Citizens League

Common ground. Common good.

Electrical Energy Project,
Phase 1 Working Document

Defining the Outcomes of Minnesota's Ideal Electrical Energy System

December 2011

Executive Summary

This working document, the product of the first phase of the Citizens League's project on electrical energy, sets out a high-level vision for Minnesota's electrical system – the outcomes that our ideal system would achieve.

This is a timely policy issue. The electrical system is not at a point of crisis. However, national trends towards declining reliability combined with a system that is not sustainable in the long-term provide warning signs for Minnesota. Changing a system so dependent on enormous and ubiquitous infrastructure takes time. We must start now, before crises arise.

The world of electricity – and energy in general – is changing rapidly. New innovations are creating policy and business opportunities that we are only beginning to understand. Minnesota has the opportunity to become a leader on electrical energy. Now is the time to act.

In this project, we have envisioned an electrical system that is:

- Affordable and competitively priced, to ensure a healthy economy while providing equal access, reliability and predictability to users.
- Efficient, minimizing losses and delivering reliable, secure and economical energy in a manner that can continue indefinitely.
- Sustainable, meeting the needs of today without compromising the ability of future generations to meet their needs.
- Self-reliant, using in-state resources, as much as practical, to generate the electricity we need in the state.
- Reliable and high-quality, delivering consistent electricity without interruption.
- Safe for workers, consumers and all citizens.
- Secure, protected from disturbances.

As we work to achieve this ideal, key considerations and drivers of decision making will include:

- Focusing on outcomes: If our destination is clear, we can be flexible in the means we use to get there.
- Economics: Making changes towards the goals presented here must have value for those involved. We should carefully examine the costs, the bills paid, and the parties paying them.
- Technology: We cannot predict the technologies that will be developed, how they will be used, or the impacts these uses will have on the electrical system. We must build flexibility into the system so that we can evaluate and incorporate new and better technology as it becomes available.
- Information, norms and convenience: The primary challenge may be motivating citizens and institutions to adopt the changes needed to achieve our goals.

This working document lays out *what* the ideal electrical system will achieve, not the *means* to achieve these goals. The next steps in this project are to examine whether we are on track to meet these goals and to imagine changes that will get us on track where we are not.

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I. Introduction

A Critical Policy Issue

The electrical grid has been called the greatest invention of our time. It has made modern life possible and become a cornerstone of our economy and our lives. Electricity lights our homes; runs our heating systems and air conditioners; and powers our computers, our businesses and, increasingly, our transportation.

Thousands of individuals have dedicated their professional lives to creating the well-running machine we call the electrical system, and we are grateful to have the legacy of their work upon which to build the future.

Realities, however, make electricity a critical policy issue now and in coming decades.

Even as we spend an increasing amount of money on electricity, the US is not keeping up with investments in grid infrastructure, and we're seeing the result in declining reliability. Minnesota is in a better position than much of the rest of the country on this count, but we should take increasing power outages in other regions as a reminder that we must stay vigilant for our infrastructure needs.

Furthermore, our electrical system is unsustainable. Our reliance on fossil fuels has detrimental impacts on health and the environment, and these resources will someday run out. This may not happen for hundreds of years, but long before supplies are exhausted, competition over limited resources will cause them to become much more expensive. In the nearer term, regulations on fossil fuel power from the federal government could mean that – even though supplies remain – we may not be able to use these fuels in the ways or for the price that we do today.

These factors present critical challenges for Minnesota, the United States, and the world. Changing a system so dependent on enormous and ubiquitous infrastructure takes time. We must confront these issues now, before they reach a crisis point.

Every challenge, of course, also presents an opportunity. Developing technologies promise access to cleaner sources of energy available here in Minnesota. New business models have the potential to transform the electrical system as we know it. Change may come from state and local government, but we will also need leadership from Minnesota's businesses, communities, and citizens.

This is the time to ask: What do we want from our electrical system? How can we achieve this? And might the path to these goals mean the future electrical system will look vastly different from today's?

Minnesota has the potential to become a leader in energy technology and policy. To do so, we'll need to know where we are headed – our ideal electrical system – and work together across sectors to get there.

This Project

With this goal in mind, the Citizens League has convened electrical companies and utilities, business and individual consumers, environmental organizations, and other citizens in this project.

Our goals are:

- To come to agreement on what the state's electrics system must achieve in the long term;
- To identify changes necessary to achieve these goals; and
- To advance reforms to do so in government, business and/or other institutions.

This working document, the product of Phase 1, represents conclusions on the first goal. This will form the foundation of upcoming work to develop and advance policy recommendations.

The Context of Electrical Energy in the Future

The energy system in 2011 could be on the brink of a transformation that has been likened to communications in the 1970s. Remember land lines? Phones fixed to a desk or a wall? Rotary dials? And how about room-sized computers with punch cards and tape drives, found only at major universities and the Department of Defense?

And yet, while planners and decision makers in the '70s set in motion the changes that shaped our modern communications infrastructure, they could not have anticipated the internet, the ubiquity of wireless technology, social networking, or the convergence of computers and telecommunications and the impacts these have had on the ways we interact.

We can't foresee the future. What we can do is understand the challenges in meeting it, and project ideal outcomes in which those challenges have been met.

Like the rapid and disruptive evolution of telecommunications technology, the role of energy and how we manage and understand it is also rapidly changing. How can we foresee the new energy technologies and economic and social forces or how they will interact? The answer, of course, is that we can't.

What we *can* do is understand the general energy needs we have today, and assume that most of those needs will apply in the future; we can identify the challenges in meeting those needs today, and project ideal outcomes in which those challenges have been met.

Electricity or Energy?

We cannot assume we'll use electricity in the same way in 30 years as we do today. Good examples of this are personal transport, which is just beginning to shift to increased use of electricity, and combined heat and power systems, which are able to use heat that would otherwise be a waste product of electrical generation to heat buildings, replacing the need for electric-, natural gas- or oil-powered furnaces. Anticipated improvements in storage and infrastructure could also change the balance of how we use energy.

The "electrical system" refers to the entire complex of materials, equipment, processes, policies, transactions, and services required to procure energy sources, transform them into usable electricity, and deliver the electricity to end users, as well as the byproducts created by those activities.

Therefore, although we are primarily considering electrical efficiency in this project, we must address energy in general to ensure that our definition is adaptable and as valid in 30 years as it is today.

The Ideal Energy Future

This document presents a vision for Minnesota's ideal electrical system, putting definition around key characteristics of that ideal. The purpose of our definition is to help guide a process toward a desired goal. If we know our destination, we can be fluid and adaptable in how we get there. As a first step, we have envisioned an ideal energy future: affordable and competitively priced, efficient, self-reliant, sustainable, safe, secure, reliable, and high-quality.

Next Steps: Building a Strong System for the Long Term

In this first phase of the project, the Citizens League has convened diverse stakeholders to create a vision for Minnesota's electrical system. This document lays out what the electrical system would accomplish in the ideal state.

The second phase of this project will recommend policy changes through which we can achieve these goals, looking thirty years into the future. By 2040, billions of dollars will be invested in our electrical infrastructure. Much of our existing infrastructure will need to be replaced or significantly upgraded. This is an enormous opportunity to re-examine the grid, and perhaps to rebuild it in a different way.

In Phase 2, the Citizens League will again convene citizens with a diversity of experience and expertise to develop recommendations to achieve the goals set out here.

There will be tensions – and there may be conflicts – among the various characteristics of the electrical system as laid out in the ideal. One of the challenges of developing policy recommendations in subsequent phases of this project will be to address these tensions and think of innovative approaches to move past them.

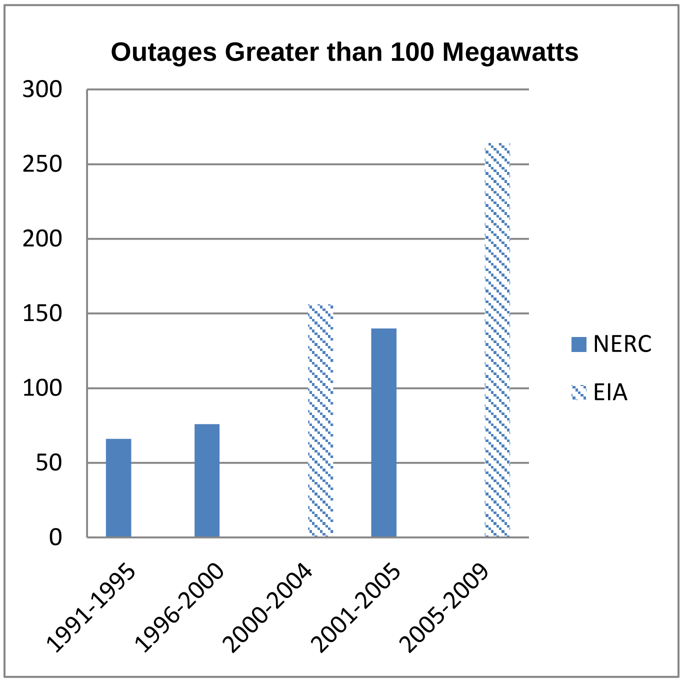
II. Findings

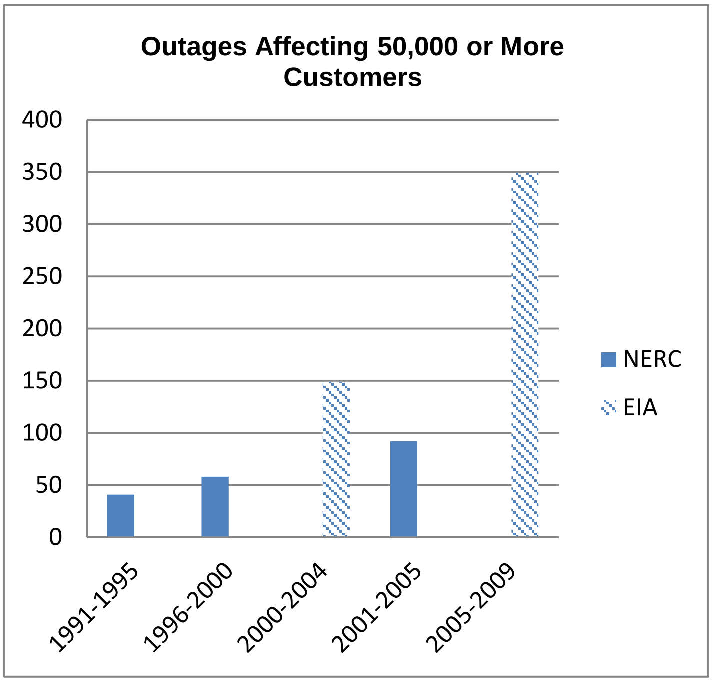
1. Declining reliability in other areas of the United States is a caution for Minnesota and the Midwest.

