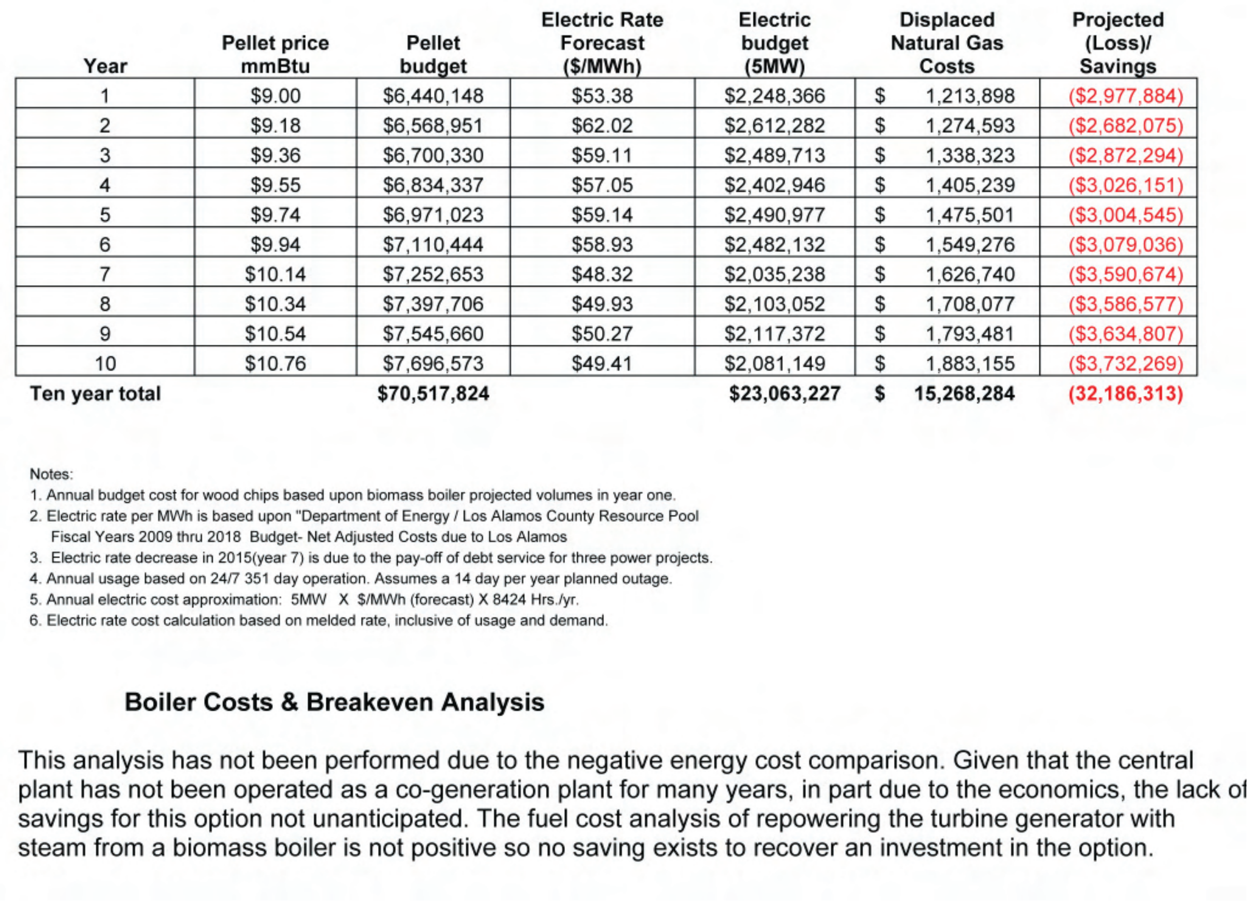
Variables:

Boiler size:	76.4	mmBtu/hr.
Steam Output:	55,000	lbs/hr.
Turbine Output:	5	MW
Operation:	8,424	hours/yr.
Steam Extraction:	10,000	lbs/hr
Steam Enthalpy:	1310	Btu/lb (@ extraction)
Annual Wood Chip Volumes:	131,432	tons
Wood Chip Cost year 1	7	
Annual fuel cost escalation factor for biomass:	2%	
Heating value: Wood chips: 50% Moisture	7	mmBtu/ton
Annual Pellet Volumes:	43,632	tons
Pellet Cost year 1	9	mmBtu
Annual fuel cost escalation factor for biomass:	2%	
Heating value:	16.4	mmBtu/ton
Natural Gas cost:	$ 11.00	/mmBtu
Annual fuel cost escalation factor for natural gas:	5%	

Ten Year - Wood Chip Energy Cost Comparison

Year	Chip price mmBtu	Chip budget	Electric Rate Forecast ($/MWh)	Electric budget (5MW)	Displaced Natural Gas Costs	Projected (Loss)/ Savings
1	$7.00	$6,440,148	$53.38	$2,248,366	$ 1,213,898	($2,977,884)
2	$7.14	$6,568,951	$62.02	$2,612,282	$ 1,274,593	($2,682,075)
3	$7.28	$6,700,330	$59.11	$2,489,713	$ 1,338,323	($2,872,294)
4	$7.43	$6,834,337	$57.05	$2,402,946	$ 1,405,239	($3,026,151)
5	$7.58	$6,971,023	$59.14	$2,490,977	$ 1,475,501	($3,004,545)
6	$7.73	$7,110,444	$58.93	$2,482,132	$ 1,549,276	($3,079,036)
7	$7.88	$7,252,653	$48.32	$2,035,238	$ 1,626,740	($3,590,674)
8	$8.04	$7,397,706	$49.93	$2,103,052	$ 1,708,077	($3,586,577)
9	$8.20	$7,545,660	$50.27	$2,117,372	$ 1,793,481	($3,634,807)
10	$8.37	$7,696,573	$49.41	$2,081,149	$ 1,883,155	($3,732,269)
Ten year total		**$70,517,824**		**$23,063,227**	**$ 15,268,284**	**(32,186,313)**

Ten Year - Pellet Fuel Energy Cost Comparison



Year	Pellet price mmBtu	Pellet budget	Electric Rate Forecast ($/MWh)	Electric budget (5MW)	Displaced Natural Gas Costs	Projected (Loss)/ Savings
1	$9.00	$6,440,148	$53.38	$2,248,366	$ 1,213,898	($2,977,884)
2	$9.18	$6,568,951	$62.02	$2,612,282	$ 1,274,593	($2,682,075)
3	$9.36	$6,700,330	$59.11	$2,489,713	$ 1,338,323	($2,872,294)
4	$9.55	$6,834,337	$57.05	$2,402,946	$ 1,405,239	($3,026,151)
5	$9.74	$6,971,023	$59.14	$2,490,977	$ 1,475,501	($3,004,545)
6	$9.94	$7,110,444	$58.93	$2,482,132	$ 1,549,276	($3,079,036)
7	$10.14	$7,252,653	$48.32	$2,035,238	$ 1,626,740	($3,590,674)
8	$10.34	$7,397,706	$49.93	$2,103,052	$ 1,708,077	($3,586,577)
9	$10.54	$7,545,660	$50.27	$2,117,372	$ 1,793,481	($3,634,807)
10	$10.76	$7,696,573	$49.41	$2,081,149	$ 1,883,155	($3,732,269)
Ten year total		**$70,517,824**		**$23,063,227**	**$ 15,268,284**	**(32,186,313)**

Notes:

1. Annual budget cost for wood chips based upon biomass boiler projected volumes in year one.
2. Electric rate per MWh is based upon "Department of Energy / Los Alamos County Resource Pool Fiscal Years 2009 thru 2018 Budget- Net Adjusted Costs due to Los Alamos
3. Electric rate decrease in 2015(year 7) is due to the pay-off of debt service for three power projects.
4. Annual usage based on 24/7 351 day operation. Assumes a 14 day per year planned outage.
5. Annual electric cost approximation: 5MW X $/MWh (forecast) X 8424 Hrs./yr.
6. Electric rate cost calculation based on melded rate, inclusive of usage and demand.

Boiler Costs & Breakeven Analysis

This analysis has not been performed due to the negative energy cost comparison. Given that the central plant has not been operated as a co-generation plant for many years, in part due to the economics, the lack of savings for this option not unanticipated. The fuel cost analysis of repowering the turbine generator with steam from a biomass boiler is not positive so no saving exists to recover an investment in the option.

Preliminary Conclusions

1. Option - 1 Baseload & Option 2 - 50% of Peak Demand are both worthy of further exploration due to their good preliminary economics. The economics are positive for both types of fuel regarding these options and the fuel decision should be based on LANL's preference. Given the narrow range of the payback window, Forest Energy would recommend sizing the largest boiler based upon the available fuel.

2. If LANL does not anticipate operating the turbines as a combined heat and power plant, they should consider replacing one of the natural gas boilers as opposed to building a separate biomass plant.

3. As part of ongoing analysis, the central plant staff should visit both types of plants (Chip & Pellet) in order to become aware of the operational considerations.

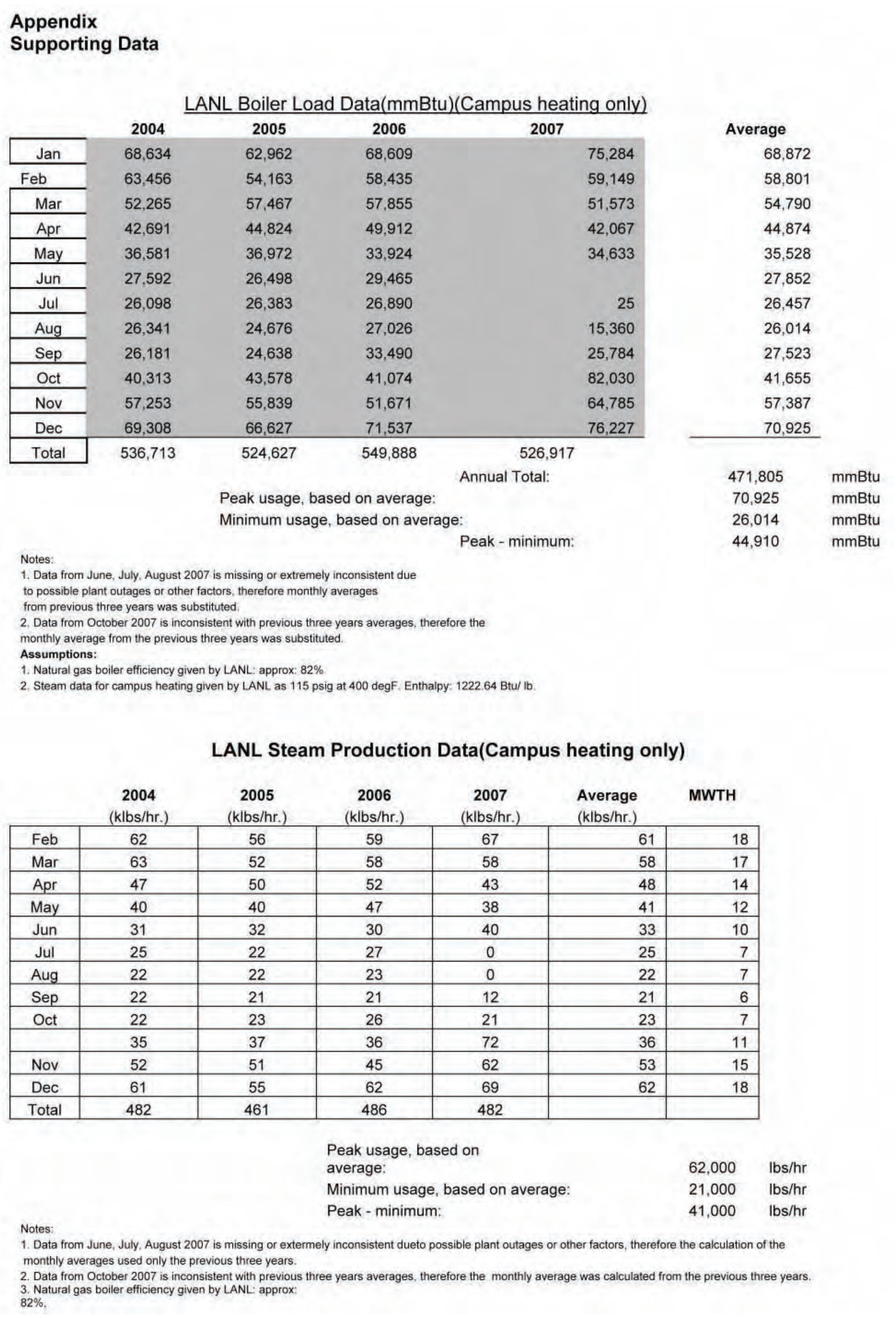
4. If the decision is made to pursue further analysis of a biomass option, a more thorough analysis of the following items should be included: heating loads, plant layout, interconnection issues, land use and zoning requirements, grant funding, onsite inspections from boiler manufacturers and natural gas fuel contracts.

5. Due to the temperature and pressure of the required steam, a biomass plant would require, by code, full time boiler operators, 24/365. The initial simple payback calculations are based upon the fuel cost savings only. Forest Energy will need to ascertain the operating budget figures for staffing a biomass plant in order to determine the life cycle cost of each option. Additional discussion with LANL and the county regarding their available manpower and financial capabilities would assist Forest Energy in determining this crucial component in a subsequent analysis.

6. Determining the flexibility of the current central plant operation based on the three options is necessary in order to eliminate any options that cannot fit within their operating parameters. Review of the three options by plant senior staff is called for.

