1 Executive Summary

This report summarizes opportunities and stakeholder value that smart grid technologies can present to the University of Minnesota’s UMore Park development. The report begins by summarizing the research approach with following sections to include: background information on the electrical grid, an overview of “smart grid”, why smart grid is important to UMore Park, and key stakeholders and technologies that should be considered when pursuing smart grid at UMore Park. In addition, current smart grid implementations are provided to demonstrate lessons learned that can be applied to UMore Park.

The team of students that authored this paper applied tools learned in the University of Minnesota Management of Technology (MOT) program to analyze the impact and opportunities of smart grid related technologies to UMore Park. The first stage was to perform a systematic scan of the technology space and stakeholder environment. This defined the parameters within which the detailed research and analysis would be carried out. MOT tools such as scenario planning, normative forecasting, technology interaction matrices (TIM™), and the technology space map were used to identify areas of opportunity. These were characterized based on the impact on and opportunity to realize the vision of the UMore Park development. The final section of the paper outlines a recommended strategy for UMore Park using the Sustained Competitive Advantage framework.

There are two broad themes that the recommendations fall into: Key differentiating factors for UMore Park and navigating the regulatory environment.

**Theme 1: Key differentiating factors for UMore Park**

The first theme is that UMore Park has an opportunity to create a differentiated community when compared to every other community in the country. Key differentiating factors are twofold:

- A vision for the usage of renewable energy sources and maximizing energy efficiency
- Lifestyle opportunities that stem from involvement of the University of Minnesota.

The main recommendation is that UMore Park should conduct a detailed analysis to show whether a district energy model to provide heating and cooling to the residents of the new community is a viable opportunity. The paper shows a prototype financial model and a potential system design that appears to be almost twice as energy efficient than using natural gas for heating and electricity for air conditioning. This model assumes that UMore Park would sell energy to the residents using a business model that would generate cash flow for the company and ultimately accrue to the University of Minnesota.

The second recommendation for product differentiation is to incorporate smart system technology into the home and integrate home management with the district energy model to build smart homes since many of the customers who will buy houses in the UMore Park development will be so-called “Digital Natives” and have a high expectation of connectedness in all aspects of their lives. The timeline for the UMore Park development is around 30 years, so there is a need for continuous scanning and adopting new technologies as they are developed. UMore Park should be bold in the adoption of new technologies that support the overall vision of the development.
The final recommendation for this theme is to ensure that the University of Minnesota does not waste an opportunity to develop new research areas arising from the data that homeowners will generate and that can be captured as part of the smart system infrastructure. Data mining will require careful planning and establishing safeguards to ensure that the data is handled appropriately by the University.

**Theme 2: Navigating the regulatory environment**

The second key theme is navigating the regulatory environment in order to realize the vision of creating the world-class community. Utility companies operate in a heavily regulated industry and any attempts by UMore Park to develop new business models around the provision of energy are constrained by existing regulations. For this reason it is in UMore Park’s interest to actively engage with Xcel Energy and the State of Minnesota Public Utilities Commission as well as follow industry trends in energy progressive states such as California, Texas, Massachusetts and Colorado. Anticipated discussion areas would be:

- Making the case for regulatory reform that would allow for different business models and changing incentives for utility companies
- Models to reduce energy usage levels and costs, such as time of use pricing, demand response, net metering and buy back agreements (these topics are presented and discussed later in the paper)
- Education opportunities within the UMore Park community that would change consumer behavior to encourage lower energy usage

In order to increase the impact of the dialogue with the PUC and Xcel Energy, UMore Park should also develop relationships with other groups, communities and organizations, who have similar motivations to change the regulatory environment. This would provide a stronger voice for the issue.
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2.1 Statement of Opportunity

The University of Minnesota Outreach, Research and Education (UMore) Park is a 5,000-acre site southeast of the Minneapolis/Saint Paul Metro area in Dakota County. The University of Minnesota Board of Regents has issued eight guiding principles for decisions made regarding UMore Park. These principles balance utilizing the UMore Park property for supporting the University’s mission of education, research and engagement while utilizing UMore to augment the financial health of the University.

The vision for UMore Park is outlined in the Concept Master Plan (Design Workshop, 2009). In short, the vision is that the park will be developed into a “sustainable, modern, University founded community” of around 25,000 people over 30 years. The community will be built incorporating “innovations in renewable energy, education, environmental quality, transit, technology, housing and other University mission strengths.” The development will be built to meet 21st century needs with 21st century technology in mind.

Since renewable energy is a cornerstone being designed into UMore Park, it is important that the community be equipped with infrastructure and technology to efficiently utilize and distribute the energy required. As will be shown in this paper, the smart grid and, more broadly, smart systems provide a method of managing and optimizing the energy needs of the community.

2.2 Methodology

The project methodology consisted of three major steps as illustrated in Figure 1.

![Figure 1 Methodology](image)
A structured process learned throughout the MOT program was utilized for the UMore Park Smart Grid project. The research phase gathered background data on the UMore Park project, Smart Grid technologies and explored other ideas that may contribute to successfully implementing the vision for the UMore Park development. The analysis phase took the information from the research phase and utilized MOT tools to dissect and make sense of the information. Once the analysis was complete, the team was able to move to the recommendations phase, which is where actionable recommendations were created for UMore Park.
3.1 Introduction
Electricity is a key type of energy and is essential to the economic prosperity for any nation. Electricity enables virtually all activities of the modern world, from purifying and pumping water to our faucets, to high-tech, cutting-edge research and development. In fact, there is a direct correlation between a nation’s ability to generate electricity and the income per person of its citizens. (See Figure 2) The relationship between electricity consumption and economic growth has a direct correlation: “as real GDP increases, the value of electricity consumption would increase too.” Examples of this correlation are documented in countries such as Malaysia, Turkey, and the continent Africa (Berrie, 1992).

The following sections of this report will provide an overview of the how electricity is generated and delivered to customers through the existing electrical grid. This introduction is followed with the definition of a smart grid and its key components, a discussion of the benefits of adopting a smart grid, key stakeholders, and reasons that UMore Park should adopt smart grid technologies in its community.
3.2 Basics of the Electrical Grid

3.2.1 Electricity

Among energy sources, electricity is unique in its ability to be transmitted efficiently over long distances. The transformative power it has on societies and quality of life is second to no other utility; in addition to providing light and powering industry, it is the basis for other essentials such as heating, cooling and running water. Unfortunately, the same physical properties that make electric energy so efficient in transmission is also its biggest drawback. The massive charge carried by the electrons makes electricity so difficult to store that almost all electrical energy is used within a second of being generated, and if not used, it is wasted (Hadjipaschalis, Poullikkas, & Efthimiou, 2009).

3.2.2 Generation

Electricity, a useful form of energy, is generated in a power plant by converting another form of energy into electricity. Common energy sources utilized in the production of electricity are coal, fossil fuels and nuclear energy. Petroleum, natural gas, coal and biomass are all converted to electricity through the process of combustion. The heat released from the combustion process is used to generate steam at high pressures, which is used to turn a turbine to generate electricity. Similarly, the heat from a nuclear reaction is utilized to generate high-pressure steam, which is also used to turn a turbine and generate electricity. Increasingly renewable sources such as wind, solar, hydro, and biomass are used to generate power. Figure 3 below illustrates the different supply sources and what percentage of each source is used to generate electric power.

![Figure 3 US Primary Energy Flow - Quadrillion BTU's](Annual Energy Review 2009 Report No. DOE/EIA 0384)

A fundamental problem with the generation of electricity from traditional sources is that there is great deal of energy wasted due to thermodynamic limits in the process. Figure 4 illustrates the amount of energy that is converted to electricity at the turbine (37%) and the amount lost in the process of
conversion from fuel source to electricity (63%). The losses during the process is waste heat that cannot be converted to electricity. This is an inherent disadvantage of electricity.

3.2.3 Transmission & Distribution – “The Grid”
“Electrical power is similar to the air you breathe: You don’t really think about it until it is missing” (Brain). Over 500,000 miles of transmission lines are staggered across the United States. Unfortunately most were installed about half a century ago. Figure 6 (Washington) shows the multiple parts of electrical transmission: main transmission line, main substation, secondary transmission line, secondary substation, main distribution line, secondary distribution line, street distribution and service line. This collection of assets is what is commonly referred to as “the grid”. The assets that make up the grid have a value estimated at one trillion dollars. The grid enables the production and distribution of power in Washington State to be transmitted to Florida if necessary. It is an amazing engineering achievement as noted by the National Academy of Engineering which identified it as the single most important engineering achievement of the 20th century.
Figure 5 outlines the present distribution available in the area surrounding UMore Park.

Figure 5 Power Lines and Substations at UMore Park (State of Minnesota, 2007) Red dots are substations, orange lines are 115 kV AC, blue lines are 230 kV AC, red lines are 345 kV AC
The grid consists of many assets and structures that people recognize and associate with electricity. Two examples are the substation, which transforms electricity as it passes through the grid, and transmission lines, which deliver electricity throughout the grid. There are also many parts of the grid that are behind the scenes and unknown to most consumers. As an example, Figure 7 below shows one of many control rooms that are used to manage the generation and distribution of electricity. Each command center is required to coordinate and control one of the most complex, interactive systems in the world.

Figure 7 Electrical Grid Control Room (Power Grid Ontario)
While it’s important to acknowledge that the current grid is a truly amazing feat of engineering, there are several well-observed trends, which indicate that a technology upgrade is needed.

![Demand for Electricity Is Projected to Increase At Least 30% by 2030](image)

**Figure 8 Forecast of Electrical Demand (Edison Electric Institute)**

Firstly, demand for electricity is projected to increase approximately 30% by 2030 (see Figure 8). The typical method used to meet increasing power demand today is for utilities to build large, expensive power plants. These plants are built with future demand in mind but must be paid for today. Therefore, the cost is passed on to the consumer through rate increases. This trend provides an argument to find methods of controlling electrical demand to reduce the need for new capital investment.

Secondly, the number of outages and the number of people they affect have been increasing over the past. According to data from the Electric Power Research Institute (known as EPRI), the average outage affected 15% more people between 1996 and 2000 than it did from 1991 to 1995. Also, there have been an increasing number of cascading failures on the grid as well as frequent “brown outs (reduced voltage)” and rolling black outs due to constrained electrical infrastructure. (Amin, North America’s Electricity Infrastructure: Are we ready for more perfect storms?, 2003). The chart below in Figure 9 illustrates the growing size and number of these power outages.
These outages have a staggering economic impact on the productivity of the country, estimated at $79 Billion per year in a report published out of Ernest Orlando Lawrence Berkeley National Laboratory in 2004. The breakdown of where costs occur is illustrated in Figure 10.

These costs are split between industrial, commercial and residential customers, and they are ultimately passed on to the consumer, even though they may not be easily traceable. For example, if a grocery store has large amounts of food spoilage due to frequent power outages, the spoilage costs will be passed on to the consumer through higher prices in the store. The bottom line is that we all pay for inefficiencies in the cost of goods and services we purchase every day. Improving and implementing a smart grid that can prevent power outages and provide a reliable source of electricity will have a positive impact for everyone.
3.2.4 **Who “Owns” the Grid?**
Electrical generation, transmission and distribution have changed since large scale generation became available. Today, “Investor-owned utilities account for ownership of over 50% of net generation and almost 80% of transmission. Public-owned utilities and cooperatives, along with the Federal power agencies, account for approximately 25% of net generation and almost all of the remaining transmission. Independent power producers account for the remaining 25% of net generation” (Department of Energy).

3.2.5 **Who Runs the Grid?**
According to the Department of Energy “There are many individuals involved in running the grid. There are generator operators and transmission owners. But from a system perspective, one of the most critical entities is the independent system operator or regional transmission organizations (ISOs and RTOs). They monitor system loads and voltage profiles; operate transmission facilities and direct generation; define operating limits and develop contingency plans; and implement emergency procedures.”

Unfortunately, because of the distributed nature of ownership and control of the grid, the technology is aging and lacks the capabilities required for the 21\textsuperscript{st} century. To illustrate this point, consider this: if the father of the grid, Thomas Edison, showed up today, he would recognize much of the equipment and technology utilized on the electrical grid. Compare this to the father of the telephone, Alexander
Graham Bell, who would recognize very little of the telephone infrastructure, which includes numerous advances such as touch-tone dialing, cellular phones, and VOIP devices. Fortunately, there is now a push to upgrade critical electrical infrastructure and equip it with 21st century technology. This is the “smart grid.”

3.2.6 What is Smart Grid?
The term “smart grid” is a vision for a 21st century electrical grid with modern technology to:

- Support alternate sources of energy
- Improve monitoring of systems
- Provide better supply and demand data
- Provide greater resiliency
- Improve electrical security and reliability
- Become a launch pad for innovation and jobs

Through a collection of technologies that monitor and manage energy consumption, the smart grid will also empower consumers to take control of their energy use through energy interfaces and proactive decisions about energy consumption. A modern, reliable, and consumer-friendly smart grid will be the backbone for innovation and jobs in the digital era. It will also be a critical component for building environmentally, socially, and economically sustainable communities, such as the one envisioned for UMore Park.

3.2.7 Consumer Technologies
One aspect to a smart grid is to enable consumers to take control of their electricity use by providing information in a convenient format while allowing them to participate and chose the best methods to meet their electrical needs. If you have ever traveled in a hybrid or computer equipped vehicle, think about the interfaces were developed to help users understand how their driving habits affect fuel consumption. Ford created a system that grew leaves on a tree as driver’s behaviors changed and fuel mileage improved. The same concepts will be applied to smart grid-enabled infrastructure. Homes will be outfitted with meters and technology that provide homeowners with real-time electrical consumption, pricing, and tools to help reduce and manage their usage via two-way communication.
between the end user and the utility company. Because electricity has to be used the moment it is generated, utilities will be able to better match just-in-time product delivery avoiding the ramp up of an additional electrical source and avoiding waste.

3.2.8 Why is Smart Grid Important to UMore Park?
For UMore Park, a smart grid is important for efficient integration of alternative power sources, maintaining electrical system reliability, enabling methods to embrace environmentally friendly systems and prepare for new technology while considering affordability. A smart grid would also enable the evaluation of a district model of electrical generation that could be combined with the district model for heating and cooling resulting in a highly efficient utility system for the community. This could ultimately mean a lower environmental impact with low cost of utilities for the community.

Because the UMore Park development is a greenfield project, it offers many unique opportunities where smart grid technologies can be built into the infrastructure as opposed to retrofitted later. The total cost is lower if the infrastructure is installed at the beginning of a project, instead of retrofitting or replacing. It offers the opportunity to pursue unique partnerships with companies who are eager to have the chance to showcase their technology in a state of the art community that UMore Park will be.

As illustrated in Figure 11 below, the technology associated with the smart grid reaches from the home to the utility. The benefits that the incorporation of these technologies could have on future residents of UMore Park, as well as the impact that these technologies could have on the community as a whole are substantial. Avoiding the status quo by incorporating 21st century technology into UMore Park will avoid the issues currently plaguing the electrical infrastructure in other areas.

Figure 11 Diagram of the Key Smart Grid Components for Transmission and Distribution (McKinsey, 2010)
3.2.9 **Electricity and the Grid pose Challenges**
Improving the performance and operation of the grid needs to be a top priority. The challenge for UMore Park is that electrical markets are heavily regulated and influential power is in hands of the utilities. While the PUC is a body that is intended to ensure fair treatment for consumers, the current climate in Minnesota shows little likelihood of regulatory changes anytime soon. There have been some changes and interpretations of rulings that show promise for the possibility of feed-in-tariffs in the near future, but they will more than likely be tested in places like California before they are ever evaluated for Minnesota. Minnesota has abundant power, low costs (relatively speaking) and high reliability. These factors prevent consumers from clamoring for change and utilities from seeking to adopt alternative price structures.

While the regulated environment around electricity presents challenges, it does not mean that UMore Park should not pursue and test the status quo. As a matter of fact, UMore Park should closely monitor and even consider getting involved and pushing for reforms of the regulated electricity market. If UMore Park wants to be a net zero community then it will need the flexibility to move power around inside the community to be used where it is needed and not necessarily where it is generated. This will require a change from the status quo. Xcel energy maintains the statutory right to sell power and intends to enforce this right in the UMore Park community (Goldberg, 2010). This will limit the options UMore Park has for maximizing the value of investments that generate electricity.

### 3.3 The Components of a Smart Grid

#### 3.3.1 Energy Storage
Large-scale energy storage is widely regarded as a critical enabler for a capable grid, “smart” or otherwise, and a wide range of potential methods for storing energy are being pursued. Error! Reference source not found. shows a comparison of different types of storage technologies rated by storage capacity and dissipation rates. Compressed Air and Pumped Hydro have the most promising attributes, but are frequently limited by geography and geology. With further advancements, electrochemical battery technology may be applied in a Smart Grid warranting focused research and development in order to foster energy independence, reduced carbon emissions and increase grid reliability.

Among electrochemical batteries, well-known Li-ion and metal-air technologies are the best for small installations (personal transport and single-home use) because of superior energy densities; while, at larger scales, lifecycle cost is more important, and it is here recent developments in “flow cells” make them a candidate for widespread adoption.

Our general inability to store electrical energy easily within the grid means that supply must always closely be matched to or above demand, and large variations in demand will persist despite efforts for demand side management. Most often spikes in demand equate to starting petroleum or natural gas fired “peaker” plants to keep the system running at the expense of efficiency (Walls, Rusco, & Ludwigson, 2007). Furthermore, the addition of solar, wind, geothermal and other intermittent energy sources will exacerbate these challenges over a scale ranging from the single-dwelling photovoltaic installation to a grid-connected wind farm for if the energy provided from these proximity generation
sources is not utilized immediately or stored, it too is wasted. For these reasons, alternative energy installations such as the proposed wind turbine at UMore Park should counterbalance the energy peaks and troughs with grid level storage that can smooth power distribution and integrate seamlessly with the primary power provider.

3.3.2 **Open Auto Demand Response Systems (ADR)**

“There is no dispute that shaving peak usage on a sustained basis can lower system costs. Meeting peak demand, of which 10 percent is concentrated in the top 1 percent of hours of the year, requires the installation of generating plants that are idle most of the year, and whose fuel costs are higher than fuel costs for other plants. Their costs-per-kilowatt-hour-generated are the highest of all plants. For this reason, if a cost-effective means can be found to shave demand off the peak in the long-term, considerable resource savings should be possible” (Brockway, 2008). The challenge with ADR is to set a precedent for “open” ADR through supporting a low-cost communications infrastructure to improve the effectiveness of demand response (DR) in commercial or residential buildings. Lawrence Berkeley National Labs is currently developing the standard for Open ADR. Standards development has lead to the OpenADR Alliance to foster collaboration and adoption of an industry solution. ADR and OpenADR benefit everyone.

3.3.3 **Advanced Metering Infrastructure**

Smart grid does not equal Advanced Metering Infrastructure (AMI) and vice versa (see Figure 12 for a visual depiction of the differences). According to the Federal Energy Regulatory Commission (Federal Energy Regulatory Commission Staff Report Appendix A (Glossary), 2007) AMI is defined as:

> “AMI is one way, but only one way, for a utility to offer time-varying utility prices and induce demand response” (Brockway, 2008). AMI **is considered the first step to a Modern Smart Grid.**

A metering system that records customer consumption (and possibly other parameters) hourly or more frequently and that provides for daily or more frequent transmittal of measurements over a communication network to a central collection point. AMI includes the communications hardware and software and associated system and data management software that create a network between advanced meters and utility business systems and which allows collection and distribution of information to customers and other parties such as competitive retail providers, in addition to providing it to the utility itself.
3.3.4 AMI: What can it do?
There are three primary benefits of AMI: Operational savings, Resource savings and Service improvements.

- **Operational savings** made possible by implementation of an advanced metering infrastructure come primarily from reduced meter reading costs and other substitutions of AMI technology for more costly labor.

- **Resource cost savings** from AMI would result from, and occur proportionate to the extent of, persistent demand reductions achieved by introducing dynamic pricing and demand response programs implemented using AMI technology.

- **Service improvements** include faster and more precise identification of outages, more accurate metering and billing, and the like.