<u>The US grid has become continually less reliable as increasing demand has outpaced infrastructure investment.</u>

Over the past 15 years, the US grid has become consistently less reliable. The US Energy Information Administration and the North American Electric Reliability Corporation (NERC) both keep statistics on power outages, and both show dramatic increases in recent years.

The Lawrence Berkeley National Laboratory estimated the annual cost of power outages at $79 billion nationally.[1] In the Northeast, the power is out for an average of 214 minutes each year, the highest in the US. The Midwest performs much better, with an average of 92 minutes of outages per year. Japan, by contrast, has only about 4 minutes of power outages each year. (This data excludes power outages due to extraordinary events like fire or extreme weather.)





The increase in power outages is attributed largely to decreased investment in infrastructure. For the past 15 years, infrastructure has depreciated more quickly than utilities have invested in upgrades and new equipment. At the same time, electrical consumption has been increasing dramatically.[2] “The result,” writes University of Minnesota professor Massoud Amin, a leading expert on the US power grid, “is an increasingly stressed grid.”[3]

Minnesota's grid is more reliable than the national average.

In Minnesota and the Midwest, the grid is more reliable than the national average. However, we must be vigilant to maintain this reliability.

Significant infrastructure investment is planned in coming years. Eleven utilities in Minnesota and neighboring areas have come together in the CapX2020 initiative, one of the largest transmission development initiatives in the country.[4] CapX2020 is planning $1.7 billion in investments in its first group of projects.[5] Some of this investment is part of a recently approved 17-project, $5 billion regional portfolio of "Multi Value Projects (MVP)" undertaken by the Midwest Independent Transmission System Operator (MISO), which manages the electrical grid in all or part of 12 Midwest states and Manitoba. This new type of project provides regional cost allocation for regional transmission projects.

Increasing pressures challenge the reliability of the grid.

The peaks of demand – such as a hot summer afternoon when everyone runs their air conditioners – are a growing challenge. Nationally, these "peak load" times are hitting new highs. This, too, should be a warning for Minnesota. Though peak loads may not present a large problem for Minnesota utilities today, demand – including peaks – is likely to increase as the economy rebounds in coming years. Having insufficient supply to meet demand at these peaks can cause enormous problems like rolling blackouts. However, to build the generation and grid infrastructure needed to handle peak loads that are reached only a handful of times per year is very costly.

Naturally occurring events are also increasing stresses on the grid. Heat waves, tornados, floods, and large storms have been occurring with greater frequency, and will likely have a significant impact on grid infrastructure. This summer, for example, Texas was close to losing power during a heat wave (causing high demand) when the wind stopped blowing (causing wind turbines to stop producing power). Minnesota must be mindful of similar challenges.

2. Money spent on electricity – and energy in general – forms a large part of Minnesota's economy.

Minnesota customers spent about $5.2 billion on retail electricity in 2009, or about $1,000 per person on average. For context, total energy expenditures (including gasoline, diesel, and other forms of energy) were estimated at $18.3 billion.[6]

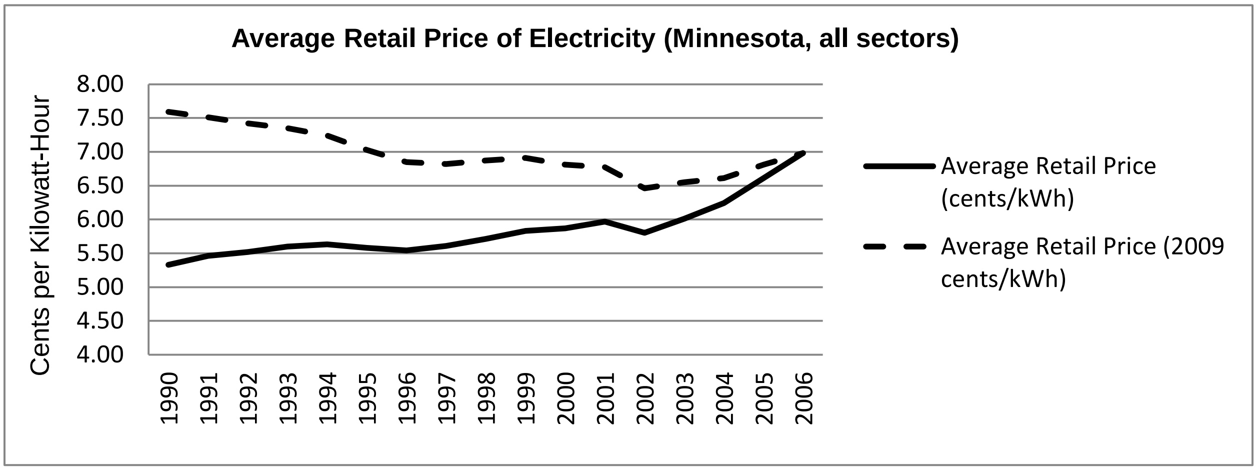
Electricity rates in Minnesota are lower than the US average but higher than the price in most other neighboring states.

Residential, commercial and industrial customers pay different electrical rates, and every state sets rates differently. Moreover, the price of electricity can be measured in multiple ways, and different measures show different pictures. For example, Minnesota's residential rates are higher than those in neighboring states, but average residential electric bills are lower.

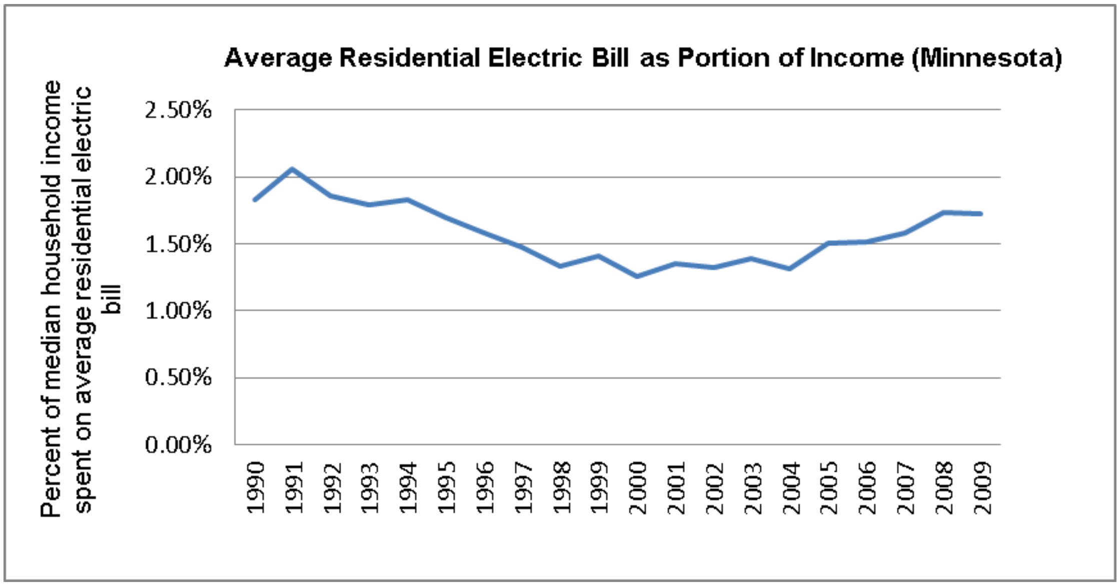
The below chart shows a comparison among Minnesota, neighboring states, and the national average across multiple categories.

	Ave. retail price (for all sectors, 2010, cents per kilowatt-hour)[7]	Ave. residential rate (2010, cents per kilowatt-hour)[7]	Ave. commercial rate (2010, cents per kilowatt-hour)[7]	Ave. industrial rate (2010, cents per kilowatt-hour)[7]	Ave. monthly residential bill (2009)[8]	Ave. annual residential bill as a percentage of household income (2009)[9]
US	9.83	11.54	10.19	6.77	$104.52	2.50%
Minnesota	8.41	10.59	8.83	6.29	$80.48	1.74%
Iowa	7.66	10.42	7.91	5.36	$86.25	2.15%
N. Dakota	7.11	8.13	7.21	5.81	$87.17	2.18%
S. Dakota	7.82	8.97	7.55	6.07	$86.88	2.31%
Wisconsin	9.78	12.65	9.98	6.85	$82.28	1.97%

<u>The price of electricity has been rising over past decades; however, this increase has not kept up with inflation</u>. The chart below shows the average price in cents per kilowatt-hour and the price benchmarked against 2009 dollars.[10]



The average residential electric bill has remained a fairly consistent portion of median household income over the past two decades.[11]



Most projections suggest the price of electricity will rise, though there is not a consensus on this prediction.

The Midwest Independent Transmission System Operator (MISO), the organization that manages the regional electrical grid, draws up “futures,” potential future scenarios and the impacts these scenarios could have on things like the price of electricity. Four of the five MISO futures predict price increases.[12] Projected increases are due to a host of factors, including needed investment in infrastructure,[13] increasing fuel costs,[14] and new regulations by the US Environmental Protection Agency (EPA).[15] However, the US Energy Information Administration projects that the national average price of electricity will increase just 1.6% between 2008 and 2035, and will actually decrease when adjusted for inflation.[16]

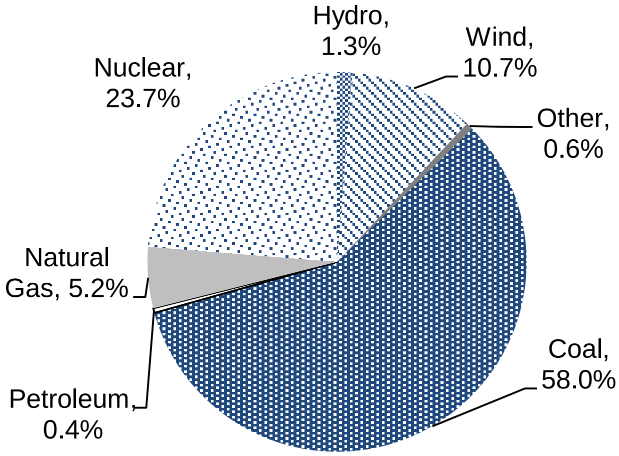
Price forecasts are, as even the forecasters acknowledge, very difficult to draw and historically quite inaccurate.[17]

3. The current electrical system is not sustainable in the long term.

An activity is sustainable when it can continue indefinitely to meet the needs of the present without compromising the ability of future generations to meet their own needs.[18] Our electrical system does not meet this standard.

