Building Sustainable Power…

# Mesa del Sol
## A Path to Perfect Power

Final Report
December 6, 2007

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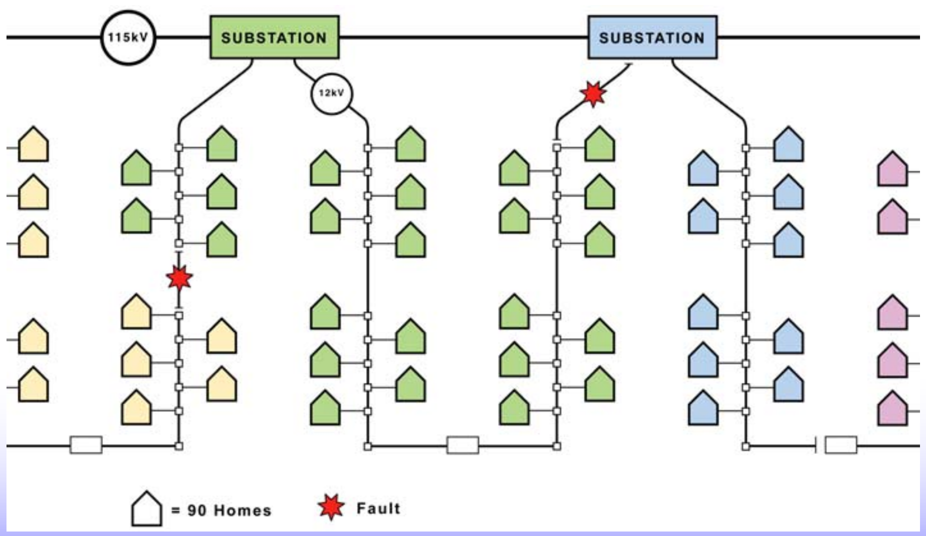
# EXECUTIVE SUMMARY

The Galvin Electricity Initiative (The Initiative) is undertaking the task of demonstrating and open sourcing an improved design for the delivery of electric power. By applying continuous improvement methods to the elements of the United States power grid, the Initiative hopes to achieve the universal adoption of a system design that will meet the power needs of every consumer. This ultimate state is called ‘Perfect Power’. The Initiative intends to demonstrate that delivering Perfect Power is not only attainable, but is ultimately the most cost-effective option.

Mesa del Sol, one of the few developments across the U.S. embracing sustainable design, collaborated with the Galvin Electricity Initiative to develop a Perfect Power prototype. The team utilized quality principals to design a prototype Perfect Power system for the Mesa del Sol development. This first step toward Perfect Power will provide a glimpse into the future of electricity. The prototype will demonstrate that cost-effective electric power can be delivered to the consumer precisely as that consumer requires it without failure and without increasing costs.

The prototype will improve reliability, reduce peak electricity demand, curb carbon emissions and reduce electricity infrastructure needs. By pioneering the Perfect Power prototype, Mesa del Sol will improve living conditions and productivity while minimizing environmental impacts associated with the massive amounts of energy required to power a development of this magnitude.

| Perfect Power Features or Elements | Mesa del Sol |
|---|---|
| Redundant transmission and distribution supply | Yes |
| Protected distribution | Yes |
| Self-sustaining infrastructure | Partial |
| Intelligent distribution system and system controllers | Partial |
| On-site electricity production | Partial |
| Demand response capability (temperature setbacks, lighting, major loads) | Yes |
| Minimal environmental impacts through efficient design and use of renewable fuels | Yes |
| Technology-ready infrastructure designed to accommodate emerging technologies | Yes |



Achieving Perfect Power at Mesa del Sol requires a coordinated effort between Public Service New Mexico (PNM), Forest City Covington, the builders, and government officials. Fortunately, PNM is embarking on several new energy efficiency, renewable, and demand response programs that can be leveraged at Mesa del Sol. Working together the team identified ways to reduce the development's projected peak load by 30 to 60 MW, potentially reducing the number of required substations and affecting the need for the planned outer transmission loop.

In order to reduce electricity infrastructure requirements and environmental impacts, the team evaluated the costs and benefits of implementing energy efficient buildings, solar energy and demand response technologies. These features will lower both electricity demand and use. According to the World Building Congress carbon footprint methodology (http://www.ghgprotocol.org/templates), the energy savings would result in a reduction of up to 30,000 tons of carbon dioxide emissions. EPA Egrid data from 2004 establishes a carbon emissions factor of 1,990 lbs/MWh for electricity supplied by PNM (www.epa.gov/cleanrgy/egrid/).

## 1.1. A Path to Perfect Power

The path to Perfect Power begins with a reliable electricity supply system. The team discovered that PNM, because of their commitment to quality, incorporates most of the Perfect Power elements into the electricity supply system design. This includes redundant transmission supply, redundant area substations, redundant local substation supply, and redundant substation feeds. In addition, the substation feeders are buried to improve reliability and esthetics. Overall, the baseline PNM design will provide a high level of reliability. The PNM electricity system averages 0.519 interruptions per customer per year (SAIFI), versus and industry average of 1.1 outages per customer per year (http://www.pnm.com/econdev/stats.htm). The Mesa del Sol transmission and distribution design should provide a SAIFI of less than 0.5 outages per customer per year.

The team identified the following Perfect Power system improvements for the Mesa del Sol development:

- The application of advanced metering, energy efficiency, and demand response to reduce the amount of distribution hardware required to serve the development. This includes managing electricity demand, which could potentially affect the need and timing of the outer transmission loop and several substations.
- Automation and communication at the substation and transmission level to allow for isolation of faults to minimize interrupting power to the development.
- Application of solar energy, distributed energy and energy storage at the consumer level to provide for permanent demand reduction. This includes distributed energy at critical facilities.
- The development of technology-ready building designs such as solar ready homes, and advanced metering infrastructure (AMI). This will facilitate the integration of emerging technologies as costs and performance improve.

Mesa del Sol will adopt building standards that require a 15% improvement above IBC standards. The Mesa del Sol E-House study identified the following energy efficiency features that could provide acceptable returns on investment from the projected energy savings. In other words, monthly electricity and natural gas savings could more than offset the investment. These features include:

- Efficient lighting
- R19 walls with R-5 Sheathing
- R38 ceilings
- Ducts inside building
- Use of overhangs and building orientation to shade windows
- Energy star appliances
- Building tight homes
- Low U glass
- Higher efficiency HVAC

Mesa del Sol will work with PNM to integrate advanced metering and a demand response program. This includes wireless communications and the control of thermostats, air conditioners, refrigerators, and washer/dryer. PNM will provide advanced meters for the first 560 homes to be built at Mesa del Sol in 2009. In addition, PNM offers residential and commercial demand response programs through third parties.

Finally, Mesa del Sol will specify that homes include solar-ready features - breaker, conduit, and roof connections. This will reduce the costs of adding solar photovoltaic systems after construction in anticipation of lower prices. PNM is offering a 13 cent/KWh payment for all KWh generated by the solar system. In addition, the homeowner will avoid the residential cost of electricity, ~10 cents/KWh. Furthermore, the homeowner will be eligible for a federal tax credit of $2,000 with a cash value of approximately $500.

## 1.2. Perfect Power Gap Analysis

The table below summarizes the recommended Perfect Power features and provides an estimate of the projected costs or savings over the 30+ year build out. The proposed Perfect Power concept includes the integration of energy efficiency, demand response, and solar PV technologies to reduce the development peak demand by 30 to 60 MW. The demand reduction will reduce PNM electric system infrastructure requirements. The distribution system savings could offset costs associated with placing a portion of the transmission system underground, installing advanced switches, and the application of demand response features.

The proposed energy efficiency and solar ready home feature costs would be reflected in the building costs. However, these costs would be recouped by the residence via monthly energy savings.

# Galvin Electricity Initiative: Mesa del Sol Perfect Power Prototype

Mesa del Sol and PNM designs provide for a highly reliable and efficient energy system, which provides a model for Perfect Power. PNM is providing redundancy in all aspects of the electric distribution system design and the energy efficiency features proposed by Mesa del Sol can reduce electric system requirements, reducing PNM first cost requirements. The cost of the energy efficiency features will be recouped through energy savings.

**Table 1 - Perfect Power Gap Analysis**

| Feature | Description | Costs | Savings |
|---|---|---|---|
| **Electric System Infrastructure Impacts** | | | |
| Redundant T&D | PNM is providing redundant areas substations, substations, and substations feeds | Included in PNM base costs | |
| Protected T&D | Transmission and substations protected from vehicular damage and distribution cables will be buried | Included in PNM base costs | |
| Automated Substations | PNM provides fully automated area and local substations. Load reductions could reduce the number of required substations from 7 to 4. This will also eliminate 12 circuits, 80 switches, and 600 transformers | | $29,400,000 |
| Automated Distribution Switches | Provide for instantaneous isolation of faults and reconfiguration of the distribution system to close into the redundant supply | Cost of 3,600,000 will be avoided based on other features | |
| Eliminate Outer Loop | PNM plans to install a 15 miles outer transmission loop may be avoided | | $15,000,000 |
| **Proposed Facility Features Designed to Reduce Electricity Peak Demand** | | | |
| Demand Response | Installation of automated meters and demand controls | Leverage PNM demand response program | |
| Energy Efficiency* | Energy star appliances, insulation, shading, and building envelop | Included | |
| On-site generation | This will be considered on a case by case basis | Under consideration | |
| Solar Ready Homes | Wiring, breaker, and roof connections | Included | |
| Solar PV | Offer 1solar PV systems through a third party. System cost of $9,000/KW could be financed for roughly $105 per month producing $70 per month in savings including incentives. | Leverage PNM solar incentives and offer solar financing with the home mortgages | |

## 1.3. Perfect Power Benefits

Employing the Perfect Power prototype elements provides for a number of benefits. This includes:

- Reduce distribution and transmission system requirements by over 30MW and associated costs of over $40 million
- Improve system reliability, lowering the costs of interruptions
- Improve safety through the elimination of manual operation
- Improve local economy by providing Mesa del Sol with a competitive advantage in the recruitment of new business and residence
- Reduced carbon footprint by up to 30,000 tons annually

## 1.4. Perfect Power Implementation

The Mesa del Sol Perfect Power prototype can be implemented in Phases over the entire 30 to 40 year development cycle.

**Phase 1: Perfect Power Buildings and Infrastructure –** In Phase 1 the team would establish a Mesa del Sol energy efficiency standard that includes demand response and on-site generation ready features. In addition, Mesa del Sol will offer solar and distributed energy systems as an optional feature through a third party. The team could establish several innovative financing and installation options to support this initiative. Examples include:

- In conjunction with local financing institutions, Mesa del Sol could offer lower financing rates for homes that are built more efficiently.
- Mesa del Sol could offer a solar energy system option in conjunction with PNM or a third party. Under this option, the customer pays PNM or a third party the retail rate plus a fee for the electricity supplied. PNM or the third party receives the PNM solar incentive.
- Mesa del Sol and PNM could offer gas fired on site generation systems as an option for customers requiring uninterruptible power. PNM could offer a monthly demand response payment for making these systems available to the demand response program. Costs could be recovered through an assessment based on 10 or 15 year financing.