3.3.5 AMI: Do we need it?
Currently, utilities are focusing on developing AMI to implement residential demand response and serve as the chief mechanism for implementing dynamic pricing (NIST, 2010). Many residents of Minnesota may not be familiar with dynamic pricing because energy is relatively inexpensive when compared to states like California or Massachusetts. The US Energy Information Administration (EIA) publishes the average electricity price per state, and the most recent data is presented in Figure 13.
Minnesota ranks in the next to lowest tier for cost of electricity. Studies have been done to evaluate the adoption drivers for a smart grid with smart metering capabilities. The cost of electricity tops the list for early adoption. Smart meters and real-time dynamic pricing are catalysts in the smart grid market, but Minnesota customers do not have to endure high prices for electricity yet. For those looking to implement smart grid homes, communities, universities, cities or states, there are many other factors influencing decisions for adoption. And, regardless of the innovator’s enthusiasm most are stagnated by policy.
3.3.6 Smart Meters: What Are They?
Existing electromechanical meters used in most homes and commercial space are technologically limited. For example, they lack the ability to show aggregated energy consumption for specific time periods or total energy amount used during a billing period. As noted in this report, studies indicate that consumers are behaviorally driven to use less energy when they are aware of their consumption habits. Smart Meters allow an immediate feedback mechanism for end users to understand their consumption and that of their community. Smart Meters also allow energy providers the ability to offer varied rate structures to incentivize energy savings.

For UMore Park to realize “lower societal energy costs over the long term, lower bills for many customer segments in the short term, and improve service” Smart Meters, Advanced Metering Infrastructure (AMI) and Auto-Demand Response (ADR) need to be implemented intelligently to allow for energy diversification and prepare for future regulatory changes in the utility markets.

A “smart” meter is any device that records energy consumption in regular intervals and then communicates this information back to the energy provider daily for monitoring, billing and demand response purposes. Several attributes create a “smart” meter:

- Two way communication between meter and energy provider that provides and Advanced Metering Infrastructure
- Real-time, or near real-time energy Time of Use (TOU) consumption data
- Remote meter reading
- Utility software that can aggregate, analyze and digest energy data
- Auto Demand Response (ADR) enabling

“Full deployment of AMI results in the elimination of old and obsolete electromechanical meters that tend to slow down as they age. Modern AMI meters maintain their accuracy over time, resulting in a more equitable situation for all consumers. In addition, modern meters are self monitoring, making it easier to identify inaccurate measurements, incorrect installations and especially, electric energy theft” (National Energy Technology Laboratory, 2008).

In areas throughout the United States where smart meters have been deployed, savings have varied depending on the utility rate structure, consumer education, real-time availability of data, initial capital expenditures and consumer education. The chart in Figure 15 shows the breakdown of savings achieved in a selection of studies.

It is not surprising to learn that in areas where Time of Use (TOU) pricing was implemented, many customers were surprised to find that electricity bills increased as they failed to curb demand during peak periods while the majority enjoyed savings.

It is estimated that by 2020 68,839,650 smart meters will be installed across the United States (Edison Foundation, 2010).
3.3.7 Smart Meters, Regulators and the Public Utility Commission (PUC)

Regulators and Public Utility Commissions are a wildcard in the advancement of Smart Meter installations. For a Smart Meter installation to be effective and maximize return on investment, it needs to utilize a TOU rate structure. In areas such as Minnesota where electricity prices are currently cheap, many will not see the immediate benefits of having technology capable of TOU rates. For this reason, the decision whether or not to implement Smart Meters is discretionary. As utility companies struggle with challenges such as high generation costs and peaker plants, the incentives of a TOU structure or Demand Response (DR) system will someday outweigh the burden of AMI investment. While skeptics will always question change, pilot results have indicated that an overwhelming majority of consumer participants are satisfied with time-varying pricing (Brockway, 2008) with smart meter implementation.

California has set examples in many energy conservation and proactive standards. The use of smart meters and AMI is an example. To create a fair price structure and incentivize consumers to change their behavior regarding energy usage, the state and the PUC decided on the strict criteria for implementing AMI which can be found in Appendix C: California PUC and AMI Requirements.

Figure 14 Average electrical savings with smart meters (ACEEE, 2010)
3.3.8 Barriers

Figure 15 Smart Meter Barriers

3.3.9 What Are the Benefits?

Electrification was one of the main enablers of the incredible economic growth that was achieved in the twentieth century and the belief is that a smarter grid would provide a platform to continue the growth trends. Proponents of the smart grid also point to the improved efficiency that could be achieved by being able to match and influence supply and demand more effectively, and the environmental benefits that would accrue as a result. A modular smart grid would be far more capable of integrating small scale renewable power generation, like residential solar installations etc.

There are also societal trends which would be supported by the introduction of a smart grid, for example, it is difficult to imagine the wholesale adoption of electric vehicles without major upgrades to the provision of electricity.

Finally there is a vision that once a smart grid is in place then alternative business models for the provision of electricity would be easily conceivable. Demand response systems and time of use pricing would allow consumers to have more control over how much electricity they would use and the price they would pay for it. In Minnesota this isn’t as significant a benefit as in other places where electricity can cost as much as 10 times as here.

Where does the smart home fit into this equation?

A smart home and the smart grid don’t completely go hand in hand. Either can be implemented without the other, although many of the required technologies are similar, both concepts rely on digital controls,
sensors and communication networks. However due to the nature of networks, the capabilities of the smart grid are augmented by smart homes and vice versa.

The concept of the smart home has been around for a very long time; in fact the trend toward home automation began with electrical appliances, which allowed normal people to multi-task by letting a machine do a manual task. Smart homes take this concept and bring it into the digital age where it is possible to build control systems that have some intelligence. This allows homes to react to external stimuli and adjust accordingly. Applications range from the relatively simple act of turning off electrical devices, such as lights or televisions, when there is nobody at home, to more complicated automation, like anticipating when the homeowner will arrive home from work based on current location and traffic patterns, cross referencing with current weather information and adjusting the thermostat so that the home is at the correct temperature when the homeowner arrives.

The reason that the smart grid and the smart home are considered to augment one another lies in the interactions possible when each network can communicate with the other. Utilities can better forecast demand if smart homes can communicate patterns and habits, and homes can be programmed to react to pricing models that could be deployed by utilities. For example, a utility might know that it needs to shed 500 KW of load in 30 minutes for one hour. It might be willing to pay consumers not to use electricity that they are currently using. If a home knows that there is nothing perishable in a refrigerator or that the home occupants will not mind a mild temperature increase due to air conditioning being deactivated for one hour, then the smart home might agree to turn off appliances for the time period, without any interaction from the consumer. At the end of the day a simple dashboard report could inform the home owner where money was saved and she could tune the home to be more or less accepting of similar offers in the future.

Retrofitting an older home with smart technology is possible, but has a payback period that is dependent upon the cost of the equipment and its installation. But for a large new build project the economics are easier to justify because the installation costs are lower and the developer has more buying power for the equipment than an individual would have. The next generation of home buyers is also more likely to expect smart homes to be available, having grown up with intelligent devices that are networked and incorporate smart technologies. Consumer electronics and appliance manufacturers are beginning to make devices that can communicate with one another and with a central control unit. As these devices become more readily available and more affordable, they are being adopted within homes.

3.3.10 What Are the Concerns?
There are also concerns about the type of information/data that could be collected from a tightly integrated smart grid and the applications that might be developed in a smart home, and the way that utilities or other parties might put that data to use. Various tests have shown that smart meters can be hacked and their data can be stolen. In some ways it’s difficult to predict how this data might be used because it simply isn’t available today. From a policy perspective it can be difficult to design privacy policies when it isn’t clear what data will be available or what it might be used for.
3.4 Who are the Key Stakeholders for UMore Park?
As the community at UMore Park develops, there are three stakeholders that will have an interest or be affected by UMore Park implementing smart grid technologies. These are:

1. Consumers
2. Developers
3. Utilities

In order to understand how these stakeholders will be affected, it is necessary to understand the current regulatory environment and policy framework for electrical utilities.

3.4.1 Regulatory Environment
Electrical power generation is a highly regulated industry. “The economic and regulatory structure of the American power industry is a contraption only a lawyer could love.” (Fox-Penner, 2010) Policy governing electric power and transmission is complex due to the layers of local, state and federal governance. Since the electrical grid was not built on a “conformance plan,” such as the interstate highways (Kaplan, 2009), attention must be given to local utility companies and governments where UMore Park is located.

Policies relating to smart grid technology are likely to change during the lifetime of the UMore Park development. However, in the current environment, the incumbent providers of electricity are not incentivized to adopt new technologies or even maintain their own infrastructure.

3.4.2 What’s the Current Situation?
The state of Minnesota has provided utility companies with an effective monopoly to sell electrical power. UMore Park is located in a section of the state that is serviced by Xcel Energy, Inc. The regulatory and legal frameworks that put this monopoly in place were designed a long time ago and did not necessarily foresee the value that could be added by incorporating smart grid technologies. These frameworks were initially focused on enabling the economic development that was realized as a result of providing reliable and affordable electricity to the masses. In recent years the emphasis for regulation has changed as society has become more aware of the environmental costs associated with the usage of the natural resources that are required to generate electricity. Utilities are being encouraged and, in some cases, forced to change their portfolio of generating capacity from fossil fuel and nuclear to renewable energy resources, such as solar or wind.

*Minnesota enacted legislation in 2007 mandates that 25% of Minnesota’s electricity to be generated from renewable sources by 2025. The requirement for Xcel is even more stringent, namely that 30 percent of the electrical power that they generate comes from renewable energy sources.*
3.4.3 Who are Stakeholders in the Regulatory Environment?

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>UMore Development LLC</td>
<td>Vision of developing a sustainable community that supports the University of Minnesota’s Academic Mission</td>
</tr>
<tr>
<td>Xcel Energy</td>
<td>Has statutory right to provide electricity to UMore Park property</td>
</tr>
<tr>
<td>Minnesota Public Utilities Commission</td>
<td>Regulates electricity, natural gas and telephone service providers in Minnesota to ensure the provision of safe, reliable and efficient services at fair and reasonable rates</td>
</tr>
<tr>
<td>Minnesota Lawmakers</td>
<td>Enacts legislation that governs the Public Utilities Commission</td>
</tr>
<tr>
<td>Consumers</td>
<td>Have interest in the quality of life that comes from living in a sustainable community and the applications that can be enabled from the communication and information capabilities that a smart grid can enable</td>
</tr>
<tr>
<td>Technology providers</td>
<td>Develop infrastructure and applications that will sustain and improve quality of life</td>
</tr>
</tbody>
</table>

Table 1 Stakeholders in the regulatory environment

3.4.4 Consumers

Consumers are the most important stakeholder for UMore Park.

Without consumers buying homes in UMore, there will be no UMore Park. In addition to people looking to buy a home, any consumer who pays an electric bill is a potential consumer that could be impacted by UMore Park implementing smart grid technologies. As mentioned above, the regulatory environment protects the utilities, and limits the ability of the consumer to affect change. They also have limited choices for providers and for pricing models. As shown in Figure 17 illustrating the power and interest relationship between all of the notable stakeholders in smart grid technologies, consumers currently have very little power and interest in smart grid. UMore Park is challenged with shifting this dynamic into one which gives the consumer more power and interest to pull the regulatory environment along into adopting smart grid technologies.
Since UMore Park will be in development over the next 30 years, changing the power and interest dynamic will begin with understanding their consumer’s needs. Segmenting potential consumer groups before each development cycle is a standard method of doing so. However, this segmentation should be more circumstance based (i.e. what problem are the consumers trying to solve) rather than attribute based (i.e. what features do they want).

Segmenting consumers in this way will help UMore Park focus on the mindset of the consumer when they are purchasing a home. For example, a first-time home buyer may be looking to buy a home because they want a yard for a pet, looking to invest instead of rent or planning a family. Understanding what problem the home buyer is trying to solve helps determine the attributes that should be incorporated into the homes in UMore Park. When implementing smart grid technologies into homes at
UMore Park, this can be a critical means for understanding what consumers want and what technologies would be best suited for them.

### 3.4.5 Consumer Segments of interest

UMore Park’s value proposition has the potential to attract consumers interested in solving a variety of problems. Each one of UMore Park’s attributes could be a solution to a potential home buyer.

A study by Accenture noted three electrical consumer segments that have the greatest potential interest in smart grid technologies. These are: Pro-actives, Eco-rationals, and Cost Conscious. Some of the characteristics of each segment are as follows:

- **Pro-actives** want to reduce their electrical consumption and are willing to take action to do so. They have low interest in reducing their impact on the environment. Products or services in the home that would help them keep their electrical consumption low or show them the results of their conservation efforts would appeal to these consumers.

- **Eco-rationals** want to reduce their impact on the environment through energy-efficient products and services. They are a key market segment for UMore Park throughout the development’s life span. Products and services that demonstrate how they are impacting the environment would appeal to these consumers.

- **Cost Conscious** want to save money on their electrical bill. This is slightly different than the Pro-actives, since they are more concerned about cost than overall use. The cost conscious want products and services that are simple and don’t require a lot of time. Anything that simplifies their energy consumption and saves them money will appeal to them.

Consumers, as noted above, have the least amount of power over electrical pricing models and the implementation of smart grid technologies. They exist in a highly regulated world. However, they do have access to a large variety of energy saving and smart home technologies that they could adopt on their own. The challenge for these consumers is to understand the impact these technologies have and how best to use them. This is where UMore Park could fill the gap. As an educational institution, consumers trust the University of Minnesota. UMore Park’s association with it could be an advantage when garnering consumer interest in smart grid technologies.

Key benefits to highlight when discussing smart grid technologies at UMore Park:

- Consumers can better **control their energy consumption** through AMI, smart meters and web portals that can give them feedback on their energy use.

- Consumers can reduce their **impact on the environment**. Many consumers do not understand the extent to which their electrical consumption affects the environment. Unlike pumping gas into a car, there is no immediate feedback to the consumer that their use does affect the environment.

- Consumers can reduce the **costs** of their energy consumption. One of the primary concerns for most consumers when smart grid technologies are implemented is that their electric bill will increase. In some situations, this may be true. However, as consumers begin to understand how
their consumption of electricity affects their bill, they will begin to adjust their behavior to consume less.

To better understand consumers and how smart grid technologies in homes at UMore Park could affect consumers, UMore Park should consider adopting these short-term strategies:

- Review and analyze outcomes from other smart grid implementations, especially those that implemented smart meters or consumer pricing models.
- Segment their consumers, both home buyers and electricity consumers. Find the areas where these overlap and devise pricing models and technologies that will fit their needs.
- Engage and Empower. Work on outreach and education programs to get consumers to understand that electricity has just as much of an impact on the environment as cars, etc. Engage consumer groups or government agencies that are working to advocate for the consumer through smart grid initiatives.

Long-term, future strategies UMore Park should consider are:

- Watch demographics and monitor changes in population growth.
- Analyze the data coming from residents of UMore Park. Compare it with other consumer studies related to smart grid.
- Begin working with K-12 educators now to educate children on the importance of energy conservation, etc.

### 3.4.6 Utilities

One of the advantages of being a new development is that UMore Park can avoid many of the concerns associated with upgrading infrastructure and how any value that is realized from a smart grid will be shared among the different stakeholders. However, there are factors in the regulatory framework that will affect how UMore Park is able to implement a smart grid. For example, the only party that can run an electrical line across a public road is a public utility. Since Xcel will be the only registered electrical utility in the UMore Park site, this means that Xcel would have to participate in the process. One way around this restriction, at least in theory, would be to develop UMore Park as a privately owned development and sell homes using a lease-hold rather than free-hold arrangement. Of course this would have other implications that extend far beyond how smart the electrical grid would be.

### 3.4.7 Developers

At first glance, the smart grid might not appear to be of much interest to developers. The challenge for UMore Park is likely going to be finding a master developer who will embrace the vision for the development. The developer will be responsible for overseeing the construction of 14,000 homes along with the infrastructure that is required to support the new community. Since this includes electrical infrastructure outside and within the home, the developer needs to be familiar with the technological opportunities that are available by making the infrastructure smart. The communications network at the electricity distribution level is less important to the developer, but if UMore Park decides to adopt a system-level approach such as a district heating model, where everything is interconnected, then the developer needs to embrace this approach, too.
3.4.8 Technology Space Map

One of the tools that is useful for understanding a technology or stakeholder landscape is the Technology Space Map (Figure 17).

![Figure 17 Technology Space Map™](image)

Technologies on this space map are positioned based on the strength of the influence for the stakeholders: Utility, Consumers and Society. Technologies that are closer to the vertices of the triangle are influenced more by the closest stakeholder than the others. The size of the bubble does not have any meaning.

The term Power Zone™ refers to sections of the space map where there are clusters of bubbles, indicating that the map is weighted in this area. In Figure 17 the Power Zone™ clearly lies in the upper third of the space map, meaning that the majority of the technologies are influenced or controlled mainly by the utility company. However the power zone does not necessarily stay in the same place over time and actions of other stakeholders can influence consumer behavior and the smart grid ecosystem.

In the status quo the utility has the most control over, and probably yields the largest benefits from, the smart grid. Xcel Energy is in a position to choose its investment level and the business model that it applies to the residents of UMore Park, because the power zone is under its control. If UMore Park wants to change the landscape and have the biggest impact on Consumers (meaning home buyers) and Society (meaning the community), then the focus should be on the technologies in the lower half of the
space map: District heating and cooling, Smart homes, and the integration of these two technologies (referred to as User Interface in the diagram).

3.4.9 What Lessons Can Be Learned from Current Smart Grid Implementations?

There are numerous sources for information on current smart grid implementations. Four sources that were reviewed for this report were:

- Smart Grid Leadership Report: Global Smart Grid Implementation Assessment, October 2010
- e8 Tokyo Summit Smart Grid Technology Innovation Group Report, May 2010
- American Recovery and Reinvestment Act (ARRA) Smart Grid Programs, SmartGrid.gov

Of the 164 implementations listed in these sources, there are four implementations that could provide UMore Park with relevant insights. These are:

**Electricity Supply Board (ESB) Networks Irish Electricity, Consumer Behavior Trials.** The project is a 2 year test deployment for a national smart metering program that ended in 2010. The consumer behavioral trials included in the project are designed to evaluate if smart metering and rate structures can change energy use. The trials include 5600 residential customers and 780 small businesses. Final results from the implementation are forthcoming and could provide valuable insights on how smart grid technologies can affect consumer behavior.

**Oncor, Smart Texas' Advanced Metering System deployment.** The project will deploy 3 million advanced meters and is scheduled for completion in 2012. Currently, Oncor has deployed more than 1.6 million meters. The deregulated electric market in Texas helped make this initiative possible, as did changes in the regulatory policy made by the Public Utility Commission of Texas. The project itself includes a comprehensive consumer education program, rate plan options, web portal for tracking consumption in dollars and CO₂ (www.smartmetertexas.com/CAP/public). To increase consumer confidence in smart meter performance, Oncor is conducting side-by-side meter demonstrations comparing the results of an electromechanical meter to that of a smart meter after complaints from consumers about the accuracy of their smart meters. Results from test areas are published on the web at [www.oncor.com](http://www.oncor.com).

**SmartGrid City, Boulder, CO.** Implemented by Excel with some notable resistance due to budget overruns three times the initial planned cost and increases in consumer electrical bills estimated at $2000 per customer. The implementation includes a technology pilot for smart grid infrastructure, smart meters, a web portal (MyAccount Web Site), and in-home smart devices. The implementation also includes initiatives for SmartGrid City Home Energy Manager Pilot and three pricing challenge programs for consumers. Recently, the project was awarded 1 of 24 IBM Smarter Cities Challenge grants worth as much as $400,000. IMB consultants will live and work in the community as part of the grant. IBM will award up to $50 million in grants to 100 cities over the next three years, which could provide a potential funding source for UMore Park.
**Smart Community Projects, Japan.** Four different communities are a part of the implementation which will include a variety of smart grid technologies to visual energy usage, real-time management of energy consumption in homes and companies. In one of the communities, Kansai Science City, the implementation is focused on creating a low carbon society and reducing household emissions by 20% from 2005 levels as well as reducing 40% in transport by 2030. As part of the implementation, 1,000 households have installed photovoltaic systems; one aspect of the implementations effective integration of Distributed Energy Resources.

**Babcock Ranch, Florida** Another development which is currently in the planning phase and that appears to have a similar vision to UMore Park is Babcock Ranch in Florida. The tagline for this development is “City of tomorrow” and it is expected to incorporate a 75 MW solar photovoltaic farm, which will generate more electricity than is required for the community. The developer for this project is Kitson & Partners and they are planning to include a smart grid in the development. Part of the vision for Babcock Ranch is that it will be a “living laboratory” or a test bed for new clean technologies. The development is at a similar stage to UMore Park, but may offer some opportunities for lessons learned as they make progress.

The challenges that many of these implementations have faced or are currently struggling with are also ones that UMore Park will encounter as they implement smart grid technology. The primary challenge for the smart grid implementations found in the sources above was the regulatory agencies. Regulatory agencies are hindering smart grid adoption by limiting investor’s ability to recover investments and by restricting pricing models, such as time of use pricing. Although regulatory agencies are the primary challenge, consumers also impose significant challenges to smart grid adoption. Consumers are unaware of what smart grid is and what its benefits are. Not only are they resistant to change, they fear higher energy costs. As mentioned above in the discussions of stakeholders, UMore Park has many options to consider when facing these challenges.