7. The cost effective operation of the central plant at LANL and the feasibility of a biomass boiler addition will greatly depend on the nature of the natural gas contract with the DOD fuels procurement division. If the contract is written on a "Take or Pay" basis, then the second and third option with larger biomass boilers is less viable. The hours of operation of the central plant will be determined by the nature of the gas contract and not necessarily by the efficient operation of the biomass plant. Shutting down, turning off and restarting large boilers with all the associated expenses will significantly reflect on the economics. The current price of $11 per mmBtu will increase, however it is necessary to obtain the forecast and escalation factors from the fuels group within DOD in order to properly determine the feasibility of a biomass option.

8. The differences in physical plant size between the three options are significant. The height of fuel storage silo for a pellet system may be a significant issue regarding planning and zoning ordinances. The final recommendations need to take this issue into design consideration.



Appendix
Supporting Data

LANL Boiler Load Data(mmBtu)(Campus heating only)

	2004	2005	2006	2007	Average
Jan	68,634	62,962	68,609	75,284	68,872
Feb	63,456	54,163	58,435	59,149	58,801
Mar	52,265	57,467	57,855	51,573	54,790
Apr	42,691	44,824	49,912	42,067	44,874
May	36,581	36,972	33,924	34,633	35,528
Jun	27,592	26,498	29,465		27,852
Jul	26,098	26,383	26,890	25	26,457
Aug	26,341	24,676	27,026	15,360	26,014
Sep	26,181	24,638	33,490	25,784	27,523
Oct	40,313	43,578	41,074	82,030	41,655
Nov	57,253	55,839	51,671	64,785	57,387
Dec	69,308	66,627	71,537	76,227	70,925
Total	536,713	524,627	549,888	526,917	

Annual Total:	471,805	mmBtu
Peak usage, based on average:	70,925	mmBtu
Minimum usage, based on average:	26,014	mmBtu
Peak - minimum:	44,910	mmBtu

Notes:

1. Data from June, July, August 2007 is missing or extremely inconsistent due to possible plant outages or other factors, therefore monthly averages from previous three years was substituted.
2. Data from October 2007 is inconsistent with previous three years averages, therefore the monthly average from the previous three years was substituted.

Assumptions:

1. Natural gas boiler efficiency given by LANL: approx: 82%
2. Steam data for campus heating given by LANL as 115 psig at 400 degF. Enthalpy: 1222.64 Btu/ lb.

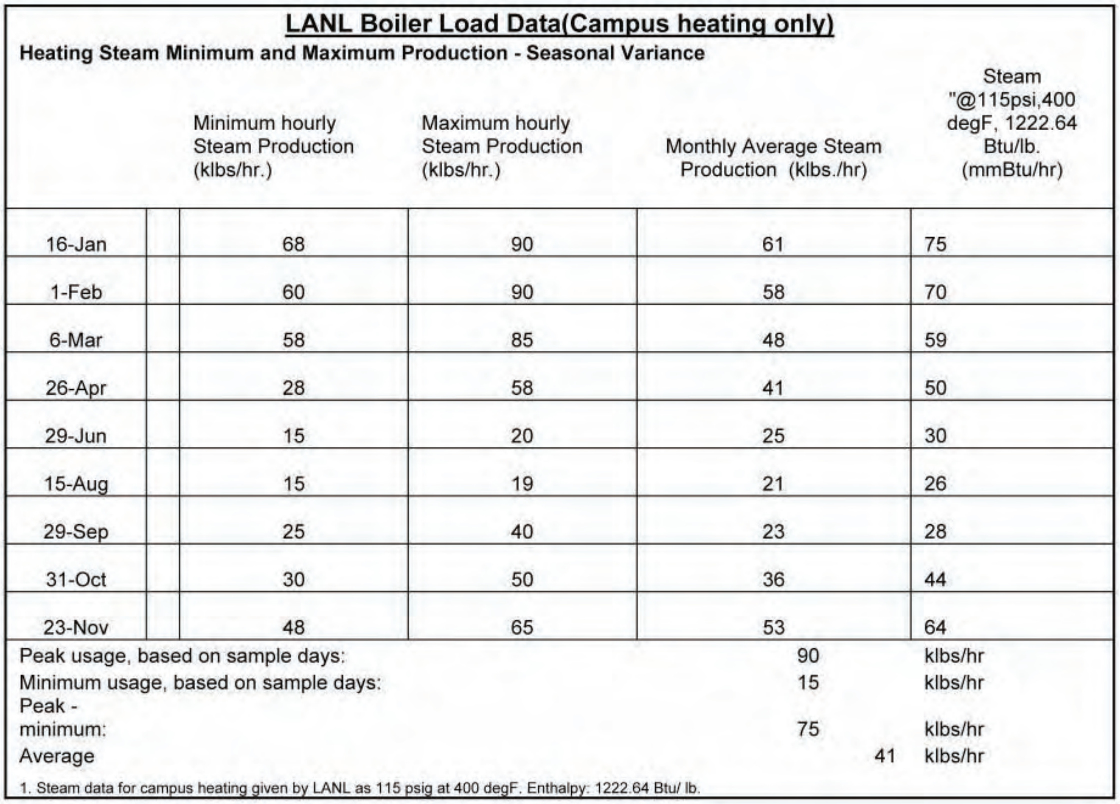
LANL Steam Production Data(Campus heating only)

	2004 (klbs/hr.)	2005 (klbs/hr.)	2006 (klbs/hr.)	2007 (klbs/hr.)	Average (klbs/hr.)	MWTH
Feb	62	56	59	67	61	18
Mar	63	52	58	58	58	17
Apr	47	50	52	43	48	14
May	40	40	47	38	41	12
Jun	31	32	30	40	33	10
Jul	25	22	27	0	25	7
Aug	22	22	23	0	22	7
Sep	22	21	21	12	21	6
Oct	22	23	26	21	23	7
	35	37	36	72	36	11
Nov	52	51	45	62	53	15
Dec	61	55	62	69	62	18
Total	482	461	486	482		

Peak usage, based on average:	62,000	lbs/hr
Minimum usage, based on average:	21,000	lbs/hr
Peak - minimum:	41,000	lbs/hr

Notes:

1. Data from June, July, August 2007 is missing or extermely inconsistent dueto possible plant outages or other factors, therefore the calculation of the monthly averages used only the previous three years.
2. Data from October 2007 is inconsistent with previous three years averages, therefore the monthly average was calculated from the previous three years.
3. Natural gas boiler efficiency given by LANL: approx: 82%.



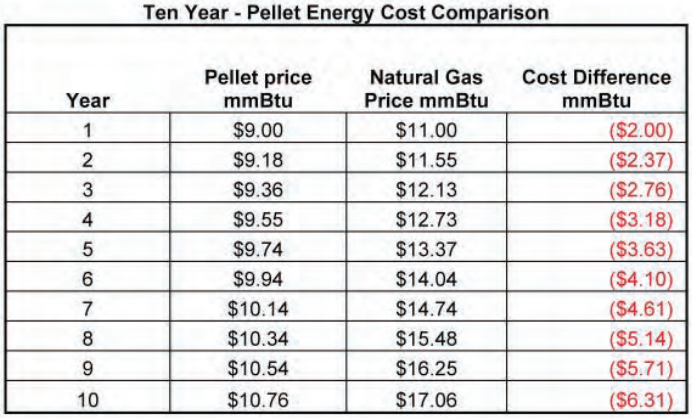
LANL Boiler Load Data(Campus heating only)

Heating Steam Minimum and Maximum Production - Seasonal Variance

	Minimum hourly Steam Production (klbs/hr.)	Maximum hourly Steam Production (klbs/hr.)	Monthly Average Steam Production (klbs./hr)	Steam "@115psi,400 degF, 1222.64 Btu/lb. (mmBtu/hr)
16-Jan	68	90	61	75
1-Feb	60	90	58	70
6-Mar	58	85	48	59
26-Apr	28	58	41	50
29-Jun	15	20	25	30
15-Aug	15	19	21	26
29-Sep	25	40	23	28
31-Oct	30	50	36	44
23-Nov	48	65	53	64

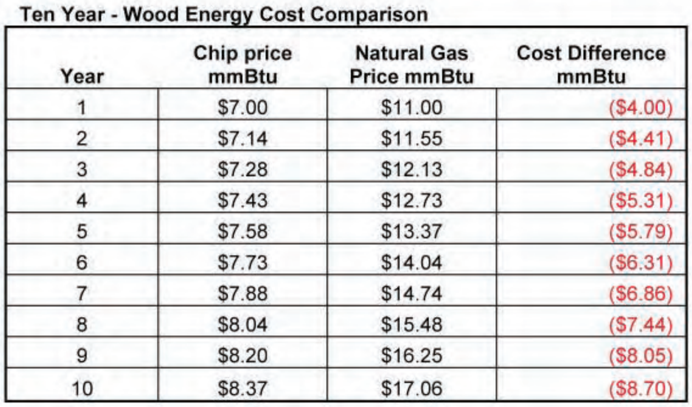
Peak usage, based on sample days:	90	klbs/hr
Minimum usage, based on sample days:	15	klbs/hr
Peak - minimum:	75	klbs/hr
Average	41	klbs/hr

1. Steam data for campus heating given by LANL as 115 psig at 400 degF. Enthalpy: 1222.64 Btu/ lb.



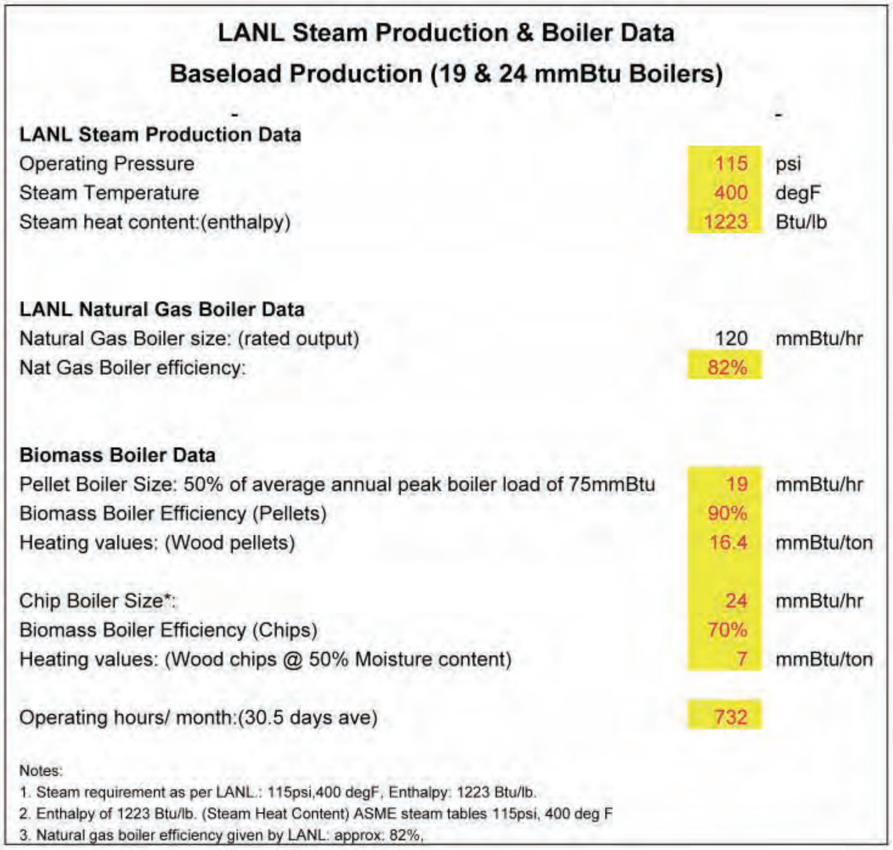
Ten Year - Pellet Energy Cost Comparison

Year	Pellet price mmBtu	Natural Gas Price mmBtu	Cost Difference mmBtu
1	$9.00	$11.00	($2.00)
2	$9.18	$11.55	($2.37)
3	$9.36	$12.13	($2.76)
4	$9.55	$12.73	($3.18)
5	$9.74	$13.37	($3.63)
6	$9.94	$14.04	($4.10)
7	$10.14	$14.74	($4.61)
8	$10.34	$15.48	($5.14)
9	$10.54	$16.25	($5.71)
10	$10.76	$17.06	($6.31)