**Phase 2: Perfect Power Infrastructure –** In Phase 2 PNM would continue to build out the transmission and distribution system providing for redundancy at both levels. This includes redundant area substations and substations that are cross connected.

**Phase 3: Demand Response Program –** In Phase 3, PNM would provide a development wide demand response program. This program could be expanded to include time of use and customer driven permanent demand response.

**Phase 4 – Eliminate Substations and Outer Transmission Loop –** Over the next ten years, the team would demonstrate a dramatic and permanent reduction in demand that will eliminate the need for several planned substations and the outer transmission loop.

### 1.4.1. Regulatory Improvements

The development of a Perfect Power system includes the integration of a number of building energy systems whose first cost must typically be born by the consumer. In contrast, utility T&D investments are financed over long periods and recouped through a KWh or KW fee. One way to increase Perfect Power and sustainable energy system adoption is to provide long term financing. Innovative financing could be a major lever for creating Perfect Power. . Any participation from the electric utilities in New Mexico will require state regulatory rule changes and approval. Some examples include:

- On bill financing programs which allows utilities to recover costs to install Perfect Power features on their system and bill the facility on a per KWh or KW basis monthly for 10 to 20 years to recoup costs. Under this program, the payments survive ownership changes.
- Establishment of Perfect Power districts that allow developers to install Perfect Power features on the customer side of the meter and charge the occupants an assessment fee or bill the customers for supplied energy (electric, chilled water, hot water, etc) for 10 to 20 years to recoup costs.
- Allow utilities to rate base Perfect Power improvements on their electric system for customers or portions of the system where the SAIFI is greater than the utility average.
- Establish a time of use or real time pricing program. These programs spur investment into Perfect Power features that reduce peak demand.

## 1.5. Getting Started

The Mesa del Sol build out will occur over the next 30 years and the path to Perfect Power begins with the first industrial customers and residential tracks. Mesa del Sol's first residential phase will include 560 homes. This phase provides an opportunity to demonstrate the recommended policies, technologies and impacts. The Perfect Power development could be accomplished through the following steps:

1. Establish an energy efficient building standard for residential and commercial properties. The cost would be recouped through an energy efficiency loan program that offers a lower rate or increases the buyers approved finance limits. Specifically, energy efficiency features could increase home costs by up to $5,000. This would increase the mortgage payment by $33/mon[i], which is less than the energy savings from these features.
2. Specify that all buildings be built solar and on-site generation ready. This includes building orientation, modifications to electrical distribution systems to accommodated on-site generation, routing of conduit to the roof, providing a breaker in the panel, and setting aside space in the utilities area. These costs would increase the monthly payment for a home by $6.5/month[ii].
3. Mesa del Sol would promote the PNM demand response program and seek to create a more robust demand response program that includes AMI, DR enabled components, and a web based demand response program with time-of-use pricing.

[i] 30 year mortgage at 7%

[ii] 15 year financing at 10%

4. Mesa del sol would offer solar PV installation to all residents as an option through a third party. The Kyocera solar website reports that a 1.5kW solar system produces 2600KWh[iii]. With the PNM incentive of 13 cents per KWh combined with offsetting the retail rate (10 cents/kWh) the customer would save $70/mo with the federal tax break. If Mesa del Sol in partnership with local financial institutions offered a solar financing program (e.g. 20 year 7% financing terms), the owners loan payment would increase by $105 per month.
5. Mesa del Sol and PNM could help manufacturing, commercial, and industrial companies with the integration of Solar PV and distributed energy to improve site reliability. Customers with distributed energy could participate in the PNM demand response program, providing additional resources to moderate peak demand.
6. Mesa del Sol and PNM could work together to minimize the number of substations and eliminate the outer transmission loop while encouraging PNM to evaluate and adopt technologies that improve system reliability such as the Vista automated switches.

All of these combined features manage the peak demand, improve system reliability, and reduce infrastructure requirements.

## 1.6. Private/Public Partnership Opportunity

The Perfect Power prototype provides an opportunity to create a living laboratory to test and prove the benefits of Perfect Power. A joint program with participants from academia, Sandia National Labs, Electric Power Research Institute, Gas Technology Institute, and private industry could be structured to design, deploy, improve, and monitor the most advanced energy system in the world. The phased build out at Mesa del Sol provides the opportunity to build increasingly more efficient phases of development while monitoring and comparing results. Mesa del Sol can serve as a model for both new development and redevelopment. The Brookings Institution's Metropolitan Policy Program reports that approximately 50% of the buildings that will exist in 2030 have yet to be designed. This presents a tremendous opportunity and challenge.

[iii] http://www.clean-power.com/Kyocerasolar/default.asp

# ACKNOWLEDGEMENTS

This Mesa del Sol Perfect Power Prototype project was sponsored by the Galvin Electricity Initiative and managed by Kurt Yeager. The report was prepared through a collaboration of Forest City Covington, the Galvin Electricity Initiative, Public Service New Mexico, S&C Electric, and Endurant Energy.

Critical contributions to the Perfect Power prototype design and report content were provided by the following:

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In addition, the project manager and authors wish to thank and acknowledge the contributions of the numerous peer reviewers that participated in several Perfect Power prototype review meetings at Mesa del Sol.

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# GLOSSARY

AC – air conditioning
AMI – advanced metering infrastructure
BIPS – building integrated power system
CTQ – critical to quality
DE – distributed energy
DR – demand response
EE – energy efficiency
EPA – Environmental Protection Agency
GDP – gross domestic product
HMI – human machine interface
ISO – independent system operator
IPPSC – intelligent perfect power system controller
KV – kilovolt
KVA – kilovolt amperes
KW – kilowatts
KWh – kilowatt-hour
LED – light emitting diode
MW – megawatt
MWh – megawatt hour
NOx – nitrogen oxide
PLC – programmable logic controller
PNM – Public Service New Mexico
POTT - permissive over-reaching transfer trip
PV – photovoltaic
RTU – remote transmitter unit
SAIDI - System Average Interruption Duration Index
SAIFI - System Average Interruption Frequency Index
SW – switch
UPS – uninterruptible power supply
T&D – transmission and distribution
V – volt
VAR – volt-amp reactance or reactive power

# 2. THE PATH TO PERFECT POWER

In 2005, former Motorola chairperson Robert W. Galvin formed the Galvin Electricity Initiative to design and promote a power system that cannot fail the end user. By applying Six Sigma quality principles and available technology to enhance the efficiency, reliability and security of our dynamic power system, The Initiative intends to demonstrate that it is both economically plausible and practical to deliver “Perfect Power” to the consumer. The ultimate goal is to meet the needs of the end-user – perfectly, primarily by eliminating outages at the consumer level and lowering costs.

Electricity has been the primary transforming agent of the nation’s economy and society throughout the twentieth century. Today, the power industry is itself transforming. Over the coming decades, the industry will face numerous challenges, namely: much higher reliability and quality requirements posed by the digital economy, pressure to reduce carbon emissions from supply, severe weather, and aging infrastructure.

The path to Perfect Power includes four phases[1]:

1. Phase One: determine the innovations necessary to meet consumers’ needs over the next 10 to 20 years.
2. Phase Two: use these innovations to develop a comprehensive blueprint for achieving and maintaining a system that cannot fail the consumer.
3. Phase Three: develop and implement prototype systems that demonstrate the technical, policy and economic viability of Perfect Power to the industry.
4. Phase Four: open-source the prototypes to entrepreneurs and industry leaders who would use the results to improve system performance.

The Initiative approached Forest City Covington to propose the Mesa del Sol development as a possible site for a Perfect Power prototype. Forest City Covington is developing a multiuse sustainable community, designed to meet the highest standards including Leadership in Energy and Environmental Design (LEED). Forest City Covington agreed to explore developing and implementing a Perfect Power System prototype for the Mesa del Sol development.

**Quality as a Transformation Agent**

The Galvin Electricity Initiative believes that continuous improvement methods, which have been developed and refined over the past century, provide utility executives and entrepreneurs with a lever for improving quality and spurring innovation in the electricity sector. Mr. Bob Galvin started using quality methods at Motorola in the 1970s. He asserted that the pursuit of perfection allowed Motorola to thrive in the face of fierce international competition. Mr. Galvin now sees an opportunity for utilities to leverage quality methods to achieve perfection, not in a few years, but over the next four decades.

*Perfect Power, in Mr. Galvin’s words, is a journey, not an end state.*

## 2.1. Applying Quality Methods: The First Step

The Initiative conducted two training courses on Six Sigma quality methods and principals, developed by the Joseph M. Juran Center for Leadership in Quality at the University of Minnesota, Carlson School of Management. The purpose of this training was to develop a replicable methodology for creating Perfect Power Systems. The path to Perfect Power leverages the following standard quality methods:

- Determine what is critical to quality (CTQ) from the customers perspective - Voice of the Customer
- Process mapping CTQ's and developing measures that quantify performance or the cost of poor quality
- Failure Modes and Effects Analysis (FMEA) for each process step
- Error proofing, innovative problem solving, and solution set generation
- Prioritization and implementation

The path to Perfect Power begins with defining the customer's needs and a set of metrics that provides evidence that the system has improved. The quality training participants developed electricity system performance metrics (see Table 1) based on consumers' needs.

> "Quality is fundamentally about looking at products through the eyes of the customer", Jim Buckman Joseph M. Juran Center for Leadership in Quality

**Table 2 - Energy System Quality or Cost Metrics**

| Metric | Description |
|---|---|
| Interruptions as defined by the customer. This could include a loss of power, loss of a phase, or power quality fluctuation | • Measure interruptions/customer/year - SAIFI<br>• Prioritize customers - life safety, economic loss, damage<br>• Use these criteria to focus limited resources |
| Economic impact of outages | A measure of the real impact of each outage in terms of the impact on customers. Lost productivity, lost product, damaged goods, etc. |
| Asset utilization | The ratio of actual KWh delivered divided by the theoretical capability of the asset (KW times 8760). |
| Esthetics | Cities, developers, and customers are seeking to eliminate the blight caused by overhead distribution systems. |
| Carbon emissions | Reducing carbon footprint to minimize the environmental impacts. |
| Energy Costs | Energy costs based on current utility rates |

Utilities may find that by working with customers to improve reliability and esthetics, they ultimately contribute to a higher growth rates and increased asset utilization for their service territory, which leads to increased profit margins.