**3.4.10 Smart Technologies and the District Energy Model**

Smart Grid is considered by many to be a pre-requisite to incorporate renewable energy into our current energy supply chain. The main driver for this is the environmental benefit of not using fossil fuels as a source of energy for the home. Another model that can leverage similar technology is the District Energy model. Implementing a smart district energy model and smart grid technologies will provide homes with a clear understanding of total energy usage. Coupling a smart grid and a district heating, cooling and power system will provide UMore Park a community that will be able to achieve the long term goals of a sustainable, energy efficient community while providing a method for reducing the cost of home ownership in the community.

**3.4.10.1 Energy: More than just electricity?**

The smart grid initiatives focus on one form of energy that is consumed in virtually every home in the US, electricity. While conducting an interview with Anders Rydaker, Executive Vice President of Sustainable Energy Solutions for Ever-Green Energy, it was pointed out that electricity is just a form of energy.
As the world population continues to grow and demand for energy grows a more holistic view of energy needs to be adopted. Energy usage needs to monitored and optimized. There are three main forms of energy used in the typical home:

1. Electricity (lighting, electronics, appliances)
2. Heating energy
3. Cooling energy

![Image](image.png)

**Figure 18** Breakdown of energy usage for a typical home (Energy Star)

### 3.4.10.2 Heating Energy

Energy is consumed in many homes in a form that is not electricity; instead it is thermal energy for heat. Figure 19 above shows that for the average American home, 43% of typical energy costs goes to providing heat. This heat is for both living space and supplying domestic hot water. Multiple fuel sources are utilized to provide this heat; natural gas, propane, heating oil, coal, and biomass are utilized to provide thermal energy to heat the home and provide domestic hot water. Renewable energy sources like solar are also utilized to provide heat energy to homes. Demand for heat is dependent on the climate in the location where a home is built. Since the UMore park development is located in Minnesota, the heating energy need is significant. In the greater Minneapolis/Saint Paul Metro area, natural gas is the predominant fuel used to provide heating.
3.4.10.3 Cooling Energy

Energy is also consumed to cool homes. Figure 19 shows that the cooling of homes accounts for approximately 17% of energy costs. Cooling energy is typically provided from an air conditioner. Electricity is typically the energy source to run the air conditioner. As a matter of fact, the cooling of buildings in the summer months is what sets the peak demand of electricity. Figure 19 below illustrates heating and cooling demand patterns over a typical year. Peak electrical demand coincides with the peak cooling demand. The chart also illustrates that there is demand for heat and cooling all year round.

![Yearly Heating and Cooling Chart](image)

Figure 19 Typical Yearly Heating and Cooling demand (Shaw, 2010)

Cooling is just another form of energy. Cooling is typically measured and discussed in units of “tons of cooling”. A ton of cooling is the amount of energy required to melt one ton of ice in 24 hours. Cooling can be accomplished without an air conditioner installed in each home; the key is a fixed amount of energy needs to be removed from the home in the summer months.

3.4.10.4 What Can UMore Park Do?

While energy into the home comes from different sources it is all energy and needs to be optimized from a holistic perspective. Is there an opportunity for UMore Park to incorporate this holistic view? Are there opportunities to incorporate new neighborhood design concepts that can utilize energy more efficiently then what is “normal”? Can the concept of the smart grid be applied to make a smart home that monitors a home’s total energy usage? Can the system be smart to minimize the cost of ownership while also reducing the impacts on the environment? Can a system be developed that will allow the incorporation of renewable sources of energy that exist today such as solar and wind while also being
designed flexible to incorporate new sources of renewable energy that are developed in the future? A district heating and cooling system provides the technology to answer each of these questions with a resounding “Yes!”

UMore Park is a blank canvas, which means the developer can take bold and meaningful steps in the design of the community to ensure that it is energy efficient for years to come, and can incorporate new and yet to be developed technologies. Strategically, UMore Park has to consider the question; can infrastructure put in the ground provide “Sustained Competitive Advantage” (SCA) over the life of the development? If UMore Park could attain and maintain SCA, would it make it easier to sell homes and develop the community?

One of the tremendous challenges that hinder the adoption of renewable energy sources is the lack of a good means of storing the electricity that renewables generate so that the electricity can be used when needed. Electricity is one source of energy that must be consumed immediately when generated. While the addition of smart grid infrastructure will make it easier in the future to add new storage technologies to the grid, there are limited options for storing electrical energy at this point in time. But, alternatives exist.

3.4.10.5 Trigeneration – District Heating, Cooling and Power Generation
As mentioned in (Carmody, 2010), “Optimum energy performance is achieved with a centralized (district) HVAC plant coupled to a zoned hydronic heating and cooling delivery system...”. A district plant provides a design that enables the development of a community that has the lowest environmental impact possible. It also creates a very flexible system that can incorporate new technologies in the future. A district heating, cooling and power system could provide the ability to store “energy” in proven low cost reliable systems. Figure 20 shows a sample district heating, cooling and power model that could be used in UMore Park. It incorporates smart grid technologies, such as sensors and a communication network, as well as smart meters for measuring heating and cooling energy. It also includes a DC microgrid to allow for the addition of renewable electricity generation.
As illustrated in Figure 4 on Page 11, generation of electrical power is about 37% efficient but the further away the power is generated from where it is used the greater the transmission losses. A cogeneration facility can be 80+% efficient. A study by the United States Clean Heat and Power Association found that combined heat and power systems yield an efficiency gain of 89% (United States Clean Heat and Power Association, 2011). The improved efficiency of the system will reduce the cost to provide the same amount of energy to consumers. These cost savings can be used to pay for capital required for the district system as well provide an opportunity to reduce the overall cost of ownership for home owners in UMore Park. This could provide a financial incentive to people to buy a home in UMore Park. A five forces analysis can be used to evaluate threats and opportunities that UMore could capture on to improve marketability.

3.4.10.6 Regulations – Winds of change

The winds of change are certainly gaining speed, especially around combined heat/power and distributed generation. California is taking a leading position when it comes to new, innovative regulations. California adopted a feed-in tariff by enacting the California Waste Heat and Carbon Emissions Reduction Act (AB 1613). That state law requires investor-owned electric utilities to purchase, at a price set by the California Public Utilities Commission (CPUC), electricity generated by eligible combined heat and power (CHP) generators. A summary of the bill from a memorandum written to the PUC in San Francisco says:

Figure 20 District Energy Model
“The bill adds Sections 2840 through 2844 to the Public Utilities Code to provide various subsidy mechanisms for combined heat and power (CHP) distributed generation technologies. It modifies the State’s preferred energy resource “loading order” and Long-Term Energy Procurement Planning process. It requires load-serving entities to purchase electricity produced by certain CHP generators. It allows non-utility DG providers to serve and bill new residential customers through master meters.”

The proposed amendment recognizes the benefits of combined heat power and the benefits to society for utilizing systems that focus on improving efficiency. The improved efficiency can be used to reduce costs to consumers, reduce pollution to the environment and improve system reliability.

3.4.10.7 Expectations of Community Residents
Every inhabitant of a community expects reliable sources of power, heat and cooling to be available in their homes. Renewable sources of energy, as they stand today do not provide this. When the wind doesn’t blow a wind turbine does generate electricity. When the sun is not shining, a solar panel cannot produce electricity. There are very few systems that can store power for windless, cloudy days in Minnesota. (Hydro from the Mississippi could help here) Therefore, there will need to be a source of power, heat and cooling that is reliable. This is where a central plant can provide value.

3.4.10.8 Central Plant Ideas
A central plant could easily be built to fuel agnostic. Boilers could be built that could burn, natural gas, oil, or biomass. With the proper selection of equipment, this system would provide a place to utilize biogas from the community waste water treatment plant or allow technology development on other forms of biogas (manure digesters, landfill gas (landfill to the north of FHR). Multiple types of combustion devices could be pursued. Microturbines have been installed at hotels, hospitals, and other locations to generate electricity, hot water and cooling. These systems are incredibly reliable due to there being a single moving part in the turbine. There are companies that specialize in the design of these systems that could be involved in development of full-blown study. A system could be built modular with room for expansion as the community grows. The system could be designed to supply the utilities need and then increased modularly over time. Another benefit of UMore Park design concept is the diversity of proposed load with the development, including schools, business industry, hospitals, residential, etc. Figure 21 illustrates that commercial and domestic demand peaks at different times of the day. This is helpful in providing a uniform load through the day. The low demand at night could be used as a time for the utility to store up energy.
The district model also lets you still utilize the ground source energy if you so desire. With the gravel mining operations you could consider putting system out in the “lakes” that will be formed.

3.4.10.9 Energy Storage in District Model

The District Energy Model provides a very convenient way to store and bank energy. The energy can be stored in the form of hot and cold water. Recall that 60% of energy used for utilities in a home is for heating and cooling. This energy can easily be provided with hot and cold water being supplied directly to homes. Renewable technologies, such as solar thermal panels, can be used to generate hot water for use in the district energy system directly. Ground source heat pumps could also be directly tied into the system to supply hot or chilled water. Solar PV, wind, or fuel cell technology could be utilized to generate electricity. The electricity could be fed to a local DC microgrid. Leaving the power generated from the renewable sources as native DC reduces energy losses associated with converting it to AC power. The DC power could then be used to supply any of the three energy systems based on real time requirements in the community. The DC power could easily be utilized to heat water or chill water or converted to AC power if there is demand. Companies such as Solar Panels Plus (www.solarpanelsplus.com) claim that it takes ½ the solar panels to run a DC air conditioner than an AC model which illustrates the benefits and efficiencies of the DC microgrid.

The district model enables systems to be added, plug and play style. As mentioned earlier the storage of energy can be accomplished by use of large water or glycol water storage tanks. At the heart of the system would be a flexible fuel system (micro turbines with heat recovery) that can run off natural gas and provide uninterruptable source of power and hot and chilled water. As the other renewable sources are available (sun shining, wind blowing) the natural gas usage would be reduced only to provide the
balance required for the system. The District Energy model also can be fitted with a sensor network and therefore be able to communicate with the smart technologies.

A district heating system can also provide cheap cooling in the winter. A very simple cooling tower or air exchanger could be utilized in the winter to maintain the cool loop. Our increasing reliance on digital technology drives the demand for providing power and cooling to these sites. The district energy model could also provide an economically attractive home for data centers and places that require cooling.

3.4.10.10 **Infrastructure Similarities to Smart Grid**

There are similar communication, data and metering requirements for district heating model. Therefore this could essentially be an “add on” to the smart grid. The HMI could be designed to show total energy if all sources of energy input to the house are monitored. This would provide community inhabitants with a holistic view of their energy consumption. It would also provide a system that is more efficient and offer savings opportunities to the community. These will be discussed later in a sample business case that was developed.

3.4.10.11 **Comparison of smart grid and district model options**

Table 2 below illustrates the impact that three different community designs would have on the attributes that are desired in UMore Park. The first state is Build Status Quo. In this state the homes in the UMore Park would be built just as they are in every other community today. The second case is Incorporate Smart Grid Technology into the community. In this state the homes and community in UMore Park would be equipped with smart grid technology such as smart meters, AMI, homes with energy management systems. The third and final state would include the Smart Grid Technology from the previous state and also incorporate a District Model for heating, cooling and power supply. In this state the homes would be built quite different than they are today. The home would not have traditional heating and cooling equipment. Instead the home would be heated and cooled with hot water from the district supply. The power for community would also, ideally be generated and used in the community by multiple sources including, wind, solar and heat integrated combustion plants such as fuel cells or microturbines.

<table>
<thead>
<tr>
<th>Concept Master Plan Attributes</th>
<th>Current State Build Status Quo</th>
<th>Incorporate Smart Grid Technology</th>
<th>Incorporate Smart Grid &amp; District Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Renewable Energy</strong></td>
<td>LOW</td>
<td>MEDIUM</td>
<td>HIGH</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>LOW</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
</tr>
<tr>
<td><strong>Environmental Quality</strong></td>
<td>LOW</td>
<td>MEDIUM</td>
<td>HIGH</td>
</tr>
<tr>
<td><strong>Transit</strong></td>
<td>LOW</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td>LOW</td>
<td>MEDIUM</td>
<td>MEDIUM</td>
</tr>
<tr>
<td><strong>Cost Benefits to Homeowner</strong></td>
<td>LOW</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td><strong>Research Opportunities</strong></td>
<td>LOW</td>
<td>MEDIUM</td>
<td>HIGH</td>
</tr>
</tbody>
</table>

Table 2 Analysis of options for smart grid and district energy model
While there is impact from the current state by implementing smart grid technologies, the benefits are limited due to the regulatory structure in the electrical market. The area where smart grid technologies make a substantial impact is on Transit. The reason for this impact is that smart grid technologies can be utilized and improve the adoption of electric vehicles. Electric vehicles with quick charging technology and off peak charging can reduce the cost of transportation and reduce the impact that transport vehicles have on the environment and community. See Appendix E for a study of the effects of electrical vehicle adoption on utility companies.

Coupling the benefits that the smart grid brings with the benefits of a district heating, cooling and power system has a substantial impact and moves UMore Park towards the desired state for the community. Many of the benefits are achieved due to the improved efficiency of the system that is installed and due to the fact that the system can be built to be energy source agnostic. The efficiency of the system is illustrated in the figure below. Figure 23 illustrates that to get the same heat and power output out of a traditional designed home would require 189 units of input. A combined heat and power system, on the other hand would require only 100 units of input to deliver the same heat and power to the user. One system uses ~53% less energy input to produce the same output. The energy savings can be utilized to pay for the capital required to build and install a district system and can also be used to reduce the cost to heat and cool a home. Since the system would be energy source agnostic, it could also be optimized from a systems perspective, utilizing the smart grid technologies incorporated into the system design.

Figure 22 Comparison of CHP to traditional electricity and traditional heating (United States Clean Heat and Power Association, 2011)
3.4.10.12 System Optimization Potential
With a system that generates power, hot and chilled water, it is relatively straightforward to also develop control software that is smart enough to maximize profits, or minimize costs based on input prices and selling prices. This would provide a unique opportunity for UMore Park to partner with different departments in the University, such as engineering or computer science to develop algorithms and advanced control strategies to optimize operational targets against known system constraints.

3.4.10.13 Develop Innovations to become a Market Leader
UMore Park could also work to develop or spin off a company, who becomes a market leader at installing and operating District Energy systems. This leadership position could be developed by finding ways to reduce the cost of installing systems by developing expertise in utilizing easier to install piping materials. For example could one use fusible, insulated HDPE on the trunk lines to eliminate welding and speed install and then utilize 1” PEX piping from the trunk to the house. This is rolled pipe and could be installed very quickly reducing costs and provide a system where corrosion would be of little or no concern. There is also an expert, St. Paul District Energy, right in the back yard that could make a very good partner.

3.4.10.14 Additional Funding Opportunities
By going after a District Heating model with a “central” combined heat power plant, this opens the opportunity to pursue additional grants, tax credits, loans that are aimed at energy efficiency improvement.

3.4.11 Prototype Business Case
In an effort to understand if a district system with a microturbine would actually be able to provide a revenue stream some data was gathered and a high-level business case developed. The operating data was gathered from a datasheet for a Capstone C65 turbine. The costs for installing were estimated at 2 times purchase cost and the purchase costs were estimated from publicly available information. Average costs for electricity and gas were found for Minnesota on the EIA website. Through some calculations it was found that a 65 kW turbine would provide the electricity and heat required for 45 to 50 average homes. Utilizing residential gas rates as well as residential electrical rates, the efficiency improvement of the systems provide around $32,000 of savings while commercial gas rates result in around $39,000 of savings annually. These savings were then split 70/30 between the investor and the homeowners. The resulting cash flow and payback information is provided below. The NPV was calculated with a 7% WCC and the MIRR was calculated with a reinvestment rate of 5%. The project life is assumed for 20 years.

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV</td>
<td>$162,599.32</td>
</tr>
<tr>
<td>IRR</td>
<td>20.8%</td>
</tr>
<tr>
<td>MIRR</td>
<td>10.2%</td>
</tr>
<tr>
<td>Profitability Index</td>
<td>2.25</td>
</tr>
</tbody>
</table>

The initial research indicates that this model could be feasibly developed and a more detailed development and analysis of a business plan should be carried out.
Data

### Generation Installed Cost

<table>
<thead>
<tr>
<th>Technology</th>
<th>Installed Cost per kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>$4,000.00</td>
</tr>
<tr>
<td>Solar PV</td>
<td>$7,000.00</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Microturbine</td>
<td></td>
</tr>
</tbody>
</table>

### Average Home Energy Usage Data

<table>
<thead>
<tr>
<th>Usage Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Home Electrical Use</td>
<td>11,400 kWh/yr</td>
</tr>
<tr>
<td>Average Home Heat use</td>
<td>80,000,000 Btu/yr</td>
</tr>
<tr>
<td>Average home hot water use</td>
<td></td>
</tr>
<tr>
<td>Average Home Cooling Load</td>
<td></td>
</tr>
<tr>
<td>Assumed Furnace Cost</td>
<td>$6,000.00</td>
</tr>
</tbody>
</table>

### Capstone Microturbine Data

<table>
<thead>
<tr>
<th>Micro Turbine</th>
<th>65 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Requirement (HHV)</td>
<td>842,000 Btu/hr</td>
</tr>
<tr>
<td>Hot Water Recovered</td>
<td>408,000 Btu/hr</td>
</tr>
<tr>
<td>Energy Extracted by Electricity</td>
<td>221,780 Btu/hr</td>
</tr>
<tr>
<td>Energy Remains</td>
<td>620,220 Btu/hr</td>
</tr>
<tr>
<td>Total Energy Recovery</td>
<td>629,780</td>
</tr>
</tbody>
</table>

### Average Energy Costs MN

http://www.eia.gov/cfapps/state/state_energy_profiles.cfm?sid=MN

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Cost per kWh/ mmBtu/ mmBtu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Cost (Residential)</td>
<td>$0.1072</td>
</tr>
<tr>
<td>Natural Gas Cost (Residential)</td>
<td>$8.58</td>
</tr>
<tr>
<td>Assumed NG Commercial</td>
<td>$7.50</td>
</tr>
</tbody>
</table>

### How much energy can a C65 Turbine with Heat Recovery Provide?

**Electrical Energy**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating time</td>
<td>24 hrs</td>
</tr>
<tr>
<td>kWh Generated</td>
<td>1,560 kWh</td>
</tr>
<tr>
<td>Average Home Electrical use</td>
<td>31 kWh</td>
</tr>
<tr>
<td>Homes Powered</td>
<td>50 homes</td>
</tr>
</tbody>
</table>

**Heat (gas & water)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Recovered</td>
<td>9,792,000 per day</td>
</tr>
<tr>
<td>Heat Required home</td>
<td>219,178 per day</td>
</tr>
<tr>
<td>Homes Heated</td>
<td>45 homes</td>
</tr>
</tbody>
</table>
### Cost to Generate

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost at Residential Rates</td>
<td>$ 5,202</td>
</tr>
<tr>
<td>Cost at Commercial Rates</td>
<td>$ 4,547</td>
</tr>
<tr>
<td>Cost per home Residential</td>
<td>$ 104</td>
</tr>
<tr>
<td>Cost per home Commercial</td>
<td>$ 91</td>
</tr>
</tbody>
</table>

### What is the Traditional Cost for Energy in home?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Days in Month</td>
<td>30 days</td>
</tr>
<tr>
<td>Electricity</td>
<td>$ 100</td>
</tr>
<tr>
<td>Gas</td>
<td>$ 56</td>
</tr>
<tr>
<td>Total</td>
<td>$ 157</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Savings per home (residential gas rates)</td>
<td>$ 53 per month</td>
</tr>
<tr>
<td>Savings per home (commercial gas rates)</td>
<td>$ 66 per month</td>
</tr>
<tr>
<td>Months per year</td>
<td>12 months</td>
</tr>
<tr>
<td>Total Savings for turbine install Res Gas (heat and power to 50 homes)</td>
<td>$ 31,599 savings per year</td>
</tr>
<tr>
<td>Total Savings for turbine install Comer Gas (heat and power to 50 homes)</td>
<td>$ 39,456 savings per year</td>
</tr>
</tbody>
</table>

### Savings Split

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer</td>
<td>30%</td>
</tr>
<tr>
<td>Investor</td>
<td>70%</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Savings</td>
<td>$ 11,837 per year</td>
</tr>
<tr>
<td>Investor Savings</td>
<td>$ 27,619 per year</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Customer Savings</td>
<td>$ 20 per month</td>
</tr>
<tr>
<td>Original Bill</td>
<td>$ 157</td>
</tr>
<tr>
<td>% Savings</td>
<td>13%</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine Cost</td>
<td>$ 65,000</td>
</tr>
<tr>
<td>Installed Cost Multiplier</td>
<td>2.00</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$ 130,000</td>
</tr>
</tbody>
</table>
Figure 23 Projected cumulative cash flow - 20 year period
4

4.1 MOT Tools
The MOT program focuses on providing students the tools necessary to understand the role of technology in an organization, develop a strategy for exploiting the technology to drive improved business results, and developing a tactical plan for implementing the technology. The first tools that are taught relate to developing knowledge of business fundamentals, such as accounting, marketing and finance. These tools develop the skills and knowledge that are required for communicating in a business setting. The next set of tools are focused around understanding technology, the role it can play in an organization and identifying the impact the technology can have. The final set of tools are focused on tying the business and technology tools together while evaluating the risk and opportunities of the macro environment to develop a robust, winning strategy.