Minnesota’s electrical system is based on natural resources that are being depleted. Most of Minnesota’s electricity is generated from resources that will someday run out. The majority of the electricity used in Minnesota is generated from coal (58%), a finite resource.[19]

Minnesota Electricity Use By Type[19]



Projections of the future availability of coal vary widely, with most predictions indicating we will not run out of coal for hundreds of years. Some predict that we will reach peak production very shortly.[20] The US Energy Information Administration predicts that the US alone has enough coal to sustain current demand for at least 200 years. The National Mining Association puts this figure at 440 years.[21]

Projections like these are difficult to make and have historically proven inaccurate. A few years ago, for example, it was widely accepted that accessible natural gas in the United States was running out, and that prices were set to spike, but technological advances made hydraulic fracturing affordable, causing gas supplies to increase and prices to dip considerably in the US, at least for the time being.

Long before supplies of coal and other fuels run out, however, we will face intense competition to get what's left, with implications for both cost and security. These pressures will encourage us to resort to lower-quality fuel sources and higher-impact extraction methods, affecting health and the environment.

On the other hand, increased environmental regulations on fossil fuels may mean that, even though supplies remain, we would not be able to use the fuels in the same ways we do today.

We must consider not only the availability of energy supplies, but also the uncertainty of the cost and usage of these supplies, including the effects of increasing demand from developing countries like China, and possible federal regulations or taxes on fossil fuels.

<u>Minnesota's current energy resources have unsustainable impacts on the environment</u>.

Emissions from electrical generation affect the environment in Minnesota and other places downwind of power plants. The National Academy of Sciences estimates that the cost of health impacts associated with air pollution from coal-burning power plants in the US was 3.2 cents per kilowatt-hour in 2005, and predicts costs of 1.7 cents per kilowatt-hour by 2020.[22] Other studies, including a recent Harvard University study, put complete life-cycle costs of coal power much higher.[23] Mercury is another example of a harmful power plant emission; it settles with precipitation and is a major pollutant of waters in Minnesota.

Electrical generation is Minnesota's primary source of greenhouse gases (GHGs) such as carbon dioxide, accounting for about a third of Minnesota's greenhouse gas emissions.[24]

Power plants use large amounts of water for cooling. Minnesota used 852 billion gallons of water to cool power plants in 2010. Much of this water is withdrawn, used for cooling, and discharged back to its original source, rather than being consumed. Approximately 10% of the water, however, is lost to evaporation[25] – an amount equal to nearly half of all of the state's public water supplied combined.[26] The discharged water is also warmer, which can have an effect on surrounding ecosystems.

There are examples of electrical systems that have lower environmental impacts.[27] Many tools to minimize environmental impact exist today and are being adopted in the United States and across the globe.

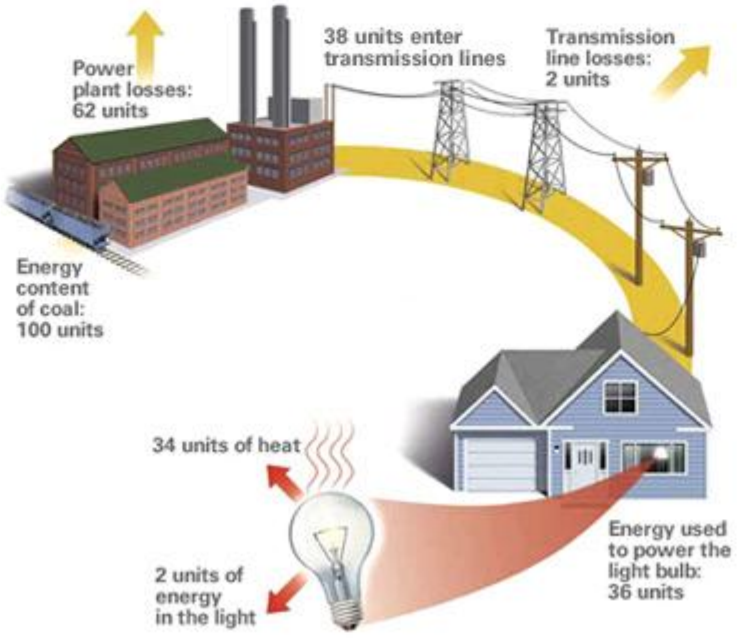
Minnesota citizens, businesses, and lawmakers are currently undertaking and/or planning a wide range of efforts to minimize the environmental impacts of our energy system.

Minnesota's GHG emissions were rising more quickly than those of the nation as a whole from 1990 to 2005, but GHG emissions have declined more recently. From 1990-2005, Minnesota's gross and net GHG emissions increased by 32%, while national gross emissions rose by 16% during this period.[28] However, from 2005-2008 (the most recent statistics available), GHG emissions declined by 1.2%. In that period, GHG emissions from electrical power generation fell 1.6%, mainly due to a reduced reliance on coal.[29]

Minnesota's Renewable Energy Standard is one of the most aggressive in the country, requiring electric utilities to secure 25% of their power from renewable sources by 2025 (33% for Xcel). State statute also establishes statewide greenhouse gas reduction goals of 15% by 2015, increasing to 80% by 2050. While greenhouse gas emissions have declined since 2005, it will likely be difficult to meet these goals.[30] (For more information on Minnesota policies related to the environmental effects of the electrical system, see Appendix E.)

4. The current electrical system is inefficient, both in energy and market terms.

According to many analyses, 60 to 90% of the usable energy is lost between extraction of fuels and raw materials through electrical generation, transmission, and distribution, to consumption by end users.[31] Many harmful wastes and expenses are generated along the way.



This illustration shows the energy lost during generation, distribution and consumption of electricity. Even without including the efficiency of extracting raw fuels and transporting them to a power plant, the National Academies estimate an incandescent light bulb as only about 2 percent efficient.[32]

To illustrate this another way, imagine you've just stopped at the store to pick up a 6-pack of your favorite beverage. When you place it on the counter to pay, the clerk smashes 4 of the bottles, puts the whole mess in the bag, and charges you full price of $8. You pay as though nothing is wrong. You shift the bag while driving home to keep the leaking beverage from staining the seat, but cut your finger on a piece of the broken glass, so you stop at the clinic (where you wait for an hour) for some stitches and pay the fee. Once home, the wet bottles fall through the bottom of the bag, and another one breaks. You ask your housekeeper – lucky you, you have a housekeeper! – to clean up the sticky, glassy mess, while you enjoy a cold one. The housekeeper doesn't mind; he gets paid hourly. This story seems absurd, yet we accept analogous waste, mess, health impacts, hazards, and direct and indirect costs in the way electricity is produced and delivered today.

The majority of energy losses – about 63% – occur in the conversion of raw fuels to electricity, released as heat in power plants.[33] Generation methods exist that are much more efficient than the methods used to produce most of our electricity. Combined heat and power systems, for example, make use of the heat produced in electrical generation to heat buildings. Whereas coal generation alone is about 33%,[34] combined heat and power systems typically achieve 60 to 80% efficiency.[35]

Many costs and benefits are not transparent and/or not accounted for in the price of electricity, making the market inefficient. In our analogy, did the consumer pay $8 for the beverage, or quite a bit more? Hidden costs lead to uninformed and distorted decision making by consumers. Government subsidies, environmental impacts, job growth, and other impacts of electrical energy spending – both positive and negative – are not readily apparent or reflected in the price. Externalization of such a high portion of the true cost of electricity obscures the true value of efficiency.

5. Minnesota is part of a regional electrical system, and we depend on out-of-state energy resources for our electricity.

Minnesota electricity producers and consumers participate in a large regional electric grid that transmits electricity generated both within and outside of the state's borders.

Minnesota electricity consumers rely largely on out-of-state fuel resources for in-state generation and consumption and, to a lesser degree, electricity generated out of state for in-state consumption. In 2009, Minnesotans spent nearly $1 billion on electricity produced out of state – 18% of what we spent on electricity in total.[36] Moreover, the vast majority of the electricity generated in Minnesota is heavily reliant on raw fuels from elsewhere – especially coal and natural gas.

Minnesota does not have the geological resources used to generate the majority of electricity consumed in state (coal, natural gas, crude oil, and uranium). Minnesota's natural resources available for electrical generation – wind, sun, water, and biomass –can be intermittent and/or variable given today's technologies. Combinations of wind, sun, water, biomass and/or storage technologies can mitigate this variability.[37]

Innovations are increasing Minnesotans' ability to achieve electrical self-reliance. Advances in energy storage, for example, could make electricity generated from solar and wind available when the wind isn't blowing and the sun isn't shining. Aggressive conservation could lower demand, making the remaining demand easier to satisfy. The state is also working on projects for generation from biofuels and by other means, some of which could soon contribute to the grid.

III. Key Characteristics of the Electrical System

Minnesota's ideal electrical system would be affordable and competitively priced, efficient, self-reliant, reliable and high-quality, safe, secure, and sustainable. These ideal characteristics are defined in the following pages.

A. Affordability and Competitive Pricing

The Goal
Minnesota needs electricity that is both affordable and priced competitively to ensure a healthy economy while providing equal access, reliability and predictability to users.

What Does Affordability and Competitive Pricing Mean?
Affordability and competitive pricing are two distinct but related goals.

Affordability
Affordability means that all users can pay for a basic level of service. It is relative to how much money you have: Your electricity is affordable if you can pay for the electricity that you need to meet your needs and maintain a basic quality of life.

A product or service can be considered affordable when it provides sufficient value as to be worth the cost to consumers when all costs and benefits are considered. It is difficult to define an absolute measure of affordability for electricity, but it is possible to identify examples of when electricity is no longer affordable, including when:

- People cannot heat or light their homes while also providing for their other basic needs.
- The percentage of median household income spent on electricity increases significantly.
- Quality of life is diminished because of the cost of electricity.
- Business profitability suffers, or businesses are forced to raise prices.
- Businesses leave or choose not to come to Minnesota because of prohibitive energy prices.
- The ability to pay becomes divisive (creating haves and have-nots).
- Shutoffs and delinquent accounts surge.

Affordability, however, encompasses more than the price of electricity charged on the monthly bill. A portion of costs created by our electrical system are not included in this bill. "Affordability" is often misconstrued to mean "inexpensive," "cheap," or even "bearing the lowest price," but these meanings are only correct in the narrowest sense. If you eat $0.99 french fries every day, your dinners will be cheap; however, this diet will have a significant cost to your health. You may not consider the price of your doctors' bills as a part of your food budget, but your medical costs are due in part to your diet choices. A similar accounting is true of the costs and affordability of electricity for society.

Competitive Pricing

The absolute price of electricity is not the only important factor; the price of electricity in Minnesota should be competitive with other locations. Businesses, especially, are affected by how the price of electricity in Minnesota compares with other places. Higher electricity prices provide a challenge (and lower prices an advantage) for Minnesota companies competing with companies elsewhere, and companies that have the option to choose their location may be motivated by relatively low electricity prices.