Ten Year - Wood Energy Cost Comparison

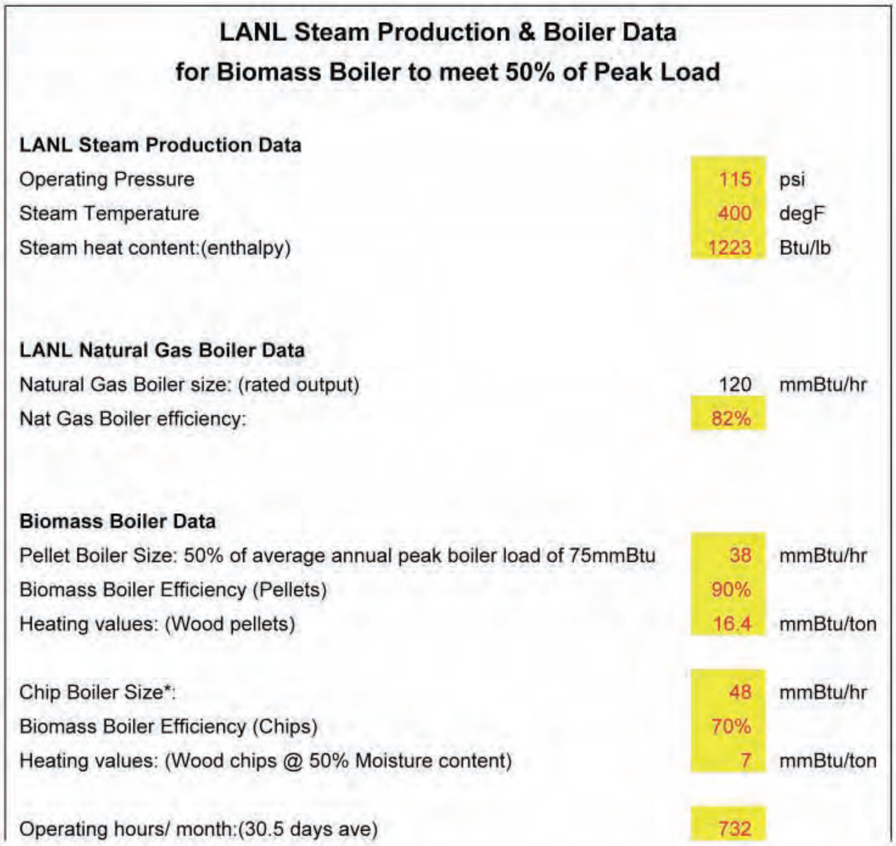
Year	Chip price mmBtu	Natural Gas Price mmBtu	Cost Difference mmBtu
1	$7.00	$11.00	($4.00)
2	$7.14	$11.55	($4.41)
3	$7.28	$12.13	($4.84)
4	$7.43	$12.73	($5.31)
5	$7.58	$13.37	($5.79)
6	$7.73	$14.04	($6.31)
7	$7.88	$14.74	($6.86)
8	$8.04	$15.48	($7.44)
9	$8.20	$16.25	($8.05)
10	$8.37	$17.06	($8.70)



LANL Steam Production & Boiler Data
Baseload Production (19 & 24 mmBtu Boilers)

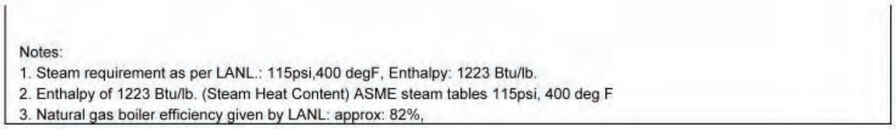
-		-
LANL Steam Production Data		
Operating Pressure	115	psi
Steam Temperature	400	degF
Steam heat content:(enthalpy)	1223	Btu/lb
LANL Natural Gas Boiler Data		
Natural Gas Boiler size: (rated output)	120	mmBtu/hr
Nat Gas Boiler efficiency:	82%	
Biomass Boiler Data		
Pellet Boiler Size: 50% of average annual peak boiler load of 75mmBtu	19	mmBtu/hr
Biomass Boiler Efficiency (Pellets)	90%	
Heating values: (Wood pellets)	16.4	mmBtu/ton
Chip Boiler Size*:	24	mmBtu/hr
Biomass Boiler Efficiency (Chips)	70%	
Heating values: (Wood chips @ 50% Moisture content)	7	mmBtu/ton
Operating hours/ month:(30.5 days ave)	732	

Notes:
1. Steam requirement as per LANL.: 115psi,400 degF, Enthalpy: 1223 Btu/lb.
2. Enthalpy of 1223 Btu/lb. (Steam Heat Content) ASME steam tables 115psi, 400 deg F
3. Natural gas boiler efficiency given by LANL: approx: 82%,

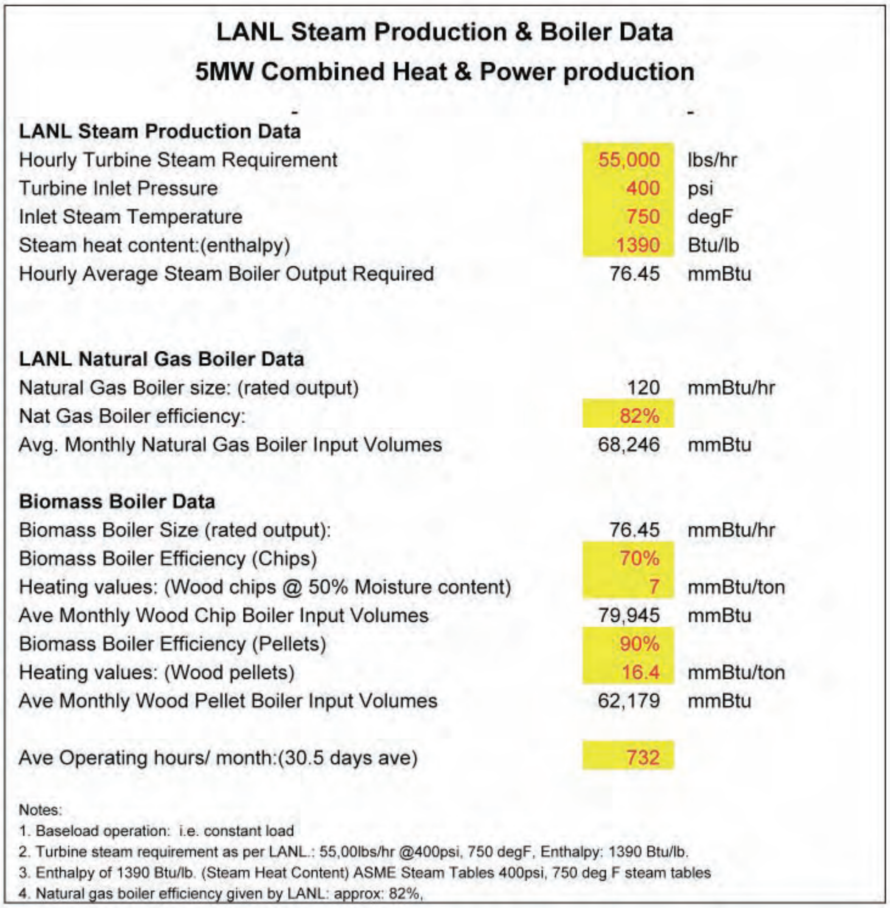


LANL Steam Production & Boiler Data
for Biomass Boiler to meet 50% of Peak Load

LANL Steam Production Data		
Operating Pressure	115	psi
Steam Temperature	400	degF
Steam heat content:(enthalpy)	1223	Btu/lb
LANL Natural Gas Boiler Data		
Natural Gas Boiler size: (rated output)	120	mmBtu/hr
Nat Gas Boiler efficiency:	82%	
Biomass Boiler Data		
Pellet Boiler Size: 50% of average annual peak boiler load of 75mmBtu	38	mmBtu/hr
Biomass Boiler Efficiency (Pellets)	90%	
Heating values: (Wood pellets)	16.4	mmBtu/ton
Chip Boiler Size*:	48	mmBtu/hr
Biomass Boiler Efficiency (Chips)	70%	
Heating values: (Wood chips @ 50% Moisture content)	7	mmBtu/ton
Operating hours/ month:(30.5 days ave)	732	



Notes:
1. Steam requirement as per LANL.: 115psi,400 degF, Enthalpy: 1223 Btu/lb.
2. Enthalpy of 1223 Btu/lb. (Steam Heat Content) ASME steam tables 115psi, 400 deg F
3. Natural gas boiler efficiency given by LANL: approx: 82%,



LANL Steam Production & Boiler Data

5MW Combined Heat & Power production

-		-
LANL Steam Production Data		
Hourly Turbine Steam Requirement	55,000	lbs/hr
Turbine Inlet Pressure	400	psi
Inlet Steam Temperature	750	degF
Steam heat content:(enthalpy)	1390	Btu/lb
Hourly Average Steam Boiler Output Required	76.45	mmBtu
LANL Natural Gas Boiler Data		
Natural Gas Boiler size: (rated output)	120	mmBtu/hr
Nat Gas Boiler efficiency:	82%	
Avg. Monthly Natural Gas Boiler Input Volumes	68,246	mmBtu
Biomass Boiler Data		
Biomass Boiler Size (rated output):	76.45	mmBtu/hr
Biomass Boiler Efficiency (Chips)	70%	
Heating values: (Wood chips @ 50% Moisture content)	7	mmBtu/ton
Ave Monthly Wood Chip Boiler Input Volumes	79,945	mmBtu
Biomass Boiler Efficiency (Pellets)	90%	
Heating values: (Wood pellets)	16.4	mmBtu/ton
Ave Monthly Wood Pellet Boiler Input Volumes	62,179	mmBtu
Ave Operating hours/ month:(30.5 days ave)	732	

Notes:
1. Baseload operation: i.e. constant load
2. Turbine steam requirement as per LANL.: 55,00lbs/hr @400psi, 750 degF, Enthalpy: 1390 Btu/lb.
3. Enthalpy of 1390 Btu/lb. (Steam Heat Content) ASME Steam Tables 400psi, 750 deg F steam tables
4. Natural gas boiler efficiency given by LANL: approx: 82%,

RESOURCE EVALUATION

Regarding forest products available in Northern New Mexico

Prepared for

Los Alamos County

July 14, 2008

Prepared by:
Rob Davis

Forest Energy Systems

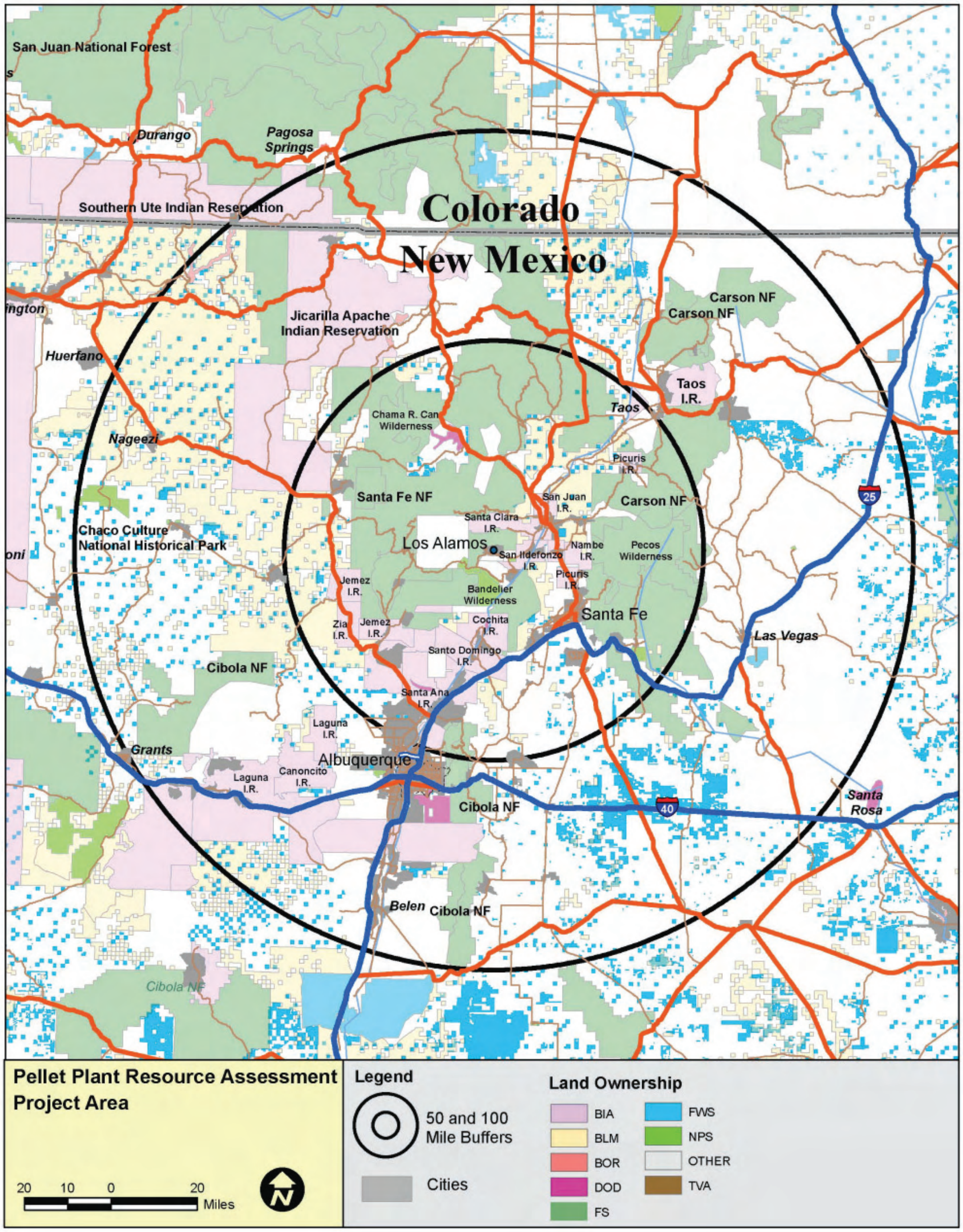
Table of Contents

I. Introduction

An analysis of the available wood resource in Northern New Mexico was undertaken to determine the available long-term supply for a biomass energy system in Los Alamos, NM. This Resource Evaluation gives an up-to-date tally of the quantity of forest products available from all sources within a range deemed economical for a biomass facility. The map below displays the geographic region considered. A 50 mile radius and a 100 mile radius were investigated. The supply of wood in the immediate future is not reflective of what will be sustained annually over decades to come. The current production has been severely curtailed due to lack of market for the materials from the forest. As additional markets develop for the various materials, the land management plans will reflect the volume of acres that are in need of treatment and the volumes of materials available will increase.