Tools from each of these areas were utilized throughout the project for UMore Park. Some of these tools have been incorporated into earlier sections of the paper. Other tools that were part of the MOT learning’s are included below and were utilized for developing the recommendations in this report.

4.2 Normative Forecast for UMore Park
Normative forecasting is a tool for gaining a future perspective on a stated goal or objective. It “Jumps ahead“ (Coates, p. 5) to the successful completion of the goal and can therefore be used by organizations to visualize and shape the actions needed to actually achieve it. By assuming that the goal is achievable, an organization can focus its efforts on allocating resources, decision making and planning. The process for developing a normative forecast includes several steps, such as stating a definitive goal, forming a team to develop the forecast, mapping out steps, and review.

In developing a normative forecast for UMore Park, the goals we focused on were the goals for energy outlined in the Concept Master Plan (i.e. “The renewable resource goal for the community is to generate production of its own energy from sun, wind, and biomass.”) and in the aspiration statements from the Academic Task Force (i.e., power generation, zero-net energy community, zero Carbon Emissions Community, building energy efficiency, and energy use). The results of the forecast are shown in a relevance tree (Figure 24) which maps the goals from its roots out to each individual technology or action needed to achieve it. When branching out, the highlighted items such as, consumer interfaces, policy, and communications, were recurring items in the separate branches of the tree. These recurring items are the interconnections or synergies within the forecast, and were the basis for our recommendation that a mix of technologies be incorporated into UMore Park.
An energy-efficient community that is differentiated by smart technologies

Note: Relevance trees are used in normative forecasting to define relevant technologies needed to achieve a stated goal (i.e., in 30 years, build a net-zero, sustainable community at Umore Park)
4.3 Technology Interaction Plot

The Technology Interaction Plot (TIP) is a tool that is helpful for identifying how technologies interact with each other. The starting point for this tool is to create a Technology Interaction Matrix that lists the technologies to be analyzed on a horizontal and vertical axis. Each technology is then given a score that shows how heavily it interacts with the technology on the corresponding axis. The total scores for each technology are used to provide the coordinates to plot each technology on a graph as shown in Figure 25.

![Technology Interaction Plot](image)

**Figure 25 Technology Interaction Plot for Smart Grid technologies**

This chart shows the intensity with which each category interacts with the other categories. The axes are labeled “Source” to indicate the degree with which the technology underpins Smart Grid, and “Utilization” to indicate how much the technology is used by the smart grid. The chart is then split into five regions to show the ways in which the technology may prove useful.

Pre-Product – categories in this region score highly on the utilization axis in comparison to the source axis. This would indicate that they are important, but are not yet developed enough to have a current impact. The only category that appeared in this region based on the scoring exercise is Smart Home. This is certainly an area with the potential to have high interactions with smart grid, in fact some commentators consider this almost synonymous with smart grid, but there has been little success in commercializing the category to allow it to cross from niche product for extremely early adopters to anywhere close to mass market acceptance. UMore Park has an opportunity to create a community with smart homes as a differentiating factor compared to competing housing developments.
Application – Eight of the categories fall into or next to this region, indicating that they have a larger performance impact, but are more evenly balanced between source and utilization. The cluster of four categories that are on the upper edge of this section all have a similar potential (Building Standards, Renewable Energy, Pricing and District Energy Model). Successful adoption or encouragement of these categories is likely to yield better results than the items that are scored lower for utilization.

Synergy – This section highlights balanced categories. These can be thought of as areas where the current investments are yielding the expected benefits and accelerating investment would not deliver a multiplied performance increase.

Feeder – The only item in this region is Incentives, although this almost fell into the synergy category. This indicates that incentives could be a driver of smart grid adoption, but are linked to other technologies and by themselves may not be sufficient.

Foundation – The final region shows the category that arguably can have the largest impact in the future, but unfortunately the impact is currently to slow the adoption of smart grid. The interaction scoring shows that Regulatory Environment is crucial as a source of smart grid adoption and there is a strong multiplier effect. Changes in regulations would have an effect on many of the other areas by changing the incentives for the other stakeholders and players in this marketplace.

4.4 Foresight and Forecasting: Scenarios
Scenarios map a path from today to one or more future states by progression through intermediate positions to determine what the future might look like based on various trends. Scenarios are excellent for decision making with paired possible outcomes as they amplify key issues that may not be obvious at start. Three discreet scenarios were chosen to theorize a future state based on dissimilar push/pull mechanisms:

- Fossil Fuels and the Grid
  - Fossil Plentiful/Fossil Shortage vs. Traditional grid reliance/Smart grid self-reliance
- Data Wars
  - Open Data/Data Privacy vs. Utility drives/Market drives
- Smart grid Drivers
  - Liberalized/Monopolized vs. Mandatory/Voluntary

4.4.1 Fossil Fuels and the Grid
Customers require affordable, reliable power. This scenario dictates the mix of energy sources (fossil fuel vs. other) and generation modes (centralized vs. distributed). In all cases, batteries have a role, whether it is in fully electric or hybrid transportation, grid-level energy storage systems, or somewhere in-between. UMore Park’s desire to install wind and solar power into the infrastructure mandates the evaluation and use of storage technology. For detailed information on Battery Energy Storage please refer to Appendix D: Future Studies in Grid Energy Storage.
This scenario, was started with a two-by-two matrix where axes represent the relative abundance of fossil fuels and the level of integration with a traditional grid (smart or otherwise), where power is generated centrally. The four scenarios are not meant to represent the entire range of conceivable futures, but rather to bring the important aspects of future power generation and transmission to life so that the impact of specific technologies can be understood.

The status quo scenario is what we are currently experiencing: traditional grid reliance favoring central generation of power, little use of combined heat and power (CHP) and consumption of fossil fuel constrained only by economics and environmental considerations. Nuclear Age was chosen to represent the identical situation with highly constrained fossil fuel use; nuclear power would ultimately have to be the predominant generation mode if centralized generation were still required.

The Emerald City moniker was meant to evoke images of abundant refineries and diesel generators in front of every home; in reality, the situation would probably favor CHP and microturbines powering local “microgrids.” In the Denmark scenario, “everyone has personal electrical generation” the trend toward self-reliance and small scale distributed power with constraints on fossil fuel means that solar, wind and possibly geothermal are being used at home and community scales.

Energy Storage is a key enabler for a Smart Grid. “Of the variety of energy storage technologies that could support a smart grid, advanced batteries may offer the broadest potential” (National Energy Technology Laboratory, 2009).
4.4.1.1 Status Quo

In the status quo scenario a large centrally controlled grid is in place and fossil fuel is plentiful. High voltage power lines run across the country and bring electricity to the places where it is needed. In this scenario the adoption of smart technology is not likely to be accelerated beyond the natural replenishment rate of electrical infrastructure. Geographical regions that are growing rapidly and have a need for infrastructure investment will be able to take advantage of the benefits of smart technology more rapidly than parts of the country where there is little new demand. Utilities in these high growth regions will also develop more expertise in using smart technology and be able to introduce new applications that consumers will be able to enjoy. This will allow business models for utilities to develop at a relatively controlled pace and regions where smart grids are not required will be able to learn from regions where they are required. The same will be true for utilities commissions and consumer electronics firms.

At some juncture a tipping point will probably be reached where slow growth regions will start to accelerate their investment. But this will likely occur after the effects of the smart grid on a utility’s business model is better understood, the utilities commissions have updated the regulatory environment to take this new business model into consideration, and after the consumers in the slow growth region see the different applications that they are not able to enjoy in their geographical region because of the shortcomings of their local grid.

This scenario differs from Emerald City due to a reliance on the central grid and it’s a valuable exercise to consider what additional factors would have an effect on society’s perception of whether a central grid is more appropriate than a large number of distributed microgrids. The wildcard in this scenario is the rate at which fossil fuels are phased out of the mix due to factors other than their availability, e.g. environmental concerns and price competitiveness.

If environmental concerns ease then a large centrally controlled infrastructure would be more appealing. Alternatively if consumer pressure continues to mount to reduce environmentally harmful emissions then this will increase dissatisfaction with the current method of producing electricity. In order to assure society that large power plants are not a large part of the environmental problem, utilities will need to invest in technologies that reduce or eliminate emissions on site. This could include carbon capture and sequestration or it could drive the industry to re-examine nuclear power. The decision is likely to be mainly determined by the cost structure and effectiveness of each alternative. Assuming that technologically viable solutions are found to support the current infrastructure and reduce or remove emissions, this debate about the importance of the environmental impact and the technological solutions that will mitigate the impact will not have a major bearing on the adoption rate of smart technology, but the adoption rate is not a determining factor in the debate.

4.4.1.2 Emerald City

If utilities cannot find a way to reduce or eliminate emissions on site, then this will be a factor that drives the adoption of distributed electricity generation. Other factors are societal, for example, desire for independence from large scale utilities, backlash against corporations, or demand for more localized control over the grid. Another driver towards this scenario could be the development of a highly efficient, highly reliable and highly affordable small scale power generating technology, e.g. a micro
turbine with heat recovery capabilities that provides a home, or group of homes, with electricity and heating/cooling needs.

In this scenario some interesting changes would probably take place in the regulatory environment. The business environment for traditional utility companies could change from the provision of energy to providing tools to manage energy generation and to support a market to trade through balancing supply and demand. Models could be tailored by geographical needs, e.g. consumers in Minnesota have much larger heating needs in the winter season consumers in Texas. If a combined heat and power model is adopted then there could easily be a situation where a generator is running to ensure that there is sufficient heat capacity, and the electricity would be a by-product. But the electricity could still be useful in other parts of the country. A sophisticated controls system would be needed to manage the supply and demand with more generating sources than today. In a network with n nodes the number of relationships is equal to n(n-1). Thus a network with 50 large power stations is significantly easier to understand, model and manage than a network with the same power capacity, but with 5,000 small distributed generators. If the business model for utilities changes to be a clearing house or marketplace then they might merge or be acquired by companies like NYSE Euronext. There would likely also be new financial products that consumers could invest in to stabilize the cost of energy in the future, this would protect against the risk of price variations due to trading.

4.4.1.3 Nuclear Age

 Humanity has conquered the natural world and worked out how to control atomic power in a safe and efficient way. For all of the twentieth and most of the twenty-first century, radioactivity was the bane of nuclear power. It took a long time but scientists were finally able to engineer nuclear reactors that were completely safe regardless of what natural or man-made disasters might befall them.

This opens the door for nuclear power to thrive as a source of electrical and heat energy. Communities clamor for nuclear plants to be located near to them because of the bountiful energy. Electric vehicles take off in a big way and cities reshape around this new paradigm. It’s as if everything in the world is better running on electricity. People can’t even remember how dirty the air had been when transportation used internal combustion engines and coal was burned to generate electricity.

For a while there was a strong movement to conserve energy. When it became obvious that fossil fuels were running low, there were several decades where everyone was encouraged to turn off lights and turn down the thermostat in the winter. Luckily the scientists at Los Alamos came to the rescue with their indestructible reactor. This technology had a profound effect in the developing world as well. Suddenly poor countries were not beholden to totalitarian regimes and were able to concentrate on internal development with a view to growing their economies.

Perhaps the nuclear age should be called the peaceful age.

4.4.1.4 Denmark

It’s hard to remember the heyday of the twentieth century when oil and gas were burned without thinking about the environmental impact or the fact that fossil fuels might not be around forever. Certainly there were lone voices in the crowds who warned that society needed to think about the future. After all there weren’t many new fossils being made, so fossil fuels were unlikely to last forever.
But, society trusted in technology to come up with a solution before oil ran out. Nuclear fusion was only a decade away, even if that was repeated for many decades. Most people who thought about the issue were convinced that Nuclear power would be the panacea. Yes, there were some technical challenges and risks, as was seen several times throughout the era, but surely those issues were just a matter of engineering. Of course they didn’t take the political backlash and immense capital costs into consideration. Every time that a new generation started to tentatively embrace the idea of nuclear power there would be an event that set the industry back for another twenty years.

So, the world turned to the original elements: Earth (geothermal), Water (hydro), Wind and Fire (solar). There were peaks and troughs in the development and fortunes were made and lost by many. Initially the economics didn’t work, because fossil fuels were just so inexpensive by comparison. But, as oil economies rose and fell, and the world slowly woke to the reality that there were more and more people and there was less and less oil, the economics changed. Enlightened parts of the world tried to accelerate the shift with feed in tariffs and subsidies, but it actually didn’t make a big difference and the money should probably have never been spent. Big oil was just too powerful for anything to beat it. Until one day it wasn’t.

4.4.2 Data Wars
Speculation continues surrounding the privacy and value of data generated by a smart grid. This scenario examines who will be interested in the data, own the data, profit from the data and how data privacy will affect data access. In all cases, data has a role, whether it is shared freely or owned by a singular party. Who drives the adoption of data sharing is equally as important: the utility or the market.
This scenario exercise was started with a two-by-two matrix where axes represent who will ultimately have access data integrated within a smart grid, whether the market will demand data sharing and if utilities will secure a place in data ownership. As noted earlier, the four scenarios are not meant to represent the entire range of possible futures, but rather to bring the important aspects of data ownership to the forefront so that the impact of specific technologies can be understood.

### 4.4.2.1 Data as Currency

In this scenario open data sharing of offers utilities and independent third parties the ability to interrogate energy usage and align covariant studies. With fanciful algorithms and promises of energy saving through interactive dashboards and automated response systems, many businesses will be looking to sell their raw data or interpretation of data for a price. For this reason data is now an energy “currency.” Energy “data” used as currency is not a new idea; multiple companies exist today for the sole purpose of using data to improve energy efficiency.

Consumers will likely balk at openly sharing the data from their personal residence instead of feeling empowered; however, in this scenario the consumer is a bystander. UMore Park and the University of Minnesota would benefit as it will open the possibility to study consumer’s behaviors and the interaction with various models of a smart grid implementation. Constant analysis of behaviors and usage patterns will expose opportunities to implement consumer-based incentive programs. The output
of data analysis will be valuable in the form of white papers, university research, real-time community feedback and the potential to create business plans and revenue streams for sharing data.

4.4.2.2 **King Capitalism**
In this scenario data is provided to a third party with money. Capitalism flourishes as every data point can be collected and sold. In *King Capitalism* data is streamed from each household to a third party *regardless* of what the consumer wants, the analysis is then sold back to the consumer for intelligent applications to save energy. In theory this scenario provides a win-win situation with both the utility and consumer triumphant. The utility can use the data to improve the operations and efficiency of the power generation and distribution and consumers benefit through methods to save energy resulting in reduced energy bills.

4.4.2.3 **Utility Reigns**
If utility companies were given the choice, they would willingly own all energy related data and keep contents private. The benefit to the utility company is an advantageous position over the consumer by understanding exact energy demands and a pricing schema that generates as much profit as the market would allow. The other benefit to the utility is government dollars dedicated to Smart Grid implementations would be funneled into their business as part of massive infrastructure upgrades offsetting investments by the utility.

4.4.2.4 **Consumer Castle**
In the *Consumer Castle* the customer is given the option to determine where they buy energy. “A major objective of electricity deregulation is to achieve a workably competitive wholesale market” (Rothwell & Gómez, 2003). In the United States utility companies wield massive power and influence which work against creating a competitive market, especially as many utility companies are guaranteed specific percentages of revenue for generating and distributing energy. Consumers may always choose to buy or retrofit their homes for energy efficiency and data gathering; however, the likelihood influencing utilities is negligible.
In the smart grid drivers scenario the question of whether a smart grid is mandatory or voluntary is juxtaposed against liberalized or monopolized grid in a two-by-two matrix. If UMore Park implements a smart grid as technology advances they will be able to benefit from multiple scenario outcomes.

### 4.4.3.1 Green Fortune 500
In the liberalized and mandatory scenario both large and small businesses emerge profitable. Existing experts continue to yield dollars from a mandated smart grid and entrepreneurs emerge, both parties interested in full deregulation of utilities to influence the market. Although the goal of a deregulated market is to afford the consumer with choices, regulated tariffs have sheltered most from steep jumps in price. If Green Fortune 500 succeeds UMore Park will have freedom to choose a tailored smart grid installation from several solution providers.

### 4.4.3.2 Geneva
A liberalized and voluntary smart grid will be expensive. Without economies of scale slow adoption will continue. Hardware and software installed on a consumer level will have minimal impact on the larger grid and incentives to adopt may price may discourage those who would otherwise implement. This scenario is the current trend in the United States. UMore Park may be able to leverage their smart grid implementation by virtue of size and a neutral starting point.
4.4.3.3  **Vegas**
A monopolized and voluntary scenario will generate smart grid adoption only if enough customers can see the benefits. A strained economy will tighten consumer incentives and as a result companies will withdraw from creating infrastructure and software needed to implement a sustainable smart grid. Although this scenario is not good for the United States UMore Park may still benefit by using their influence as a university and a scaled installation to implement a smart grid.

4.4.3.4  **Halliburton**
A monopolized and mandatory scenario is tricky for UMore Park. This scenario demands that consumers and developers buy into the smart grid no matter the price; however, if UMore Park is selling energy to residents, a method to shift profits from big business into the community will exist.
5.1 Sustained Competitive Advantage: a Recommended Strategy for UMore Park

The goal of any enterprise is to find ways to enhance their inherent advantage over competitors. If an enterprise is successful, they will create monopoly like conditions for their products; the result, if maintained over time, is Sustained Competitive Advantage (SCA). Since UMore Park is going to be developed over the next 30 years, there should be a focus on what it takes to create and maintain SCA. As illustrated in Figure 29 above, SCA is the sum of three main activities: Analysis, Making Moves, and Execution.

5.2 Analysis
Analysis is an important activity to help understand the business environment that surrounds UMore Park, both from an internal and external perspective. Internal Analysis (IA) is used to understand the business environment inside UMore Park. For example, what are the strengths and weakness of the organization? External Analysis (EA) is used to understand the environment outside UMore Park. For example, what does a Porter five forces analysis tell us about threats from outside UMore Park? The analysis can then be used to improve and plan moves.

5.2.1 Internal Analysis
A strengths/weakness analysis was carried out. The analysis first focused on the Strengths of UMore Park that can and should be leveraged. The University of Minnesota brand is a trusted and valued brand, especially in the metro area. UMore Park has a 5,000 acre plot of land, a large tract from a development perspective which is being leveraged to design an entire community. This is a distinct advantage over a typical development of houses and light commercial space. The ongoing gravel mining provides immediate revenue and will be utilized to create unique landscaping throughout the community. Since the development is large, the time horizon for the development is on a longer time scale than typical developments. This timeline provides the opportunity to incorporate learning’s from phase to phase and to take a longer-term view on the development itself. Often longer time horizons are associated with higher quality design and construction. The “green” and environmentally friendly design that is being incorporated into the community provides UMore Park a differentiated product at a scale that cannot be matched in the metro area. UMore Park, through its staff and association with University of Minnesota has access and influence with political figures that provide a key advantage in the marketplace. The right to use cutting edge research, faculty, and students also provides UMore Park a unique opportunity for collaboration and a knowledge network that is superior.

Next, the analysis focused on the Weaknesses of UMore Park. The idea is that all efforts should be made to mitigate the impact of the weaknesses because they provide areas for competitors to strike and gain an advantage. One area of concern is that UMore will be competing against local developers who are also eager to build and sell homes. It will be critical to develop a differentiated product that will not be in direct competition with other local builders. UMore Park is a “Mission” focused organization which can lead to tunnel vision with a loss of focus on what is practical. It is important that UMore Park recognize and ensure that a proper balance is maintained. The site for UMore Park is not ideal as it is set about 25 miles southeast of the Minneapolis without easy freeway access. Developing a differentiated product offering to “draw” people to this development can help offset this weakness. Because of the

**Figure 30 Internal Analysis**

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tightening state budgets, access to capital and funding for the development of UMore Park may be more difficult to obtain. In order to design and build UMore Park, it is going to require establishing partnerships with others, which tends to weaken the position and bargaining power. Finally, as is the case with many companies, competing priorities can certainly slow or even derail progress. The unfortunate budget crisis that is plaguing the state of Minnesota could trickle over and impact the goal of UMore Park. Understanding internal weaknesses can be turned into a source of leverage if the weaknesses are honestly identified and mitigation strategies put in place.