The price of electricity (and energy prices in general) is one of many factors upon which business decisions are based, but it can be an important factor. Industrial energy managers tell us that, even at just 3% of total manufacturing costs, electrical costs can influence siting decisions.

Stability

The price of the service that electricity provides should not fluctuate drastically or unpredictably. Businesses and households must be able to predict approximately how much of their income will be spent on electricity. This does not necessarily mean that the price per kilowatt-hour must remain constant, but that customers can expect to accomplish a service – e.g. lighting or heating their homes – for a relatively consistent price, and that changes to that price will be reasonably predictable.

B. Efficiency

The Goal

An efficient electrical system minimizes losses and delivers reliable, secure, and economical energy in a manner that can continue indefinitely.

Why Pursue Efficiency?

If usable energy were cheap and abundant and had no negative impacts, there would be little reason to care about efficiency. Today, usable energy is costly, scarce, and problematic enough for efficiency to make a significant difference. In general, the less of a resource we use, the lower the costs of producing, transporting, and processing the resource. In addition, lower usage means less environmental and health impacts and smaller risks to security and reliability.

What Does Efficiency Mean?

Efficiency can be thought of as simply the ratio of outputs to inputs.

The most efficient system produces the most useful outputs possible from a given input. Efficiency can be improved by maximizing the useful output and/or minimizing the needed input.

When you get that BTU in your hand, use it as many times as you can before you let it go.

Whole-Systems Approach

All of the inputs and outputs, the systems that connect them, and the sequences and processes from beginning to end must be considered when measuring efficiency.

The production, delivery, and use of electricity require a chain of inputs and outputs. The outputs of one step become the inputs of the next. Take, for example, how solar power works. Sunlight (an input) is captured by a solar array (itself a complex of inputs and outputs). The array uses that input to produce electricity (an output) and waste heat (another output). Waste heat is carried off and dissipated by water (an input).

Conservation is an important related concept. Whereas efficiency means getting the most output per input, conservation means reserving resources for other potential current or future uses. It is possible to have efficiency without conservation and conservation without efficiency, but the two often go hand in hand.

Some outputs or side effects may have nothing to do with providing electricity to an end-user, but may be harmful or useful and may require additional energy to safely process, store, mitigate, or eliminate. For example, a hydroelectric dam may change the seasonal flooding regime of a river, with both positive and negative consequences for property, erosion, deposition, habitat, recreation, etc.

If we look only at the energy invested in turning raw materials into delivered electricity, the result is a skewed picture of the true cost of electricity. It would be inefficient to invest heavily in infrastructure with a life cycle of 100 years, for example, if a key resource supporting that system is expected to become rare or expensive in 20 years. If we choose to rely on energy sources that cause air and water pollution, we must be sure that we account for the cost of fully mitigating those impacts for generations. If we opt for reliance on imported fuels or electricity, we must budget for the expense of securing those supplies from allies who may someday be enemies, and in competition with other nations that make similar choices.

Thus, in the context of our energy use in the future, the most efficient system is, by definition, the one that is the most *sustainable*, *affordable*, *reliable*, and *secure*.

> Sustainable: To be efficient, an electrical energy system should minimize wasted resources and make the optimal use of those resources over the long term.
>
> Affordable/competitively priced: Wasted energy or resources in the generation, transmission, and use of electricity leads to unnecessary costs. An efficient electrical system saves money by recognizing all costs and benefits at all stages, minimizing the costs, and maximizing the benefits. The most affordable system may not necessarily be the “cheapest” in terms of dollars per kilowatt-hour. It may require deliberate intervention to reallocate costs for the optimal system to be within the financial means of all consumers.
>
> Reliable: To be as reliable as possible, the energy system requires redundancies, such as back-up generators for businesses that cannot afford to be without electricity. Redundancies are inherently inefficient, so a system that minimizes the need for such backup is more efficient.
>
> Secure: In general, the less energy you need, the easier it is to ensure the supply and the less subject you are to price volatility, fuel shortages, competition for resources, and other pitfalls. We can heat a large building more efficiently, but we can also use building space more efficiently, meaning there is less space to heat and cool.

Integration

We anticipate that our future electrical system will merge and integrate with information technology. In addition, the distinction between electrical usage and other modes of energy use, such as transportation and heating, will grow less important (systems will grow more integrated) as we evolve an optimized system for generating and delivering useful energy where it is needed. The economic analysis of the electrical system must integrate a broader understanding of the costs and benefits of each choice, even when those values are intangible.

In our ideal future, Minnesota will have an integrated energy system that enables us to create the products, services and environments we need in a sustainable and affordable way.

Minnesota’s goal must be to increase efficiency in order to reduce the amount of energy required to meet our needs. Our goal is to maintain or improve our economy and standard of living while using less electricity.

C. Sustainability

The Goal
Minnesota's electrical system must be sustainable, meeting the needs of today without compromising the ability of future generations to meet their needs.

What Does Sustainability Mean?
The framework of sustainable development has three dimensions: environmental responsibility, economic viability, social equity.[38]

Environmental Responsibility
Minnesota's ideal electrical system would have zero impact on the environment. We recognize that this is an unachievable goal – it is an aspirational one. Minnesota should continually reduce the environmental impact of its electrical system toward zero impact.

While zero impact may be unattainable, the system *must* achieve long-term sustainability. We should focus on continuous improvements and efficiencies through a whole-systems approach to minimize the effects of climate change and other impacts on the environment.

Economic Viability
Economic viability is a key aspect of sustainability. A system that cannot continue indefinitely without bankrupting the participating people or institutions cannot be sustained.

To evaluate economic viability, net costs and benefits of the entire system over the long-term should be integrated into policy and consumer decision making. This includes positive and negative impacts to the economy, environment, and health.

Social Equity
The electrical system should provide a basic quality of life for all Minnesota citizens. We should consider who receives the majority of the benefits of our electrical system, and who bears the brunt of negative impacts. The assessment described above should ensure a more equitable and transparent accounting of costs and benefits when evaluating energy alternatives and their impacts across the system.

Whole-Systems Approach
Evaluating sustainability inherently requires a whole-systems approach. While this project focuses on electrical energy in Minnesota, the lines of environmental and other impacts cannot be drawn at the state's borders. We must consider regional and global impacts, as many resources may come from outside the state, and the impacts of energy generation, transmission and use are not exclusively within the state.

To balance these factors will require change in the existing electrical system, and courage from citizens and leadership to achieve this change.

Many technologies and tools needed to dramatically increase the sustainability of the electrical system exist today and are being adopted throughout the United States and across the globe. However, many efficiency, conservation and other opportunities have yet to be broadly deployed or adopted.

While technology will continue to evolve and provide more solutions, the primary challenge today is how to motivate citizens, business and government to adopt the changes needed to achieve the goal of sustainability in energy moving forward. The biggest challenge to is setting in motion today the broad and fast adoption of known solutions that will benefit us tomorrow.

D. Self-Reliance

The Goal

In a self-reliant system, Minnesota would generate as much electricity as it consumes using in-state resources, thus maximizing economic benefit to the state.

Why Pursue Self-Reliance?

The purpose of striving for electrical self-reliance is to spur economic development throughout the state. A self-reliant electrical system would leverage Minnesota's commercially viable natural resources and encourage development of technologies and businesses.[39] Rather than sending money out of state to meet our electricity needs, electricity would be produced in Minnesota from Minnesota resources, allowing our money to stay in-state and maximizing a range of economic benefits.

Self-reliance also maximizes contributions to the local tax base. When Minnesotans buy electricity from plants elsewhere, our payments contribute taxes to those localities. A self-reliant system keeps those tax payments locally.

Pursuit of electrical self-reliance is worthwhile so long as it does not compromise reliability or affordability nor unreasonably impact the environment.

What Does Self-Reliance Mean?

In a self-reliant electrical system, Minnesota would generate as much electricity as it uses. The state would remain connected to and share electricity over the regional grid. At times, Minnesota may be a net exporter of electricity; at other times, Minnesota may be a net importer – but over the course of a year, the amount of electricity generated in Minnesota would be equal to or greater than the amount consumed. Self-reliance does not imply a desire to isolate Minnesota from the electrical system that connects us with other states and nearby provinces.

Electrical self-reliance can help advance – or be advanced by – complementary goals. Efforts toward electrical self-reliance tend to produce environmental benefits for Minnesota. Minnesota does not have fossil fuels or uranium resources, so a self-reliant system would depend on renewable resources. Increasing supply- and demand-side electrical efficiency and conservation will also contribute to achieving electrical self-reliance.[40]

Furthermore, electrical self-reliance is one of the first identifiable phases towards comprehensive energy independence, because electricity is a universally usable form of energy.

E. Reliability and Quality

The Goal

Minnesota's ideal electrical system will deliver electricity of consistent quality without interruption.

What Does Reliability Mean?

Power Availability

Reliability can be thought of as the percentage of time that electricity is available when needed. In a completely reliable system, electricity is available 100% of the time that a customer turns on a switch. The fewer power outages a system experiences, and the faster power is restored after an outage, the more reliable the system.

A number of indices exist to measure reliability. They generally take into account the frequency and duration of power outages and the number of customers affected as a portion of the number of customers served.[41]

Agencies such as the North American Electric Reliability Corporation (NERC), the Midwest Reliability Organization (MRO), and the Minnesota Public Utilities Commission (PUC) set standards for reliability and enforce penalties on utilities that violate these standards. The Midwest Independent Transmission System Operator (MISO) and local utilities undergo planning processes to minimize power outages. Utilities and their Regional Transmission Organizations (RTOs) monitor the grid at all times to ensure a constant balance between generation and load. These reliability efforts also work to isolate outages when they do occur.[42]

Power Quality

Electricity is not simply on or off; the range between "power on" and "power off" relates to power quality. Ideally, the electrical voltage from an outlet remains constant. Any variation in voltage diminishes power quality.

These variations can either come over the power lines or be caused by the equipment that consumers use. Large motors and furnaces can cause power quality disturbances, as can appliances as small as a laser printer. Sometimes, one customer's usage can affect the power quality of another customer on the line.

Disturbances to power quality are a source of inefficiency and can cause damage to sensitive equipment. For example: A standard 100-watt light bulb requires 120 volts to produce the designed light output. If the voltage drops to 108 volts, the light bulb still works and is not damaged, but it is dimmer. If the voltage rises to 130 volts, the light bulb is brighter than it is designed to be, causing overheating and stress to the filament wire. This shortens the life of the bulb.[43]

Low power quality has a small effect on most consumers. However, it can have a huge impact on sensitive industries such as hospitals, data centers, and much modern manufacturing, including many of the industries that Minnesota would like to retain in our state.