Forest materials were the primary consideration of this study. Los Alamos is surrounded by forests of various species from a variety of land ownerships. In all cases, there is a great need to improve the heath and safety of the forests. The materials from the resulting treatments will comprise the available biomass. Many years will be required to treat the volume of acres that need to be restored. In addition the annual growth of the forests will increase both the demand for treatment and the available volumes.

The added consideration is the social will to perform these treatments and remove the residuals. Due to the conflicts in the 90’s there is some concern about the security of supply due to the potential recurrence of this conflict. This was also explored.


San Juan National Forest
Durango
Pagosa Springs
Southern Ute Indian Reservation
Colorado
New Mexico
Jicarilla Apache Indian Reservation
Carson NF
Carson NF
Huerfano
Taos I.R.
Taos
Chama R. Can Wilderness
Nageezi
Picuris I.R.
Santa Fe NF
San Juan I.R.
Carson NF
Santa Clara I.R.
Chaco Culture National Historical Park
Los Alamos
San Ildefonzo I.R.
Nambe I.R.
Pecos Wilderness
Picuris I.R.
Jemez I.R.
Bandelier Wilderness
Santa Fe
Zia I.R.
Jemez I.R.
Cochita I.R.
Las Vegas
Santo Domingo I.R.
Cibola NF
Santa Ana I.R.
Laguna I.R.
Grants
Albuquerque
Laguna I.R.
Canoncito I.R.
Cibola NF
Santa Rosa
25
40
Belen
Cibola NF
Cibola NF
Pellet Plant Resource Assessment Project Area
20
10
0
20
Miles
N
Legend
50 and 100 Mile Buffers
Cities
Land Ownership
BIA
BLM
BOR
DOD
FS
FWS
NPS
OTHER
TVA

II. Biomass

Biomass is technically any organic non-fossil material. This includes any plant or animal materials including trees, crops, urban green waste, municipal solid waste, dairy waste, etc. Every type has its unique characteristics, but in general they are all expensive to transport due to the low energy density and we have therefore focused on local biomass, which is forest biomass. Although all sizes of trees and all parts of the trees are technically biomass, common usage by land managers has defined biomass as that material that has little other use for conventional forest products. The tops and limbs from larger trees and the small diameter trees that have no other higher value market. Forests currently require treatment to reduce fire hazard to both communities and wildlife and to restore more natural forest regimes. The value of our forest resources is increasing, so conventional forest products are also needed. But the primary basis of forest management now is restoring and maintaining the health and safety of our forests.

The Federal Government has defined woody biomass as the by-product of management, restoration and hazardous fuel reduction treatments, including trees and woody plants (i.e., limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment).

III. Forest Biomass Characteristics

Forests are comprised of a variety of species, all of which possess different physical characteristics and require different types of treatments. The predominant species in northern NM are ponderosa pine, pinon, juniper, white fir and douglas fir. The characteristics vary depending on the species as well as the location of growth. Moisture, Btu, ash, density, ash fusion temperature and chemical content are all variables that affect a biomass energy system. These characteristics also vary from tree to tree within a species. A biomass system therefore must allow for and function within the range of this variability or the biomass must be prepared in some manner to provide more consistency in the fuel.

As an example; Ponderosa pine has an average Btu / dry ton of 8,250, but it varies from 8,000 – 8,500. The moisture content of small diameter ponderosa pine averages 55%, but samples from across the forest will run from 49% - 63%. Chemicals may vary depending on soils where the tree grew. Not often is there any amount to create problems, but there is variation.

Ash content also varies greatly depending on both which part of the tree is utilized and how clean the material is maintained during harvest. Ash is inorganic material that is a part of the tree or is introduced during harvest but the presence of ash during combustion and removal of ash from a boiler are critical to consider during design.

IV. Biomass Harvesting and Storage

The ability to perform forest treatment work in the forests is seasonal and the season varies, generally depending on the weather. The forests may be closed to treatment due to conditions that are too wet or too dry. If it is a wet season or a mild winter with moisture and unfrozen soil, it may be too wet and equipment in the forest would damage roads and terrain due to muddy conditions. If it is too dry, there is a potential fire hazard from in woods activity. There are also seasonal closures due to wildlife, such as goshawk nesting times. A biomass facility must therefore plan to be out of the forest at various times during any year at least 3 months. This doesn't normally occur in one time span, but that is a potential as are periods longer than 3 months.

Biomass must therefore be obtained when the forests are open and stored to provide a consistent supply throughout the year. There are several considerations for deciding the best plan for storage and for utilization from the stored supply. Logs can be stored longer than chips and provide a good fall back position when all other materials are depleted. They do not deteriorate rapidly during storage or create as great a fire hazard. Wet chips or ground material are far more susceptible to problems if stored over 3 months. They will begin to decompose in the pile and also have more of a tendency for internal combustion. It is therefore recommended that any material of this type be used in a cycle of shorter than 3 months.

When removing material from the forest, the highest transport load volumes are obtained from logs. Chips would be next in density, ground slash material next and slash last. There are also balers available, but it has not been proven that they improve the economics of biomass removal and storage for reasonably short haul distances. Energy density of biomass is the key and therefore dry, densified material is the most economical to ship and store, but there are no proven processes for accomplishing these tasks in the forest. Therefore, logs, chips and ground material will all have a place in a biomass fuel plan and must be stored and on hand to assure a year around supply of biomass fuel.

V. Fuel Preparation, storage and material handling

Since biomass from the forest has various characteristics, fuel preparation is required to assure fuel consistency and consistent boiler performance. The primary concerns are size, density, moisture content and ash content. The preparation can occur before or after the bulk storage. Preparation can include all of the steps of drying, size reduction and densification, or any one of them. The fuel preparation is determined by the storage, material handling and boiler. It requires three times as many truck loads of chips to equal the energy content of a truck load of densified pellets. It requires four times the storage volume for

comparable energy contents of chips vs. pellets. Therefore, depending on the distance that the material must be transported, the area available for storage and the boiler various preparation is suitable and various design
The drier and smaller the particle size, the easier the combustion and generally the cleaner and more efficient the combustion and the boiler heat exchange.
Therefore, a combination of economics and performance dictates the optimum fuel solution.

VI. Potential forest residues planned treatments and resulting volumes

a. State & Private Lands

The State Forest Service has evaluated the volumes that exist in Rio Arriba and Sandoval Counties. Table 25 and Table 26 are the results of that evaluation. The Tables are in CCF which equal approximately 2.5 – 3 tons each.

Table 25. Rio Arriba County Growing Stock Net Volume (cubic feet).

Forest Type	**Volume (2-inch size class)**										**Total**
	5.0-6.9	**7.0-8.9**	**9.0-10.9**	**11.0-12.9**	**13.0-14.9**	**15.0-16.9**	**17.0-18.9**	**19.0-20.9**	**21.0-28.9**	**29.0+**	
Ponderosa pine	663,278	834,752	1,451,528	1,531,764	587,201	0	0	0	0	0	**5,068,524**
Douglas-fir	1,743,821	2,561,144	875,164	2,408,421	1,507,601	3,336,402	0	4,387,372	0	0	**16,819,926**
White fir	512,921	1,586,853	1,994,875	1,509,456	4,633,982	2,558,242	5,441,897	7,933,585	4,112,315	4,011,373	**34,295,499**
Aspen	7,283,995	7,214,690	3,655,908	4,250,111	2,532,546	2,147,412	3,889,604	919,085	8,962,401	0	**40,855,752**
Spruce	4,436,629	8,203,432	11,154,055	12,318,781	13,918,077	10,435,070	4,825,960	5,748,619	0	13,537,660	**84,578,283**
Spruce-fir	3,937,129	6,599,559	8,690,584	9,760,028	11,992,140	7,065,293	5,145,286	3,571,061	3,253,073	0	**60,014,153**
Total	**18,577,774**	**27,000,430**	**27,822,115**	**31,778,561**	**35,171,547**	**25,542,418**	**19,302,746**	**22,559,721**	**16,327,789**	**17,549,033**	**241,632,136**

Table 26. Sandoval County Growing Stock Net Volume (cubic feet).

Forest Type	Volume (2-inch size class)									Total
	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-28.9	
Ponderosa Pine	0	735,229	0	2,530,859	1,815,081	1,194,944	3,083,877	0	0	**9,359,989**
Douglas-fir	1,075,285	772,825	3,191,291	2,972,598	2,834,340	4,006,743	0	2,179,461	4,053,341	**21,085,883**
Spruce-fir	2,479,452	3,651,105	5,693,244	6,635,086	8,282,300	8,386,317	5,529,795	1,927,526	0	**42,584,825**
Blue spruce	128,594	0	262,348	624,004	1,534,932	2,113,421	0	2,839,722	3,930,840	**11,433,860**
Total	**3,683,330**	**5,159,160**	**9,146,882**	**12,762,546**	**14,466,653**	**15,701,425**	**8,613,672**	**6,946,709**	**7,984,181**	**84,464,557**

In addition, the State evaluated the Products other than Logs (POL) and biomass that is available from forest projects. It is estimated that they would approximate an additional 30%.

b. Tribal

Low stumpage values and lack of market has prevented the tribe from regular commercial sale offerings. The Santa Clara Pueblo Forest & Management Plan indicates a yield of 3.1mmBdft annually of sawtimber. Stocking levels dictate high removal rates for 10.0 - 15.0" trees to achieve desired post-harvest stocking. This harvest would result in biomass materials from the smaller material and from the tops and slash from the 3.1 mmBdft of timber (24,800 green tons) in approximate quantities of 6,400 green tons annually. In addition, there may be POL available, the smaller trees that require removal for forest restoration. Although there has been no calculation, the volumes from POL and biomass are usually 3 – 5 times the volume of sawtimber resulting in 73,000 to 124,000 green tons annually..

c. Federal

A. USFS

Due to a court ruling, Forest Management Plans are in the process of being revised. The Santa Fe National Forests is expected to be released soon. The quantities utilized in this analysis are from the previous plan which the new plan is expected to follow to a great degree. Sustained Yield and Allowable Sale Quantity numbers are calculated during the planning process, but in the recent past these numbers have had little bearing on actual timber sales. Sales will increase if there is a market and bidders on the sales.

USFS

Santa Fe	Ave Annual
Project Treatment Acres	8,678
Sum of CCF Volume 5.0 to 8.9" Trees	11,973
Sum of CCF Volume 9.0 to 11.9" Trees	15,864
Sum of CCF Volume 12.0"+ Trees	4,747
9+ CCF	20,611
5+ CCF	32,584
OD Tons	86,462

Carson	Ave. Annual
Project Treatment Acres	10,811
Sum of CCF Volume 5.0 to 8.9" Trees	42,838
Sum of CCF Volume 9.0 to 11.9" Trees	21,011
Sum of CCF Volume 12.0"+ Trees	3,333
9+ CCF	24,344
5+ CCF	67,183
OD Tons	178,498

It is estimated that approximately 50% on the Santa Fe and 30% on the Carson fall within the 50 mile radius of Los Alamos. An additional 30% of the Santa Fe and 20 % of the Carson fall with 100 miles. Although at this time there is not significant market for the sawtimber, for this study, it was assumed that the sawtimber would be utilized by existing or new sawmills and the material <9" plus the tops and slash would be available for biomass types of utilization. Therefore, on the Santa Fe there would be 11,973 CCF or 33,524 green tons of POL and 86462 OD tons available from project treatments. On the Carson 42,838 CCF of 119,946 green tons and 178,498 OD tons available.

Based on projects being performed across the forest over the next 20 years, on the Santa Fe there would be an average of 16,762 green tons and 43,231 ODT or 51,612 dry tons total available annually within 50 miles. On the Carson, there would be 35,984 green tons and 53,549 OD tons or a total of 71,541 dry tons available within the 50 miles radius. A total of 123,153 dry tons is available from the USFS.

Within the 100 mile radius, the average annual resource available would be 82,580 dry tons from the Santa Fe NF and 119,235 dry tons from the Carson or a total of 201,815 dry tons.

Although these quantities are available based on the forest plans, they are not a certainty. The availability and cost would vary significantly depending on success of timber sales. If there were no timber sales sold, the slash and the tops wouldn't be available.

B. BLM

The plan for the Taos Field office calls for potential harvest of 2,000 acres per year on the average, primarily from the pinon juniper in the area north of Los Alamos and within 50 miles. This plan has not been approved, but is likely. This would yield an average of 3,000 cords per year or at least 36,000 oven dry tons.

C. Valle Caldera

Within a year the Trust expects to be completing their forest plan and thereafter begin implementing regular treatments, harvesting small diameter material (<16"). The Trust provided the following: We have about 58,000 acres of forest. About 2/3 is over stocked with trees 9-16" (ponderosa pine, mixed conifer; the mixed conifer varies in composition.) Although developing plans for forest management has not been the priority, that livestock management and recreation have been, I have been progressing with inventory etc. As soon as I get the direction I will be ready to initiate an efficient planning process for preserve-wide management. We have been meeting with the Forest Service and a variety of stakeholders to form a strong collaborative group to better access available funding for treatment. We have already initiated our cultural clearances for some priority areas. I am very optimistic that we will be on the ground starting an aggressive annual implementation schedule for forest restoration and risk reduction by autumn 2010.