5.2.2 External Analysis

Performing an External Analysis provides insight to the world outside UMore Park and can help to shape the strategy to provide SCA. There are two key parts to the External Analysis: the macro environment and Porter’s five forces. The macro environment focuses on looking at forces that may impact UMore Park at a high level. The Porter’s five forces focus more specifically on the industry in which UMore Park is competing to determine the attractiveness of the industry.

There are unlimited forces at work in the macro environment. The key is to try to identify the forces that will impact UMore Park. Demographics will be important to design and marketing. The population is aging but over the 30 year development timeline, people born today might buy their first home in UMore Park. That means they will have been immersed in a wired world from the first day of their lives. The technologies that they will utilize and possibly expect in their first home could be very different than what people are accustomed to today.

The financial turbulence that has swept across the globe and specifically plagued the US housing industry is having an impact today and will continue to have an impact on the housing industry for years to come. There has been talk about eliminating the tax subsidies for mortgages, lenders are imposing stricter lending standard, the list goes on and on but these forces in this area will certainly influence UMore Park.
Population growth on the planet is high but is slower in the US. Will more of the population in the future be immigrants or local, will tastes and expectations change with the population?

Technology is obviously changing quickly and shows no signs of slowing. Technology is becoming more pervasive and imbedded in our daily lives. As technology continues to advance it will likely have an impact on the expectations that people have on how they interact with their homes and communities.

Security is obviously important to people after 9/11 and will continue to be on people’s radar for the foreseeable future. Security also spans the electronic world and as technology moves deeper into our lives people’s expectations for security will likely increase.

The use of fossil fuels has enabled the growth and prosperity of the world as we know it. Their supply is limited and no one knows exactly how long the fossil fuels will last. How will this impact the world over the next 30 years? Will the wave of environmental awareness curb the use of energy or drive innovations in new technology?

Each of the macro environmental forces mentioned above is important forces that will impact UMore Park over the next 30 years. They need to be monitored to help ensure a robust strategy that incorporates the dynamic, outside world!

A Porter’s Five Forces analysis is used to analyze the attractiveness of an industry. This analysis was performed with two goals in mind. First, identify who or what fills each of the five forces? The five forces that are considered are:

1. Existing rivals
2. Threat of New entrants
3. Substitute Products
4. Suppliers Power
5. Customers Power

Second, the analysis focused on which of the five forces, if any, provide a competitive advantage to UMore Park.

The chart below (Figure 32) shows each of the five forces categories and answers the first question of who needs to be considered in each space.
After the players in each space have been identified, the question of which of the five forces can be leveraged to provide UMore Park a competitive advantage? UMore Park has a strong position that can be leveraged against existing rivals and threat of new entrants. This position is the design of unique, one of kind community that offers a differentiated product in the market place. The application of smart technology in homes certainly will help to differentiate the homes that are built and sold. The design of a “from scratch” community that incorporates green and smart technology into the community will also differentiate the UMore Park development from that of rival developers. The scale of UMore Park and the fact that the plan is for the development of an entire community, together provide a strong position against new entrants.

In looking at consumer’s power, currently the consumer does have a position of power when it comes to purchasing homes. Currently there are a number of new and previously owned homes on the market. Prices are still falling in the Twin Cities and inventories are high. Consumers will always be comparing the price, location and amenities of the homes that are available on the market. For the immediate future, it appears as though the Consumer will hold the power. In looking at Suppliers Power, it does appear that UMore can leverage its size and obtain some power over suppliers. Supplier, especially those selling smart technology have products that are available and on the market at time when many people are not spending as freely on their homes as they were at one time. This could mean a position of power for UMore to find partners that are eager to deploy their new products and technologies into

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**Figure 33 Full five forces analysis**

<table>
<thead>
<tr>
<th>Suppliers Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developers</td>
</tr>
<tr>
<td>Financing - Capital Outlay for development</td>
</tr>
<tr>
<td>NGO/Non Profits</td>
</tr>
<tr>
<td>Research Grants</td>
</tr>
<tr>
<td>Government(Local, State, Federal)</td>
</tr>
<tr>
<td>Utilities</td>
</tr>
<tr>
<td>Private Public Partnership - PPP</td>
</tr>
<tr>
<td>OEM’s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Threat of New Entrants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Developments</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Existing Rivals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Developers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Customers Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used Homes</td>
</tr>
<tr>
<td>New Homes</td>
</tr>
<tr>
<td>Renting</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Substitute Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rentals</td>
</tr>
</tbody>
</table>

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the unique, community of the future that UMore aspires to be, to prove the value and benefits their technologies.

In looking at Substitute Products, as long as UMore Park develops and markets a differentiated product, the substitutes will be the same products that give the Consumer Power.

5.3 Making Moves
Enterprises can make moves across several dimensions: Business Strategy, Corporate Strategy and Innovation strategy are the three areas that we are exploring in this section.

5.3.1 Business Strategy

Business Strategy seeks to answer the question “How do we do business?” UMore Park LLC has a number of strategic assets that can be used to develop competitive advantage that will help make the development a successful venture.

The University of Minnesota is recognized as a trusted brand across broad cross-sections of the general public. There is an opportunity to leverage this brand by marketing the UMore Park development in conjunction with the University.

The university also has many faculty and students with expertise in design and urban planning and this can also be used to increase the local appeal of the development, as well as a source of generating economic benefits within the broader community.

Ultimately these two factors will help to differentiate the UMore Park development in the eyes of prospective home buyers. This is important because the location of the development is not ideal, being several miles from major highways and having little public transportation. The expectation is that many residents will commute north to the central metro area, and the fact is that there will be other developments at similar price points that offer easier commutes. The UMore Park development
therefore has to set itself apart from the competition in other ways. One other factor that is worth mentioning is that the financial risk is lower for the University as the cost basis for the land is low, since it was granted to the University many years ago. Rather than having to purchase land, the main costs will be for preparing the land to be ready to build upon.

5.3.2 Corporate Strategy

The next type of moves that is available for UMore Park LLC falls into the category of Corporate Strategy. This is more about deciding how the business is structured and what business the enterprise is really in.

UMore Park is a for profit entity that belongs to the University of Minnesota. This gives it some benefits, like the ability to enter into commercial partnerships with other entities who can share some of the financial risk of developing UMore Park.

As it relates to the scope of this project there are certainly opportunities to create partnerships with interested companies. Partners might include utility companies, like Xcel Energy or Centerpoint Energy, or consumer electronics and appliance manufacturers. If there is a clear vision and UMore provides a marketplace with 25,000 or 30,000 customers then there are likely to be companies that are interested in serving that market.

There are also other types of business model that can be explored as relates to selling energy. For example, it is technically possible today to generate electricity with small scale micro-turbines that burn natural gas and to use the heat that is produced by the turbines to generate enough hot water to be used in homes for both central heating and warm water needs. An initial financial analysis indicates that this type of model could reduce the energy costs for a home. It would also be an opportunity for UMore Park to build a business that generates a stream of cash flows that would ultimately accrue to the
University of Minnesota. The system would be modular in nature such that new, greener, technologies could be incorporated as they become available, and the emissions and net energy usage of the community would decline over time. By incorporating smart technology into the model and by including energy storage capacity, like hot and cold water tanks, it would be possible to build an extremely efficient system that could be managed to transfer solar energy or wind energy into stored thermal energy, which would then be available at times when solar energy and wind energy are not available.

A final area where choosing a different business model could provide a source of revenue for UMore Park applies to the question of gathering and using energy usage data. Overlaying sensor networks from the transmission level down to the home level allows for the capture of extremely detailed usage data, potentially at the device or appliance layer. This data has value to many different parties, whether it is an appliance manufacturer who wants to build a better dishwasher, or a university researcher who really wants to understand how we use energy in our lives. There are tools today that consumers can buy if they wish to track their energy usage for their own purposes, but by building the data collection into the smart system, it could be made available for other purposes. The challenge will be determining who is willing to pay for the data, and then to build a financial model that shares the value with the consumer so that there is a clear benefit to sharing. Executing this in such a way that the data cannot be used to the detriment of the consumer or society as a whole is critical.

5.3.3 Innovation Strategy

The final strategic category is innovation strategy. This is the section where development and application of technology really comes into play and provides a differentiating force for the UMore Park development.

Energy costs and usage are certainly large differentiators when it comes to buying a home. But another differentiating factor is simply the amount of technology in the home and the applications that it can be put to. Assuming that UMore Park is built with a smart grid around it that includes an overlay of sensing technology all the way to the electricity meter, then there is also an opportunity to continue the
progression of the smart technology and put it into the home. This would involve modules that are incorporated into electrical outlets, devices and appliances, and that form a communication and control network within the home. It’s actually difficult to predict all of the applications that could be developed if there were a community of smart homes connected to a smart, reliable grid. It’s hard to remember back to pre-iPhone days, but there weren’t many predictions that there would be billions of apps downloaded in only a matter of years. Ultimately the smart home could allow consumers to control their entire house with intuitive tools that would be accessible through Smart phones, web browsers or control screens in the home. As Artificial Intelligence develops further the home would learn to react and predict and even make intelligent decisions on behalf of the home owner that would enhance quality of life and extend the environmental benefits from energy efficiency.

The opportunity for UMore is to build a community of smart homes that will enable this innovation to take place, and become a test bed for the country.

5.4 Price Estimates for Energy Efficient, Smart Grid-Ready Homes at UMore Park

Based on a financial analysis by Design Workshop, the University could make an estimated $185 million by developing the property for homes, retail, and businesses. (DesignWorkshop, 2008) If they form an energy company, as was recommended in the Concept Master Plan and in a study on the feasibility of forming a utility company (6Solutions, LLC, 2010), UMore Park could make an additional $34 million. For either of these estimates to actually happen, UMore Park must first sell homes. Without a customers buying houses, UMore Park will make no money. Focusing on the opportunity to create customers instead of on potential revenue streams brings two important questions to light: how much will it cost someone to buy a home in UMore Park, and, are they willing to pay it.

Developing estimated home prices is the first step to answering these questions. Maxfield Reearch, Inc. estimated that a single family home in UMore Park would average from $287,500 for a small lot, to $587,500 for a large lot as shown in Table 3. These estimates can be used as a basis for estimating the costs to include energy-efficiency and smart grid technologies into the home. Additional assumptions to develop a price estimate for these homes are:

- Infrastructure development for the UMore Park property as a whole is not included in the costs. Maxfield Research, Inc. also made this assumption when estimating the prices listed in Error! Reference source not found.
- 8% in costs must be added to build energy-efficient homes for cold climates. This is an estimate based on the work of Patrick Huelman and John Carmody of the NorthernSTAR team. The team has built at least four of these homes. The NorthernSTAR team was formed in 2010 through the US Department of Energy (DOE) and the National Renewable Energy Lab’s (NREL) Building America Partnership
- Approximately $10,670 to $27,190 per home for smart grid technologies. Price estimates are based on current pricing for these technologies if it is available or from cost estimates from the report on the costs of smart grid by the Electronic Power Research Institute
A breakdown of the smart grid technologies that should be incorporated into a home and estimated prices for each is listed below in Table 4.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photovoltaic Inverter</td>
<td>A micro-processor based unit that transforms DC power coming from the PV panel to AC power for consumption in the home (Note: the cost of the PV panels are not included in this estimate)</td>
<td>$ 800</td>
<td>$ 1000</td>
</tr>
<tr>
<td>Battery Storage Backup</td>
<td>Batteries, either lead-acid or lithium ion in the future, to help maintain uninterrupted power, or to store energy collected from PV panels on the home</td>
<td>$ 2200</td>
<td>$ 2400</td>
</tr>
<tr>
<td>Residential Energy Management Systems</td>
<td>A system for managing components in the home such as lighting, temperature, etc.</td>
<td>$ 150</td>
<td>$ 300</td>
</tr>
<tr>
<td>In Home Displays</td>
<td>A device that can display electrical consumption, prices, or other energy information to the consumer</td>
<td>$ 20</td>
<td>$ 50</td>
</tr>
<tr>
<td>Smart Grid-Ready Appliances</td>
<td>Appliances that can be managed by demand response systems to help reduce energy consumption. Costs listed here are the estimated price differences between Smart Grid ready appliances and conventional ones over time with the high estimate showing the price difference now.</td>
<td>$ 0</td>
<td>$ 40</td>
</tr>
</tbody>
</table>
PEV/PHEV Charging Station | Allows a PEV/PHEV to charge in the home. This price estimate is based on a Level II charging station. Currently the Coulumb CT500 is priced at approximately $2500. The high cost estimate includes installation costs, which should be included in home construction. These costs are added here to highlight that these costs must be considered in the home’s construction. | $ 2500 | $ 3400

Communication Devices for Home Automation | Devices, such as sensors and micro-processors, or wiring that will allow home automation for heating, cooling, and electrical use | $ 5000 | $ 20,000

| Total Estimated Costs | $ 10,670 | $ 27,190 |

If the above assumptions are made, price ranges for single-family, energy-efficient smart grid ready homes would be as follows in Table 5:

<table>
<thead>
<tr>
<th>Table 5 Estimated Prices for Energy-Efficient, Smart Grid Ready Homes in UMore Park</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price Ranges</strong></td>
</tr>
<tr>
<td><strong>Low</strong></td>
</tr>
<tr>
<td>Small Lot</td>
</tr>
<tr>
<td>Traditional</td>
</tr>
<tr>
<td>Large Lot</td>
</tr>
</tbody>
</table>

In summary, these homes would cost an average of $41,930 to $65,930 more than a conventionally built home. However, the low and average prices for these homes do fall within the original estimated price range for future UMore Park homes. While these increased costs are well over the $6,000 that some surveys have indicated customers are willing to pay for energy efficient homes, there are several strategies that could be used to mitigate these increased costs, such as:

- **Energy-Efficient mortgages** which can increase the mortgage amount of the loan to the lesser of 5% of:
  - the value of the property, or
  - 115% of the median area price of a single family dwelling, or
  - 150% of the conforming Freddie Mac limit.
- **Shared equity homeownership** which can share some of these increased costs across the total life of the home and not just the time of ownership for each resident.
Employer assisted homeownership can also help reduce the mortgage amount or stretch out costs across the life of the home.

Another method that could help consumers understand these costs and increase their likelihood in buying a home in UMore Park would be to compare the monthly costs (i.e., mortgage and utilities) of an energy efficient, smart grid ready home in UMore Park to those of a conventional home. The purpose would be to highlight that the increased upfront costs would reduce the monthly costs of the home. In addition to the monthly costs, home owners could also be shown how a home in UMore Park compares to conventional homes in total estimated annual energy consumption or savings, carbon footprint, or the total costs to own the home over specific time periods (e.g., 5-7 years). Calculators that compute some of this information are available on the web. However, most are used to help people decide if they should rent or buy a home or are used for calculating the return on investments for energy-efficient appliances. A website or report used at the point of sale that can aggregate cost information specific to UMore Park could be a powerful marketing tool for selling homes.

To help calculate energy savings, there are a variety of methods available to first determine energy consumption. PAS smart grid project are one method. In an ACEEE study of advanced metering from 1995-2000, consumers were able to achieve between 9.2 to 12% in electrical savings through real-time pricing and feedback. (ACEEE, 2010) Implementing AMI at UMore Park could potentially achieve the same or better results. LEED standards and Home Energy Rating Systems, Energy Star ratings, Minnesota Green Communities standards and other standards could also be applied to homes in UMore Park to help narrow down actual energy costs. However, the Concept Master Plan recommended LEED and Minnesota Green Communities standards be considered. Regardless of the method, translating energy consumption into dollars would be a useful way for home buyers to understand that they may pay more up front, but they will pay less over time. This is the same value proposition that hybrid-electric vehicles are using to overcome the challenge of a higher initial price point. Unfortunately, without additional specifications on future homes in UMore Park, such as the ones listed above, only an estimate of future home prices is included in this report instead of a complete report on the costs.

5.5 Recommendations
Table 3 shows a list of recommendations that has been compiled based on the SCA framework with an analysis of the costs, benefits, associated risks and likely reactions from other parties.
<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Who</th>
<th>When</th>
<th>Cost</th>
<th>Risk</th>
<th>Competitive Reaction</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage with Xcel – Develop Partnership</td>
<td>UMore Park Management</td>
<td>Ongoing</td>
<td>Low Cost – Time</td>
<td>M - Could try to sabotage &amp; obstruct</td>
<td>Xcel – Partner, Ignore or Obstruct</td>
<td>High Potential</td>
</tr>
<tr>
<td>Engage with PUC – Change Utility Incentives</td>
<td>UMore Park Management</td>
<td>Ongoing</td>
<td>Low Cost – Time</td>
<td>Low</td>
<td>PUC – Embrace or Resist Xcel – Sabotage, Ignore or Partner</td>
<td>High for UMore and Consumers</td>
</tr>
<tr>
<td>Participate in Standards</td>
<td>UMore Park Management</td>
<td>Ongoing</td>
<td>Low Cost – Time</td>
<td>Low</td>
<td>Xcel – Embrace or Resist</td>
<td>High Potential for synergy in standards and planned development</td>
</tr>
<tr>
<td>Find Partners</td>
<td>UMore Park Management</td>
<td>Ongoing</td>
<td>Low Cost – Time</td>
<td>Low</td>
<td></td>
<td>Increase chance of partnership – Xcel &amp; PUC</td>
</tr>
<tr>
<td>District Model – Business Plan</td>
<td>UMore Park or Subsidiary</td>
<td>Pre-Phase I</td>
<td>Explore cost - L/M Start Up Cost – M/H Running Costs – L/M</td>
<td>L M/H L/M</td>
<td>Xcel – Sabotage or Partner CenterPoint Energy – Embrace</td>
<td>Save Money for consumer, maximize efficiency, lower emissions</td>
</tr>
<tr>
<td>Build Smart Homes</td>
<td>UMore Park &amp; Developer or Builder</td>
<td>Pre-Phase I</td>
<td>X% above target cost</td>
<td>M – Market won’t pay extra</td>
<td></td>
<td>Consumer can save money, increased efficiency, home security, peace of mind</td>
</tr>
<tr>
<td>Integrate ADR into Commercial Space</td>
<td>Developer or Builder</td>
<td>Pre-Phase I</td>
<td>Low cost-built into infrastructure</td>
<td>M – lagging TOU rebates</td>
<td>Energy Providers</td>
<td>University and consumers save money and own intelligence Proactive stance for OpenADR adoption</td>
</tr>
<tr>
<td>Monitor Grants and Funding Opportunities</td>
<td>UMore Park or Subsidiary</td>
<td>Ongoing</td>
<td>Low Cost</td>
<td>Low</td>
<td>All-Partner or compete</td>
<td>High Potential for outside funding</td>
</tr>
<tr>
<td>Monitor Technology Opportunities</td>
<td>UMore Park &amp; Academic Affairs</td>
<td>Ongoing</td>
<td>Low cost</td>
<td>L</td>
<td>Supports academic mission, improves product long-term</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Develop Data Collection and Use Policy</td>
<td>Service Providers, UMore Park Academic Affairs</td>
<td>Pre Phase I &amp; Ongoing</td>
<td>Low Cost – UMN has framework</td>
<td>M – consumer backlash without it, loose future research ops</td>
<td>Consumer – Accept or Reject</td>
<td>New Services New Research Build Trust</td>
</tr>
<tr>
<td>Develop Outreach &amp; Education Plan specific to Energy</td>
<td>UMore Park Academic Affairs</td>
<td>Ongoing</td>
<td>M- Research Costs L – UMore Park LLC</td>
<td>L – no impact</td>
<td>Utility – Embrace or Ignore</td>
<td>Build Trust Build Brand</td>
</tr>
</tbody>
</table>

Table 6 Strategic Recommendations
6

6.1 Conclusion

The goal of UMore Park, as with any business, is “to create and keep a customer” (Drucker, 2008). In this case, people who want to live and work in the new development. The SCA framework can guide the organization to make moves that support this goal.

The focus has to be providing a differentiated product when compared to other communities in the country. Key differentiating factors include the vision for the usage of renewable energy sources and maximizing energy efficiency, as well as the lifestyle opportunities that stem from the involvement of the University of Minnesota.