## 2.2. The Cost of Imperfect Power

Six Sigma quality black and green belts learn that the cost of poor quality is not readily apparent. Specifically, many businesses do not measure the costs associated with quality. One key electricity industry measure for reliability – System Average Interruption Frequency Index (SAIFI)[2] - does not include interruptions resulting from weather damage. In addition, the electricity sector does not measure or track the costs incurred by customers due to a loss of electricity. Without knowing precisely the cost of interruptions, utilities cannot justify investments needed to reduce interruptions and their associated costs. Figure 1 provides a glimpse of the hidden costs of electricity interruptions. This includes economic losses and the impact of interruptions on regional economic development. Cities and utilities today are competing for people and business and the electricity system can be a marketing asset or liability.

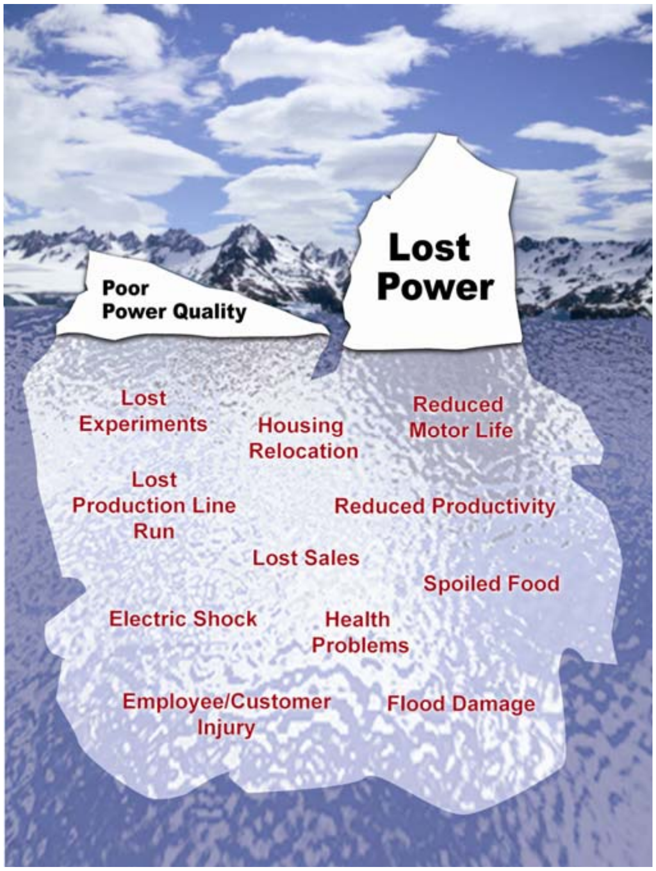



**Figure 1 - Quality Hidden Costs**

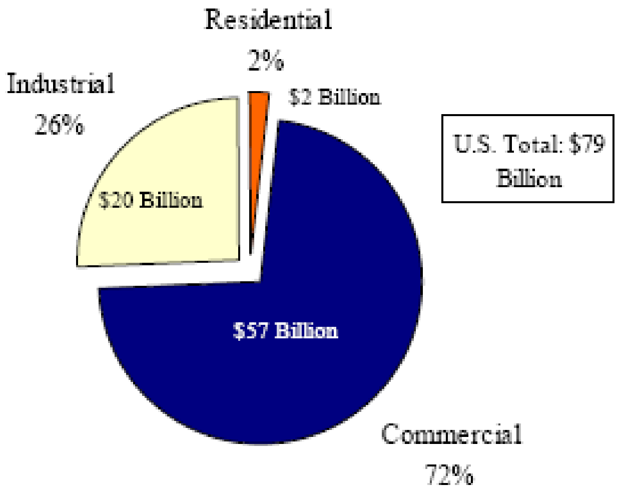



**Figure 2 - Power Interruption Costs**

Lawrence Berkley National Labs (LBNL) attempted to capture these costs in a September 2004 study titled, Understanding the Cost of Power interruptions to U.S. Electricity Consumers[2]. This report reveals that the cost of power interruptions approaches $80 billion annually with the bulk of the cost being born by commercial users (see the adjacent figure from the LBNL report). EPRI estimated the annual cost of interruptions and power quality events at $119 to $188 billion annually. These costs add 3 to 5 cents per KWh to the electricity costs nationwide[3].

LBNL recommended that utilities and regulators develop new metrics that will track the cost of interruptions in order to help justify the expenditures associated with improving power quality.

## 2.3. Where to Start?

While the current utility reliability metrics do not capture all power interruptions, these metrics provide a means for identifying a customer or group of customers with higher incidents of interruptions. The electricity industry SAIFI average is 1.2. Utilities or others could initiate perfect Power projects for cities, campuses, or customers that are experiencing more that two to three outages per customer per year. Perfect Power projects should focus on customers with higher reliability requirements – life safety and significant economic loss potential.

**Utilizing Quality to Gain a Competitive Advantage**

According to Joseph M. Juran, founder of the Center for Leadership in Quality, quality is an attitude. Toyota adopted a quality attitude in 1954 and utilized this philosophy to become the world leader in automobile manufacturing. Toyota is focused on continuous improvements in all aspects of their business – quality is their culture. This culture led to continuous improvement in all aspects of the business, including a fundamental strategic shift toward hybrid cars in the early 1990's, well before the rest of the industry. Exceptional companies continuously look for new technology, processes, etc – new marginal practices.

# 3. BASELINE ENERGY SYSTEM

The project began with the assessment of present conditions at Mesa del Sol. Mesa del Sol's energy system can be divided into the following major subsystems. This section details the existing conditions found in each of the following subsystems:

- Area Substation Supply
- Campus Distribution
- Building Distribution
- Backup Power
- Energy Procurement
- Energy Sustainability

## 3.1. Site Overview

Mesa del Sol is a 15 square mile development located in the southeast corner of Albuquerque New Mexico. The project will be a master planned city over 9500 acres of land. The land will be developed for manufacturing/business, residential university, commercial, shopping, and mixed use. The first 3000 acres will include nearly 5,000 single family homes, 300 town homes, 3400 condominiums, 300 office buildings, and 2000 retail buildings.

## 3.2. Electricity Usage Projections

**Table 3 - Residential Electric Loads**

| Residential | Watts |
|---|---|
| Lighting | 1000 |
| Dishwasher | 1350 |
| Refrigerator | 350 |
| Washer | 500 |
| Dryer | 3000 |
| AC | 3000 |
| Plug Load | 500 |
| Microwave | 750 |
| Jet Tub | 750 |
| Wine Chiller | 750 |
| **Total** | **11950** |

PNM typically experiences about 2 to 2.5 KW per residence at the substation level. ME Engineers based on experience with a similar development in Denver expects loads closer to 4KW per home on average. The limiting distribution system design criteria may be voltage at the home. The first phase of the Mesa del Sol housing development includes 530 houses. At 4KW per home, the aggregate peak demand for this first development would be about two MVA, slightly above the rating of one PMH switch.

The Mesa del Sol homes will include the loads shown in the adjacent table. These loads are not coincident.

ME Engineers projected electricity demand growth by year to determine the number of required substations. The projections are conservative and project a need for eight substations for the Phase 1 development.

## 3.3. Transmission Supply

Public Service New Mexico (PNM) is the local electric distribution utility. At the north end of the development, running east and west is an 115kV transmission line. PNM plans include a future new switching station that will supply bulk power requirements to Mesa del Sol from the north. PNM will extend transmission line(s) from the switching station to new distribution substations located within the development. New distribution lines will emanate from these distribution substations and be routed underground to each customer or load. These facilities will be installed as electricity demand increases over time. PNM also has another 115kV transmission line running north and south along the west end of the development. PNM will provide redundant transmission from this line via another future planned switching station, which will be located at the southwest corner of the development. This will provide redundant transmission supply

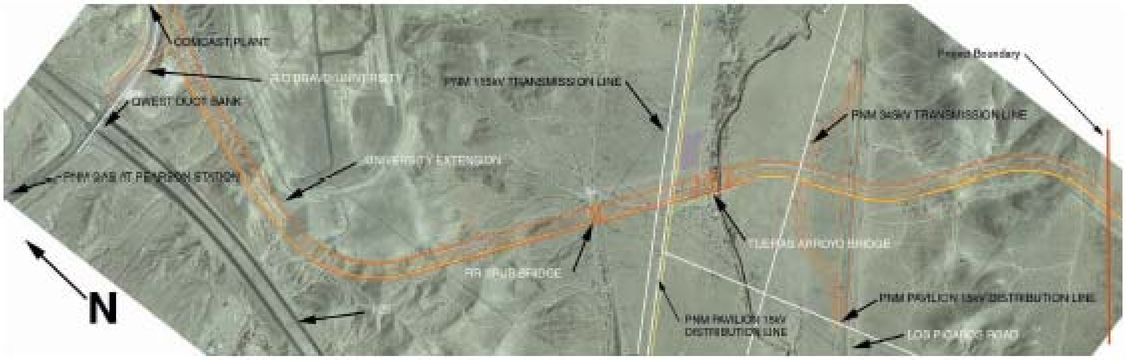



**Figure 3 - Transmission Supply**

Mesa del Sol requested that the transmission lines routed throughout the development be installed underground to reduce the amount of land required for right of ways, improve esthetics, and minimize system disturbances.

The first phase of development is to be supplied by a transmission line that runs directly though the center of the Mesa del Sol development as shown in the blue line in the adjacent Figure.

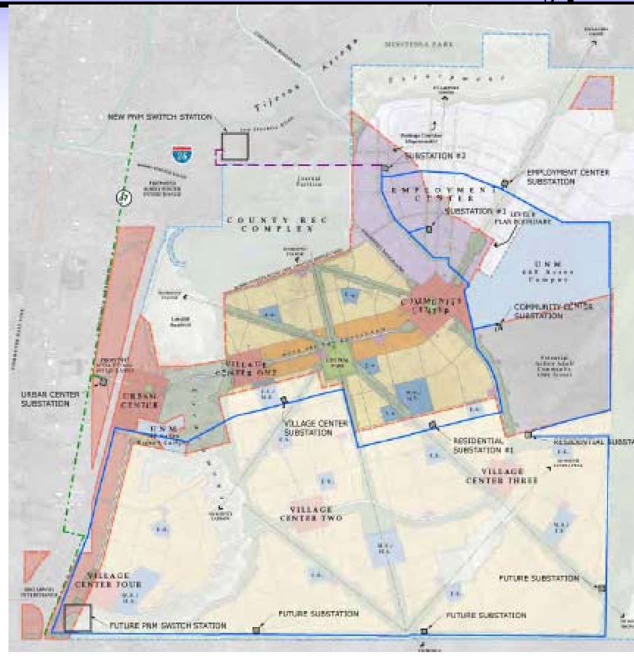



**Figure 4 – T&D Layout**

## 3.4. Site Distribution System

Based on the electricity load demand projections provided by Mesa del Sol, the adjacent site distribution layout was developed. This includes both and inner and outer transmission loop with eleven area substations. The substation design is shown below. Each substation is designed to accommodate two 33.6 MVA unit buses with an 115kV breaker to isolate faults on the transmission system. . The installation of two transformers within a substation will depend on the demand for electricity.