It would be anticipated that the plan would be to restore the overly dense forest within 20 years; and would result in 1,943 acres treated annually during the initial restoration treatment. This would result in sawtimber, POL and biomass material being available. At this time there is little market for any of those classifications other than the over 10" sawtimber. The remaining materials would be available for boiler fuel. The POL (under 9.9") and Biomass (slash, tops and under 5") average annual volumes would be approximately 13 green tons and 8 oven dry tons per acre respectively, or 25,259 green tons of POL and 15,544 dry tons of biomass for a total of 28,173 - 40,160 dry tons annually.

d. Mill Waste

There is no significant volume of available mill waste at this time. The small mills and viga mfg operations do not generate significant quantities and don't have an economical means of storing, loading and transporting materials to the boiler site. This material could be utilized for pellet fuel and will be taken into consideration for this purpose.

NEW MEXICO TIMBER SUPPLY SUMMARY

Study/Ownership Area Covered	**Growth Rate or Long Term Availability**	**(MMBF/Year)**	**Comments**
Jicarilla Apache 10 Year Forest Management Plan	Reservation	8.0	Based on 10 Year Forest Mgmnt Plan for 1996 - 2005; Short term availability per Rob Davis Timber is 90+% Ponderosa Pine and likely a larger average log size than other sources.
Santa Clara Pueblo Forest & resource Resources Management Plan MMBF total; 3.1	Reservation	3.1	October 2005 draft integrated management plan. 4.2 MMBF on land <40% slope. Stocking levels dictate high removal rates for 10.0 - 15.0" trees to achieve desired post-harvest stocking.
State & Private Lands in NM -			
Reg. 2 - Bernalillo, Cibola, Los Alamos, standing McKinley, Rio Arriba, Sandoval, Santa Fe, 2002		27.8	Based on 2% net growth and a timber volume of 1,390,666 MBF.

		study Torrance based on USFS FIA data with 1994 – 1998 timber inventory.
Santa Fe National Forest 5 Year Veg. Treatment Plan	8.9 19,823 CCF of Scribner per	Based on annual removal of 9"+ trees and a 4.5 board foot cubic foot conversion factor. Note: this volume is very heavy to 9 - 12 inch trees (70% of volume).

X. Assurances / Collaboration

The bulk of the biomass available will be from public lands. Although there is a great need to perform restoration and a consensus that it should occur, there is still no firm assurance available to obtain a long-term guarantee for the resource. There are currently several tools available to the federal land managers to contract for the removal of the materials including 10 year contracts. But the best assurances are to participate or procure your wood supply from those that participate in local collaboratives. The consensus derived from these groups provides the social license to perform the treatments and the best assurance of a long-term wood supply. Through these collaboratives and the development of markets, the land managers will perform the volumes of work that are needed and thus supply the volumes of wood indicated as available.

XXI. Summary

There is a large volume of available biomass within a radius that would be acceptable for an energy facility in Los Alamos. Within the 50 mile radius the sources of wood can provide 193,726 dry ton from timber < than 10" and slash on a portion of the Santa Fe National Forest, Carson National Forest, the Valles Caldera Trust, and Santa Clara Pueblo. Within a 100 mile radius of Los Alamos the sources of wood expand to include nearly the majority of the Santa Fe National Forest except for the far east side, additional Carson NF resource and additional private and reservation lands. The 100 mile radius increases the supply of wood available in the immediate future, to an estimated 272,388 dry tons annually.

A summary of available biomass to fire a boiler in Los Alamos and sources for the forest products and the expected volumes available can be found in Table 3 below. For all sources, the historic volumes available reflect an average volume per year sold. The future volume expected to come from federal land is not an annual average, but rather reflects the total of planned projects covered by NEPA. The volume will likely be offered over a period of years. Likewise tribal land displays a greater than 20 fold increase from historic to future volume levels. This future volume number is inflated by one large sale to be offered by the Navajo and does not reflect an annual average. The newly approved Resource Management Plan for the Navajo projects close to 16 MMBF (128,000 green ton) will be harvested annually, but a historic track record for this is lacking. Only in the case of state land, private land and mill waste does the future volume reflect an annual average volume available.

Pellets are currently available from one small instate producer in Milan, NM. A new plant is in limited production in Raton. Three additional plants are scheduled to begin operation in '09. A 50,000 ton per year plant near Tularosa, a 35,000 ton plant on the Jicarilla Reservation near Los Ojos, and a 35,000 ton per year plant in Espanola. Both of the northern NM plants have the ability to double in capacity if the market warrants. Therefore, the resource is available for those plants and there would be 70 – 140,000 tons of capacity within a 90 mile radius. And an additional 80,000 tons of capacity from 200 – 230 miles for backup, although needing it wouldn't be anticipated.

It would appear that with the USFS, Valle Caldera and even potentially some activity on the Jemez Pueblo land, there is a firm resource that has the potentially to be larger if markets are developed.

Table 3. – Summary of Available Average Annual Volume (ton)

SOURCE	50 miles	100 miles	
Federal	159,153	237,815	Dry tons
State & Private			
Valles Caldera	28,173	28,173	
Tribal	6,400	6,400	
TOTAL	193,726	272,388	Dry ton
mill waste			dry ton
Pellets		95,000	

XXII. Conversions and Abbreviations

CCF = hundred cubic feed, MCF = thousand cubic feet, MMCF = million cubic feet
MBF = thousand board feet, MMBF = million board feet
DBH = diameter breast height
2 CCF = 1 mbf = 2 cords = 8 green ton = 4 dry ton, 1 load = 4 mbf
1 cubic foot sawdust = 17 lbs

XXIII. References

Web sites

Schedule of Proposed Action, Carson National Forest. USDA – Forest Service. http://www.fs.fed.us/sopa/forest-level.php?110302

Schedule of Proposed Action, Santa Fe National Forest. USDA – Forest Service. April–June, 2008. . http://www.fs.fed.us/r3/sfe/projects/projects/SOPA/Apr_June_2008.pdf

CROP Report, 2006
http://www.forestsandrangelands.gov/Woody_Biomass/supply/CROP/documents/roms/New_Mexico_CROP_PowerPoint_Summary_Final.pdf

http://www.forestsandrangelands.gov/Woody_Biomass/supply/CROP/documents/roms/New_Mexico_CROP_ROMs_Summary.pdf

Interviews (personal, phone or e-mail)

Marie E. Rodriguez, Natural Resource Coordinator - Valles Caldera Trust -
2201 Trinity Drive, Los Alamos, NM 87544, (505) 660-1194;
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Ann Bradley, The Nature Conservancy
Naomi Engleman , Executive Director, New Mexico Forest Industry Association

Mike Debonis - Southwest Region Director, The Forest Guild

Appendix E. Sample Department of Energy Request for Proposal for an On-Site Solar Installation with Power Purchase Agreement[1]

Description of Services and Background

The Los Alamos County Department of Public Utilities (DPU) is requesting proposals from a third-party developer for the design and installation of a ___ MW solar system. The DPU goals include ___. The solar system will be procured, financed, installed, owned, operated and maintained by the third-party developer. The solar system will be a ___ system. There are ___ acres available for the system. DPU will purchase the electricity through a ___ term-year PPA. DPU [will/will not] retain the RECs.There [will/will not] be net metering.

The Contractor will be provided use of DPU [land/building roof-top] through a [term]-year easement. A Site Access Agreement will contain site access, security, environment and safety requirements, as well as other pertinent information.

The solar system is restricted to ___ types. Other solar system restrictions include [height, reflectivity, other visual impact concerns, etc]. Inverters must be on California's approved inverter list, (http://www.consumerenergycenter.org/cgi-bin/eligible_inverters.cgi).

There [is/is not] road access to the site. Other site requirements include: [roads, fence, meter(s), etc]. Interconnection information is as follows: [type, capacity, location of transformer; transmission line, other electrical infrastructure requirements, etc].

The PV system must be operational no later than [date, include any incentive related deadlines]. The third-party developer is responsible for all incentive related applications and contracts. [The third-party developer is also responsible for REC sales.]

Period of Performance

The PPA contract length shall be [Term] years with a [Term]-year easement. Construction shall begin no later than [Date], with commissioning complete and system operational by [Date]. The PPA contract length may be increased if federal contracting authority is extended.

National Environment Protection Program

The DPU will carry out all Environmental Assessment (EA) or EIS requirements associated with compliance with National Environmental Policy Act (NEPA). Construction shall not commence until the Contractor is notified that NEPA compliance requirements are completed. The Contractor must fulfill any and all requirements from the EA/EIS such as the Findings of No Significant Impact (FONSI).

(Note: It may be preferable to have completed NEPA process before issuing RFP since there will likely be NEPA-related requirements.)

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[1] Modified from DOE Sample RFP, National Renewable Energy Laboratory, Version 6 (March 5, 2008). This template will require expansion to include Laboratory-specific security, electrical interconnection, access, and other yet-to-be-determined requirements.

Permits and Responsibilities

The Contractor shall, without additional expense to DPU be responsible for obtaining any necessary licenses and permits, and for complying with any Federal, State, and municipal laws, codes, and regulations applicable to the performance of the installation, maintenance, and operations work under this contract. The Contractor shall also be responsible for all damages to persons or properties that occur as a result of the Contractor's fault or negligence. The Contractor shall also be responsible for all materials delivered and work performed during installation and throughout the contract term.

Construction

The PV system shall be constructed to meet the following milestones and deadlines:

The contractor shall submit final plans and schedules for the PV System installation to the DPU for review and approval. Not withstanding any other provision of this contract, DPU shall incur no liability as a result of its review and approval of any plans and schedule. The Contractor shall meet the site access, safety and other requirements contained in the Site Access Agreement.

Right to Enter

The right is reserved by DPU, its agents, employees, or representatives to enter upon the premises for the purpose of inspection and when otherwise deemed necessary for the protection of the interests of DPU, and DPU shall be responsible for the actions of its agents, representatives, or employees arising directly as a result of such inspection, or entry.

Design, Installation, Inspection, Commissioning, and Acceptance

The system design and installation must substantially conform to the system proposed in the Contractor's Offer, unless DPU gives approval to make substantive changes.

The Contractor shall submit design documents for approval; including drawings, details of any specifications, electrical single-line diagrams, and complete product literature. A structural engineer shall stamp structural drawings, and an electrical engineer shall stamp electrical drawings. Five hard copy submittals shall be submitted, as well as a CD with electronic copies of all documents. The Contractor may not proceed with construction until approval of the design submittal has been received from DPU. Upon completion of the system, an updated set of the design documents reflecting all changes shall be provided.

DPU and/or contractor personnel acting on behalf of DPU may inspect the system at any time during construction or after the system has been put in operation. The Contractor may be ordered to stop work, or shut the system down, if unsafe conditions or code violations are noted. DPU will inspect the system prior to acceptance. DPU reserves the right to reschedule the proposer's work requiring service interruption at any time if such interruption might adversely affect DPU operations.

The power purchase phase of the contract will not begin until the DPU Contracting Officer agrees that the system has been fully commissioned by verifying system performance and ensuring that all safety systems and disconnects work and meet all DPU requirements. DPU will also verify that the system is complete, safe, functional, constructed to all code requirements, does not interfere with DPU or tenant operations, and otherwise meets all contract and associated requirements. The Contracting Officer will notify the Contractor of this decision by letter. The Contractor should anticipate roughly two weeks between notifying DPU of completion, and DPU acceptance. The contractor shall use the latest National Electrical Code (NEC) and other applicable federal, state, and industry standards as applied to this project. All work performed by Contractor shall be guided by these specifications in conjunction with this statement of work. The Contractor is responsible for reading and understanding the specifications and statement of work.

The PV system will be operated in parallel with the electricity supplied by DPU. The contractor will provide all inverters, transformers, switchgear, wiring and protective devices to connect to the base electrical distribution system. The contractor shall take action to ensure operation is compatible with the DPU electrical distribution system. Any proposed modifications that would affect the DPU electrical distribution system will require the approval of DPU. The PV system shall not have any adverse effects on the DPU electrical distribution system, or on loading, power factor, voltage levels, transformers, structural integrity, protection device coordination, or the operation of any base electrical equipment.

The contractor will be responsible for all site modification required for the installation. See attached drawing [and soils report] for existing conditions. [Installation of electrical conduit on the surface of the ground is acceptable.] The proposer shall obtain a written excavation permit from DPU site operations before commencing any digging or excavation on the installation. The excavation permit will contain requirements normally applied to similar excavation work on the installation. The Contracting Officer or designated representative will notify the contractor as to reasonable time periods for applying for an excavation permit.

The site shall be protected on all sides to prevent unauthorized persons from entering the area, tampering with the PV system and to protect against the danger of electric shock. DPU shall approve the type of fence.

Metering

DPU will own and read the PV production meter. Contractor shall coordinate the installation of the meter. The contractor shall include meter readings in the [monthly or quarterly] invoice. The meter shall include a modem for remote data collection and web site display that is accessible by DPU. System performance shall include at a minimum solar irradiance, DC power, AC power, ambient air temperature, PV cell temperature and AC energy during different monitoring periods. A sample of the proposed web site shall be provided in the proposal. [Add any other metering requirements.]

Rebates and Other Subsidies

The Contractor shall apply for and receive all rebates and other subsidies.

Interconnection, Net Metering, and Insurance Requirements

The contractor shall meet all interconnection requirements of the DPU and is responsible for all required contracts, including those associated with Net Metering. The contractor shall also meet all the insurance requirements laid out by the DPU.

Renewable Energy Certificates

RECs will be [retained by DPU or sold]. RECs are defined as all renewable and environmental attributes of a renewable generating facilities, including greenhouse gas and all other emissions.