A community based approach to energy, such as the district energy model described in this paper can provide significant improvements in energy efficiency. According to a study by the National Renewable Energy Laboratory:

“Integrating the Renewable Energy Community as a whole system can accrue significant benefits. Cost advantages from the systems approach—linking homes with vehicles and addressing energy issues on a community level rather than on individual households—can be gained compared to the costs of each individual part.” (Carlisle, 2008)

An initial financial model contained in this paper indicates that UMore Park could develop a business model to sell energy to the residents that would generate cash flow for the company and that would ultimately accrue to the University of Minnesota.

UMore Park should plan to incorporate smart system technology into the home and integrate home management with the district energy model to build a truly smart community. The demographic driver for this is that most of the new residents will be “Digital Natives” and will have a high expectation of connectedness in all aspects of their lives. Given that the timeline for the UMore Park development is around 30 years, there is a need to scan for and adopt new technologies as they are developed. UMore Park should be bold in the adoption of new technologies that support the overall vision of the development.

Incorporating the new technologies also provides the University of Minnesota an opportunity to develop research areas arising from the data that the community will generate and that can be captured as part of the smart system infrastructure that should be included. This will require some careful planning and putting safeguards in place to ensure that the data is handled appropriately by the University. It also provides the University the opportunity to develop and spin off new businesses around managing and utilizing the data from smart communities in the future.

The regulated electrical markets in Minnesota provide a hurdle to the development. UMore Park has to navigate the regulatory environment in order to realize the vision of creating the world-class community that it seeks to become. Utility companies operate in a heavily regulated industry and any attempts by
UMore Park to develop new business models around the provision of energy are constrained by existing regulations. For this reason it is in UMore Park’s interest to actively engage with Xcel Energy and the State of Minnesota Public Utilities Commission.

In order to increase the impact of the dialogue with the PUC and Xcel Energy, UMore Park should also develop relationships with other groups, communities and organizations, who have similar motivations to change the regulatory environment. This would provide a stronger voice for the issue.

By incorporating the appropriate technologies into the development and by effectively navigating the regulatory environment, UMore Park has an opportunity to build a smart community of the future.
7

7.1 Δ MOT

The MOT program is designed to help technology professionals bridge the gap between technology and business. Throughout the two-year curriculum, we have been forced out of our comfort zone, the technology space, into the space of technology management. Technology management involves developing a holistic view of technology across the entire value chain of an organization. The holistic view has forced each of us to ask questions within our organizations such as:

- What is the financial impact to the top and bottom lines of a new technology?
- Who is the target market for the product or service?
- What does the future hold so that we can develop a robust and sustainable corporate wide technology strategy?

The program has provided us the tools to answer these questions and have a positive impact on the future of our organizations.

Throughout this project for UMore Park, we have utilized many of the classes and tools specific to MOT.

MOT 8213 – The Macro Environment of Technology
Utilized scenario planning and development of moves and strategies

MOT 8233 – Strategic Management of Technology
SCA analysis performed and utilized to develop a strategy for UMore Park to develop and sustain an advantage

MOT 8212 – New Product Development
Utilize and develop stage gate process for the phases of UMore Park development

MOT 8122 – Financial Accounting
Developed and utilized financial accounting tools to evaluate the possible financial benefits of installing capital equipment

MOT 8214 – Technology Foresight and Forecasting
Utilized analysis tools such as Normative Forecasting, scenario planning, and TIM/TIP analysis

MOT 8114 – Strategic Analysis of Technology
Utilized tools for scanning the technology landscape and evaluating technology interactions and defining a Power Zone

MOT 8111 – Marketing for Technology Intensive Companies
Utilized learning’s such a Porter’s five forces analysis, marketing analysis and consumer adoption
Appendix A: Methodology

1. **Initiation** – In the initiation phase of the project, we met with Carla Carlson, Charles Muscoplat, and Larry Laukka to discuss the project’s goals. We also conducted a site visit to the UMore Park property to understand the project in the context of its location. After a few meetings and discussions, it was determined that the goals of the UMore Park development were twofold: make money for the University of Minnesota, find the killer app that will help sell the community to potential residents and businesses. For our project, the goal was to assess how smart grid technologies could help UMore Park achieve their goals.
   a. Meet with the customers at UMore Park
   b. Scope the project
      i. Goal is to find ways to make money for the U
      ii. Goal is to find the killer app that will help sell the community
   c. Visit the site

2. **Planning/Discovery** – In the discovery and planning phase, all of our efforts where aimed toward discovering what we needed to know in order to achieve our goals and then devising a plan of action to achieve them. This was the most time consuming part of the project. With our goals in mind, we each began reviewing the available information on UMore Park. The academic initiatives office and UMore Park, LLC have both commissioned research and design projects to understand how to best utilize and monetize the property. To expand our knowledge on smart grid, we investigated numerous sources of information which formed into a team reference library with information covering topics such as regulation, key technologies, current implementations, etc. To round out our research, we also attended smart grid related events and conducted expert interviews. Lastly, this phase also included a discussion on how to separate out the project into areas of interest for each of us on the team. This not only made our work more efficient, but was also intended to give us each our own area of interest to use when presenting our individual Capstone projects.
   a. Research the following
      i. Design master plan for UMore Park
      ii. Studies related to UMore Park
      iii. Current smart grid implementations
      iv. Smart grid technologies
      v. Housing market
   b. Attend events
      i. E3 Energy Conference
      ii. Sustainability Lecture
      iii. Best Buy Conference
      iv. Honeywell Smart Grid Summit
   c. Interview experts
      i. Louise Goldberg
      ii. Anders Rydacker
      iii. Larry Laukka
      iv. CSBR Director
d. Divide the work
   i. Hope – consumers, marketing
   ii. Shanna – advanced metering, ADR, Energy Storage
   iii. Eric – infrastructure, district energy
   iv. Andrew – policy, consumers, software

3. Select Technologies
   a. Power Zone
   b. Technology Interaction Matrix
   c. Forecasting

4. Develop business case
   a. Build proposed district energy model
   b. Build proposed smart home model

5. Develop Recommendations
   a. SCA

6. Develop Implementation Plan
   a. Stage Gate

7. Present Findings
   a. Individual Capstone Presentations
   b. Report delivered to UMore Park
   c. Presentation with UMore Park Stakeholders
Appendix B: Smart Grid Ecosystem

HEMS Ecosystem: Components, Level/ Layers

*Controls/ comms may be embedded in the equipment. Tstat, a basic component of EMS???
**Assumes energy generated from renewables is stored in battery/ energy storage

NYtimes: Home-charging for electric vehicle
HEMS Ecosystem: Interface Connections

Currently Offered Products

*HAN may be integrated with the EMS or a separate entity that may include security, cable, telecoms, etc.

*ESI (Energy Service Interface) may be in several locations i.e. meter, EMS

*EMS may be single unit controlling whole house or multiple

Beyond the Thermostat

*General: Connections/ components need to further verified
EV Ecosystem: Players in Product Sector

\( \text{(ALL) Major car mfrs have EV in their pipeline} \)
\( \text{EV batteries are mostly Li-ion} \)
\( \text{Charging Stations take power from grid or solar} \)
\( \text{Associated EMS for R, C – still emerging} \)

**Resd’l Home Charging**
- Players:
  - AeroVironment
  - Eaton
  - ECOTality: Mint-Charger
  - Eltek Valere (portable type)
  - Greenlight, PlugSmart

**Comm’l Charging Station**
- (Fast~30 mins, Std., ?) (Electric Power Grid or Solar)
  - Players:
    - Delta-Q Technologies
    - Eaton-Takaoka Electric Mfg
    - ECOTality
    - Eetrex
    - Electromotive (UK)
    - E-TOTEM: ABB
    - EV-Charge America
    - Evatran – only Plugless solution!
    - Evoasis
    - GE (Ongoing dev’t)
    - LOTUR Energy (EVCO)
    - Optimization Technologies
    - Panasonic, PlugSmart
    - ReVolt Technology/ ARPA-E
    - Samsung (Ongoing)
    - Shorepower
    - Coulomb Tech’s Smart Charge, Siemens (ongoing)

**Smart Charging (Public) – EM software**
- Players:
  - GE-Nissan (ongoing dev’t)
  - Gridpoint (EV-Charge America)
  - SilverSpring-ClipperCreek

**Battery Switching Station** (For lower wait time)
- Players:
  - Better Place

**Electric Vehicle**

**EV Cars – Personal Use**
- Players: Model (Mileage, kWh)
  - Audi: e-tron
  - BMW: MINI, ActiveE
  - BYD: Daimler: e6, Smart Fortwo, Mercedes-Benz e-car
  - Coda Automotive: China: saloon car
  - Daihatsu: Mira
  - Fisker Automotive: Karma, Nina
  - Fiat/ Chrysler: GEM 25, Fiat 500 EV
  - Ford: Focus
  - General Motors: Chevy Volt (40-mi, 16kwh)
  - Honda: CR-Z
  - Mitsubishi/ PSA Peugeot: i-MiEV
  - Renault-Nissan: Leaf (160mi)
  - Smart
  - Subaru
  - Tesla (Toyota?): Roadster (240mi), Model S (300mi)
  - Think Global: ThinkCity
  - Toyota: Prius (14mi-5kwh), FT-EV

**EV – Commercial**
- Bright Automotive Inc: IDEA
  - i.e. for USPS? (Consortium - Alcoa, GOOG, JCI, Eaton)

**Battery**
- Players:
  - A123
  - Bosch-Samsung (BMW, Li-Ion)
  - BYD
  - Eetrex
  - Ener1 of EnerDel
  - Hitachi
  - LG Chem (GM)
  - NEC
  - Panasonic
  - Sanyo (Li-Ion)
  - OEMs like AC Propulsion

**VMS, Vehicle Mgmt System**
- Players:
  - AC Propulsion

**Extra Service**
- Telematics, Smart Phone apps,
  (To locate charging next charging station, remote booking/ charging, battery life)
- Players:
  - GM’s OnStar for Chevy Volt

*In Japan, Nissan, Toyota, Mitsubishi and Subaru have teamed with Tokyo Electric Power Co. to form the CHAdEMO Association, to work on a global standard for fast-charging stations.*
Appendix C: California PUC and AMI Requirements

California Public Utilities Commission AMI Requirements

1. Supports implementation of time-varying tariffs for:
   i. Residential and small commercial customers (under 200 kW):
      i. Time-of-Use (TOU) rates;
      ii. Critical Peak Pricing with fixed notification (CPP-F) and CPP with variable or hourly notification (CPP-V);
      iii. Flat/inverted tier rates.
   ii. Large customers (200 kW to 1 MW) on an opt-out basis:
      i. Critical Peak Pricing with fixed or variable notification;
      ii. Time-of-Use rates; iii. Two part hourly Real-Time Pricing.
   iii. Very large customers (over 1 MW) on an opt-out basis:
      i. Two-part hourly Real-Time Pricing;
      ii. Critical Peak Pricing with fixed or variable notification;
      iii. Time-of-Use Pricing.

2. Allows collection of usage data at a level of detail that supports customer understanding of hourly usage patterns and how those usage patterns relate to energy costs.

3. Provides customer access to personal energy usage data with sufficient flexibility to ensure that changes in customer preference of access frequency do not result in additional AMI system hardware costs.

4. Compatible with applications that (1) use collected data to provide customer education, energy management information and customized billing; and (2) support improved complaint resolution.

5. Compatible with utility system applications that promote and enhance system operating efficiency and improve service reliability, such as remote meter reading, outage management, reduction of theft and diversion, improved forecasting, workforce management, etc.

6. Capable of interfacing with load control communication technology.
Appendix D: Future Studies in Grid Energy Storage Technologies

Specific technologies for grid energy storage are divided between those that store electrical energy directly (like batteries and capacitors) and schemes that convert electrical or mechanical energy into an intermediate form that can be converted to electrical energy on demand. We included the most common of these on the technology axes of the interaction matrices in Figure 25. These were:

**Direct storage:**
- **Electrochemical batteries.** These employ reversible oxidation-reduction reactions at metal or metal-hydride plates to store and release electrical energy. Although these are technically chemical reactions, batteries can be understood to store electrical energy directly, since the conversion process occurs inside the cell.
- **Supercaps.** These are electric double-layer capacitors that store energy in the electric field produced by separating equal and opposite charges on the capacitor “plates.”

**Indirect storage:**
- **Fuel cells.** These are like batteries except that during discharge the anode itself is not reduced, but the “fuel” is; as long as the fuel continues to be supplied, the fuel cell generates electricity. If hydrogen is the fuel, then the system could be recharged by regenerating hydrogen from the water produced by the cell.
- **Compressed air energy storage.** This involves pumping air into a storage vessel or large space (like an abandoned mine), and generating electricity on demand by evacuating the air through a turbine.
- **Flywheels.** These are wheels with large moments of inertia that store rotational energy, usually for short periods.
- **Pumped Storage Hydroelectricity.** This is similar to compressed air energy storage except that water is pumped to a higher elevation, in order to generate electricity on demand as with a hydroelectric dam.

The conclusion from Figure 37 is that the direct energy storage options have the greatest impact on both the scenarios and the strategies with an edge leaning to electrochemical batteries. This is because—assuming a certain adequate level of performance—they are the *most convenient* and *scalable*. They are convenient in the sense that they do not have special site requirements, are low-maintenance, and are potentially modular and “hot-swappable.” Their scalability means that they can be used in electric transport, centralized generation facilities, or anywhere in-between.

The questions now are *what constitutes an adequate level of performance, and which technologies have the greatest promise?*
Analyzing the interactions of grid energy storage technologies with the four scenarios and with technological applications shows that electrochemical batteries have the broadest applicability.
**Cost Benefit of CAPEX**
To allow a comparison of the varied storage options these were compared by the cost of kWh cycled which measures both efficiency and cycle life added to the capex. This baseline is a more meaningful comparison for systems that utilize natural gas (NG) peaker plants and cogeneration (CCGT) plants.

![Cost Benefit of CAPEX](image)

**Figure 38 CAPEX per kWh cycled (Kluza, 2009)**

<table>
<thead>
<tr>
<th></th>
<th>Zn-Br Flow Battery</th>
<th>VRB Flow Battery</th>
<th>NaS Battery</th>
<th>Lithium Ion Battery</th>
<th>High-Speed Flywheel</th>
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<td>T&amp;D capacity deferral</td>
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<td>-</td>
<td>0/4</td>
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</table>

**Electrochemical Battery Types and Applications**
Figure 39 shows an industry trade association’s qualitative evaluation of a similar set of technologies, and it supports the general conclusions from the previous section. For this analysis there are seven battery types (see Figure 39). Because no single battery type will excel at all applications, we chose three applications that are important to all of the scenarios described: (1) electric personal transportation, (2) house-scale energy storage and (3) grid-scale energy storage.
Li-ion

These cells employ Lithiated graphite as the negative electrode and transition metal oxides as the positive electrode, producing a cell voltage of over 2.5 volts. This gives Li-ion the highest energy density (size and weight) of any electrochemical cell technology, and its dominance in this performance characteristic is assured by Lithium’s position in the periodic table. The state-of-the-art in Li-ion technology is within a factor of one or two of the fundamental limits for electrochemical cells established by the electronegativities of the elements in the periodic table. The main challenges with this technology are related to cost and safety.

Because millions of Li-ion cells have been used in laptops since the late 1990s, these industry-standard cells have well-known characteristics and excellent reliability. Practical experience has therefore led some companies to use hundreds or thousands of such cells in larger energy storage applications, for example Tesla roadster’s power unit. “Large format” cells would have greater volumetric and weight performance if their safety could be assured and reliability proven (Voelcker, 2008).

NaS

Sodium-Sulfur cells also have excellent energy density, but because the Sodium and Sulfur are used in molten form (above 300°C), they are suitable only for large, immobile installations. Research is on-
going to improve this performance (http://ceramics.org/ceramictechtoday/materials-innovations/ceramatecs-home-power-storage/), though such batteries will still have to be heated to function in terrestrial climates.

**Flow cells (Zn-Br)**
Flow cells (Zinc-Bromide being the most prevalent) use “liquid electrodes” which are circulated through a reactor stack much like in a fuel cell, except that the mechanism of electricity production is still a redox reaction. These cells have a huge advantage in large installations because of their potentially very low lifecycle cost, which arises from two unique aspects of this technology.

The first is that the power that can be delivered is related to the surface area in the reactor stack, while the energy that can be stored is related to the amount of liquid electrode available in the system. This decoupling of energy and power density components eliminates the tradeoff between the two inherent in other cell types, and means that the energy storage capacity can actually be increased after the system is put into service. The second distinguishing feature of this technology is that the design of the system lends itself to lifecycle extension—the electrode liquid can be replaced easily, and the stack can also be refurbished. With appropriate development, these two features could dramatically reduce the cost of flow cells (National Energy Technology Laboratory, 2009).

**Lead acid**
Lead acid batteries have been used for over 100 years and are found most commonly as starter batteries for internal combustion engines. Their use in grid storage is more limited due to their size, weight, poor deep-discharge performance, and environmental concerns. They are safe, well-characterized, cheap and have good power density (Armand & Tarascon, 2008).

**Nickel-cadmium**
For years these were the most common rechargeable cell in consumer electronics, but were replaced almost entirely by Li-ion in the late 1990s, due to the latter technology’s higher energy density. Ni-Cd is cheaper and less susceptible to explosions than Li-ion, but it suffers from a memory effect and contains toxic Cadmium (Huggins, 2007).

**Metal air**
Metal air cells, particularly Nickel-Metal hydride, are the only current alternative to Li-ion in personal transportation applications due to its similar volumetric energy density. NiMH replaces the Cadmium negative electrode with a hydrogen-absorbing metal. The chief disadvantage to NiMH is that its high self-discharge means that it does not hold a charge as well as Li-ion (Armand & Tarascon, 2008).
Applications

Electric personal transportation
Electric personal transportation would play a role in all of the scenarios under consideration. This application places a premium on size, weight, charge speed, cycle life and safety, trading all of these for cost. Li-ion technology is currently favored in this application, having proven itself adequate in all of these dimensions, with the greatest remaining challenges being around safety and cost.

House-scale energy storage
In comparison, energy storage at the individual home scale would favor a lower cost at the expense of Li-ion's volumetric and weight performance. The purpose of such storage systems would be matching the home's own energy generating capacities to its consumption, or to allow homeowners to store off-peak power for usage during peak times (a single-home version of “peak shaving”).

Grid-level energy storage
Requirements for grid-level energy storage systems put even less emphasis on size and weight, with more emphasis on total lifecycle cost—a large initial cost of installation could be justifiable for a system that can be refurbished mid life.

Comparison
To evaluate the battery types in each application, we used the process illustrated in Figure 41. First, we rated each battery type on a relative scale with regard to six performance dimensions, producing the matrix on the left. Next, we used a similar relative scale to capture the importance of each performance dimension to the specific application in a “weighting vector.” Finally, a matrix multiplication on each of the weighting vectors to produce a third vector for each application, this one indicating the relative suitability of the technology to the application.
Calculating suitability ratings for battery type relative to three applications. (The suitability numbers are calculated from the characteristics and weights using matrix multiplication.)

The outcome of the analysis is that Li-ion and Metal-Air cells are ideal for personal transport—applications in which these two cell types are currently dominant. More surprising is the appearance of Zn-Br (and other) flow cells for grid level storage. The reason for this is that flow batteries’ lower lifecycle cost dominates in the larger storage applications, where Li-ion’s size and weight advantages are less beneficial.

Research Priorities and Recommendations
To bring about radical change in power generation, transmission and usage, we recommend focusing battery research and development efforts to improve the viability of the technologies identified in Figure 41. The top priorities should be

1) Reducing the cost of Li-ion and metal air cells. If cost were no object, these cells would be the ideal choice for all of the applications described. Further reduction in their cost is the single most important step towards more widespread adoption of electric personal transportation. Of all the strategies considered, adoption of electric transportation will have the greatest impact on the natural environment, national security and energy independence.

2) Improving the safety of Li-ion cells. The propensity of energy storage system manufacturers to construct systems out of laptop cells instead of more cost-effective and volumetrically efficient large format cells comes down to safety. Improving the fundamental safety of these cells through improved separators, new electrode chemistries and protection circuitry is essential.

3) Reducing the total lifecycle cost of Zn-Br flow batteries. This technology is a relative newcomer, but it has tremendous potential to make intermittent energy sources a large source of power to the overall grid, and eliminate the need for inefficient gas-fired and other peak energy sources.
Executive Summary

The emergence of personal electric vehicles (PEVs) has varied but important implications to the power generation, transmission, and distribution industry. Utilities have the potential to become the biggest winners, or losers, depending on how the PEV industry emerges. There are a large number of potential benefits of PEVs for the utilities, for example, the potential to balance their load demand curve. However, there are an equal number of potential problems, like expensive infrastructure upgrades and increased peak load demands.