Each substation can serve roughly a 3-mile diameter circle due to power quality limitations. As such a minimum of four substations is needed to serve the first 3000 acres.

Endurant reviewed the ME Engineer load analysis and concluded that the development electricity demand would require six substations under a business as usual condition. The higher load projections are the result of the high end nature of the development that will attract a greater use of air conditioning and business/home electronics.

**Figure 4 - Transmission Tower**

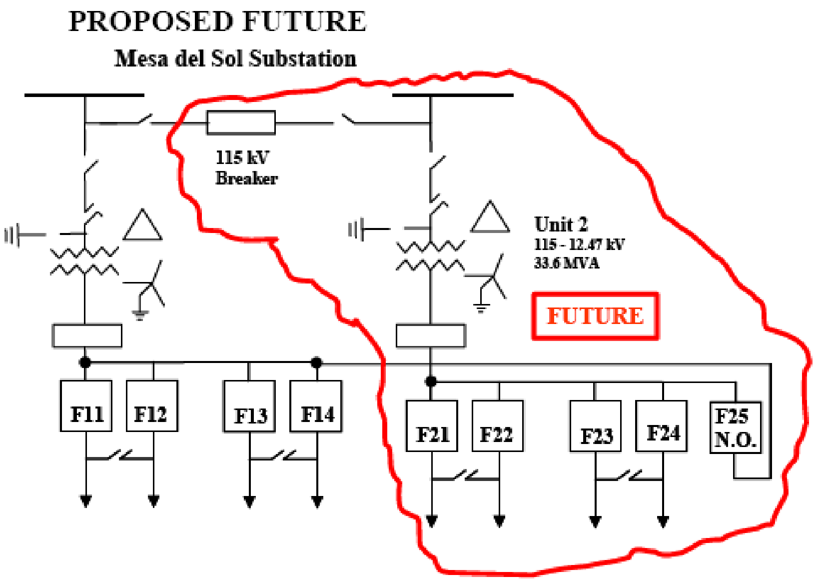



**Figure 5 - Typical Substation Design**

The first four substations will only require one 33.6 MVA bus. The second bus could be installed to supply the second phase of development, serving the southern portion of the development. This might provide the ability to serve the entire development from one central transmission line.

PNM designs the site substations to be single failure proof. Each substation is designed to carry only 50% of its rated capacity so that adjacent substation loads can be fed in case of failure. Circuits from adjacent substations are connected through an open switch. Each feeder is subdivided into sections using manual switches.

## 3.5. Energy Sustainability

Mesa del Sol will develop building standards that specify that builders achieve a 15% improvement upon the latest International Building Code. Mesa del Sol commissioned a study to evaluate the impact of various energy efficiency measures on a typical residential building. The results indicate that the following building features could reduce demand and usage by 30 to 40%.

Residential energy efficiency features include:

- Efficient lighting
- R19 walls with R-5 Sheathing
- R38 ceilings
- Ducts inside building
- Use of overhangs and building orientation to shade windows
- Energy star appliances
- Building tight homes

Commercial energy efficiency features include:

- Features listed above

- Low U glass
- Higher efficiency HVAC

**Carbon Footprint**

The World Building Council developed standard methods for estimating the carbon emissions from buildings. This methodology relies on the U.S. Environmental Protection Agency's eGrid database (www.**epa**.gov/cleanrgy/**egrid**/ ) to determine the average carbon emissions on a ton per megawatt hour (MWh) from local electricity generation. An analysis of the EPA's EGRID data revealed that the electricity use carbon factor New Mexico is 1.992 lbs/KWh[5]. The proposed sustainable energy features could eliminate more than 30 MW of demand and 50,000 tons of annual carbon emissions.

# 4. PERFECT POWER MODEL DEVELOPMENT METHODS

The team working with the Joseph M. Juran Center for Leadership and Quality learned that Six Sigma quality methods serve as the guiding principles when developing Perfect Power Systems. The methodology involves the steps shown below, which are applied to the Mesa del Sol development in this chapter.

1. Determining what is critical to quality (CTQ) from the customers perspective - Voice of the Customer
2. Process mapping CTQ's and developing measures that quantify performance or the cost of poor quality
3. Failure Modes and Effects Analysis (FMEA) for each process step
4. Error proofing, innovative problem solving, and solution set generation
5. Prioritization and implementation

Utilities can apply this methodology to utility distribution systems, campuses, cities, major developments or one customer. The methodology leverages standard Six Sigma methods. This Chapter summarizes the results of applying these quality methods to the Mesa del Sol development.

Utilities, suppliers, and manufacturers can utilize quality methods to improve all aspects of the power delivery business. Utilities such as Public Service New Mexico have trained Six Sigma black and brown belts and applied these methods to improve quality for customers while also lowering costs. The electricity supply system design for Mesa del Sol reflects PNM's commitment to quality.

## 4.1. Customer Requirements/Voice of the Customer

The Mesa del Sol development serves several different customers with varying needs. This includes residential, commercial, institutional, manufacturing, and special uses. A loss of power can destroy production runs, result in lost productivity, and require capital resources to mitigate the impacts of the outage and restore power.

Forest City Covington identified the following strategic priorities for the Mesa del Sol power system going forward as well as a number of factors that are critical to quality for residents.

**Table 4 - Voice of the Customer**

| Strategic Priorities | Voice of the Customer, Critical to Quality |
|---|---|
| Improve power reliability and quality | • Not losing production runs |
| Manage energy costs | • Mitigate higher peak power prices |
| Build efficiency into all aspects of operation and maintenance of the energy system | • Renewable energy systems<br>• High efficiency buildings |
| Develop a more sustainable energy system | • Reduce carbon emissions<br>• Incorporate sustainable power generation |
| Improved esthetics | • Reduce the number of substations<br>• Underground transmission, distribution, and site switches |

## 4.2. Process Mapping

The utility system was divided into the following major processes:

- **Supply** - this included transmission systems, larger area switch stations, area substations, and step down transformers
  - **Site Distribution** - substations, substation breakers, building feeders, building isolation, and communications
    - **Building Distribution –** switches, transformers and circuits within the building
      - **Procurement and Sustainable Energy Systems –** minimizing the energy and environmental impacts of the loads being served

Each process was further divided into key sub-processes, which are summarized in Exhibit B.

## 4.3. Failure Modes and Effects Analysis/Error Proofing

The team applied Six Sigma quality principals to identify and define the types of failures possible as well as how they can be prevented in the Perfect Power System. Most organizations fix problems after the fact, thereby incurring the costs. According to the Juran Center for Quality many organizations fix problems after the fact, thereby incurring the costs of failure, others avoid fixing problems by adding costs – inspectors and redundancy. The Juran Center for Quality stated that 94% of failures are due to the system, not human error. Error proofing involves the following steps:

Step 1 - Diagram the process identifying each step and sub process.

Step 2 - List the failure mode for each sub process – what can go wrong?

Step 3 - Determine the severity – minor, moderate, major, catastrophic – see Table 4

Step 4 – Determine the probability – remote, uncommon, occasional frequent – see Table 5

Step 5 – Apply the decision tree to the highest priority failures mechanisms based on multiplying probability index by the severity index.

- Single point weakness – no – stop
- Existing control measure – yes – stop
  - Detect and mitigate in an acceptable time frame
- If not proceed to error proofing

Step 6 – Perform error proofing

- Prevent
  - Elimination – eliminate the step or the failure mode; locate sensors so that they are not likely to be damaged by maintenance or walkthroughs. Post maintenance performance test.
  - Replacement – increase replacement interval and assess condition. Determine and assess reliability metrics, replace human input with electronic recording
  - Facilitation – make it easer to do, reduce wear, operate at lower T or P, reduce flow, improve water quality, etc…
  - Purchase higher quality device
- Minimize effect
  - Detection – monitoring and trending to predict failure before occurrence
  - Mitigation - redundancy

Exhibit B provides the results of the Failure Modes and Effects Analysis (FMEA) and Error Proofing The team determined the severity and probability for each failure mode. The severity of the impact of a power failure depends upon the severity of the impact of the loss of power on the customer and may vary from customer to customer. See Table 5 for several possible severity designations:

**Table 5 - Failure Severity Designations**

| Severity | Description | Comments |
|---|---|---|
| Major | Loss of life and personal safety | Hospital, nursing home, home care, police, fire, and shelters<br>Manual switching of high voltage feeds can result in damage to equipment and injury to personnel |
| Major | Significant economic loss | Flooding, manufacturing process, loss of produce/food, etc. Customers in areas that are subject to flooding, can incur significant economic loses if electricity is interrupted. |
| Moderate | Economic impact | Loss of productivity |
| Moderate | Esthetics | Cities, universities, and businesses are competing for resources and the esthetics of a site is now more important than ever. Overhead distribution systems and above ground switches and transformers take up valuable land, degrade views and reduces tree planting. |
| Minor | Little to no impact on operations | |

Once the severity was determined then the probability of occurrence – or how many times per year a failure can be expected – was assessed. . Table 5 provides the criteria for determining the probability.

**Table 6 - Failure Probability Designations**

| Probability | |
|---|---|
| Frequent | Several times a year |
| Occasional | Every 1 to 2 years |
| Uncommon | Every 2 to 5 years |
| Remote | Every 5 to 30 years |

The probability of occurrence is impacted by the distribution system design, age, and usage. The probability of failure increases depending upon a number of factors – see Table 6.

### Table 7 - Failure Severity Factors

| Factor | Description |
|---|---|
| Severe Weather | Overhead systems subject to exposure to hurricanes, tornado's, high winds, and or lighting should be assigned a probability of frequent |
| Aging | Underground direct buried cable older than 20 years should be assigned a probability of frequent. |
| Usage | Systems operating at conditions above component ratings should be assigned a probability of frequent |
| Human Error | Above ground systems near roads and not protected from vehicular damage should be assigned a probability of frequent |

The combination of probability and severity was utilized to determine the type of solution pursued. The higher impact failure modes shown in red were addressed through a design change aimed at eliminating the failure mode. The lower impact failure modes will be resolved be through the application of technology or resources to detect and mitigate the failure mode.

### Table 8 - Failure Categories

| | Major | Moderate | Minor |
|---|---|---|---|
| **Frequent** | | | |
| **Occasional** | | | |
| **Uncommon** | | | |
| **Remote** | | | |

These methods were applied to the Mesa del Sol development and the results are shown in Exhibit B. Exhibit B provides a standard list of electricity system sub-processes. The next chapter provides a summary of the results of error proofing.