PV System Operations and Maintenance

The Contractor is responsible for the operation and maintenance of the PV system and for ensuring that the PV system meets all specified performance requirements. An O&M manual shall be provided (electronic and hard copy) to DPU so that they can monitor the requirements. Should the system fail to meet all specified performance requirements, the contractor is responsible for any resulting financial or other obligations. All outages shall be reported to DPU and repairs shall be coordinated with the DPU site operations staff.

PV system maintenance, includes but is not limited to cleaning the system, replacing broken or worn out system components such as the inverter – including those components that have a degradation level greater than specified, performing maintenance in accordance with equipment manufacturer recommendations, and ensuring that every part of the system is operating according to design, producing the maximum amount of power possible and free of power quality issues. The contractor shall schedule maintenance and repair of the PV system at times when system output is at a minimum level [early morning or late afternoon].

Disposition of PV System

The parties will negotiate a mutually agreeable plan for the PV system both at the end of the [term]-year contract and at the end of the [term]-year easement. Options include, but are not limited to: purchase of the system at fair market value, system removal and site rehabilitation, contract extension or a solicitation for a new contract.

Contractor's Responsibility for Restoration

Upon completion of the PV System installation and during any O&M work, the premises shall be restored as soon as practicable by the Contractor at the Contractor's own expense, to the same condition that existed at the time Contractor began work under this contract.

Upon expiration or termination of this Contract, DPU shall either direct the Contractor to remove the PV System from the premises and restore the premises to a condition subject to DPU approval or allow the Contractor to abandon the PV System in place as long as abandonment is consistent with applicable safety rules and reasonable engineering practices.

Removal of the PV system and restoration of the premises (if appropriate) shall be without expense to DPU and within a timeframe that is subject to DPU approval. In the event the Contractor shall fail, neglect or refuse to remove the PV system and restore the premises, DPU shall, consistent with applicable law, have the option either to take over the PV system as the property of the Government, without compensation, or to remove the PV system and perform the restoration work all at the expense of the Contractor. In no event shall the Contractor have any claim for damages against the DPU or the Government, their officers, agents, or employees, or their successors in interest, on account of taking over of the PV system or on account of its removal.

Price Schedule

The PV system will generate electricity, measured in kilowatt-hours (kWh) and RECs. DPU will purchase the electricity [and RECs]. The maximum acceptable price is [cents/kWh]. Escalation [is/is not] acceptable. The DPU [will/will not] keep the RECs. See the attached cost proposal form for requested price information.

Tax Incentives and Tax Exemption

Purchases by the federal government are exempt from state and local taxation. DPU tax exemption certificate will be provided to the resultant contract awardee. The Contractor may take advantage of any tax incentives that are available to it as system owner; the Contractor is responsible for submitting supplemental terms and conditions that are consistent with maintaining the appropriate tax status.

Indemnification – Contractor's Liability for Personal Injury and Property Damages

The Contractor shall indemnify, defend, and hold DPU, their employees, agents, representatives, affiliates, and successors, harmless against any and all claims, demands, liens, lawsuits, judgments, or actions of whatsoever nature that may be brought on account of the installation, maintenance, operation, repair, or replacement of the PV system or any component equipment of the system.

Other Terms

Termination for Convenience

DPU reserves the right to terminate this contract, or any part hereof, for its sole convenience. In the event of such termination, the Contractor shall immediately stop all work hereunder and shall immediately cause any and all of its suppliers and subcontractors to cease work. If the contract is terminated in accordance with the Termination for the Convenience of the Government clause after the Contractor has begun installation or otherwise incurred substantial costs, or after the power purchase phase of the contract has begun, the termination will be subject to a negotiated settlement, with DPU having right of first refusal for the equipment purchase. Depending on the circumstances, this may involve reimbursement of unamortized costs or purchase of the system at fair market value. Liability associated with rebates, REC buys and/or other associated incentives and contracts will be considered in the negotiated settlement. The Contractor shall not be paid for any work performed or costs which reasonably could have been avoided.

Termination for Cause

DPU may terminate this contract, or any part hereof, for cause in the vent of any default by the contractor, or if the contractor fails to comply with any contract terms and conditions, or fails to provide DPU upon request, with adequate assurances of future performance. In the event of termination for cause, DPU shall not be liable to the Contractor for any amount for supplies or services not accepted, and the Contractor shall be liable to the Government for any and all rights and remedies provided by law. If it is determined that DPU improperly terminated this subcontract for default, such termination shall be deemed a termination for convenience.

Assignment

The conditions of this Contract shall extend to and be binding upon and shall inure to the heirs, representatives, successors, and assigns of the contractor. The Contractor shall neither transfer nor assign this contract or any Contractor furnished personal property on the premises, nor sublet the premises or any part of the property, nor grant any interest, privilege, or license whatsoever in connection with this contract without the express permission of DPU.

Notification of Ownership Changes

1. The Contractor shall make the following notifications in writing:
    a. When the Contractor becomes aware that a change in its ownership has occurred, or is certain to occur, that could result in changes in the valuation of its capitalized assets in the accounting records, the Contractor shall notify the DPU Contract Administrator within 30 days.
    b. The Contractor shall also notify the DPU Contract Administrator within 30 days whenever changes to asset valuations or any other cost changes have occurred or are certain to occur as a result of a change in ownership.

2. The Contractor shall –
    a. Maintain current, accurate, and complete inventory records of assets and their costs;
    b. Provide the DPU Contract Administrator or designated representative ready access to the records upon request;
    c. Ensure that all individual and grouped assets, their capitalized values, accumulated depreciation or amortization, and remaining useful lives are identified accurately before and after each of the Contractor's ownership changes; and
    d. Retain and continue to maintain depreciation and amortization schedules based on the asset records maintained before each Contractor ownership change.
3. The Contractor shall include the substance of this clause in all lower tier subcontracts under this Contract that meet the applicability requirement of FAR 15.408(k).

Invoice Requirements and Payment

Payment will be made on a [monthly or quarterly] basis. The invoice must meet the requirements described herein. Invoices must reflect actual consumption as measured by the meter during the [month/quarter] and the awarded per kWh price. The Contractor shall coordinate meter readings with [Serving Utility]. During each quarter, the invoice should list output sold to DPU to date and cumulative output sold to DPU for that quarter.

Invoices must contain the following information:

1. Meter reading (in kWh)
2. Electricity price
3. Building name, address, or other descriptive information to identify the location
4. Contractor's name and remittance address

Invoices shall be submitted [monthly or quarterly] to: ______

Confidentiality

The awarded contract, to include prices, will be treated as a public document. Offers that do not result in award will be protected as confidential to the extent permitted by law. The awardee's offer, except for price information included in the contract, and other proprietary information from the awardee (Contractor) that is marked "proprietary" or "confidential" will be protected as confidential to the extent permitted by law. Nothing in this provision will be construed to prevent DPU from providing reference information regarding performance and integrity of the Contractor on request.

Instructions to Offerors

1. A pre-proposal conference/telecon will be held [date]. A site visit will be held [date]. The proposal must include the RFP title and number, name of your organization and project manager (with postal address, telephone and fax numbers, and email address). The title should be succinct and capture the essence of your offer.
2. Formatting instructions
    a. A page is defined as one side of an 8 ½" x 11" sheet of paper.
    b. Use a 12-point font.

    c. Maintain at least 1-inch margins on all sides.

    d. Copies may be either single or double sided.

3. A technical proposal in an original and [___] copies directed toward meeting the requirements of this RFP and evaluation criteria (see item * below)]. The technical proposal shall be organized in the following sections:

   [Section Descriptions]Each section shall be a maximum of [x] pages (resumes not included in page count) and the total proposal shall not exceed [x] pages.

4. A completed "Price Proposal" form (in an original and [X] copies submitted with the offer. An individual offeror's price proposal standard format can be used if the data included is substantially the same as the Price Proposal Form. The offeror's price and delivery terms must be valid for [X] days from the date of the offer. The price proposal should include support documentation.

5. This solicitation does not allow the submittal of facsimile or electronic proposals.

6. This solicitation does not commit DPU to pay costs incurred in the preparation and submission of a proposal in response to this RFP.

Solicitation Provisions

1. Late submissions, modifications, and withdrawals of offers

   Offer modifications will be considered on a case-by-case basis and are subject to approval. Offers may be withdrawn by written notice received at any time before award. Offers may be withdrawn in person by an offeror or an authorized representative, if the representative's identity is made known and the representative signs a receipt for the offer before award.

2. Disclaimer

   NEITHER DPU NOR ANY OF ITS CONTRACTORS, CONTRACTORS, OR THEIR EMPLOYEES MAKE ANY WARRANTY, EXPRESS OR IMPLIED, OR ASSUME ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS FOR ANY PURPOSE OF ANY OF THE TECHNICAL INFORMATION OR DATA ATTACHED OR OTHERWISE PROVIDED HEREIN AS REFERENCE MATERIAL.

3. Solicitation disputes

   DPU will address each concern received from an offer or on an individual basis.

Submission Requirements

Cover Letter

The cover letter shall include the contact person, email, phone number and facsimile number; and identify whether the Offeror is a single entity, partnership, corporation or joint venture, or other legal entity.

Price

The price and estimated annual production shall be submitted using the Price Proposal Form. There shall be no price stipulations (i.e., the price shall not be dependent on factors such as potential REC sale prices).

Past Performance and Experience

List information for all completed (or in progress) PV projects greater than 100 kW. Include customer, name of client contact, location, size and financing arrangement/project type (PPA or other), design and construction time, on-line date, and name of project manager. This past performance information shall be submitted using the Past Performance Information form.

Include a physical description of the project (equipment manufacturer, model, etc), as well as brief discussion of any specific challenges and how they were overcome, including causes for any schedule delays.

Financial Capability

Provide audited financial statements for the two most recent available years. If not available, instead submit a copy of two most recent tax returns or compiled financial statements by an independent CPA. The statements shall be provided for the proposer or the lead/prime firm if a team proposal.

Include an official letter from the financier, confirming the planned financial arrangement, if financing from an outside source is required. If outside financing is not being used, provide verifiable information regarding planned internal financing. Provide a plan that demonstrates the Offeror's (or a partner) ability to fully utilize the federal investment tax credit, as well as all other tax and other incentives.

PV Supply

The Offeror must provide a letter from the PV supplier and/or manufacturer substantiating the availability of PV panels to meet the proposed implementation plan timeline. Also include procurement plans and timelines for inverters and other balance-of-system equipment.

PV System Design, Construction, Performance, O&M

Proposers shall provide a technical description of the proposed PV project and how it complies with all applicable codes (including seismic codes where applicable). Description shall include items such as: type of PV cells, guaranteed power capacity (DC and AC), efficiency, capacity factor, kWh/square feet, mounting including structural information and flat vs. tilted [also roof penetration if applicable], tracking method if any, inverter, balance of system components, interconnection plan, [other important features such as plans to reduce light reflection, minimize PV system visibility, etc.]. The panels and inverters must be UL listed. The panels must carry a manufacturer's warranty of at least 20 years and inverters must come with 10-year warranty.

Other Submission Requirements

A one line diagram of the proposed system with all major components (PV panels and array, disconnects, inverters, transformers, meters, proposed interconnection to existing electrical distribution system at DPU).

1. Estimated monthly energy production as well as representative hourly electricity production for a day in January, April, July and September.
2. Guaranteed PV panel average annual degradation rate.
3. What is the estimated reliability of the chosen system? For example, what is the expected downtime?

4. O&M plan: How often will the system receive preventative maintenance? What are the inverter and other balance-of-system replacement plans?
5. Description of web-based performance monitoring system that is accessible to DPU including equipment requirements, data output, report capabilities.
6. Net metering plans if relevant.

Design and Construction Schedule

An installation plan with a system operational date of no later than [X] is required. Include estimated construction schedule in calendar days, showing significant milestones including the following: project design, review and approval, interconnection application, incentive application, procurement and delivery of PV modules, delivery of inverters, support structures construction, installation of components, construction completion, testing and verifications, turn-key delivery for operations (including training and monitoring and O&M manuals), punch list, completion of as-builts. Include typical lead times for PV and balance-of-system equipment.

Evaluation Criteria

The Offeror's proposal must be deemed to conform to the solicitation requirements, terms and conditions, and the representations and certifications. Notwithstanding any other aspects of the evaluation process, an Offeror who will not or cannot bring its supplemental terms and conditions into conformity will be eliminated from the competitive range, and not receive further consideration.

RFP Minimum Requirements

The Offeror must first meet the guaranteed minimum annual output [and other minimum technical requirements if any] specified in the RFP. Offerors that do not meet the minimum requirements will not be further evaluated.

Price

Price evaluation is based on price per kWh. The total evaluated price will be the present value of the stream of monthly payments the DPU is expected to make to the Contractor over the contract term. Each monthly payment will be calculated by multiplying the projected metered electricity of the solar array times the Offeror's proposed price ($/KWh). The annual cost will be the sum of the monthly payments.

Non-Price Factors

Non-price factors include:

- Factor 1: Past Performance and Experience
- Factor 2: Financial Capability
- Factor 3: PV Supply
- Factor 4: PV System Design, Construction, Performance and Operations & Maintenance
- Factor 5: Design and Construction Schedule
- Factor 6: Miscellaneous Cost and Non-Cost Benefits

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Appendix F. Types of State and Federal Incentives and Renewable Energy Certificate Markets

Corporate Incentives

Accelerated Depreciation – capital investments are recovered through accounting rules that allow for recovery over differing periods of time for different classifications of assets. The time periods are established by IRS rules. Accelerated depreciation therefore allows a company the ability to get a faster return on a renewable investment.