Through various forecasting techniques we have identified some potential future scenarios of personal electric transport and analyzed the effects each will have on the utility industry. In the development of these scenarios we looked at the drivers of PEV adoption including existing and emerging technology trends, government policies, adoption rates, and public perception. Some of these drivers could be influenced by the utilities while others could not. Our scenarios were created by combining different outcomes of these drivers. Each scenario resulted in a different set of implications to the utility industry.

The recommendations of this report are based upon the drivers which can be influenced and result in the most positive outcomes for the utility industry. Based on these criteria, this report finds that
incremental adoption of centralized charging/battery swap stations not only has the least negative impact on the utilities, but also the highest potential of benefits. The utilities can influence the adoption of this model by providing both incentives in the form of rate reductions and capital investments (i.e. substations) for charging/switching station companies as well as disincentives like special rate increases for decentralized plug-in charging customers.

Overview of Electric Car Technology

The PEV is not a new invention; in fact, it is among the earliest automobiles. Robert Anderson of Scotland invented the first crude electric carriage powered by non-rechargeable primary cells in the 1830s, and in 1835, American Thomas Davenport built the first practical electric vehicle – a small locomotive. The technology slowly started to progress into the commercial market, with more companies taking interest in investing in electric vehicles. However, in the 1920s, electric vehicles ceased to be a viable commercial product due to a variety of factors including desire for long-distance driving, lack of horsepower, and increasing availability of gasoline. However, due to recent advancements in battery technology and increasing research in control systems, electric vehicles are coming back into the picture, and are now comparable in terms of commercial feasibility to a gasoline-powered vehicle.

A PEV differs from a gasoline-powered vehicle in that a PEV is propelled with an electric motor. Energy can be provided to the motor in different ways, e.g. from batteries or fuel cells. For the purpose of this analysis, we will focus on the electric car using rechargeable batteries for energy storage. The battery can receive its power via a direct electrical connection from a range of sources, including fossil fuels, nuclear power, or renewable energy.

A PEV looks like a gas-powered vehicle except that it lacks a tailpipe (there is no exhaust system) and a gas tank. It also has different contents under the hood (see figure 1 in Appendix A). The PEV has three main parts: the electric motor, the controller, and the battery. The PEV contains many battery packs that work in conjunction to store energy and power the vehicle. A typical gasoline engine is replaced by an electric motor, and two types of motors can be used: DC and AC. The DC motor runs on DC electric power and are best used for short bursts of acceleration. AC motors are driven by alternating currents and generating electricity, and can achieve fast-forward and rewind operations without extra gears and clutches. The electric motor gets its power from a controller, which gets its power from an array of rechargeable batteries. The batteries can be charged by plugging the car to an electrical outlet at your home, business, or recharging station, or by swapping the battery packs with fully charged batteries.
PEVs can also recover energy from braking, which can increase the driving range between battery charges. One method is to restore energy back to the on-board battery using a concept called regenerative braking. When driving, the energy flows from batteries to motors, turning the wheels and providing kinetic energy for the vehicle to move. When you hit the brakes, the motors work like generators and start producing electricity instead of consuming it. Power flows back from the motor-generators to batteries to partially recharge them.

Residual battery energy can also be sent back to the grid (termed vehicle to grid, or V2G). V2G works in such a way that excess rechargeable battery capacity can be used to provide power to the electric grid in response to peak load demands. Vehicles can be re-charged during off-peak hours at cheaper rates while helping to absorb nighttime generation. The PEVs therefore buffer the power demand.

There are advantages to PEVs when compared to gasoline-powered vehicles. PEVs are more environmentally friendly. They do not produce the pollution associated with internal combustion engines, and have less than 1% carbon emission. The batteries can also be recycled. Studies have shown that PEVs also have a lower cost per mile, and the battery-to-wheels efficiency of an electric motor is 5-6 times greater than the tank-to-wheels efficiency of a gas-engine.

However, there are certain limitations to PEVs related to battery technology, energy, power, and infrastructure. The amount of energy in the batteries indicates the distance you can travel before refueling (the driving range). The power rating of your electric motor tells you how quickly you can turn that energy into useful work (vehicle acceleration). The amount of electric charge that can be stored in batteries depends upon the number and size or shape of the batteries and their recharging and discharging capabilities. The weight of electric car batteries (battery packs) can also be an issue if the cars are not designed with a lighter frame; for instance, the Li-ion battery packs in a Tesla Roadster weigh ~1000 lbs. With current technologies, the batteries in an PEV are bulky and have limited capacity, giving the car a short driving range. Recharging is also an issue because recharging using a common household outlet (120V) would mean that it could take anywhere from 10-12 hours to have a fully charged vehicle. With a 240V circuit, the recharge time could be reduced to approximately 6 hours. Regardless, the vehicle is typically out of service during this recharging time. Recharging infrastructure is also not fully established to handle a large number of PEVs.

Overview of Battery Technology

EV Battery History
Prior to the invention of the nickel-metal hydride (NiMH) battery, PEVs were usually powered by nickel-cadmium and lead-acid batteries. These batteries had limited commercial use due to fatigue and discharge problems. Battery technology took a huge leap forward when Stanford R. Ovshinsky developed the NiMH battery. The NiMH proved to have high storage capabilities, required no maintenance, could be easily recycled, and was environmentally sound. In the past, PEVs powered by lead-acid or NiMH batteries, such as General Motor's EV-1 and Toyota's RAV4-EV, have sold poorly, leading the automakers to discontinue their production. However, the emergence of Lithium Ion (Li-ion) batteries was a breakthrough in the PEV industry (See figure 2 in Appendix A).

Lithium Ion Battery

Li-ion batteries have several advantages when compared to NiMH. The energy density is vastly superior, the charge cycles do not have a memory effect, and they have very slow charge loss when not in use. In addition to uses for consumer electronics, lithium-ion batteries are growing in popularity for defense, PEVs, and aerospace applications due to their high energy density. The three primary functional components of any battery are the anode, cathode, and electrolyte. The anode of a conventional Li-ion cell is made from carbon, the cathode is a metal oxide, and the electrolyte is a lithium salt in an organic solvent. Commercially, the most popular material for the anode is graphite. The cathode is generally one of three materials: a layered oxide (such as lithium cobalt oxide), one based on a polyanion (such as lithium iron phosphate), or a spinel (such as lithium manganese oxide).

PEV Battery Future

Not only is advancement driven by the need to improve battery performance but it is balanced by the need to reduce the environmental impact of the potentially harmful chemicals found in many batteries. A large amount of grants in the recovery act are devoted to expanding battery recycling capacity. The European Union’s 2009 Waste Batteries and Accumulators Regulations require battery makers and sellers to take responsibility for their safe disposal.

Government regulation and funding are the foundation driving automotive battery advancement. The level of effort and cost to move away from gasoline vehicles is too great for government not to play a huge role in this transition. Government regulation is the catalyst to forcing companies to think about improving batteries and government funding is the assistance that companies require to progress in battery research (See figure 3 and figure 4 in Appendix A).

Battery Management System
For vehicle applications, a large multi-cell battery pack is required, running at voltages of 72-200V with a minimum of 100MJ capacity, compared to 0.2MJ for a laptop battery. Safety issues become paramount, due to the implications of a thermal event with a battery pack that has more than 500 times the energy of a laptop battery. The full potential of Li-ion technology in automotive applications can only be exploited safely and reliably by the use of a battery management system (BMS) together with the battery pack. A modern BMS provides management of both charging and discharging, monitoring temperature levels, and diagnostics, thereby preventing further damage or degradation of the battery pack by damage to individual cells due to overcharging or fully discharging. This requires balancing the battery pack by ensuring the equal discharge of all the individual cells to their recommended minimum charge level.

Battery Charging

PEV charging stations need to be designed to do two things:

charge batteries in as short a time period as possible
monitor the process to ensure that batteries are charged safely and are not damaged

The most sophisticated charging systems monitor battery voltage, current flow and battery temperature to minimize charging time. The charger sends as much current as it can without raising the battery temperature too much. A smart battery monitoring system would prove useful for more than just hybrid cars. For instance, it could evaluate the health of batteries currently used to store excess energy from the grid.

The standard wall socket in most U.S. garages outputs 120 Volts at 20 Amps of current. Multiplying these units together provides the Watts, or energy per unit of time. With this amount of power, it could take a whole night (8+ hours) to get the full electrical storage into a car battery. For car owners wanting to drive far distances without the impossible hassle of waiting 8 hours between charges, there are a couple options available. Plug-in charging stations could deliver 240 Volts at 70 Amps, thus charging a vehicle in less than two hours. For individuals who only drive short distances each day, simply charging their car overnight should be practical and simple. Other prospective buyers will have to take into account the charging options available to them, as well as the vehicle itself. And in the not-so-distant future, advancements in battery technology can be expected to further change the equation.

Information Technology

PEV manufacturers are also thinking about how mobile computing could be used to provide consumers with better information to manage their battery systems. For example, GM is expecting to provide an OnStar mobile app (see figure 5 in Appendix A) at the same time as the Chevrolet Volt is launched. This
Better Place is another company that is applying information technology to PEVs. The underlying business plan involves installing a network of charging stations where customers can swap depleted batteries from their cars with fully charged batteries. According to the company this will happen without human involvement and will take less than one minute. Sophisticated software will allow Better Place to determine when to charge the empty batteries based on electricity prices. At peak hours when demand is high, they will be able to sell excess power back into the grid. To be successful two things are required: standardization by auto manufacturers and their battery suppliers, and significant investment in electricity infrastructure.

Regulations and Policies

The US Government has the potential to greatly hinder or advance the acceptance of PEVs. It is doing so with its choices for tax laws for consumers and utilities, research grants, and government fleet purchases.

Currently qualified plug-in electric drive vehicles purchased after Dec. 31, 2009 have a tax credit of $2,500 to $7,500, depending on the battery capacity and manufacturer. A qualified plug-in electric drive vehicle must be newly purchased, have four or more wheels, have a gross vehicle weight rating of less than 14,000 lbs, and draw propulsion using a battery with at least four kilowatt hours that can be recharged from an external source of electricity. The tax credit will begin to be phased out for a given manufacturer when they have sold 200,000 vehicles. If the government were to eliminate these programs, or initiate others to promote other technologies, the adoption of PEVs would be hampered.

The government is now promoting renewable energy usage by utilities through production incentives, property tax exemptions, and sales tax exemptions along with research grants. It has also issued mandates like the one issued in 1990 by the California Air Resources Board (CARB), the “EV Mandate” which required that two percent of cars and light trucks sold in 1998 be zero-emission vehicles (ZEVs). The advancement in renewable energy is hampered by the utilities’ ability to store this energy for peak times. The renewable energy push is not tightly tied to the advancements in batteries. By providing grants, loans or other financial support to companies who are researching battery or recharging technology or who are developing manufacturing capabilities, the government is supporting the industry growth. Some examples include:
Michigan signed new battery legislation into law in April, 2009, devoting $220 million in tax credits to the development of advanced battery technologies.

In June 2009, the U.S. Department of Energy (DOE) awarded $2.4 billion in grants for the advancement of battery and electric vehicle technology amongst 48 different companies.

The awards are part of the American Recovery and Reinvestment Act of 2009 and cover $1.5 billion to produce batteries and their components, $500 million to produce electric drive components for vehicles, and $400 million to purchase plug-in hybrid and all-electric vehicles for testing.

The DOE has also funded the U.S. Advanced Battery Consortium (USABC) since 1992, a joint effort from the “Big Three” automobile makers (GM, Ford, and Chrysler) to “develop electrochemical energy storage technologies which support commercialization of fuel cell, hybrid, and electric vehicles.”

A loan of $528 million to Fisker Automotive that vows to produce 130,000 plug-in hybrids by 2013 as mentioned in the Business Week article "A Long Bet on Electric Cars."

Tesla Motors has received $465 million in federal money.

The amount of investment needed for the research, retooling, or starting PEV companies is significant and even more so to get them to a mass production level. Without the government’s financial support a technology like PEV will take much longer to be adopted.

Government fleet purchases are one more way the government effects adoption of PEVs. PEV are well suited for urban driving and some government fleets have started the conversion, like Wisconsin’s DNR and the University of Delaware. This early adoption will fuel the infrastructure changes needed to support PEVs. If they however continue to support the mainstream gasoline powered vehicles as they expand and refresh their fleets, they will be signaling to the public that they do not believe in the new technology.

Adoption

We conducted a scenario planning exercise to explore a collection of potential futures, in particular we wanted to understand how different future events would affect the rate and level of PEV adoption. This exercise began with a discussion of the factors that drive adoption and an evaluation of how likely they would be to occur. These drivers were mapped to an uncertainty/impact matrix as shown below:
The drivers that were considered most likely to have a high impact on adoption were then discussed in more detail to determine how they would interact together. It was apparent from discussions that High oil prices, Low battery cost and Incentives could be combined into a new category called Total Cost of Ownership (TCO). The interactions were then mapped as follows:

<table>
<thead>
<tr>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of ownership</td>
<td>Flexibility</td>
<td>Environment</td>
</tr>
<tr>
<td>Lower</td>
<td>Quick/Swap</td>
<td>High Concern</td>
</tr>
<tr>
<td>Higher</td>
<td>Quick/Swap</td>
<td>High Concern</td>
</tr>
<tr>
<td>Lower</td>
<td>In-Car</td>
<td>High Concern</td>
</tr>
</tbody>
</table>
Higher | In-Car | High Concern | 15% |
Lower | Quick/Swap | Low Concern | 10% | If you build it....cheap, they will buy
Higher | Quick/Swap | Low Concern | 2% |
Lower | In-Car | Low Concern | 3% |
Higher | In-Car | Low Concern | 12% | (Electric) Carmageddon

Key scenarios were developed into a story line and the impact of the adoption level for utility companies was described.

Scenario A - "EVentual adoption"

The car companies are working closely with battery companies and have developed clever technological solutions that have greatly improved the capability of Full Electric Vehicles (FEV). This trend began to accelerate when Nissan launched the Leaf at the end of 2010. The Leaf turned out to be more commercially successful than even Nissan expected and other car manufacturers quickly jumped on the bandwagon and brought their own FEVs to the market. Early adopters were eager to show their green credentials and as the U.S. economy grew rapidly out of the recession that had begun in 2008, more and more people were able to afford the premium that FEVs commanded. As the adoption rates climbed the manufacturers were able to take advantage of economies of scale and the per unit cost of FEVs, in particular the battery packs, fell to a point where FEVs no longer had higher production costs than Internal Combustion Vehicles (ICV). However, after 3 years of rave reviews from passionate customers, demand started to slow with the 2015 model year.

Car manufacturers were finding it difficult to continue to drive adoption to the mass market customers. At the time the effective range with a fully charged battery was around 150 miles, a 50% improvement when compared to the 2011 Nissan Leaf. But, this was still considered too short a range for many demographics, especially suburban families and people who lived in sprawling metropolitan areas, like Dallas and Los Angeles. The other decelerator for demand was the requirement to charge vehicles at home and the cost associated with upgrading in-home electric systems to enable this. Many people said they wanted to change from ICV to FEV but they would lose the flexibility they got from being able to fill up at any gas station in the country. Fortunately for the industry public opinion supported a strategy of replacing aging public owned vehicles with new FEVs. The demand for public vehicles was enough to keep the production lines running and to keep improving the technology.

Now, in 2020, demand has finally begun to grow again and it looks like FEVs will begin to outsell ICVs in 3-5 years. For the past 5 years car manufacturers have been working with utilities and regulators to
upgrade the electrical infrastructure funded through increased electricity rates. Consumers are willing to accept these increases as they understand the benefits to society of having more FEVs on the road and that they are no longer required to spend up to $4,000 to upgrade their home circuitry. The other major factor for the increase in demand is the incremental increase in available range with each model year. FEVs are now capable of 200 miles between charges and this is more acceptable to many car owners. The last factor that is enabling FEV owners to continue to drive wherever and whenever they want to without being overly concerned with the charge level of their batteries was a little unexpected.

In 2018 the restaurant chain, Denny's, signed a nation-wide agreement with Eaton Corporation, where every Denny's in the country has installed a rapid recharge station that can fully recharge a battery pack in the time that it takes for drivers to eat their meal. This is thought to be the main reason that Denny's is now the third-largest restaurant chain in the United States of America.

The adoption of FEVs will occur in clusters, certain communities will have high adoption rates while in others it will be very low. Because less than one quarter of the FEVs have a garage to park in, the utilities will also have to supply curbside 220V circuits and secure metering systems on every block. With more and more FEV owners installing 220V circuits in the home capable of drawing large loads, localized substations and distribution systems begin to fail. The utilities begin upgrading this infrastructure as needed. In an effort to be proactive and stay ahead of the curve, the upgrades are implemented across the board. However, due to the “clustered” adoption of FEVs many of these upgrades go unused.

The only real way for the utilities to control the time when FEV owners charge their cars will be to install separate meters for the new 220V circuit and charge varying rates based on peak load demand at the time of charging. Both the infrastructure capital costs and maintenance and monitoring costs will require utilities to demand a rate increase. This rate increase adds to the total cost of ownership of FEVs and slows the rate of adoption even further.

It becomes apparent early on that although V2G capabilities exist, the economics involved make it impractical. Participants in the V2G program are upset to find that their FEV is almost completely discharged when they need it unexpectedly. Also, the frequent charging and discharging of the batteries shortens their lifespan by nearly half. The rate at which the power is bought back does not make up for the decreased life of the battery. Both the consumers and the Utilities quickly learn that it is more economical to generate more power than to discharge FEV batteries.

Scenario B - "(Electric) Carmageddon"

When Nissan launched the all-electric Leaf at the end of 2010 it was a time of great optimism about PEVs. Hybrid vehicles had been selling well for years, Hollywood was producing a string of new movies with names like "Revenge of the Electric Car", venture capital funding was flowing to battery companies,
traditional car companies were partnering with electric car start-ups (like Daimler and Tesla Motors), and governments at the state and federal levels were doing all they could to encourage consumers to buy low or zero emission vehicles. California was leading the way by mandating adoption of ZEVs at rates that would lead to 100% of new sales of vehicles being zero emission at tail-pipe by 2050.

Ten years later, in 2020, it's worth stepping back and reviewing why the electric car as it was envisioned in 2010 never achieved the promise that was hoped for by so many parties.

Nissan launched the Leaf without lining up any external infrastructure and hoped that the demand for the vehicle would appear from early adopters who were eager to show the world how environmentally aware they were. There was a lot of buzz at launch-time with the Nissan CEO, Carlos Ghosn, declaring that 10% of new vehicle sales would be FEVs by 2020, and initial orders were in line with expectations, but in the end there were not enough consumers who were willing to pay a premium of 30%-40% for a comparable vehicle and then have to pay to install a 220V in-home charging unit with a total installed cost of up to $4,000. As we know, Nissan ultimately declared bankruptcy as a result of this error in reading the market and were bailed out by the Japanese and French governments. It's not surprising that other car manufacturers tread extremely carefully after watching the self-destruction of Nissan, and no company ever scaled up production to the point where they could achieve sufficient economies of scale to reduce the production cost to the level of an internal combustion vehicle (ICV). The existing partnerships between traditional and new car manufacturers fell apart as they had been made in anticipation of sales, and the manufacturers were not able to agree on standards that would have reduced costs across the industry. The production cost of a FEV, including the battery pack, is still 20% higher today than a comparable ICV. Ultimately it turned out that consumers were more interested in the economic cost of buying a car than in the perceived benefits to the environment of low or zero emissions.

However, car manufacturers have been working hard on improving the fuel efficiency of their internal combustion vehicles and it is routine now for vehicles to achieve 40-60 mpg under normal driving conditions. Consumer tastes have also changed since the beginning of this century, there are far fewer SUVs and trucks on the road today than 15 or 20 years ago. Consumers have also finally accepted that diesel fuel is just as effective in ICV as gasoline.

As for California and the ZEV mandate; that turned out to be very messy politically. There were months of demonstrations by consumer groups demanding that the rules be revised to allow car companies to sell the vehicles that consumers wanted to buy, instead of restricting vehicle supply to meet an arbitrary and unachievable quota. Eventually the state government acceded to public demand, but many of the state representatives were ousted at the next election and Eric Schmidt, former CEO of Google, Inc. was elected as state governor after campaigning on a popular platform of less state involvement in markets.
And yet the Electric Car still hasn't died. As oil supply continues to diminish over time there are still many people who believe it is a question of when, not if, electric cars will be accepted and driven by the masses. When these PEV advocates get together you hear stories of the improvements to society that PEVs will herald. If only society would understand or if only they could create the right conditions for this technology to be accepted. And who knows, maybe this time they will be right.

Because of the limited adoption of PEVs, the impact to the utilities was almost non-existent. However, the utilities did miss out on increased revenue and advanced smart grid and power storage technologies that would have come along with PEVs. The utility business continues along as it always has incrementally repairing infrastructure and trying to manage peak loads.