F. Safety

The Goal
The electrical system should not cause injury or harm to workers, consumers, or other citizens.

What Does Safety Mean?
Safety includes both immediate protection (e.g. people can be near power lines and workers can service electrical infrastructure without undue risk) and longer-term effects (e.g. power generation that produces smog causing asthma is not safe). Many issues of safety overlap with environmental issues.

G. Security

The Goal
A secure system is protected from disturbances and able to continue delivering electricity even if there is a disturbance to the system.

What Does Security Mean?
Threats to security can be natural or man-made, physical or virtual, and includes the security of assets and energy sources. Examples of threats to security include:

- A tree falling on a power line.
- The tsunami that took Japan’s Fukushima power plant offline.
- Theft of copper wires.
- The Stuxnet virus that infected Iran’s nuclear program.
- The wind not blowing or a shortage of fossil fuels.
- The price of fuels skyrocketing.

Making a system secure implies dependability of fuel sources and infrastructure, and mitigation of other risks. To a degree, security may be served by self-reliance. The more of our energy we generate in Minnesota from Minnesota resources, the less subject we are to outside politics and the pricing decisions of outside entities. Diversification of electrical energy resources can also mitigate energy price volatility and increase flexibility.

IV. Important Considerations and Drivers of Decision Making

Managing Change

We must focus on outcomes. If our destination is clear, we be flexible in the means we use to get there. For example, public policy that provides incentives for efficiency need not specify the use of wind or solar but can allow the free market to determine the best way to fulfill the parameters. These parameters can include environmental and social guidelines, efficiency requirements, and other long-term objectives.

We must also be willing to allow outmoded ideas or ways of doing things to die. We can provide some assistance to those stakeholders who face temporary hardships as a result, until they can adapt. Change does not need to be ruthless.

Economics

Making changes towards the goals presented here must have a value for those involved.

The electrical system includes many costs: fuel, technology, and infrastructure costs; taxes and fees; research and development; etc. The questions are: Who ends up paying these costs? Are they being distributed properly? At what point do these costs become unacceptable?

Complete Economic Information and Accurate Signals

In an ideal system, all the costs and benefits of electricity (all the inputs and outputs) are reflected in the prices paid throughout the supply chain in order to rationally drive choices.

Currently, electric bills only reflect a portion of the actual costs and benefits of producing, transmitting, and distributing electricity. The remainder (air and water pollution, job growth, etc.) are “paid” or received by society in general, sometimes in real money but more frequently indirectly through impacts on health, the environment, and the economy. We pay these additional costs whether or not we choose to recognize that fact. Likewise, there may be benefits from certain choices that are not recognized by the market. If we can find ways to signal the desirability of these values, those signals can drive better, more informed choices.

Externalities: Costs or benefits of a transaction or activity that are incurred by a party who is not a voluntary participant in that transaction. These costs and benefits are not reflected in the price of the activity.

An honest assessment of externalized costs and benefits of electricity will reflect the true value of changes towards efficiency, minimal environmental impact, self-reliance, and other goals, and it will make the signals much clearer. Currently, for example, it can be difficult for a single consumer to see much economic benefit in electrical efficiency – especially if efficiency requires an investment of time or money on their part. This is in part because the consumer’s bill does not reflect the complete cost of the electricity they are using.

An honest assessment of externalized costs and benefits of electricity will reveal the true value of our decisions.

Over time, more costs have been internalized by applying environmental regulations to the power sector. Others are considered in utility resource planning as part of the total costs of alternatives for meeting electricity demand, even though the costs are not necessarily recovered in actual utility rates to customers.

That all costs and benefits should be considered does not necessarily mean that all externalities can or should be translated into dollar amounts and included in the price per kilowatt-hour – this may prove both impossible and undesirable. However, to the extent possible, information about all the costs and benefits should be part of consumer and policy decision making. The extent and timing of, as well as how, these considerations are made and/or costs are internalized must be addressed carefully to balance the economic ideal of fully internalized costs with very real concerns about affordability, competitiveness, and unequal impacts of these policy changes.

Fair and Reasonable Rates

In the ideal, to drive informed decision making, all customers would pay prices based on the actual cost of generating and delivering electricity to them.[44] In reality, certain customers are probably paying less than these actual costs while others pay more, and there may be good reasons for customers not to pay the exact cost of delivering electricity to them.

We must consider how implementing this ideal may impact affordability, competitiveness, and equity. Rate policy should consider the impacts of economic poverty and the impacts of prices on businesses. That is not to say that all policy goals related to the costs of electricity should be accomplished through the rate structure. (The food stamps program is an analogy: We agree on a policy principle that all people should be able to afford food. Rather than requiring supermarkets to change their prices, we provide food stamps as targeted support to families that need it.)

Beyond overall fairness in setting electric rates, specific rate elements and options will become increasingly important. Today, most consumers pay for electricity through rates that reflect seasonal cost differences (summer vs. other months) and include demand charges for larger commercial customers. While some utilities offer electric rates that vary by time of day, few consumers voluntarily choose to pay for electric service this way. Since the cost of electricity tends to vary by time of day as well as season, continued expansion of time-differentiated rates may have the potential to enhance fairness in payment for electric service.

Supply

The long-term availability and abundance of energy resources will become a critical driver of decision making in the future as the cost of these supplies goes up, especially if factors that currently interfere with market economics are removed. If nonrenewable resources are not conserved and continue to be a major component of electricity production, they may not be available for other, potentially much more valuable uses in the future. And as developing economies like China and India boom, global demand for fuels like coal is skyrocketing. Eventually, these resources will not be economically viable, and all the dependent infrastructure will become a liability.

Technology

While we can anticipate certain advancements, such as improvements in solar PV panels, we can't predict all of the interactive effects of the propagation of these innovations. Likewise, new technologies will become available in coming years, some of which may be disruptive and paradigm-shifting.

Rather than attempt to figure out what technology will best provide for our future energy needs, we offer these guidelines for helping to ensure that, over the long term, we can use technology to implement the most optimally efficient energy system:

- Utilize the technology that is currently available wherever warranted by a realistic analysis of costs and benefits.

- Support the development and implementation of new technologies that improve the efficiency and sustainability of the energy system. Phase out that support when it is no longer needed, and put those resources to use assisting the next wave of innovation.

- Analyze the activities and transactions that transform raw energy and materials into electricity delivered to an end user as a system, and re-analyze it whenever it changes. Understand all the inputs, outputs, and flows – the connections between them.

- Build flexibility into the system so that new and better technologies can be quickly adopted as they become available.

Information, Norms and Convenience

Information is a powerful tool for shaping behaviors and choices. If stakeholders are well-educated regarding the impacts of their energy choices, they will tend to optimize their choices.

Information alone, however, will not be sufficient. Information must be assimilated as a shared set of knowledge and values and backed up by societal supports, becoming a cultural norm.

Ideally, the infrastructure and most readily available options for goods and services (such as vehicles, appliances, industrial equipment, energy services, mass transit, etc.) would be those that best accomplish the goals set forth here. These choices would be positively supported by policies, regulations, education, and programs. A well-informed public may also exert social pressure on businesses, governments, and their peers to make choices that better accomplish long-term goals.

VI. Appendices

Appendix A: About the Electrical Energy Project

In the Electrical Energy Project, the Citizens League is convening Minnesotans from diverse perspectives on electricity to:

- Come to agreement on what the state's electrical system must achieve in the long term (as well as potentially identify areas of disagreement);
- Identify changes necessary to achieve these goals; and
- Advance reforms in government, electrical producers, business, and/or other institutions; while
- Laying the foundation for all of this by building agreements among participants from all sectors and political perspectives.

Participants in this project have included individuals from businesses, electrical companies and utilities, environmental organizations, universities, and unaffiliated citizens.

Led by a steering team of members, the Citizens League engaged about 150 stakeholders in 2010 and early 2011 to frame this project. In interactive forums in September and December 2010 and many meetings following that, we identified seven key characteristics of that Minnesota's ideal electrical system would achieve:

- Affordability/Competitive Pricing
- Efficiency
- Self-Reliance (initially termed "independence")
- Reliability and Quality
- Safety
- Security
- Sustainability (initially termed "minimal environmental impact")

Though there is broad agreement on these key characteristics, we do not all use the words with the same meaning.

In Phase 1 of the Electrical Energy Project, citizens organized in four teams to define the four characteristics prioritized by participants: affordability/competitive pricing, efficiency, self-reliance, and sustainability.[*] This paper is the result of this work, setting out what Minnesota's ideal electrical system would accomplish.

In the next phase, participants will begin to develop recommendations to accomplish these goals.

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[*] The characteristics of reliability, safety, and security were raised in connection to all four working teams, but no dedicated group defined these characteristics. The project had capacity to organize four working teams, and the focuses were chosen based on how participants chose to spend their time; this does not reflect a higher prioritization for certain characteristics.

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Appendix B: Minnesota Average Annual Residential Electric Payment as Portion of Median Income

	1990	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*
Total residential electric revenue (thousands of dollars) [1]	$1,010,592	$1,082,883	$1,040,668	$1,105,316	$1,146,132	$1,216,609	$1,223,071	$1,234,992	$1,272,958	$1,334,265
Number of residential electric customers [2]	1,755,161	1,781,196	1,811,852	1,833,753	1,866,391	1,893,713	1,888,279	1,962,628	1,988,091	2,017,362
Ave. annual residential electric payment per customer	$575.78	$607.95	$574.37	$602.76	$614.09	$642.45	$647.72	$629.25	$640.29	$661.39
Median household income, Minnesota [3]	$31,465	$29,479	$30,981	$33,682	$33,644	$37,933	$40,991	$42,564	$47,926	$47,038
Ave. annual res. elec. payment as percent of median income	1.83%	2.06%	1.85%	1.79%	1.83%	1.69%	1.58%	1.48%	1.34%	1.41%

	2000	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Total residential electric revenue (thousands of dollars), cont'd	$1,400,071	$1,476,460	$1,531,480	$1,579,058	$1,624,406	$1,799,428	$1,905,115	$2,078,498	$2,176,352	$2,212,341
Number of residential electric customers, cont'd	2,051,355	2,078,775	2,117,928	2,154,095	2,204,694	2,211,000	2,240,891	2,267,167	2,279,850	2,290,881
Ave. annual residential electric payment per customer, cont'd	$682.51	$710.25	$723.10	$733.05	$736.79	$813.85	$850.16	$916.78	$954.60	$965.72
Median household income, Minnesota, cont'd	$54,251	$52,681	$54,622	$52,823	$56,104	$54,215	$56,211	$58,058	$54,925	$56,090
Ave. annual res. elec. payment as percent of median income, cont'd	1.26%	1.35%	1.32%	1.39%	1.31%	1.50%	1.51%	1.58%	1.74%	1.72%

Sources:

1. US Energy Information Administration. "Revenue from Retail Sales of Electricity by State by Provider, 1990-2009." http://www.eia.gov/electricity/data.cfm#sales. Accessed October 5, 2011.