Tax Credits – once taxes are computed for a corporate entity, credits can be applied that directly reduce their tax liability. These incentives are very meaningful and significant for those companies that have sufficient tax liabilities to make use of them (if the company has no tax liability in any given year, they are worthless). Credits have been given for:

- Investment. A percentage of the capital invested in a project becomes a direct tax credit.
- Production Credit. The tax credit is based upon a dollar amount per KWh of renewable electricity produced. This is different from production incentive payments that are available to all entities.
- Sales Tax (NM Gross Receipts) Exemptions. Equipment purchase and installation taxes may be eliminated or reduced.
- Property Tax Exemptions. Typically used to recruit new renewable energy businesses to a region.

Special Programs for Governmental Entities

Federal and state programs have been created that authorize (and fund) the sale of tax exempt bonds by local authorities to construct renewable energy facilities. These are formally referred to as Clean Renewable Energy Bonds (CREBs). Originally authorized by the Energy Policy Act of 2005, an additional $800 million of new CREBs became available through the Energy Improvement and Extension Act of 2008.

Incentives Available to All Entities

Grants and Loans – normally federal, direct grants and loans are available to certain categories of renewable energy projects. Grants rarely cover the entire cost of the project. Loans (and loan guarantees) free up credit in circumstances where renewable energy projects are regarded as too risky for conventional loans and/or reduce costs by offering lower interest rates than commercially available.

Electricity Production Incentives – per kWh payments by state and federal agencies for verifiable renewable energy production.

Renewable Energy Certificates

As shown in Figure F-1, renewable energy generators provide three value propositions: the electricity itself; the incentives that come from state and federal initiatives to promote its generation; and the separate value of the "green attributes" of the power, quantified in the form of the RECs.

Each REC, also known as Green tags, Renewable Energy Credits, or Tradable Renewable Certificates (TRCs), certifies that 1 MWh of electricity was generated from an eligible renewable energy resource. A certifying agency gives each REC a unique identification number to make sure it is not double-counted. The green energy is fed into the electrical grid (by mandate), and the accompanying REC is sold on the open market.

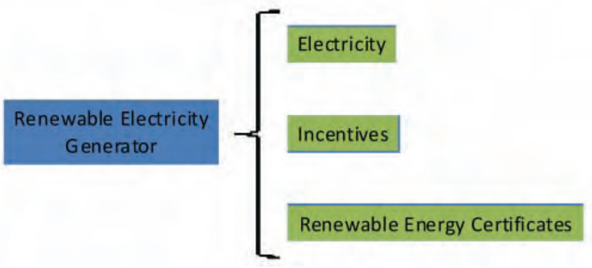

Figure F-1. Valued products of a renewable electricity generator.

There are 2 two types of RECs and each has a different value basis: "Compliance Market" RECs used by utilities to satisfy a state's Renewable Portfolio Standards (RPS) have one set of values and very limited markets; "Voluntary Market" RECs are bought by companies and individuals, and, while regional, have much less stringent generation eligibility requirements.

Compliance Market RECs

RPS programs typically require that each retail power supplier obtain a certain percentage of its total annual energy sales from renewable sources. If these suppliers cannot meet their portfolio requirements, they can purchase RECs from elsewhere to meet their requirements. The retail power supplier is buying the attributes of renewable energy that their state legislators have defined as necessary from other generators. Values for RECs vary considerably.

At present, there is effectively no national, liquid market for these RECs: rather, there are a number of state and regional markets in place. These fragmented markets exist for several reasons:

- The demand for RECs is driven by each state RPS, and no two are alike.
- Each state RPS has differing qualifications for whether or not a REC can be used.
- Each state has differing rules for the "shelf life" of a REC.

State RPS

Figure F-2 presents a quick summary of each state and their respective RPS requirements. The diversity is apparent.

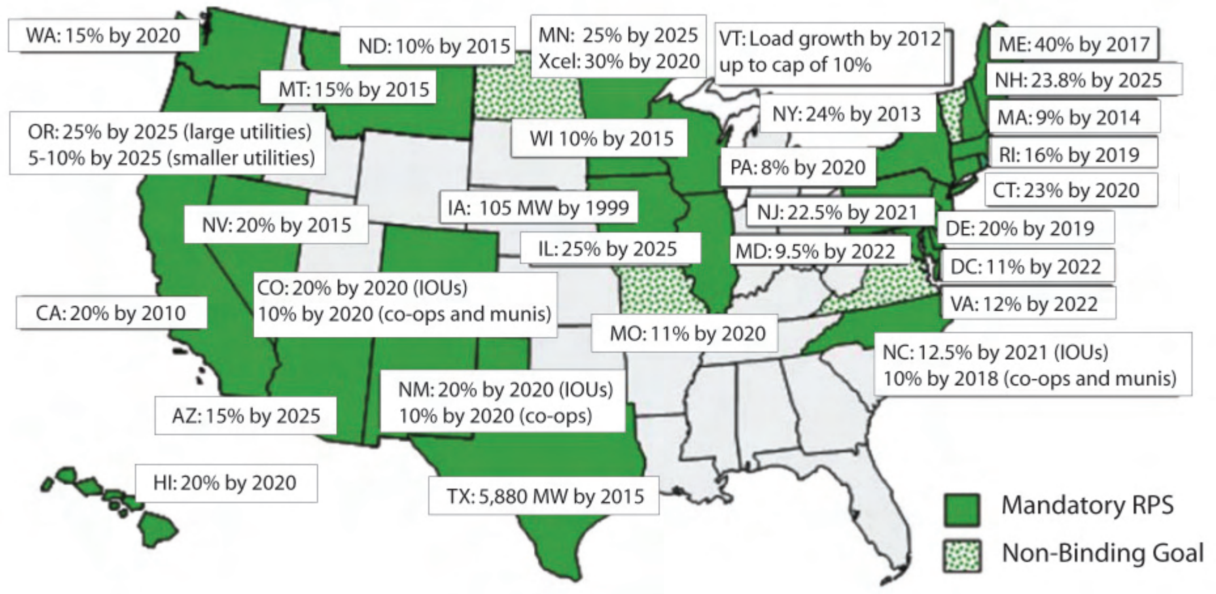

Figure F-2. Renewable portfolio standards by state, as of Q1 2008 (percentages indicate the amount of energy that utilities are required to generate from renewable sources) (Lawrence Berkeley Laboratory).

REC Generation Type Eligibility

RECs are qualified on the basis of renewable generation source and location. Table F-1 presents the renewable sources permitted at the State level. Solar, for example, qualifies everywhere, while fuel cells only qualify in a few states.

REC Geographic Eligibility

In addition to the generation source, location is an important factor in REC eligibility. In some states, the renewable electricity must originate in the state; in others the generation must have an identifiable contract path from an out of state generator to an entity in the state; renewable generation delivered anywhere in the power pool is eligible; but very few states will accept RECs from every State.

Table F-2 presents the geographic restrictions on RECs on a state by state basis.

REC Shelf Life and Banking

RECs are only valid for certain periods of time after they have been generated. Shelf life can be as short as three months (in New England) to as long as four years (in Nevada and Wisconsin).

Some "banking" of RECs is allowed – oversupply in one year can be used for compliance in subsequent years. For example, in Massachusetts RECs can be banked for 2 years; in Delaware, Maryland, and Washington, DC – 3 years.

Compliance Market REC Values

At present, there is no real liquid market for compliance RECs because of the patchwork quilt of differing state rules and requirements. REC sales prices are therefore limited to state or small regional markets. As a consequence, as of October 6, 2008, a REC in DC could be valued as low as 0.6 cents/kWh, while

Table F-1. Generation Source Eligibility for Renewable Energy Certificates by State (NREL)

State	Solar	Wind	Bio-mass	LFG	Biogas	MSW	Geoth.	All Hydro	Increm. Hydro	Small Hydro	Fuel Cells	RE-only Fuel Cells	Ocean/ Wave/ Tidal
AZ	X	X	X	X	X		X		X	X		X	
CA	X	X	X	X	X	X	X			X			X
CO	X	X	X	X	X		X			X		X	
CN	X	X	X	X		X				X	X		X
DE	X	X	X	X	X	X	X			X		X	X
DC	X	X	X	X	X	X	X	X				X	X
HI	X	X	X	X	X	X	X	X				X	X
IL	X	X	X	X					X				
IA	X	X	X	X	X	X				X			
ME	X	X	X	X		X	X	X			X		X
MD	X	X	X	X	X	X	X	X				X	X
MA	X	X	X	X	X	X		X				X	X
MN	X	X	X	X	X	X				X		X	
MT	X	X	X	X	X		X			X		X	
NV	X	X	X	X	X	X	X			X			
NH	X	X	X	X	X		X			X			X
NJ	X	X	X	X		X	X			X	X		X
NM	X	X	X	X	X		X		X			X	
NY	X	X	X	X	X			X	X	X	X		X
NC	X	X	X	X	X		X			X			X
OR	X	X	X	X	X		X	X				X	X
PA	X	X	X	X	X	X	X	X		X	X		
RI	X	X	X	X	X		X			X		X	X
TX	X	X	X	X			X	X					X
WA	X	X	X	X	X		X		X				X
WI	X	X	X	X			X			X		X	X

Table F-2. Geographic Eligibility by State for Renewable Energy Certificates (NREL)

State	Geographic Eligibility
Arizona	State generation or interconnection
California	State generation or delivery (CAISO)
Colorado	No restrictions
Connecticut	Regional generation or delivgery (ISO-NE)
Delaware	Regional generation or delivery (PJM)
District of Columbia	Regional generation or delivery (PJM) or from states adjacent to PJM
Hawaii	In-state projects only
Illinois	In-state projects only, unless cost-effective alternative available from adjacent state
Iowa	In-state projects only
Maine	Regional generation or delivery (ISO-NE)
Maryland	Regional generation or delivery (PJM) or from states adjacent to PJM
Massachusetts	Regional generation or delivery (ISO-NE)
Minnesota	State generation or delivery
Montana	State generation or delivery
Nevada	State generation or delivery
New Hampshire	Regional generation or delivery (ISO-NE)
New Jersey	Regional generation or delivery (PJM)
New Mexico	State generation or delivery
New York	State generation or delivery (NYISO)
North Carolina	State generation or delivery
Oregon	Regional generation or delivery
Pennsylvania	Regional generation or delivery (PJM)
Rhode Island	Regional generation or delivery (ISO-NE)
Texas	State generation or interfconnection
Washington	Regional location or state delivery
Wisconsin	State generation or delivery

a solar REC in New Jersey was valued at 26.5 cents/kWh. Such an open and transparent market will only occur if and when national standards are established.

Voluntary Market REC Values

Voluntary market RECs are far less restrictive than Compliance Market RECs, although exporting beyond reliability council/power pool is still an issue. Voluntary RECs have much lower value than compliance RECs. As of this writing, values range from 0.5 to 1 cent/kWh.

RECs and Power Pool Projects

The value of RECs produced in New Mexico may soon be determined by regulatory proceedings underway in California. In late October the California Public Utilities Commission issued a draft order that allows for unbundled trading of RECs with a ceiling price of 5 cents/kWh ($50/REC), where eligible generation can originate anywhere within the Western Electricity Coordinating Council (WECC). The WECC is the western U.S. transmission grid that includes New Mexico. The proposed rule sets the ceiling price allowable for California utilities to pay for a REC at the current California price for noncompliance, which is 5 cents/kWh. While the rule only applies to RECs that will be used by California utilities to meet their RPS requirements, it effectively creates a large regional market that could influence the New Mexico market in the future.

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Appendix G. Energy Coordination Agreement Proposed Modifications

The last modification (#14) to the Energy Coordination Agreement between the DOE and the County enabled both parties to extend the contract in five year increments starting on July 1, 2015.

The study recommends that the parties consider a new modification (#15) to the agreement. This modification should be negotiated as soon as possible. The recommended modification would make the following changes:

- Renewable generation can be added to the portfolio of generation resources at any time.
- Amend Article II – Statement of Services, such that the County would be enabled to purchase power from a renewable energy generation developer, using NMEAA debt to prepay the developer.
- Further amend Statement of Services to define how a renewable generation developer would be contracted by the County to own, operate, and maintain its assets on DOE property that is provided to the County under a special use permit.
- Amend Article II – Resource Costs and Payments, to include a fee to the County for managing power purchase agreements for renewable energy.
- Replace Article III – Term, with language that permits the Energy Coordination Agreement to be extended to match the longest term of any renewable PPA that is negotiated between the County and a renewable generation developer.
- The County may face a circumstance where the most economical purchase opportunity could require a commitment longer than the then existing term of the ECA. It would be to both parties' benefit to be able to take advantage of such a proposal in the same manner that the commitment for previous generation asset purchases are handled, given the DOE 10-year contract limitation.

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Appendix H. Major Programmatic Impacts on Future Electricity Demand

Proposed Line-Item Projects and Laboratory Initiatives

Demand profiles of the following proposed line-item projects, footprint reduction efforts, and energy conservation initiatives were used to project a range of future Laboratory demand curves. The data used to forecast future load growth was collected from interviews with Laboratory subject matter experts familiar with the existing facilities and their anticipated new and disposed loads over the next 10–15 years. Each SME gave an estimate of the anticipated range of load impacts reflecting a margin of error (the difference between minimum and maximum) illustrated in Chapter 2, Table 2-2, Figure 2-5, and Figure 2-7. Major projects and initiatives were considered in the forecast.