# 5. SOLUTION: THE PERFECT POWER PROTOTYPE

Mesa del Sol is fortunate that PNM's electricity system design philosophy includes redundant transmission, area substation, substation, and distribution feeder design. Perfect Power design incorporates similar concepts. The entire distribution system is designed to be single failure proof. The distribution cables will be buried while PNM's preliminary design includes two above ground transmission lines that will run through and around the development, twelve to fourteen substations, above ground switches, and above ground transformers.

The Mesa del Sol development team's primary concern is minimizing the land that must be dedicated to distribution and esthetics. Mesa del Sol developed a detailed master plan that includes significant amounts of green space, green ways, and beautified landscape. The development team is seeking to underground as much of the distribution system as practical. Mesa del Sol believes that the success of the development hinges on sustaining the greening and beautification inherent in the design. Cities such as Chicago are being recognized nationally for their focus on esthetics and green space.

The Galvin Electricity Initiative identified the following attributes that will contribute to Perfect Power:

- Universal connectivity – connecting communications and electricity, think about services and value, not just KWh
- Power quality – microprocessor embedded into every device – digital power quality
- Portability – allow operation of devices without connectivity – storage
- Smart, self correcting infrastructure – auto coordination, reconfiguration, self healing. Digital switching and controls, sense system state, predict, and act. Isolate, reroute, add generation, and reduce demand – without impacting the consumer
- Value-based Cost – real time communications between devices and system

## 5.1. Perfect Power Elements

- Redundant and Protected T&D
- Self-Sustaining Infrastructure
- Intelligent distribution system
    - High quality, properly sized cable and transformers
    - Feeder redundancy
    - Automated breakers and switches
    - Automated restoration
    - Coordinated communications
    - Intelligent Perfect Power System Controller
- On-site electricity generation
    - Substation or building integrated generation
    - UPS/Storage
- Demand response capability (AC, lighting, major loads)
- Sustainable/Green Building Technology Capability

- ASHRAE Proposed Standard 189 or CA Title 24-2005
- Use of the most advance lighting systems throughout the campus
- Advanced window glazing, insulation, exhaust heat recovery, and building re-commissioning
- Direct Current Circuits – provide perfect power quality to state-of-the-art digital laboratories
- Use of higher efficiency HVAC components, improved insulation, variable air volume controls, soft start motors, and variable speed drives
- Integration of district energy systems – hot water and/or chilled water loops
- Installation of advanced building control systems to better manage heating, cooling and lighting
- Use of enthalpy wheels to minimize ventilation system energy requirements and recover rejected energy from vented air streams.
- Use of landscaping to provide solar shading and beautify the campus
- Integration of renewable energy sources and/or procurement of electricity from renewable generators.

## 5.2. Perfect Power Benefits to the End-User

- Economic:
  - Savings
    - Reduced procurement costs
      - Real-time pricing
      - Day ahead demand reduction markets
    - Peak shaving
    - Energy efficiency
    - Improved power factor
    - Reduced and shorter outages
  - Revenue from ancillary services
    - Demand response
    - Spinning reserve
    - Load reduction
    - Grid support programs
      - VAR support
- Functional:
  - Reliability
  - Power quality
  - Power independence
  - Improved sustainability
  - Significant teaching and research opportunities and income

In the pursuit of Perfect Power the team utilized the following Galvin Electricity Initiative documents as guidance in identifying solution to address energy system failure modes and Mesa del Sol constituent power needs.

- Master Controller Requirements Specification for Perfect Power Systems, Revision 2, November 9 2006[4]
- The Path to Perfect Power: New Business Opportunities for A Customer-Demand Driven Electricity World, November 2006[1]
- The Galvin Electricity Initiative: Task 3 – Technology Scanning, Mapping and Foresight, March 2006[5] Can box these references I think – note we changed the title of the New Technologies report when we released it to New Technologies Advance Consumer Control

The team then applied these Perfect Power elements and Initiative guidelines to the Mesa del Sol system to design the Mesa del Sol Perfect Power prototype.

# 5.3. Redundant Transmission and Distribution

Since the 2003 Northeast blackout, considerable effort was applied to update and automate transmission functionality and controls. The achievement of redundant or self-healing transmission supply to an area substation provides the most important step in stabilizing an area's power reliability. PNM provides redundant transmission supply to the Mesa del Sol development through two separate and redundant area substations. Local substations are designed for redundancy, sized for only half of their rated capacity and interconnected through a loop configuration, which allows two adjacent substations to carry the entire load for a failed substation. Feeder Redundancy will allow the re-routing of power to buildings in the event of a fault on a distribution feed. Used in concert with high-speed automated breakers and switches, redundant feeders allow for the instant reconfiguration of the system to keep power flowing to all buildings.

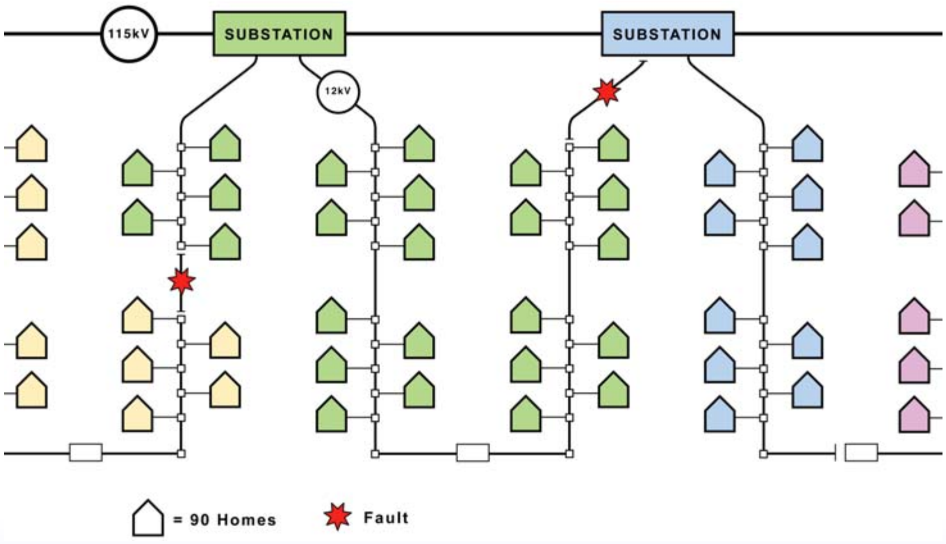



**Figure 6 - Substation Redundancy**

## 5.4. Self-Sustaining Infrastructure

Self-sustaining electric infrastructure is crucial for the success of a Perfect Power system. The many factors that can negatively affect power supply must be mitigated automatically by the system if outages are to be avoided. Many self-sustaining elements need to work in concert to achieve a true self-sustaining or self-healing electric infrastructure.

### 5.4.1. Intelligent Distribution System

An intelligent distribution system consists of properly-sized cable and transformers capable of carrying the full expected load; feeder redundancy to offer an alternate power supply to buildings where power is interrupted; automated breakers and switches to execute the split second isolation of faults; automated restoration; and a communications system capable of orchestrating this split-second reconfiguration of the system.

### 5.4.2. Automated Breakers and Switches

The isolation of faults will be executed by automated breakers and switches that will sense fault conditions and open within 1/4 cycle, simultaneously isolating the fault and allowing power to flow along a secondary feeder route. This system of automated breakers and switches will employ:

- High speed, fault interrupting switchgear for the north and south main buses
- Automatic high speed transfer system – either at the individual building level, mid-distribution loop level, or substation level
- Multifunction directional over-current relays
- Automated switches with vacuum fault interrupters

PNM typically utilizes manual switches at a cost approximately $30,000 installed. These lower cost manual switches must be reconfigured locally to restore power in the event of a fault. It can take up to 3 hours to restore power. These manual switches can be automated or more advanced intelligent switches can be deployed which would isolate faults without interruption of power to customers. Two options include:

- Add supervisory capability to the PMH switches, ~$70,000 total installed with PMH switch
- Utilized the S&C Vista type switch that provides increased capability, ~$90,000 installed.

### 5.4.3. Distributed Intelligence

The Perfect Power System's first line of defense is the deployment of intelligent components that can monitor system conditions and take action to sustain proper operation locally. Smart switches combined with UPS and on-site generation will automatically respond to abnormal system conditions to maintain system stability and normal operations.

### 5.4.4. Coordinated Communications

In order for the system to function as a whole, to be efficient and flexible while maintaining a system wide cohesiveness, distributed intelligence will need to be connected and coordinated. In certain fault scenarios, there will be various and competing solution strategies. The proper diagnosis of problems and often the proper *sequencing* of solution steps is crucial, so disparate intelligent parts will have to be both aware of each other and controllable by a system overseer that can orchestrate the actions of the whole system.

The Mesa del Sol Perfect Power prototype will leverage the research and design capabilities of Mesa del Sol and PNM to develop an advanced communications system. The team will explore technologies ranging from fiber optics that would follow cable conduit to highly flexible and cost-effective ZigBee wireless technology.

## 5.5. On-Site Electricity Generation

For sites such as Mesa del Sol, with redundant transmission and area substation feeds, full coverage of the demand through on-site generation may not be needed to achieve acceptable levels of reliability. However, in other cases, where redundant transmission and area substation feeds are not feasible or cost effective, on-site generation increases reliability and provides for demand response. Reliability is increased in the form of back up and grid-support generation. On-site generation comes in many forms, each with its own advantages and disadvantages based on the application. These range from load-specific back up (75-100KW), to building back up (300-600KW), to substation back up (2-4MW), to district energy (4-20MW) and can encompass renewable sources and UPS flywheels and batteries.

**Table 9 - Time Response for Generation Options**

| Option | Start Time | Discussion |
|---|---|---|
| Diesel Fired Generation | 10 sec | Diesel generators start and load quickly but do not support demand response or real-time pricing due to run time restrictions (emissions limits and fuel storage) |
| Natural Gas-Fired Generation | 1 min | Start times are longer, improved environmental performance provides for longer operation to support demand response and real-time pricing. |
| Uninterruptible Power Supply (UPS) | Instantaneous | UPS ensures that power is not interrupted. However, it typically only provides a few minutes of power and is used to transition to diesels or natural gas-fired generation. Mesa del Sol residences and businesses will deploy UPS as necessary to support local building Perfect Power needs. |

### 5.5.1. Substation Level Generation

The Mesa del Sol transmission and distribution supply system provides sufficient reliability. However, in other situations where redundant transmission and distribution cannot be provided customers should consider other options, such as on-site generation (solar, storage, engines, or turbines) or generation at the substation.

### 5.5.2. Building Integrated Power Systems (BIPS)

Certain customers or loads may not be able to tolerate interruptions to power, such as a data center of movie production studio. In these cases, local generation sources can mitigate distribution system failures. In addition, local generation sources provide for the ability to provide PNM with demand response and ancillary services.