2. US Energy Information Administration. "Number of Retail Customers by State by Sector, 1990-2009." http://www.eia.gov/electricity/data.cfm#sales. Accessed October 5, 2011.

3. US Census, Current Population Survey. "Table H-8. Median Household Income by State: 1984 to 2010." http://www.census.gov/hhes/www/income/data/historical/household/2010/H08_2010.xls. Accessed October 5, 2011.

Appendix C: Sustainable Development Framework

The Minimal Environmental Impact Working Team reviewed the framework of sustainable development[45] – environmental protection, economic development, and social equity – and found it to be a useful framework to organize its work. Sustainable development practices can be considered to achieve the goals we envision as the ideal for electricity in Minnesota.

Assessment would begin with the sourcing of raw materials, to the resource refinement, the mechanical developments, the impacts created in the production of energy, and/or energy producing technologies, the transportation and transmission of energy and their related environmental impacts, the waste in the distribution of energy, and the use of the energy. The assessment would weigh the energy options relative to their impacts on environmental protection, economic development, and social equity.

Listed below are tools used today in sustainable development decision making to assess impacts.

- Carrying capacity: A common modeling technique used by designers, scientists and planners to help define the impacts of development and future operations on existing environments, typically defined as “the maximum demand or load that may be placed on a machine, resource, or system for extended periods under normal or specified conditions.”[46] When used in projections, it refers to the theoretical limit to the capacity of a natural ecosystem to support consumption of its resources and generation of pollution without being overwhelmed, and is dependent on factors such as population size and density and rate of renewability of its resources.

- Direct and indirect costs, internal and external impacts: A full, complete and accurate accounting of the “true cost” of the manufacturing and distribution of a product or service. This accounting reflects the industry subsidies, tax breaks and incentives offered to producers, which are not usually reflected in the market price.

- Green supply chain: The sequence of suppliers that move a product from raw materials to the consumer and that actively seeks improve the profitability of a company while minimizing impacts on the environment.[47]

- Life cycle assessment: As defined by the US Environmental Protection Agency, “LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by compiling an inventory of relevant energy and material inputs and environmental releases; evaluating the potential environmental impacts associated with identified inputs and releases; interpreting the results to help you make a more informed decision.”[48]

- Cradle-to-cradle design: The design and manufacture of products so that, after the end of the products’ useful life, they become either "biological nutrients" or "technical nutrients." Biological nutrients are materials that can re-enter the environment. Technical nutrients are materials that remain within closed-loop industrial cycles.[49]

Appendix D: Greenhouse Gases and Climate Change

Members of the Minimal Environmental Impact Working team include minimizing climate change impacts in the vision of Minnesota's energy future, because:

a. Carbon dioxide is a greenhouse gas, as gas that contributes to the greenhouse effect by absorbing infrared radiation (heat);
b. Increasing carbon dioxide should cause the Earth to warm;
c. Human activities have increased carbon dioxide concentrations in the atmosphere. Since 1750 (the eve of the Industrial Revolution), the EPA estimates that global concentrations of carbon dioxide have increased about 35%;[50]
d. The Earth has warmed.

In addition, more severe weather is being documented, i.e. more droughts, more heavy rainfall and more extreme weather events. Scientific measurements demonstrate that the ocean is becoming more acidic and Arctic ice is being lost at a very rapid rate. Climate zones are moving, and weather patterns are shifting.[51]

From 1990 to 2005, Minnesota's GHG emissions were rising more quickly than those of the nation as a whole. The Minnesota Climate Change Advisory Group, convened by Governor Pawlenty in 2006, reported:

> "From 1990 to 2005, Minnesota's gross and net GHG emissions increased by 32% while national gross emissions rose by 16% during this period.
>
> "On a per capita basis, Minnesotans emitted about 30 metric tons (t) of gross CO2e [carbon dioxide emissions] in 2005, greater than the national average of about 24 tCO2e [metric tons of carbon dioxide emissions]. […] In Minnesota per capita emissions have increased from 1990 to 2005, while per capita emissions remained fairly flat for the nation as a whole. In both Minnesota and the nation as a whole, economic growth exceeded emissions growth throughout the 1990–2005 period. From 1990 to 2005, emissions per unit of gross product dropped by 26% nationally, and by 23% in Minnesota. […]
>
> "The principal sources of Minnesota's GHG emissions in 2005 are electricity use (including electricity imports) and transportation, accounting for 34% and 24% of Minnesota's gross GHG emissions, respectively. The use of fossil fuels – natural gas, oil products, coal, and wood – in the residential, commercial, and industrial (RCI) sectors accounts for another 20% of the state's emissions in 2005.
>
> "Agricultural activities, such as manure management, fertilizer use, livestock (enteric fermentation), and changes in soil carbon due to cultivation practices, result in CH4 and N2O emissions that account for another 14% of state GHG emissions. Landfills and wastewater management facilities produce CH4 and N2O emissions that accounted for 3% of total gross

> GHG emissions in Minnesota in 2005. Emissions associated with the transmission and distribution of natural gas accounted for 1% of the gross GHG emissions in 2005. Industrial process emissions accounted for about 1% of the state's GHG emissions in 2005, and these emissions are rising due to the increasing use of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) as substitutes for ozone-depleting chlorofluorocarbons (CFCs). […] Other industrial processes emissions result from taconite, lime, and peat manufacturing; PFC use in semiconductor manufacture; CO2 released during limestone, dolomite, and peat use; SF6 released from transformers used in electricity transmission and distribution systems; and N2O from medical uses."[52]

Since 2005, GHG emissions in Minnesota have been falling. From 2005 to 2008 (the most recent figures available), emissions in the state fell 1.2%, and emissions from electrical generation fell 1.6%, mainly due to a reduced reliance on coal.[53]

Appendix E: Environmental Policy Context

Minnesota has adopted several state policies in recent years to curb emissions.

Minnesota’s Next Generation Energy Act (2007) intended to reduce the pollutants that contribute to climate change and encourages utilities to invest in local energy sources. It has four main components:

- Energy savings goals: It establishes an energy savings goal for all utilities at 1.5% of annual retail energy sales, and also sets goals to achieve a certain number of high-performance buildings within Minnesota.
- Community Based Energy Development: It expands and strengthens Minnesota’s commitment to the development of locally-owned renewable energy projects.
- Climate Change and Greenhouse Gas Reduction: It establishes statewide GHG reduction goals of 15% by 2015, 30% by 2025, and 80% by 2050.
- Next Generation Energy Board: The board develops next generation energy and biofuels policy, and makes recommendations to the Governor and Legislature about how the state can invest its resources to most efficiently achieve energy independence, agricultural and natural resources sustainability, and rural economic vitality.

The Minnesota Renewable Energy Standard (2007) mandates that electric utilities procure 12% of their power from renewable sources by 2012, 17% by 2016, 20% by 2020, and 25% by 2025. Xcel Energy has additional requirements (due to a 1994 agreement relating to its nuclear generating facilities): 15% by 2010, 18% by 2012, 25% by 2016, and 30% by 2025.

Under then-governor Tim Pawlenty, who then chaired the Midwestern Governors Association (MGA), Minnesota also signed onto the MGA's Energy Security and Climate Stewardship Platform for the Midwest (2007). The platform includes goals for energy efficiency, advanced coal and carbon capture and storage, and renewable electricity (which are less ambitious than goals in Minnesota policy). It was signed by the governors of Illinois, Iowa, Kansas, Michigan, Minnesota, Missouri, North Dakota, Ohio, South Dakota, and Wisconsin and the premier of Manitoba.

The Green Solutions Act (2008) established the Legislative Greenhouse Gas Advisory Group and required studies and reports to the legislature regarding a cap and trade program for greenhouse gases.

The Minnesota Climate Change Advisory Group (MCCAG), a stakeholder process convened by then-Governor Tim Pawlenty and comprised of business interests, academics, agricultural interests, academics among others, developed a list of recommended actions to achieve the state’s reduction goals and submitted it to the 2008 legislature. To date, very few of these recommendations have been implemented.

In Minnesota utilities currently plan ahead for 15 years and must state their intentions in resource plans which are reviewed by the Minnesota Public Utilities Commission.

In addition to state policy actions, addressing carbon reductions and climate change was a focus of a 2002 Citizens League report *Powering Up Minnesota's Energy Future: Act Now on a Long-Term Vision*.[54] This could be a good starting point for Phase 2 to review and analyze which recommendations have been enacted and to what result.

Appendix F: Issues to Consider in Subsequent Phases of This Project

Big changes may be coming:

- Opportunities presented by new and developing technologies have the potential to create a period of disruption in the electrical system. For example, new technologies may make distributed generation and combined heat and power as affordable as traditional centralized generation. However, the complete grid infrastructure – and the investment it reasonably requires – may still be necessary for the few days that demand is so high distributed generation cannot meet it.

Points of leverage: There are ways to bring about substantial change by exerting pressure at key points of leverage.

- What will happen to the demand for electricity in the future? Through efficiency and conservation improvements, we may need less electricity to accomplish what we are accomplishing today. But increased uses for electricity (like transportation) may cause demand to increase. However, we use electricity in an ever-increasing number of ways, and electricity may also begin to supplant other energy sources (e.g. electrified transportation).
- Greenhouse gases may be regulated and/or taxed at the federal level. Minnesota should be prepared, including having diversified power generation.
- Can we live with less energy?
- Will the population stabilize, or will it continue to increase?

Imagine new business, utility and energy models:

- What could different business models for generating, transmitting and distributing electricity look like?
- Should licensing of new power plants consider whole-system efficiencies?
- What do the data show on regulated vs. deregulated market structures?
- How can efficiency be made profitable (for consumers, utilities) through more transparency and direct incentives? How can economics become a driver of efficiency?
    - Because utilities charge per kWh, in general, if they sell more they increase revenue – this does not encourage conservation or efficiency improvements. What are effective alternatives?
    - Is putting a premium price on electricity usage above a certain level (or charging less below a certain level) a good idea?
- Could we employ complementary effects of centralized and distributed generation? Consider the interplay and coordination between energy generation that is geographically dispersed near the electrical load with existing and new centralized infrastructure. As the electrical grid becomes more robust and generation more diverse, how will electrical policy shape how these systems work together?
- Given the complexity of accounting for all costs and benefits of electricity, dollars per kilowatt-hour may not be the best measure of the cost of electricity. What are better options?
- Minnesota could move to conservation pricing, especially for households, charging less for the first increment of electricity, with increasing amounts for the next increments. We could also consider “decoupling,” which guarantees utilities a certain amount of revenue regardless of the amount of electricity sold. Would this type of pricing facilitate energy conservation?