Scenario C - "Worldwide Interchangeable Li-ion Battery Exchange Re-use Scheme"

It was pretty rare for the CEOs of Toyota, Nissan, GM, Ford and Daimler to all be in the same place at the same time, but these were unusual times. Despite the US government's best intentions Chrysler had closed its factories and that had forced the other major car manufacturers to wake up and realize that they had to listen more closely to their customers. In the US it was pretty clear that the environmentalists were winning the debate and were convincing the population that is was time to embrace PEVs. But consumers were also making it clear that they didn't want to accept the limitations of having to plug their cars in every night. All the car manufacturers had somehow managed to agree on standards for battery packs and they came together to officially launch the Worldwide Interchangeable Li-ion Battery Exchange Re-Use Scheme.

The economies of scale that were achieved through this agreement led to the rapid reduction of the production cost of PEV batteries and made PEVs even more desirable. The government also stepped in and offered generous tax incentives to encourage customers to change over to PEVs. Gas stations have added battery changing stations provided by companies like Better Place and consumers embraced the idea of not owning the battery and leasing it, especially once they understood it was like changing the propane tank for your grill.

Of course the final nail in the coffin for the internal combustion vehicle was the unforeseen increase in the price of oil. Some of this increase was due to increases in federal and state gasoline taxes to offset the reduction in revenues as people bought PEVs. Ironically the population is only now accepting that roads still have to paid for and the money has to come from new sources as less gasoline is being sold due to the switchover to FEVs.
For the electric utilities, this means a higher use of electric power but not necessarily higher peak output. They will have complete control over when the charging will occur resulting in no contribution to the peak load. The possibility of utilizing excess stored power to stabilize peak loads is now more feasible. By utilizing the battery storage capacity available in the battery banks, the electric utilities can level their production. The battery swap stations will eliminate the need to make widespread and expensive high technology upgrades to the transmission and distribution systems. Ideally these battery banks would be owned and operated by a third party with a contract to the power utilities specifying rates to and from the grid and acceptable hours of usage. Ideally the utilities will have the power to control the flow to and from the battery banks while maintaining an agreed upon level of charged batteries. This would allow the utilities to adjust electricity inventory level of the batteries and adjust the charge rates according to the power needs of the grid. To make the battery banks a reality three areas need to change. First, a standard battery packs needs to be established between car manufactures so batteries are interchangeable in the vehicles and standardized in how they are charged. Second, facilities for the swapping, recharging, and storage of batteries need to be established. Third, power management technologies need to be developed to manage the electric inventory so facilities can level the power production and ensure sufficient batteries on hand for consumers. When battery banks become reality, PEVs will be as common to consumers as the gas car is today.

Scenario D - "if you build it... cheap, they will buy"

In this scenario the future is very similar to Scenario C. The same economic drivers are at play and the same technologies are developed. The only difference is the level of concern for the environment. In this scenario PEVs are adopted at a less rapid pace than in scenario C, because the demand is based solely on the fact that it makes financial sense to do so. People buy PEVs as they are retiring their existing vehicles, rather than rushing to show their green credentials.

The negative impacts on the utilities in this scenario are minimal due to the slower adoption rate, yet they will still eventually benefit from higher revenues and more level load demand. The public indifference to environmental concerns and the levelized power demand will allow the utilities to better utilize their existing base load generating fossil fuel facilities. A greater percentage of power could be generated by the more efficient base load plants.
The adoption of the battery swap PEV model has substantial benefits for the power utilities. The utilities should concentrate on building alliances and partnerships to support the implementation of the battery swap station model and prevent the adoption of plug-in PEVs. We recommend a goal of building these battery swapping stations so that 75% of the US population live no further than 10 miles from the nearest station.

Utility companies should build partnerships with companies like Better Place to support the building of battery exchange stations. Existing gas stations and convenience stores would make for logical locations for battery swap stations and should be also be considered in this partnership. Contracts should be established to provide the utility companies with control over the charging and discharging of the batteries. In exchange for this control, the utilities can offer pricing incentives for power and infrastructure investments.

As standardization is essential to this model, partnerships should also be made with PEV and battery manufacturers. Renault-Nissan and Better Place already have formed a partnership. Efforts should be made to demonstrate the benefits of standardization of batteries to all PEV manufacturers. The success of this model will result in a larger market for each manufacturer to get a piece of.
The utility companies should also use their influence with the government to create policies around PEVs that favor the battery swapping model. The government can provide subsidies to battery swap companies and PEV customers. The government can also influence the creation of standards. Another way that the government could influence the success of this model is by updating their fleet of vehicle with swappable battery PEVs.
APPENDIX 1

Figure 1: Comparison of HEV, PHEV and EV

Figure 2: Comparison of Battery types
Figure 3: Recovery Act Awards for PEV Battery and Component Manufacturing

Figure 4: Recovery Act Awards for Transportation Electrification
APPENDIX 2: Specifications of selected PEVs

<table>
<thead>
<tr>
<th></th>
<th>Nissan Leaf</th>
<th>Tesla Model S</th>
<th>Coda Sedan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launch:</strong></td>
<td>2010</td>
<td>2012</td>
<td>2010</td>
</tr>
<tr>
<td><strong>Sticker price:</strong></td>
<td>$24,000-$30,000, excluding the battery, which may be leased</td>
<td>$57,400</td>
<td>$45,000</td>
</tr>
<tr>
<td><strong>Funding:</strong></td>
<td>Internal; $1.6 billion DOE loan</td>
<td>Venture capital; $465 million DOE loan</td>
<td>Venture capital</td>
</tr>
<tr>
<td><strong>Maximun range:</strong></td>
<td>60 miles city driving, less for highway</td>
<td>Standard Battery Pack = 160 miles, Premium Battery Pack = 300 miles</td>
<td>90-120 miles</td>
</tr>
<tr>
<td><strong>Expected max speed:</strong></td>
<td>76 MPH</td>
<td>120 MPH</td>
<td>80 MPH</td>
</tr>
<tr>
<td><strong>Key partners:</strong></td>
<td>Renault, plus utilities and governments in California, Oregon and throughout Europe and Asia</td>
<td>Daimler</td>
<td>Lishen, Hafei, UQM Technologies</td>
</tr>
<tr>
<td><strong>Production volume:</strong></td>
<td>50,000 units in the first year</td>
<td>15,000-20,000 units per year</td>
<td>2,700 units in 2010, scaling up to 20,000 units in 2011</td>
</tr>
<tr>
<td><strong>Acceleration:</strong></td>
<td>Unknown</td>
<td>0-60 in 5.6 seconds</td>
<td>0-60 MPH in under 11 seconds</td>
</tr>
<tr>
<td><strong>Standard charging time:</strong></td>
<td>16 hours at a 100V outlet, 8 hours at a 200V outlet</td>
<td>4 hours at a 220V outlet</td>
<td>Less than 6 hours at 220V</td>
</tr>
<tr>
<td><strong>Fast charging time:</strong></td>
<td>Less than an hour</td>
<td>30 minutes (0-80 percent)</td>
<td>33.8 kWh</td>
</tr>
<tr>
<td><strong>Battery Type:</strong></td>
<td>Lithium-ion</td>
<td>Lithium-ion</td>
<td>Lithium-ion</td>
</tr>
<tr>
<td><strong>Battery Capacity:</strong></td>
<td>24 kWh</td>
<td>42 kWh</td>
<td>33.8 kWh</td>
</tr>
<tr>
<td><strong>Who will supply the batteries:</strong></td>
<td>Nissan’s joint venture with NEC</td>
<td>Panasonic</td>
<td>Coda and China-based cell giant Lishen</td>
</tr>
</tbody>
</table>
APPENDIX 3: References


Symons and Butler.  


## Appendix F: Smart Grid Standards and Noteworthy Groups

<table>
<thead>
<tr>
<th>Committee or Group</th>
<th>Overview / Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGIP Governing Board</td>
<td>NIST supported Board to provides guidance and tools that make it an impartial and practical resource for SG stakeholders. Members represent a broad community based on breadth of experience and involvement with each stakeholder community represented on the Governing Board. Consensus driven with all legitimate views and proposals are considered.</td>
</tr>
<tr>
<td>SGIP SGAC</td>
<td>The Smart Grid Architecture Committee (SGAC) is responsible for creating and refining a conceptual reference model, including lists of the standards and profiles necessary to implement the vision of the Smart Grid.</td>
</tr>
<tr>
<td>SG Federal Advisory Committee</td>
<td>The Committee provides input to NIST on the Smart Grid standards, priorities and gaps, and on the overall direction, status and health of the Smart Grid implementation by the Smart Grid industry including identification of issues and needs.</td>
</tr>
<tr>
<td>UCAIug</td>
<td>Utility User Group, develops use case and requirements</td>
</tr>
<tr>
<td>GridWise Alliance</td>
<td>Founded in 2003, an organization that represents a broad range of the energy supply chain from utilities to large tech companies to academia to venture capitalists to emerging tech companies to transform the electric grid to achieve a sustainable energy future.</td>
</tr>
<tr>
<td>OpenADE</td>
<td>Being Standardized in NAESB</td>
</tr>
<tr>
<td>EIS Alliance</td>
<td>The Energy Information Standards Alliance (EIS Alliance) is an industry association for organizations interested in products and services which enable energy management in association with smart grid technologies. The group’s objective is to be a customer advocate for effective energy utilization through data exchange, benefiting residential, commercial, and industrial energy consumers. This will be accomplished through consumer view-point research, promotion, and support for smart grid standardization, automation systems, and government related activities</td>
</tr>
<tr>
<td>USNAP - EPRI Project for unified socket interface for HAN devices</td>
<td>Group to create a standard socket interface specification. This specification incorporates features from a variety of sources and information compiled from several existing protocols and requirements, including: 1. A simple option for devices with limited memory and/or processing capability, 2. The USNAP interface protocol, 3. The ClimateTalk protocol, 4. The Smart Energy Profile, 5. Advanced Internet / Web Interfacing (IP), 6. Numerous contributions from individual companies. This specification describes how these interface ideas have been harmonized into a single approach that allows for simple devices, but is also extensible to allow for pass-through of a number of existing protocols. A method is provided that allows manufacturers the flexibility to choose which protocols they will support, and yet guarantees interoperability of all systems by requiring universal support of a minimal set of demand response indicators.</td>
</tr>
<tr>
<td><strong>NEMA</strong></td>
<td>National Electrical Manufacturers Association (NEMA) announces the Smart Grid Interoperable &amp; Conformant™ (SGIC™) testing scheme to promote testing for products and devices based on the Smart Grid standards identified by the National Institute of Standards and Technology (NIST) and the Smart Grid Interoperability Panel (SGIP).</td>
</tr>
<tr>
<td><strong>DEWG - h2g (home-to-grid)</strong></td>
<td>Applications and communications linking energy service providers (utilities and other 3rd-party providers) with customer equipment in residential buildings via the electric grid and associated networks. Customer equipment may include home appliances, consumer electronics, plug-in electric vehicles (PEVs), plug-in hybrid electric vehicles (PHEVs), and local power sources (such as photovoltaics)</td>
</tr>
<tr>
<td><strong>DEWG - b2g (building-to-grid)</strong></td>
<td>Commercial building interaction with the electric grid, including the energy service provider as well as interactions with other producer/users on the net</td>
</tr>
<tr>
<td><strong>DEWG - i2g (industry-to-grid)</strong></td>
<td><strong>Industry-to-grid:</strong> NIST coordinated Domain Expert Working Groups (DEWGs) whose members are subject matter experts representing from utilities, vendors, academia, industry, standards groups, and federal agencies.</td>
</tr>
<tr>
<td><strong>BPI Standards</strong></td>
<td>Building Performance Institute, Inc.; national standards development and credentialing organization for residential energy efficiency retrofit work – providing training through a network of training affiliate organizations, individual certifications, company accreditations and quality assurance programs. BPI is approved by the American National Standards Institute, Inc. (ANSI) as an accredited developer of American National Standards.</td>
</tr>
</tbody>
</table>
Appendix G: Eric Bohnert Presentation Slides
Can the application of smart grid technologies, and more broadly, smart systems provide a method for managing the energy needs of the community?
UMore Park should conduct a detailed analysis to show whether a district energy model to provide heating and cooling to the residents of the new community is a viable opportunity.
Recommendations & Conclusions

Heating, Cooling & Power
Energy Source
Agnostic
Provides Means for “Energy Storage”
Efficient DC Microgrid
Sensor Network

“innovations in renewable energy, education, environmental quality, transit, technology, housing and other University mission strengths”
“There is only one valid definition of business purpose: to create a customer” Peter Drucker

Recommendations & Conclusions

Differentiation is KEY!
CoBranding with UMN
Cost basis for land is low
Experts for design

Partnerships to share risk
Partnerships/JV
Xcel
Centerpoint Energy
OEMs

Incorporating New Technologies
Scanning
Renewable Technology

Business Strategy
Corporate Strategy
Innovation Strategy

Execution
Continuous Repositioning
Implementation
Sustained Competitive Advantage

Analysis
Internal Analysis
Strategic Analysis

Making Moves
Resource Strategy
Innovation Strategy

Corporate Strategy
Innovation Strategy
Questions?
• UMore Park – A sustainable community that the University of Minnesota can be proud to have founded.
• From the concept master plan: “Innovations in renewable energy, education, environmental quality, transit, technology, housing and other University mission strengths”
• Can the application of smart grid technologies, and more broadly, smart systems provide a method for managing the energy needs of the community?
**Opportunity** * Approach * Recommendations * “Delta MOT”

- Smart Community
- Convergence of digital and real worlds
- Intelligent
- Reactive
- Interactive
- More efficient

Examples presented by Prof. Masoud Amin in "Smart Grid Cities," 2010 Tufts Energy Conference (tuftsenergyconference.com/schedule), April 17, 2010, Medford, Massachusetts

---

**Opportunity** * Approach * Recommendations * “Delta MOT”

- **Research**
  - Expert Interviews
  - Conferences/Lectures
  - Literature Scanning
  - Current Implementations
  - Tours/Site Visits

- **Analysis**
  - Normative Forecast
  - Scenarios
  - Technology Space Map
  - TIM/TIP
  - Internal Analysis
  - External Analysis

- **Recommendations**
  - Business Strategy
  - Corporate Strategy
  - Innovation Strategy

---

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Opportunity * **Approach** * Recommendations * “Delta MOT”

**Status Quo**
- Traditional grid reliance
- Central generation of power
- Minor use of (CHP)
- Consumption of fossil fuel constrained only by economics and environmental considerations

**Emerald City**
- Abundant refineries
- Diesel generator proliferation
- CHP & microturbines for local microgrids

**Nuclear Age**
- Highly constrained fossil fuel use
- Nuclear power predominates generation
- Centralized generation

**Denmark**
- Personal power generation
- Self-reliance and small-scale distributed power
- Constraints on fossil fuel means
- Solar, wind, and geothermal are being used at home and community scales
## Analysis

### • Internal Analysis

### • External Analysis

## Making Moves

### • Business Strategy

### • Corporate Strategy

### • Innovation Strategy

## Execution

### • Continuous Repositioning

### • Implementation

## Sustained Competitive Advantage

### Recommendations

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Who</th>
<th>When</th>
<th>Cost</th>
<th>Risk</th>
<th>Competition Reaction</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage with PUC - Develop Utility Incentives</td>
<td>UMore Park Management</td>
<td>Ongoing</td>
<td>Low Cost - Thin</td>
<td>Low</td>
<td>Xcel – Partner or Ignore</td>
<td>High Potential</td>
</tr>
<tr>
<td>Engage with PUC – Change Utility Incentives</td>
<td>UMore Park Management</td>
<td>Ongoing</td>
<td>Low Cost - Thin</td>
<td>Low</td>
<td>PUC – Embrace or Resistant</td>
<td>High for UMore and Consumers</td>
</tr>
<tr>
<td>Build Smarthomes</td>
<td>UMore Park &amp; Developer or Builder</td>
<td>Pre Phase</td>
<td>Low above target cost</td>
<td>Low</td>
<td>Xcel - Partner or Ignore</td>
<td>Consumer can save money, increased efficiency, home security, peace of mind</td>
</tr>
<tr>
<td>District Model – Business Plan</td>
<td>UMore Park or Subsidiary</td>
<td>Pre Phase</td>
<td>Explore cost – UM</td>
<td>Low</td>
<td>Xcel – Partner or Ignore</td>
<td>Consumer can save money, increased efficiency, lower emissions</td>
</tr>
<tr>
<td>Monitor Technology Opportunities</td>
<td>UMore Park &amp; Academic Affairs</td>
<td>Ongoing</td>
<td>Low Cost</td>
<td>Low</td>
<td>Xcel – Partner or Ignore</td>
<td>Supports academic mission, improves product long-term</td>
</tr>
</tbody>
</table>

### Next Actions

Present findings to UMore Park management team

4/21/2011   UMore Park Capstone Project   Andrew Fraser

---

### Andrew Fraser

Opportunity * Approach * Recommendations * “Delta MOT”
Andrew Fraser
Opportunity * Approach * Recommendations * “Delta MOT”

The ability to explain what a technology means, not just how it works!

Questions?
Appendix I: Shanna Leeland Presentation Slides

Agenda

- Background
- Opportunity
- Approach
- Recommendations
- Δ MOT
Create UMore Park as a technology driven self-sustaining community development.

Can the application of smart grid technologies, and more broadly, smart systems provide a method for managing the energy needs of the community?

Will equipping the community with a smart grid infrastructure and technology end in:

"innovations in renewable energy, education, environmental quality, transit, technology, housing and other University mission strengths"

If we build it, will they come?
Data as Currency
• Govt mandate of aggregated open data
• Utility is provided revenue incentives to share data with third parties (Google? Microsoft? Others?)
• Consumers do not own data

Utility Reigns
• Private funding to SmartGrid slows
• Organizations waiting for govt $,
• Traditional Utility market dominates
• Consumers accept traditional supplier

Consumer Castle
• Utility or independent 3rd party chosen by consumers to evaluate electric consumption and offer savings opportunities
• Consumers have limited plays

King Capitalism
• Data provided from utility and homeowner to 3rd party sources
• Intelligence of network moves from home to web
• Benefits balanced between utility and consumer

Utility Drives
Market Drives
Open Data

Data Privacy
Recommendation | Who | When | Cost | Risk | Competitive Reaction | Benefits |
--- | --- | --- | --- | --- | --- | --- |
Engage with Xcel – Develop Partnership | UMore Park Management | Ongoing | Low Cost – Time | Low | Xcel – Partner, Ignore or Obstruct | High Potential |
Engage with PUC – Change Utility Incentives | UMore Park Management | Ongoing | Low Cost – Time | Low | PUC – Embrace or Resist; Xcel – Sabotage, Ignore or Partner | High Potential for UMore and Consumers |
Participate in Standards | UMore Park Management | Ongoing | Low Cost – Time | Low | Xcel – Embrace or Resist | High Potential for synergy in with planned developments; Influence State or National legislature |
Integrate ADR into Commercial Space | Developer or Builder | Pre Phase I & Ongoing | Low cost built into infrastructure | M – Lagging TOU rebates | Energy Providers | University and Consumers save money and own data; Proactive stance for OpenADR adoption |
Develop Data Collection and Policy | UMore Park Academic Affairs & LLC | Pre Phase I & Ongoing | Low Cost – UMN has framework | M – consumer backlash & lose future research ops | Consumer – Accept or Reject | New Services |

Class Real Business Applications
Strategic Management of Technology (8233) | **Finessing the strategic value of business and formulating strategies to maintain a competitive advantage** |
Operations Management (8113) | **Foundations for enabling other areas of the business how important it is to understand the “big picture”**
  - Created a bridging forecasting system for the business based on a simple exercise in class while we await SAP to go 100%
Financial & Managerial Accounting (8112, 8122) | **Understanding the flaws of financial models and how to show internal projects worth investing**
  - Evaluating potential partners via their pro forma to determine risk of developing with their technology
Organizational Strategy and Design (8233, 8113, 8221) | **SCA**
  - Creating customers
  - Alfie Tables
Technology Assessment (8114, 8214, 8212, 8232) | **Technology’s role in all levels of the business and the tools to demonstrate where future investigation should be funneled with strategic analysis**
  - TIM™/TIP™

Shanna Leeland
MOT 2011
This capstone has...
- Allowed me to build relationships with people across all LOBs and expertise by asking questions
- Opened doors within the company requesting my participation on corporate Tiger Teams
- Secured my position as a go-to-doer who may not know the answer, but likely knows someone who does!

MOT has...
- Introduced me to concepts that make me a more valuable person on the leadership team
- Resulted in more challenging exposure and confidence within the engineering groups
- Introduced me to exceptional people in technology to network with as I continue in my technology career

Shanna Leeland
MOT 2011

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