A building integrated power system (BIPS) will provide local generation, power conditioning, and uninterruptible power ride through capability. This typically requires local generation, inverters, and electricity storage, which is integrated with the building distribution system and loads. This may also require isolation of the building from the Mesa del Sol distribution system.

The BIPS system, shown in Figure 9, will include:

- Local building generation to carry the building load for an extended distribution system outage
- UPS/storage to provide electricity while the local generation is starting
- Inverters or power quality conditioning devices
- A load controller to modulate that generator output to gradually unload the UPS and to follow the building loads
- Motor soft start capability for large motor loads such as elevators
- Non-critical load shedding capabilities
- Communication to Intelligent Perfect Power System Controller (probably through a building-level master controller)

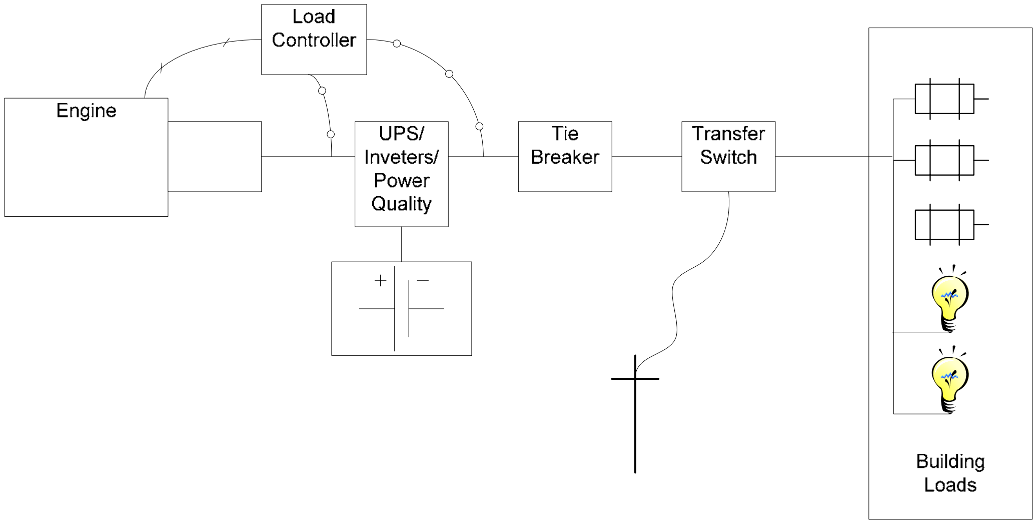



**Figure 7 - Building Integrated Power System**

### 5.5.3. UPS and Electricity Storage

Uninterruptible Power Supplies (UPS) can be designed to carry the load of a system for up to 120 seconds - for minor outages on a system that cannot tolerate even milliseconds without power (such as data and server centers) and as such is an important part of a self-sustaining infrastructure. A UPS can be coordinated with generators to carry system load for more than 120 seconds. The UPS would instantly assume the load during an outage event and supply ride-through power until the generators are running and synchronized. The UPS can utilize either flywheel or battery technology depending on the application. The Perfect Power prototype will utilize flywheels for loads where a small UPS footprint is necessary.

## 5.6. Demand Response Capability

A development like Mesa del Sol contains thousands of loads, building energy systems and temperature controllers. The integration of AMI and load controllers on key components provides the foundation for a robust utility demand response program.

## 5.7. Technology Ready Infrastructure

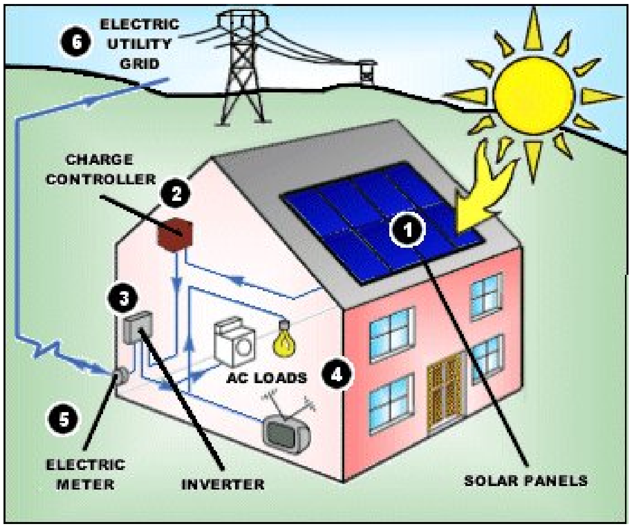
Not all of the Perfect Power features can be implemented today due to economic constraints. The team discussed the potential to utilize a phased approach to implementing perfect power. This could include:

- AMI – Advanced metering
- Building solar ready buildings
- Installing intelligent capable switches
- Communications backbone
- Building commercial buildings with natural gas fired generation for backup. These units can then be integrated into demand response or real time pricing programs.
- On-site generation ready buildings

**Advanced Metering Infrastructure (AMI)** - PNM has commission approval for an advanced metering demonstration in two parts of their service territory, not Mesa del Sol. Costs very significantly for advanced metering depending upon the features and functions and the building types. Residential meters can cost up to $100 and commercial meters can cost up to $500.

- o AMI will provide usage, interval data, tamper detection, outage monitoring, automated reading, customer usage profiles, and dynamic load research. AMI provides the ability to manage residential loads and communicate usage/costs to the owner.

**Solar Ready Buildings** – While the costs of solar photovoltaic system remains in the $8,000 to $9,000 range, some consumers cannot justify investment in this key sustainability technology. Utilities such as PNM offer large incentives to stimulate this market. However, even the 13 cent per KWh incentive offered by PNM provides marginal returns on investment. One way to prepare for the inevitable technology breakthroughs and facilitate future adoption of solar PV technology, is to build solar ready homes.




A solar ready home is equipped with an advance meter that will allow for the hourly reporting of the homes demand and the solar PV system output. AMI discussed above also supports demand response and energy conservation measures. Significant retrofit costs can be avoided by adding a solar PV breaker, leaving space for the inverter, and installing conduit from the panel to the roof. As an option, roof penetrations and structural supports can be installed so that the building owner can later bolt the panel on and make the final electrical connections. In addition, the building should be oriented and designed to maximize the solar incidence.

The solar panel and inverter can now be easily and cost effectively added to a residence at some future date.

**Intelligent Switches –** Control of loads and instantaneous isolation of faults are needed to maintain a stable grid. Fast intelligent switches provide for local reconfiguration to isolate faults and remote operation to isolate loads.

**Communications Backbone –** The Mesa del Sol development will include both fiber optics and wireless communications throughout. In addition, PNM will implement a radio communications system for the intelligent switches. These systems can be leveraged to provide a robust and redundant communication system for demand response and system operation.

**Natural Gas Fired Backup –** Cities such as New York and Chicago now allow the use of natural gas for emergency backup generation. Use of natural gas fired backup generation provides significant environmental benefits while also providing an asset that can be deployed for use in utility demand response or real time pricing programs. Diesel fired backup generation's poor environmental footprint limits its use to just backup power.

**On-site Generation Ready Buildings –** Facilities can be designed to later accommodated electricity generation and storage by designing site distribution systems with common buses and an open breaker for the future generation source. In addition, mechanical and electrical equipment rooms can include storage space, which can be later converted and used to house the added generation source.

## 5.8. Sustainable/Green Building Technology Capability

Mesa del Sol's sustainability goals will be accomplished by reducing pollutant and carbon emissions through energy conservation, leveraging renewable resources, and reducing peak demand, which strains the distribution system and increases energy costs. The World Resource Institute published methods for determining the carbon footprint of a development[6].

The team discussed the potential to develop a residential and commercial builder energy guide that could be included in the current Mesa del Sol builder's guide. This could include elements from the New Mexico Home Builders Guide, CA Title 24-05, and ASHRAE draft standard 189.

Energy consumption will be reduced as much as possible through initiatives such as:

- Use of the most advance lighting systems throughout the development – LED's, day lighting, T8 fixtures, compact fluorescent lamps, and occupancy sensors.
- Advanced window glazing, insulation, exhaust heat recovery, and building re-commissioning designed to reduce building energy losses to the environment.
- Use of higher efficiency HVAC systems, soft start motors, and variable speed drives
    - Use of enthalpy wheels
    - Outside air control systems or economizers
- Building designs that maximize solar shading
- Use of landscaping to provide solar shading and beautify the campus
- Local high efficiency hot water systems supplemented with solar hot water and geothermal systems.
- Use of LCD monitors (and televisions) rather than cathode ray tube or plasma-based units.

- Heat recovery processes from server rooms, computer labs, and other computer-intensive locations that require extensive cooling.

PNM offers a 13 cent/KWh incentive for solar PV and pays customers the retail electricity rate for the power produces. This equates to a total incentive of approximately 24 cents/KWh. Solar PV could reduce peak demand by 25% or more if combined with electricity storage. PNM noted that ice storage could be an effective demand reduction tool for commercial buildings.

# 6. GAP ANALYSIS

The gap analysis provided in Exhibit C provides a summary of the costs and savings from each of the Perfect Power features. The gap analysis credits energy efficiency, demand response, and solar PV installations as a means to reduce the projected load and resulting electric infrastructure requirements. The gap analysis projects a total reduction of about 30 MW from the baseline of 90MW. This could reduce the development inner transmission loop substations from 7 to 4 and may eliminate the need for the outer transmission loop. This assumes that the second phase of development could be served by adding a second 33MVA bus to each of the first four substations.

The electricity system costs provided in Exhibit C were provided by PNM through a series of project review meetings. The facility energy efficiency, demand response, and solar costs were based o industry experience. The gap analysis provided in Exhibit C includes the following:

Column 1 is the perfect power feature

Column 2 provides an estimate of the electricity demand impact in KW per unit

Column 3 is the cost for the component/system, as is, without being upgraded to the Perfect Power specifications.

Column 4 is the incremental per unit cost of upgrading the component to perfect power

Column 5 is the baseline number of units projected to be required or built

Column 6 is the number of units projected assuming all of the demand reduction features are implemented

Column 7 is the baseline costs

Column 8 is the Perfect Power costs

Column 9 is the delta or gap including savings produced

Column 10 is the projected reduction in electricity demand

**Substation** – PNM reported the installed cost of a substation with automated breakers and communications at $3,500,000. The team estimated that the number of substation could be reduced by up to 3 through the integration of EE, DE, DR, and solar; reducing overall costs by $10,500,000

**Circuits –** PNM reported the installed cost of a circuit at $1,000,000. The team estimated that the number of circuits could be reduced by up to 12 through the integration of EE, DE, DR, and solar; reducing overall costs by $12,000,000.