- What shows promise (or has failed) in other states or countries?
    - Germany may be an example to look to. The price of electricity continues to rise, the public seems supportive, and industry remains competitive with subsidies.

<u>What are our future infrastructure needs, and how will this impact cost?</u>

- Getting electricity most efficiently from generator to consumer maximizes affordability and competitive pricing. A more robust transmission grid allows Minnesota to tap into lower-cost energy. We will need to make major investments to serve Minnesota customers, which may increase costs somewhat[55] but may also provide significant benefits.[56]
- The system must ensure a fair return on investment for those entities that invest in the infrastructure to produce and deliver electricity.
- How do our physical infrastructure, the structure of our communities, and our future decisions about growth impact the electrical energy system?
- Closely related to transmission investment is the concept of cost allocation. Like the interstate highway system, regional transmission lines need regional cost allocation. Historically, transmission was largely funded at a local level to serve local needs. MISO recently developed and is implementing a major regional transmission cost allocation system – Multi Value Projects (MVP) – to serve regional needs. Maintaining regional buy-in for this cost allocation mechanism will be key to building regional transmission projects.

<u>How can we set accurate price signals?</u>

- Externalities are included in some policy decisions. The PUC has set values for a number of externalities, which must be included in utility resource planning. Is this an effective approach? Is it sufficient?
- To what extent does cross-subsidization exist between residential, commercial and industrial customer classes today? What are the effects of this policy?
- Is it possible to measure true costs? If so, how, and to what extent? Who does it? How is it incorporated into policy and other analyses? How do you account or provide transparency for costs that cannot be measured? What consequences does this have for the electrical energy system, and how might these effects ripple out?

Including all costs in pricing is the ideal; this may prove impractical or impossible, and it may not be necessary to *literally* account for every cost and benefit. In our discussion, we did not draw conclusions, but we present points and counterpoints for consideration as we move forward toward the goal of electrical efficiency:

1. It may be impossible to quantify all external costs.
    - That should not stop us from quantifying those that we can and estimating the rest. Some assessments may be controversial, but these will be the subject of debate and re-evaluation.

2. It may raise the price of electricity so high so as to be unaffordable to businesses and many residential consumers.

    - The cost is the cost. Understanding the true cost doesn't raise or lower it by one cent. It is better to recognize the true costs and benefits than to make choices based on willful denial of the consequences. The real question and challenge is how the costs should be allocated, and how policies can support fair and beneficial cost allocation.

3. It may put Minnesota at a competitive disadvantage compared to others.
    - Accurate information is a competitive advantage and allows us to choose and build the most authentically sustainable, affordable and competitive energy system for the long term. Again, the question is not whether the information itself will have negative consequences, but how policies can use this information to support the best system.

4. It has the potential to be used as a screen to skew prices for political reasons.
    - Measures can be taken to isolate market mechanisms from political manipulation. Any policies or public programs in support of efficiency must be transparent (especially with regard to funding mechanisms and allocation of costs and benefits) in order to remain effective.

Accurate information is a competitive advantage.

Approaching the Future

- How do we develop a system and a plan that is efficient by current standards, yet flexible enough to incorporate technologies and ideas that we cannot even imagine?
    - Be sure to consider the entire system, and each component, from beginning to end. There are opportunities for efficiency at each stage, and in the system as a whole.
    - Think creatively and question all assumptions. What if we treat the delivery of electricity to end users as a service, rather than a commodity? What if users had complete freedom to choose where their electricity comes from and how it is generated? Are the ideas we're considering biased toward conventional energy sources, existing infrastructure, and norms that we take for granted? Are we being dazzled by glamorous new technologies and unproven approaches?
    - Look at programs that have attempted to change energy use habits and gain best practices from them.
    - Evaluate today's current, new, and emerging technologies (such as smart grid, energy storage, heat recovery, etc.) for their potential to provide near-term benefits.

Leadership

- Should Minnesota choose to be an energy leader? What are the short-term and long-term consequences (positive and negative) of such a role? Are we willing to bear those costs? Can we make the commitment to follow through with a vision that may take 20 or 30 years to realize? Minnesota imports electricity and fuel. What influence can we exert beyond our borders to improve efficiency?
- Electrical self-reliance presents Minnesota with the opportunity to become a leader in developing innovative electrical infrastructure.

- While technology and operations will continue to evolve, the primary remaining challenge is motivating consumers, business and government to broadly adopt available knowledge and technology, both now and as it becomes available. We suggest the Phase II teams explore how to motivate citizens, business and government to adopt the changes needed to balance the sometimes competing goals of economic viability, social equity, and environmental responsibility.

Self-Reliance

- Consider the broader effects of self-reliant energy policy: The transition from a coal and natural gas-based electrical system to one more dependent on Minnesota resources will alter political, social, and economic balances. Jobs will be gained and lost, the dynamics of communities hosting new or old energy facilities will change, and certain animal species may be threatened while others thrive. We suggest that Phase II participants consider the accompanying impacts of self-reliant energy policy.

Technology

- How can we encourage the development and adoption of technologies without prematurely implementing technologies that are not yet ready, or losing gambles of technologies that prove to be less effective than anticipated?
- Can some technologies or approaches have net positive environmental benefits?

Security

- Increasing digitalization of our electrical system – both generation and consumption – may increase the security risk. For example:
    - In 2010, Iran's nuclear program was damaged by the Stuxnet virus, which sent centrifuges used to enrich uranium spinning out of control. Could electrical generation equipment in the United States be open to similar attacks?
    - Web-based email, bank accounts, and other personal information have proven to be vulnerable to hacks. Could smart meters and other electronic controls for electrical consumers be similarly vulnerable?

Reliability

- There are detailed rules governing reliability, from the North American Electric Reliability Commission (NERC), the Federal Energy Regulatory Commission (FERC), the Midwest Independent Transmission System Operator (MISO), the Midwest Reliability Organization (MRO) and the Minnesota Public Utilities Commission (PUC). Are these rules effective?
- How should distributed generation be regulated?
    - Effective regulation of distributed sources will be very important if/when generation becomes more de-centralized. Many small sources putting power onto and drawing power from the grid has the potential to make the grid unstable if it is not well regulated.
    - Cooperative and municipal utilities are not regulated by the state; co-ops are regulated by their members, and municipal utilities are regulated by city councils or administrators appointed by the city councils. All utilities are subject to the same MISO, NERC, and FERC requirements.

VII. Notes and References

[1] Hamachi LaCommare, Kristina and Joseph H. Elo. "Cost of Power Interruptions to Electricity Consumers in the United States." Ernesto Orlando Lawrence Berkeley National Laboratory. February 2006. http://www.eia.gov/cneaf/electricity/chg_str_fuel/execsumm.html. Accessed November 21, 2011.

[2] Consumption has doubled in Minnesota, Wisconsin, and North and South Dakota since 1980. (Source: "CapX2020 Transmission Line Projects." http://www.capx2020.com/documents/CapX2020_project_overview.pdf. October 31, 2011. Accessed November 29, 2011.)

[3] Amin, Massoud. "US Electrical Grid Gets Less Reliable." *IEEE Spectrum.* January 2011. http://spectrum.ieee.org/energy/policy/us-electrical-grid-gets-less-reliable. Accessed November 21, 2011.

[4] Patel, Priti. "CapX2020 Transmission Initiative Case Study." http://www.eei.org/meetings/Meeting%20Documents/TWMS-21-Patel-Priti.pdf. August 5, 2010. Accessed November 29, 2011.

[5] CapX2020. "Frequently Asked Questions." http://www.capx2020.com/faq.html#14. Accessed October 4, 2011.

[6] US Energy Information Administration. "Table ET1. Primary Energy, Electricity, and Total Energy Price and Expenditure Estimates, Selected Years, 1970-2009, Minnesota." 2009. http://www.eia.gov/state/seds/sep_prices/total/pdf/pr_MN.pdf. Accessed October 31, 2011.

[7] US Energy Information Administration. "Average Retail Price for Bundled and Unbundled Consumers by Sector, Census Division, and State, 2010 (Cents per kilowatthour)." http://www.eia.gov/electricity/sales_revenue_price/pdf/table4.pdf. Accessed November 21, 2011.

[8] US Energy Information Administration. "Average Residential Monthly Bill." 2009. http://www.eia.gov/energyexplained/index.cfm?page=electricity_home#tab2. Accessed October 5, 2011.

[9] Based on 2009 median household income. (Source: US Census Bureau. http://quickfacts.census.gov/qfd/states . Accessed October 5, 2011.)

[10] US Energy Information Administration. "Retail Sales, Revenue, and Average Retail Price by Sector, 1990 Through 2009." http://www.eia.gov/cneaf/electricity/st_profiles/sept08mn.xls. Accessed October 5, 2011.

[11] US Energy Information Administration. "Revenue from Retail Sales of Electricity by State by Provider, 1990-2009." http://www.eia.gov/electricity/data.cfm#sales. Accessed October 2011.
US Energy Information Administration. "Number of Retail Customers by State by Sector, 1990-2009." http://www.eia.gov/electricity/data.cfm#sales. Accessed October 5, 2011.
US Census, Current Population Survey. "Table H-8. Median Household Income by State: 1984 to 2010." See Appendix B for data.

[12] Midwest Independent Transmission System Operator. "MISO Transmission Expansion Plan 2011." https://www.midwestiso.org/Library/Repository/Study/MTEP/MTEP11/MTEP11_Draft_Report_for_Stakeholder_Review.pdf. 8. Accessed October 20, 2011.

[13] CapX2020. "Frequently Asked Questions." http://www.capx2020.com/faq.html#14. Accessed October 4, 2011.

[14] Between 2008 and 2035, the US Energy Information Administration projects that the price of coal delivered for electrical power will increase 2% and natural gas 3.2%. (Source: Energy Information Administration. “Annual Energy Outlook 2001, Table 15: Coal Supply, Disposition, and Prices” and “Table 13. Natural Gas Supply, Disposition, and Prices.” December 2010. http://www.eia.gov/forecasts/aeo/excel/aeotab_13.xls and http://www.eia.gov/forecasts/aeo/excel/aeotab_15.xls. Accessed October 25, 2011.)