Metropolis Supercomputing Platforms

The Nicholas C. Metropolis Center for Modeling and Simulation (Metropolis) currently demands approximately 4.6 MW of power 24 hours a day. Approximately 500 kW of the round the clock load is attributed to general building loads. The load will be changing as Roadrunner 3 (RR3) is placed in service.

The Q machines were the Metropolis' original super-computers, and have recently been removed and are being replaced by Roadrunner super-computers. The Roadrunner equipment should be completely installed by October 2008. The Roadrunner computing equipment is expected to increase the Metropolis demand by 3.0–6.0 MW when completed, plus an additional 1.1–2.3 MW for cooling. By late 2008, the total Metropolis load should be approximately 8.7 to 18.7 MW total.

Two future supercomputing platforms are planned for the Metropolis, the Zia and the Trinity. The Zia machine will arrive in late 2009. Its projected computing load is 6–10 MW plus an additional 2.3–3.8 MW for cooling. The Zia equipment should be installed in early 2010. This equipment does not replace the Roadrunner equipment, and creates an incremental electrical demand on the utility system. The addition of Zia brings the total expected Metropolis load to 17.0–32.5 MW by mid-2010.

In early 2014, the Trinity supercomputing platform is to begin arriving in the Metropolis. Trinity equipment will replace all the Roadrunner supercomputers. Trinity is anticipated to have a 30–50 MW demand plus an additional 11.4–19 MW for cooling. The Metropolis utility system would then need to serve the load for both Zia and Trinity. Completion of the Trinity equipment installation is expected to bring the Metropolis building demand to 50.2–83.3 MW. Load estimates for RR3, Trinity, and Zia are shown in Table H-1.

The Trinity supercomputing equipment will likely require a new review of the WTA utility substation capacity and distribution feeder arrangement. Additionally, the physical size of the Metropolis building will need to be re-evaluated to determine whether it can accommodate the required cooling systems equipment.

Laboratory Data Communications Center (LDCC)

The LDCC electrical load includes power for the institutional loads of the CCF, the ACL, the Library, and additional computers owned

Table H-1. Electrical Load Estimates for Super-Computing Platforms at the Laboratory (MW)

Fiscal Year	Computer	Computing (MW)	Cooling (MW)	Building (MW)	Balance (MW)
2008		3.6–7.2	1.0–2.7	0.5	4.6–10.4
2009	RR3	3.0–6.0	1.1–2.3		8.7–18.7
2010	Zia	6.0–10.0	2.3–3.8		17.0–32.5
2014	Trinity	30.0–50.0	11.4–19.0		50.2–83.3[1]

by the IST Division. The load for this system ranged from 1.5 to 2.1 MW in early 2008. By late 2008 the LDCC load is expected to range from 2.1 to 3.3 MW with the addition of the new Institutional Open Computing equipment and its requisite increase in cooling capacity.

Chemistry Metallurgy Research Replacement – Radiological Laboratory Utility Office Building (CMRR-RLUOB)

CMRR-RLUOB is being constructed as the first phase of the CMRR line-item project. When CMRR-RLUOB is completed and occupied in 2012, two of its four chillers will be operated simultaneously. The CMRR-RLUOB is expected to demand 2.5–3.0 MW operating in this configuration.

Chemistry Metallurgy Research Replacement – Nuclear Facility (CMRR-NF)

When the CMRR Nuclear Facility becomes operational in approximately 2015,[3] CMRR-RLUOB demand will increase 600–800 kW due to an additional chiller being placed in service. The CMRR-NF load is currently estimated to add 3.5–4.5 MW on the system at that time.

The current load of the old Chemistry, Metallurgy Research CMR facility is approximately 2.1 MW. After the CMRR project is completed in 2015, the load of the CMR is expected to drop to approximately 1 MW by 2016, and remain there until it is demolished.

Los Alamos Neutron Science Center Refurbishment (LANSCE-R)

Before radio frequency (RF) tubes and some of the electronics became problematic for LANSCE, full power output required approximately a 20 MW demand on the utility system. In recent years LANSCE has been running at half-power (60 Hz instead of 120 Hz), since the RF tubes are not able to achieve their full power rating. When running at 60 Hz (with all the 201 MHz drift tube LINAC power supplies operating, plus all the 805 MHz self coupled LINAC power supplies operating, plus all magnets in service) , LANSCE typically demands 14 MW from the utility system. The LANSCE-R project will replace a portion of the RF tubes, all the 201 MHz power supplies, and a portion of the 805 power supplies. The demand is expected to reach 18.5 MW, when the LANSCE-R project is completed in 2015.[2]

Material Test Station (MTS)

The MTS, planned for LANSCE Sector A, is a Global Nuclear Energy Partnership project. This load requires LANSCE-R to be

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[1] Since Roadrunner equipment is removed for the installation of Trinity, the expected minimum load equals the Building load (0.5 MW) plus the Zia computing and cooling loads (6 MW + 2.3 MW) plus the Trinity computing and cooling loads (30 MW +11.4 MW), for a total 50.2 MW.

[2] In July 2008 work was underway to evaluate an option that reduces the scope of LANSCE-R by not replacing the 805 power supplies. If this reduced project scope is selected, LANSCE will demand 20 MW instead of 18.5 MW, after LANSCE-R is completed.

[3] For the purpose of this load growth study, CMRR-NF is assumed to be completed in 2015, and CMR is assumed to be vacated in 2016. These assumptions are dependent on the line-item appropriation for the CMRR-NF facility.

completed, and the beam line running at 120 Hz output. This project is expected to add a 0.5–1.0 MW demand to the Laboratory system in the 2017 timeframe. The new load is predominantly attributed to a chiller system to serve new hot cell chambers.

Short Pulse Experimental Facility (SPEF)

LANSCE has been identified as a possible site for developing a new test facility that qualifies weapons to neutron fluxes. This facility would be located southeast of the Weapons Neutron Research (WNR) facility and requires a target dome, beam line-E extension, control room, and a vault type room. Since a feasibility study for SPEF is just commencing, the Isotope Production Facility (IPF) electrical load is used as a surrogate for SPEF's load growth estimate. The IPF load is approximately 1 MW. The SPEF project is expected to be in service approximately 2018.

Free Electron Laser (FEL) at the LEDA Facility

The Office of Naval Research (ONR) is funding the design, development, fabrication, integration and test of a 100-kW class FEL, which can be used to demonstrate scalability of the necessary FEL physics and engineering for an eventual MW class system. ONR is working with industry to select a Laboratory site to perform this system integration and testing. The LEDA facility is on the short list (less than 3) of facilities that industry (and ONR) is considering. ONR is currently funding LANL to test a high-average-current injector for the 100-kW FEL. Starting August 2008, the LEDA building started drawing approximately 2 MW of electricity off and on. The LEDA facility is of particular interest to the Navy because it already has three MW klystrons operating in the right frequency range for the 100 kW FEL. If selected, the LEDA facility will be brought into active status circa 2013 when its electrical power consumption will rise to 6 MW to power three MW klystrons. For the purpose of this study a demand of 5-6 MW is included for this project in 2014.

Science Complex

The SC is planned as a 450,000 gsf facility that is expected to be constructed and operational in 2012. Using the general rule of thumb of 8–12 watts/square foot for office/light laboratory facilities, the SC has the potential to increase Laboratory demand by 3.6–5.4 MW. It is important to mention that the SC is anticipated to vacate an equivalent facilities footprint. However, for this study, electrical demand is not adjusted for offices vacated based on the minimal demand reduction found when buildings were selected for the 2M FRI project.

Another key electrical demand aspect of the Science Complex is its planned inclusion of the Director's Unclassified Computing facility, a 20 MW load that is expected to come to fruition in 2014. It is anticipated that 2 MW for computing power may shift from the LDCC to the complex. An additional 18 MW could be required to support super-computing capabilities in the facility.

Matter-Radiation Interactions in Extremes (MaRIE)

The MaRIE proposed science signature project is being planned for funding in the 2020 timeframe. Again, several buildings will be vacated to build this multi-building project. Currently, a preliminary demand for this facility using a rule of thumb approach similar as used for the SC is 3–10 MW. However, as currently envisaged, the LANSCE accelerator may be modified to become superconducting. This would reduce the power demand for the beam line to approximately 14.4 MW, which could potentially offset the MaRIE load. For the purpose of this study, MaRIE is projected to increase electrical demand by 3–10 MW in the 2020 timeframe.

Two Million GSF Footprint Reduction Initiative (2M FRI)

The potential load reduction resulting from the 2M FRI project is estimated to range between 0.5 and 1.0 MW when the buildings are placed in a surveillance status.[4] Buildings currently slated for elimination are listed with the 2M FRI project. The buildings are primarily transportable, and many are unused. The Administration building represents the largest load with 150kW of demand recorded in April 2008.

Energy Savings Performance Contract

In May 2008, NORESCO, under contract to the NNSA submitted an initial proposal projecting Laboratory energy savings resulting from implementation of an energy savings performance contract. Energy efficient lighting upgrades, improved lighting controls, and improved heating/cooling systems and controls were recommended. Table H-2 lists the facilities included in the NORESCO scope.

NORESCO projects a reduction in electricity consumption of approximately 2,824 MWh/yr, and a 645 kW/mo demand reduction if all its recommendations were implemented.

Since NORESCO surveyed only a small subset of Laboratory buildings for their initial proposal, more demand reduction could be realized throughout the Laboratory by expanding the scope of the project. However, the Laboratory may choose to follow only a few or none of their initial proposed recommendations. For the purpose of this study, it is assumed that some of NORESCO's recommended measures will be implemented, and result in a demand reduction between 0.5–1.0 MW in 2011 (the proposed final implementation year).

Table H-2. List of Facilities Included in the NORESCO Scope

TA-3-22	TA-3-200	TA-3-502	TA-48-1
TA-3-30	TA-3-207	TA-3-1420	TA-48-107
TA-3-32	TA-3-215	TA-3-1498	TA-52-33
TA-3-34	TA-3-216	TA-3-1698	TA-53-1
TA-3-38	TA-3-218	TA-3-2322	TA-53-24
TA-3-41	TA-3-223	TA-35-86	TA-59-1
TA-3-125	TA-3-261	TA-46-31	TA-59-3
TA-3-132	TA-3-332	TA-46-154	

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[4] In a surveillance mode the buildings consume only the energy required to keep temperatures above freezing and fire protection systems operable.

Acronyms

2M FRI	Two Million Gross Square Feet Footprint Reduction Initiative
ACL	Advanced Computing Laboratory
AFC	alkaline fuel cell
CCF	Central Computing Facility
CHP	combined heat and power
CMR	Chemistry Metallurgy Research
CMRR	Chemistry Metallurgy Research Replacement
CMRR-NF	Chemistry Metallurgy Research Replacement—Nuclear Facility
CMRR-RLUOB	Chemistry Metallurgy Research Replacement—Radiological Laboratory Utility/Office Building
CoE	cost of electricity
CREB	Clean Renewable Energy Bonds
DG	distributed generation
DMFC	direct methanol fuel cells
DOE	Department of Energy
DPU	Department of Public Utilities
EA	Environmental Assessment
ECA	The Los Alamos County/Department of Energy, Electric Energy and Power Coordination Agreement
EGS	enhanced geothermal systems
FCE	Fuel Cell Energy
FEL	Free Electron Laser
FONSI	Findings of No Significant Impact
Forest	Forest Energy Systems, LLC
gsf	gross square feet
GWh	gigawatt hours

HDR	hot dry resources
IPF	Isotope Production Facility
kV	kilovolt
kVA	kilo volt-amperes
kWh	kilowatt hours
LANSCE	Los Alamos Neutron Science Center
LANSCE-R	LANSCE Refurbishment
LDCC	Laboratory Data Communications Center
LEDA	Low Energy Demonstration Accelerator
MaRIE	Matter-Radiation Interactions in Extremes
MCFC	molten carbonate fuel cell
Metropolis	The Nicholas C. Metropolis Center for Modeling and Simulation
MMBtu	million British thermal units
MTS	Material Test Station
MVA	mega volt-amperes
MW	megawatt
MWh	megawatt hours
NEC	National Electrical Code
NEPA	National Environmental Policy Act
NL	Norton Line
NMAQB	New Mexico Air Quality Bureau
NMEAA	New Mexico Energy Acquisition Authority
NMED	New Mexico Environmental Department
NMRETA	New Mexico Renewable Energy Transmission Authority
NNSA	National Nuclear Security Administration
ONR	Office of Naval Research
PAFC	phosphoric acid fuel cell
PEFC	polymer electrolyte fuel cell
PEMFC	proton exchange membrane fuel cell
PNM	Public Service Company of New Mexico
PPA	power purchase agreement
PV	photovoltaic

REC	Renewable Energy Certificate
RF	radiofrequency
RFP	request for proposal
RL	Reeves Line
RPS	Renewable Portfolio Standards
RR3	Roadrunner 3
SAM	Solar Advisor Model™
SC	Science Complex
SDG&E	San Diego Gas & Electric
SES	Sterling Energy Systems
SME	subject matter experts
SOFC	solid oxide fuel cells
SPAR	Special Purpose Approved Resource
SPEF	Short Pulse Experimental Facility
STA	Southern Technical Area
STC	standard test conditions
TEAM	Transformational Energy Action Management
TRC	Tradable Renewable Certificate
USGS	U.S. Geological Survey
WECC	Western Electricity Coordinating Council
WGA	Western Governors Association
WNR	Weapons Neutron Research
WTA	Western Technical Area

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