**Manual Switches –** PNM reported the installed cost of a manual switch at $30,000. Each circuit includes about five switches that provide for isolation of faults so that power can be restored while the fault is being repaired. The manual switches require dispatch of a crew to restore power. This takes two to four hours. The team estimated that the number of switches could be reduced by up to 80 through the integration of EE, DE, DR, and solar; reducing overall costs by $2,400,000.

**Smart Switches** - PNM reported the installed cost of a smart switch at $90,000. The automated switches will immediately identify the fault and reconfigure such that power is not lost. The total estimated cost of upgrading to smart switches is $3,600,000.

**Transformers –** PNM reported the installed cost of a transformer at $7,500. The team estimated that the number of circuits could be reduced by up to 600 through the integration of EE, DE, DR, and solar; reducing overall costs by $4,500,000.

**Underground Transmission** - PNM reported the installed cost of a buried transmission line at $5,000,000 per mile. The costs were not considered acceptable for the minimal impact on overall system reliability. The main driver for buried transmission lines is esthetics.

**Eliminate Outer Transmission Loop –** PNM reported the installed cost of an overhead transmission line at $1,000,000 per mile. The current distribution design calls for a 10-mile outer transmission line that will span the east and south borders of the development. The team estimated that the outer loop might no longer be needed due to the reduction in demand caused by the integration of EE, DE, DR, and solar; reducing overall costs by $10,000,000.

**AMI –** Endurant estimated the cost of AMI at about $200 per facility. PNM is implementing an AMI program, which will provide advanced meters for the commercial and residential units in Mesa del Sol.

**Demand Response –** Endurant estimated the cost of demand response features at $800 per residence and $2,000 per commercial facility. These costs will be born by a third party under the PNM demand response program. However, this program may not provide all of the features associated with a robust demand response program. The team will assume that the PNM demand response program will be upgraded over time to include increasingly more sophisticated methods.

**Energy Efficiency –** Mesa del Sol will establish minimum energy efficiency standards that will likely increase the cost of each home by $5,000 and a commercial building by $30,000. This cost would be incorporated into the home mortgage or building financing and recouped through energy savings. A homeowner's mortgage payment would be increased by $33/mon[4], which is less than the estimated energy savings from these features.

**Solar PV –** Mesa del Sol can offer solar PV systems during the initial home or property sale through a third party program. PNM could simply work with solar PV suppliers and builders to require that each builder offer solar PV as an option. Another more aggressive approach is to establish an "Energy District" where Mesa del Sol provides the solar PV system based on a monthly assessment fee that survives ownership changes. In either case, the owner would save about $70/month with incentives and tax brakes and pay about $105/month for the life of the home. In either case, Mesa del Sol would not bear the cost of the Solar PV.

[4] 30 year mortgage at 7%

# 7. PERFECT POWER BENEFITS

A power system that never fails to meet the customer's every functional need but is out of the financial reach of that customer is not perfect. Perfect Power meets the economic needs of the customer as well as the functional. The Mesa del Sol Perfect Power prototype demonstrates that the very improvements that make it functional also make it affordable – not only saving the customer money but in some cases producing revenue.

## 7.1. Avoided Distribution System Upgrades

Mesa del Sol and PNM can work together to apply advanced energy efficiency and demand response features that can reduce the overall development electricity demand, thereby reducing the number of above ground substations and the planned outer transmission loop.

## 7.2. Reliability and Power Quality Benefits

The Mesa del Sol development will provide the highest level of reliability and power quality reducing the costs associated with outages.

## 7.3. Improved Safety

The Perfect Power system will provide Mesa del Sol with a significantly more robust energy system that can respond to weather, aging, and other threats, ensuring power to residents, businesses, and institutions.

In addition, the Perfect Power system will automate high voltage switching throughout the development, eliminating the potential for personal and equipment damage resulting from misoperation during manual reconfigurations.

## 7.4. Ancillary Services

The Perfect Power system provides for robust demand response capability and local generation sources that can be called upon to improve power quality.

## 7.5. Economic Development

The proposed improvements to the Mesa del Sol electrical distribution system and the Perfect Power prototype will attract new residence and businesses to this state of the art, low carbon community.

## 7.6. Reduced Carbon Footprint

The proposed energy efficiency and solar energy features of the Perfect Power system could reduce the carbon footprint for the Mesa del Sol development by up to 100,000 tons per year. This is based on the following carbon inputs

| Input | Size | Business as Usual | Carbon Emissions, tons |
|---|---|---|---|
| Mixed Use | 11,000,000 sq-ft | 200,000 MWh | 200,000 |
| Residence | 12,455 units | 125,000 MWh | 125,000 |
| | | **Total** | **325,000** |

# 8. BUILDING PERFECT POWER

Because many upgrades cannot be supported without a prerequisite improvement to the infrastructure, Mesa del Sol's Perfect Power system would be implemented in phases. The Mesa del Sol Perfect Power prototype can be implemented in Phases over the entire 30 to 40 year development cycle.

**Phase 1: Perfect Power Buildings and Infrastructure –** In Phase 1 the team would establish a Mesa del Sol energy efficiency standard that includes demand response and on-site generation ready features. In addition, Mesa del Sol will offer solar and distributed energy systems as an optional feature through a third party. The team could establish several innovative financing and installation options to support this initiative. Examples include:

- In conjunction with local financing institutions, Mesa del Sol could offer lower financing rates for homes that are built more efficiently.
- Mesa del Sol could offer a solar energy system option in conjunction with PNM or a third party. Under this option, the customer pays PNM or a third party the retail rate plus a fee for the electricity supplied. PNM or the third party receives the PNM solar incentive.
- Mesa del Sol and PNM could offer gas fired on site generation systems as an option for customers requiring uninterruptible power. PNM could offer a monthly demand response payment for making these systems available to the demand response program. Costs could be recovered through an assessment based on 10 or 15 year financing.

**Phase 2: Perfect Power Infrastructure –** In Phase 2 PNM would continue to build out the transmission and distribution system providing for redundancy at both levels. This includes redundant area substations and substations that are cross connected.

**Phase 3: Demand Response Program –** In Phase 3, PNM would provide a development wide demand response program. This program could be expanded to include time-of-use and customer driven permanent demand response.

**Phase 4 – Eliminate Substations and Outer Transmission Loop –** Over the next ten years the team would demonstrate a dramatic and permanent reduction in demand that will eliminate the need for several planned substations and the outer transmission loop.

### 8.1.1. Regulatory Improvements

The development of a Perfect Power system includes the integration of a number of building energy systems whose first cost must typically be born by the consumer. In contrast, utility T&D investments are financed over long periods and recouped through a KWh or KW fee. One way to increase Perfect Power and sustainable energy system adoption is to provide long term financing. Innovative financing could be a major lever for creating Perfect Power. Any participation from the electric utilities in New Mexico will require state regulatory rule changes and approval. Some examples include:

- On bill financing programs which allows utilities to recover costs to install Perfect Power features on their system and bill the facility on a per KWh or KW basis monthly for 10 to 20 years to recoup costs. Under this program, the payments survive ownership changes.
- Establishment of Perfect Power districts that allow developers to install Perfect Power features on the customer side of the meter and charge the occupants an assessment fee or bill the customers for supplied energy (electric, chilled water, hot water, etc) for 10 to 20 years to recoup costs.

- Allow utilities to rate base Perfect Power improvements on their electric system for customers or portions of the system where the SAIFI or SAIDI is greater than the utility average.
- Establish a time of use or real time pricing program. These programs spur investment into Perfect Power features that reduce peak demand.

### 8.1.2. Getting Started

The Mesa del Sol build out will occur over the next 30 years and the path to Perfect Power begins with the first industrial customers and residential tracks. Mesa del Sol's first residential phase will include 560 homes. This phase provides an opportunity to demonstrate the recommended policies, technologies and impacts. The Perfect Power development could be accomplished through the following steps:

1. Establish an energy efficient building standard for residential and commercial properties. The cost would be recouped through an energy efficiency loan program that offers a lower rate or increases the buyers approved finance limits accordingly. Specifically, energy efficiency features could increase home costs by up to $5,000. This would increase the mortgage payment by $33/mon[5], which is less than the energy savings from these features.
2. Specify that all buildings be built solar and on-site generation ready. This includes modifications to electrical distribution systems to accommodated on-site generation, routing of conduit to the roof, providing a breaker in the panel, and setting aside space in the utilities area. These costs would increase the monthly payment for a home by $6.5/month[6].
3. Mesa del Sol would promote the PNM demand response program and seek to create a more robust demand response program that includes AMI, DR enabled components, and a web based demand response program with time-of-use pricing.
4. Mesa del sol would offer solar PV installation to all residents as an option through a third party. The Kyocera solar website reports that a 1.5kW solar system produces 2600KWh[7]. With the PNM incentive of 13 cents per KWh combined with offsetting the retail rate (10 cents/kWh) the customer would save $70/mo with the federal tax break. If Mesa del Sol in partnership with local financial institutions offered a solar financing program (e.g. 20 year 7% financing terms), the owners loan payment would increase by $105 per month.
5. Mesa del Sol and PNM could help manufacturing, commercial, and industrial companies with the integration of Solar PV and distributed energy to improve site reliability. Customers with distributed energy could participate in the PNM demand response program, providing additional resources to moderate peak demand.
6. Mesa del Sol and PNM could work together to minimize the number of substations and eliminate the outer transmission loop while encouraging PNM to evaluate and adopt technologies that improve system reliability such as the Vista automated switches.

All of these combined features are designed to manage the peak demand, improve system reliability, and reduce infrastructure requirements.

[5] 30 year mortgage at 7%

[6] 15 year financing at 10%

# 9. REFERENCES

1 The Path to Perfect Power: New Business Opportunities for A Customer-Demand Driven Electricity World, Galvin Electricity Initiative, 3412 Hillview Avenue, Palo Alto, CA 94304, (650) 855-2400, www.galvinelectricity.org, November 2006.

2 Lawrence Berkley National Labs Report, Understanding the Cost of Perfect Power interruptions to U.S. Electricity Consumers, September 2004, prepared by Kristina Hamachi LaCommare and Joseph H. Eto Ernest Orlando.

3 Department of Energy, Energy Information Association, Annual Energy Outlook 2006 Table A8 reports that the U.S. used 3,730 billion KWh in 2004.

4 Master Controller Requirements Specification for Perfect Power Systems Rev. 2.1, Galvin Electricity Initiative, 3412 Hillview Avenue, Palo Alto, CA 94304, (650) 855-2400, www.galvinelectricity.org, November 2006.

5 The Galvin Electricity Initiative: Task 3 – Technology Scanning, Mapping and Foresight, Galvin Electricity Initiative, 3412 Hillview Avenue, Palo Alto, CA 94304, (650) 855-2400, www.galvinelectricity.org, March 2006.