[15] MISO found compliance costs in the MISO region to meet EPA regulations to be about $30 billion dollars, increasing average rates by about 7 percent. (Source: MISO. “MISO Transmission Expansion Plan 2011.” https://www.midwestiso.org/Library/Repository/Study/MTEP/MTEP11/MTEP11_Draft_Report_for_Stakeholder_Review.pdf. 81. Accessed October 20, 2011.)

[16] Energy Information Administration. “Annual Energy Outlook 2011, Table 8: Electricity Supply, Disposition, Prices, and Emission.” December 2010. http://www.eia.gov/forecasts/aeo/excel/aeotab_8.xls. Accessed October 25, 2011.

[17] The EIA electrical price projection was off by an average of more than 17% between 1982 and 2004. US Energy Information Administration. “*Annual Energy Outlook* Forecast Evaluation.” February 2005. http://www.eia.gov/oiaf/analysispaper/forecast_eval.html#contact. Accessed November 29, 2011.

[18] This follows the United Nations definition. (Source: World Commission on Environment and Development. *Our Common Future*. Oxford University Press, USA: 1987.)

[19] The Offices of Energy Security and the Reliability Administrator, Minnesota Department of Commerce. “Minnesota’s Electrical Transmission System – Now and Into the Future.” 2011. 9.

[20] Professors Tadeusz Patzek and Greg Croft predict that we have reached about the peak of production now. (Reis, Patrick. “Study: World’s ‘Peak Coal’ Moment Has Arrived.” *New York Times*. September 29, 2010. http://www.nytimes.com/gwire/2010/09/29/29greenwire-study-worlds-peak-coal-moment-has-arrived-70121.html?pagewanted=all. Accessed November 21, 2010.)

[21] Ibid.

[22] National Academy of Sciences. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. National Academies Press, Washington DC: 2010. http://www.nap.edu/catalog.php?record_id=12794. Accessed November 28, 2011.

[23] Epstein, Paul R. et al. “Full Cost Accounting for the Life Cycle of Coal.” *Annals of the New York Academy of Sciences*. Article first published online February 17, 2011. http://onlinelibrary.wiley.com/doi/10.1111/j.1749-6632.2010.05890.x/abstract. Accessed January 12, 2012.

[24] “Midwest Climate Change Advisory Group Report.” April 2008. http://www.mnclimatechange.us/MCCAG.cfm. 2-8. Accessed September 26, 2011.
Minnesota Department of Commerce and Minnesota Pollution Control Agency. “Annual Legislative Proposal Report on Greenhouse Gas Emissions Reduction and Biennial Greenhouse Gas Emissions Reduction Report to the Minnesota Legislature.” January 2011. http://www.state.mn.us/mn/externalDocs/Commerce/Greenhouse_Gas_Emissions_Reduction_Report_2011_122910041040_GreenhouseGasEmissions2010.pdf. 3. Accessed December 20, 2011.

[25] University of Minnesota Water Resources Center. *Minnesota Water Sustainability Framework*. 2011. http://wrc.umn.edu/prod/groups/cfans/@pub/@cfans/@wrc/documents/asset/cfans_asset_292471.pdf. 82. Accessed 21 December 2011.

[26] Minnesota Department of Natural Resources. "Water Use: Water Appropriations Permit Program." http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html. Accessed November 28, 2011.

[27] For example, in the 2007 book *Carbon-Free and Nuclear-Free: A Roadmap for US Energy Policy*, Dr. Arjun Makhijani presents his extensive research defining the feasibility of an energy system that does not rely on fossil fuels or nuclear energy. (Makhijani, Arjun. *Carbon-Free and Nuclear-Free: A Roadmap for US Energy Policy*. Nuclear Policy Research Institute and the Institute for Energy and Environmental Research. IEER Press and RDR Books, Tacoma Park, MD: 2007.)

[28] "Minnesota Climate Change Advisory Group Final Report." April 2008. http://www.mnclimatechange.us/ewebeditpro/items/O3F16693.pdf. 2-4. Accessed September 26, 2011.

[29] Minnesota Department of Commerce and Minnesota Pollution Control Agency. "Annual Legislative Proposal Report on Greenhouse Gas Emissions Reduction and Biennial Greenhouse Gas Emissions Reduction Report to the Minnesota Legislature." January 2011. http://www.state.mn.us/mn/externalDocs/Commerce/Greenhouse_Gas_Emissions_Reduction_Report_2011_122910041040_GreenhouseGasEmissions2010.pdf. Accessed November 28, 2011.

[30] Minnesota Department of Commerce and Minnesota Pollution Control Agency. "Annual Legislative Proposal Report on Greenhouse Gas Emissions Reduction and Biennial Greenhouse Gas Emissions Reduction Report to the Minnesota Legislature." January 2011. http://www.state.mn.us/mn/externalDocs/Commerce/Greenhouse_Gas_Emissions_Reduction_Report_2011_122910041040_GreenhouseGasEmissions2010.pdf. 2. Accessed November 28, 2011.

[31] The Lawrence Livermore National Laboratory, for example, estimates that 68% of total energy is lost somewhere in the electrical energy system. (Source: Lawrence Livermore National Laboratory. "Estimated US Energy Use in 2009." https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2009/LLNL_US_Energy_Flow_2009.png. Accessed June 2, 2011.)

[32] The National Academies. "What You Need to Know About Energy: Sources and Uses." http://www.nap.edu/reports/energy/sources.html. Accessed 3 November 2011.

[33] US Energy Information Administration. "Annual Energy Review 2010." http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf. Accessed December 16, 2011.

[34] US Energy Information Administration. "What is the efficiency of different types of power plants?" http://205.254.135.7/tools/faqs/faq.cfm?id=107&t=3. Accessed December 16, 2011.

[35] US Environmental Protection Agency. "Combined Heat and Power Partnership: Efficiency Benefits." http://www.epa.gov/chp/basic/efficiency.html. Accessed December 16, 2011.

[36] US Energy Information Administration. "Minnesota Electricity Profile. Table 1: 2009 Summary Statistics (Minnesota)." http://www.eia.gov/cneaf/electricity/st_profiles/minnesota.html. Accessed November 21, 2011.

[37] For example, Minnesota Power is combining Manitoba Hydro and Bison Wind projects to establish renewable base load power.

[38] This draws on *The Johannesburg Declaration on Sustainable Development*. (September 4, 2002. http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/POI_PD.htm. Accessed October 27, 2011.)

[39] For example, wind turbine developments have increased landowner payments and triggered the expansion of modern transmission infrastructure. Minnesota-owned energy projects have potential for even greater economic impact.

[40] For example, capturing and using waste heat from electrical generation in combined heat and power systems can reduce the demand for fuels like coal and natural gas.

[41] Three of the most commonly used reliability indices are the following:

$$\text{System Average Interruption Frequency Index, SAIFI} = \frac{\text{Total \# of customer interruptions}}{\text{Total \# of customers served}}$$

$$\text{System Average Interruption Duration Index, SAIDI} = \frac{\text{Sum of all customer interruption durations}}{\text{Total \# of customers served}}$$

$$\text{Customer Average Interruption Duration Index, CAIDI} = \frac{\text{SAIDI}}{\text{SAIFI}} = \frac{\text{Sum of all customer interruption durations}}{\text{Total \# of customer interruptions}}$$

(Source: Short, T.A. *Electric Power Distribution Handbook.* New York: CPC Press, 2004.)

[42] For example, devices called relays sense when there is a problem and signal the circuit breaker to trip, preventing cascading outages.

[43] Computer Power and Consulting. “Power Quality.” http://www.cpccorp.com/pq.htm. Accessed November 21, 2011.

[44] The prices (rates) that utilities charge for electric service are based on the cost of providing such service, while taking into consideration many other factors. For rate-regulated utilities, the Minnesota Public Utilities Commission has established precedence in utility proceedings that provides guidance on how cost analysis should be performed and factors to consider in developing specific prices (rates). The ultimate goal is to have rates that are “just and reasonable.” (As specified in Minnesota Statute 216B.03.)

[45] *The Johannesburg Declaration on Sustainable Development*. September 4, 2002. http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/POI_PD.htm. Accessed October 27, 2011.

[46] Business Dictionary. http://www.businessdictionary.com/definition/carrying-capacity.html. Accessed September 26, 2011.

[47] Penfield, Patrick. *The Green Supply Chain*. Whitman School of Management, Syracuse University: August 2007.

[48] US Environmental Protection Agency. “Life Cycle Assessment Research.” http://www.epa.gov/nrmrl/lcaccess/. Accessed September 2, 2011.

[49] Braungart, Michael. *Cradle to Cradle*. North Point Press, New York, NY: 2002.

[50] US Environmental Protection Agency. “Climate Change: Greenhouse Gas Emissions.” http://www.epa.gov/climatechange/emissions/co2.html. Accessed October 27, 2011.

[51] Anderegg, William R. L., et al. “Expert credibility in climate change.” *Proceedings of the National Academy of Sciences of the United States of America*. June 2010. http://www.pnas.org/content/early/2010/06/04/1003187107.full.pdf+html. Accessed September 2, 2011.

[52] "Minnesota Climate Change Advisory Group Final Report." April 2008. 2-4. http://www.mnclimatechange.us/ewebeditpro/items/O3F16693.pdf.

[53] Minnesota Department of Commerce and Minnesota Pollution Control Agency. "Annual Legislative Proposal Report on Greenhouse Gas Emissions Reduction and Biennial Greenhouse Gas Emissions Reduction Report to the Minnesota Legislature." January 2011. http://www.state.mn.us/mn/externalDocs/Commerce/Greenhouse_Gas_Emissions_Reduction_Report_2011_122910041040_GreenhouseGasEmissions2010.pdf. Accessed November 28, 2011.

[54] Citizens League. *Powering Up Minnesota's Future: Act Now on a Long-Term Vision*. December 2002.

[55] CapX2020. "Frequently Asked Questions." http://www.capx2020.com/faq.html#14. Accessed October 4, 2011.

[56] For example, the current MISO-proposed Multi Value Project (MVP) portfolio builds about $5 billion of new regional transmission throughout the Midwest to integrate renewable energy, improve reliability, and improve access to least-cost energy. MISO estimates the MVPs provide the average residential customer $23 in annual benefits at an annual cost of $11. (Source: Midwest Independent Transmission System Operator. "Proposed Multi Value Project Portfolio: Business Case Workshop." September 19 and 29, 2011. https://www.midwestiso.org/Library/Repository/Meeting%20Material/Stakeholder/MVP/2011%20MVP/20110919/20110919%20MVP%20Proposed%20Portfolio%20Business%20Case.pdf. Accessed October 24, 2011.)