6 World Business Council Greenhouse Gas Protocol, Imported electricity emissions factors are from http://www.ghgprotocol.org/templates/GHG5/layout.asp?type=p&MenuId=OTAx, which provides a spreadsheet tool with CO2 emission factors. For this region, a factor of 1.424 lbs/KWh is provided for 2000. The average electricity grid CO2 emissions factor from EPA Egrid database is 1.992 lb/KWh for 2004

7 http://www.clean-power.com/Kyocerasolar/default.asp

# EXHIBIT A:  FAILURE MODES AND EFFECTS ANALYSIS

## PNM Supply

| Sub-Process | Failure Modes | Severity | Probability | Solution Set |
|---|---|---|---|---|
| PNM Transmission | Lose supply power due to system event or weather Component failure | Major | Remote | Supply Mesa del Sol from two separate transmission lines |
| PNM Switch Stations | Lose supply power due to system event or weather Component failure | Major | Remote | Animal and lighting protection |
| PNM Switch Station Breaker | Overload trip | Major | Remote | Automated breakers for re-closure after event |
| | Nuisance or fault | Major | Remote | |
| PNM distribution to site substations | Cable failure - lost feeder due to weather, equipment failure, or human error | Major | Remote | Underground transmission lines – 3 miles in center of development - $5,000,000 per mile.  Above ground transmission costs $500,000 per mile. |
| | Truck knocks down pole | Major | Remote | Above ground sections are isolated and protected from vehicular damage |
| | Lightning strike damages equipment | Major | Remote | Lighting protection |
| | Cable failure, loss of phase, or voltage sag | Major | Remote | |
| Step down Transformers | Animal, weather, lightning, accident | Major | Remote | Animal and lighting protection |

# EXHIBIT A: FAILURE MODES AND EFFECTS ANALYSIS

## Site Distribution

| Sub-Process | Failure Mode | Severity | Probability | Solution Set |
|---|---|---|---|---|
| Mesa del Sol substations | Over capacity | Moderate | Remote | Robust demand response program |
| | Power quality | Moderate | Remote | Redundancy from adjacent substations |
| | Equipment failure due to aging | Major | Remote | Single failure design, 50% margin |
| | Substation esthetics | Major | Frequent | Robust EE and DR program to reduce # of substations<br>Landscape |
| Substation Breaker | Overload trip | Moderate | Occasional | Automated reclosure |
| | Nuisance Fault | Moderate | Occasional | |
| Building Feeders | Over Capacity | Moderate | Varies | Redundancy from adjacent substations<br>Loop design to provide for rerouting of power<br>Robust demand response and EE program |
| | Aging – short to ground | Major | Uncommon | |
| | Accident or weather damage | | | |
| | Dig inn | Major | Occasional | |
| | Voltage sag/power quality | Moderate | Occasional | |
| Fault Isolation Switches | Manual switches require manual operation | Moderate | Frequent | Automated for isolation of faults and rerouting of power |
| Communications | Wire fault or damage | Moderate | Frequent | Fiber and wireless and fiber to all switches and loads |
| | Router failures | Moderate | Uncommon | intelligent switch communications |
| | Wireless fault | Occasional | Occasional | Radio communications to smart switches |

## Building Distribution

| Sub-Process | Failure Mode | Severity | Probability | Solution Set |
|---|---|---|---|---|
| Distribution Feeder | Lost power | Major | Occasional | Building UPS, storage, and/or DE |
| Distribution Switch | | Major | Remote | Automated building switches for isolation of major loads |
| Building meter | Loss of data<br>Lack of interval data | Minor | Remote | Advanced metering with wireless communications |
| Building Transformer | Overload | Moderate | Remote | Building demand response program |
| | Voltage sag | Moderate | Frequent | Local generation assets |
| | Harmonic distortion | Moderate | Remote | |
| Building Equipment Demand Controls | Lost signal | Moderate | Occasional | Load controllers for major equipment and building isolation capability |
| Integration of DR | Building distribution systems not supportive of DR | Moderate | Occasional | Develop solar and DR ready building designs |

## EXHIBIT A: FAILURE MODES AND EFFECTS ANALYSIS

# Procurement and Sustainability

| Sub-Process | Failure Mode | Severity | Probability | Solution Set |
|---|---|---|---|---|
| Asset Utilization | Higher capital costs due to poor utilization of site distribution components | Moderate | Frequent | Prioritize loads and develop load transfer and shed capability |
| | | | | Reduce cooling loads |
| | | | | Energy storage |
| | | | | Monitor all feeder loads |
| | | | | Install generators or electricity storage for demand response |
| | | | | Create real time price response program |
| Efficiency | Poor process efficiency | Major | Frequent | Build to ASHRAE 189 or CA Title 24 05 standards |
| | | | | Advanced lighting, windows, and HVAC |
| | | | | Improve building envelop and controls |
| | | | | Exhaust heat recovery via sensible wheel |
| | | | | Occupancy sensors and smart thermostats |
| | | | | Variable speed drives |
| | | | | Solar shading |
| Emissions | | | | |
| | High carbon reduction | Moderate | Frequent | On-peak cogeneration to offset carbon emissions |
| | | | | |
| **Sustainability** | | | | |
| Reduce carbon footprint | Procurement of coal generated electricity | Major | Frequent | On-peak cogeneration to offset coal purchases |
| | Poor energy efficiency | Major | Frequent | See above |
| | | | | Building shading using trees which also consume carbon |
| | | | | |
| Increase use of renewable sources | Low renewable resource | Major | Frequent | Solar hot water, PV,<br>Purchase renewable generation<br>Geothermal |

# EXHIBIT B:  SOLUTIONS SET

| Upgrade | Purpose/Benefit | Specification[7] | | |
|---|---|---|---|---|
| **Enabling Technologies/Perfect Power Foundation –** | | | | |
| | | | | |
| Automated Distribution System Switches | Isolate fault and reroute power to alternate sources | Solid state transfer switches, quarter cycle response time, smart switches | | |
| Automate Building Switches | Enable remote and automatic reconfiguration of building loads | | | |
| Building Meters | Provide for demand response, solar PV, and time of use pricing | AMI | | |
| Loop system/redundant building feeds | Provide ability to | | | |
| Building Management Systems | Maximize building efficiency | | | |
| High speed dedicated communications network | Provide for communication with third party web based energy management systems and utility demand response | | | |
| **Intelligent Monitoring** | | | | |
| System meters | | | | |
| Weather monitoring and lightning sensors | | | | |
| Power quality monitors | | | | |
| | | | | |

[7] List of key functions, requirements, features.

## EXHIBIT B: SOLUTIONS SET

| Upgrade | Purpose/Benefit | Specification[7] | | |
|---|---|---|---|---|
| **Master Controller** | | | | |
| Develop Perfect Power system modes of operation | Provide for modes of operation which sustain system operation | Island mode, safe mode, real time pricing mode | | |
| Automatic load shedding and sequencing | Supports islanding and robust demand response | | | |
| **Building Integrated Power Systems/Local Generation/Demand response** | | | | |
| Backup generation | Carry the building load for an extended distribution system outage | | | |
| UPS/Storage | Ride through capability | | | |
| Install load controllers on large equipment | Provide for ability to match building output with generator capability | | | |
| **Sustainability** | | | | |
| Advanced lighting | Reduce electricity and natural gas consumption and associated carbon emissions | T8, LED, day lighting, compact fluorescent lamps, occupancy sensors | | |
| Advanced windows | Reduce electricity and natural gas consumption and associated carbon emissions | Higher R value, tinted, low-E windows. | | |
| Higher efficiency HVAC | Reduce electricity consumption and associated carbon emissions | Higher coefficient of performance, variable speed drive motors | | |
| Exhaust heat recovery | Reduce electricity and natural gas consumption and associated carbon emissions | Sensible wheel | | |
| Solar shading | Reduce electricity and natural gas consumption, improve esthetics, and consume carbon | | | |
| Solar hot water | Reduce natural gas use and carbon emissions | | | |
| Geothermal | Reduce natural gas use and carbon emissions | | | |

# EXHIBIT C: GAP ANALYSIS

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| **Feature** | **Impact (KW)** | **Cost Factor Base** | **Cost Factor PP** | **Units Base** | **Units PP** | **Baseline Cost** | **Perfect Power Cost** | **Gap** | **Impact (KW)** |
| **Transmission and Distribution Perfect Power Features** | | | | | | | | | |
| Switch Stations | | | | 2 | 2 | | | | |
| Substations | | $3,500,000 | $3,500,000 | 7 | 4 | $24,500,000 | $14,000,000 | $10,500,000 | |
| Circuits with crossties | | $1,000,000 | $1,000,000 | 28 | 16 | $28,000,000 | $16,000,000 | $12,000,000 | |
| Manual Switches | | $30,000 | $30,000 | 140 | 60 | $4,200,000 | $1,800,000 | $2,400,000 | |
| Smart Switches, delta | | $60,000 | $60,000 | | 60 | | ($3,600,000) | ($3,600,000) | |
| Transformers | | $7,500 | $7,500 | 2400 | 1800 | $18,000,000 | $13,500,000 | $4,500,000 | |
| Underground Transmission | | $5,000,000 | $5,000,000 | 0 | 0 | $0 | $15,000,000 | $0 | |
| Eliminate Outer Loop | | $1,000,000 | $1,000,000 | 10 | 0 | $10,000,000 | $0 | $10,000,000 | |
| AMI | | $0 | $200 | | | $0 | ($2,591,000) | PNM DR prog | |
| Demand Response | 0.325 | $0 | $800 | 0 | 12,455 | $0 | ($9,964,000) | PNM DR prog | 2,000 |
| Demand Response | 18.5 | $0 | $2,000 | 0 | 500 | $0 | ($1,000,000) | PNM DR prog | 6,000 |
| **Facility Perfect Power Features** | | | | | | | | | |
| EE Residential | 0.5 | $0 | $5,000 | 0 | 12,455 | $0 | ($62,275,000) | Offset by savings | 4,000 |
| EE Commercial | 25 | $0 | $30,000 | 0 | 500 | $0 | ($15,000,000) | Offset by savings | 10,000 |
| Solar PV Residential | 1.5 | $0 | $13,500 | 0 | 12,455 | $0 | $0 | Offset by savings | |
| Solar PV Commercial | 20 | $0 | $180,000 | 0 | 500 | $0 | $0 | Offset by savings | 0 |
| Solar Ready Homes | | $0 | $600 | 0 | 12,455 | $0 | ($7,473,000) | ($7,473,000) | 6,000 |
| Solar Ready Commercial | | $0 | $3,000 | 0 | 500 | $0 | ($1,500,000) | ($1,500,000) | 2,000 |

* While the results show a reduction in infrastructure costs, the energy efficiency and solar PV upgrades will reduce annual revenues by $2 to 3 million annually.