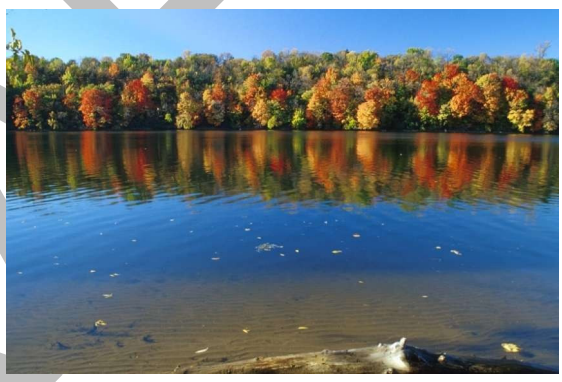
Energy Transition Roadmap

Fostering a Renewable and Carbon-neutral Energy System across the Region by 2055



Powering the Plains

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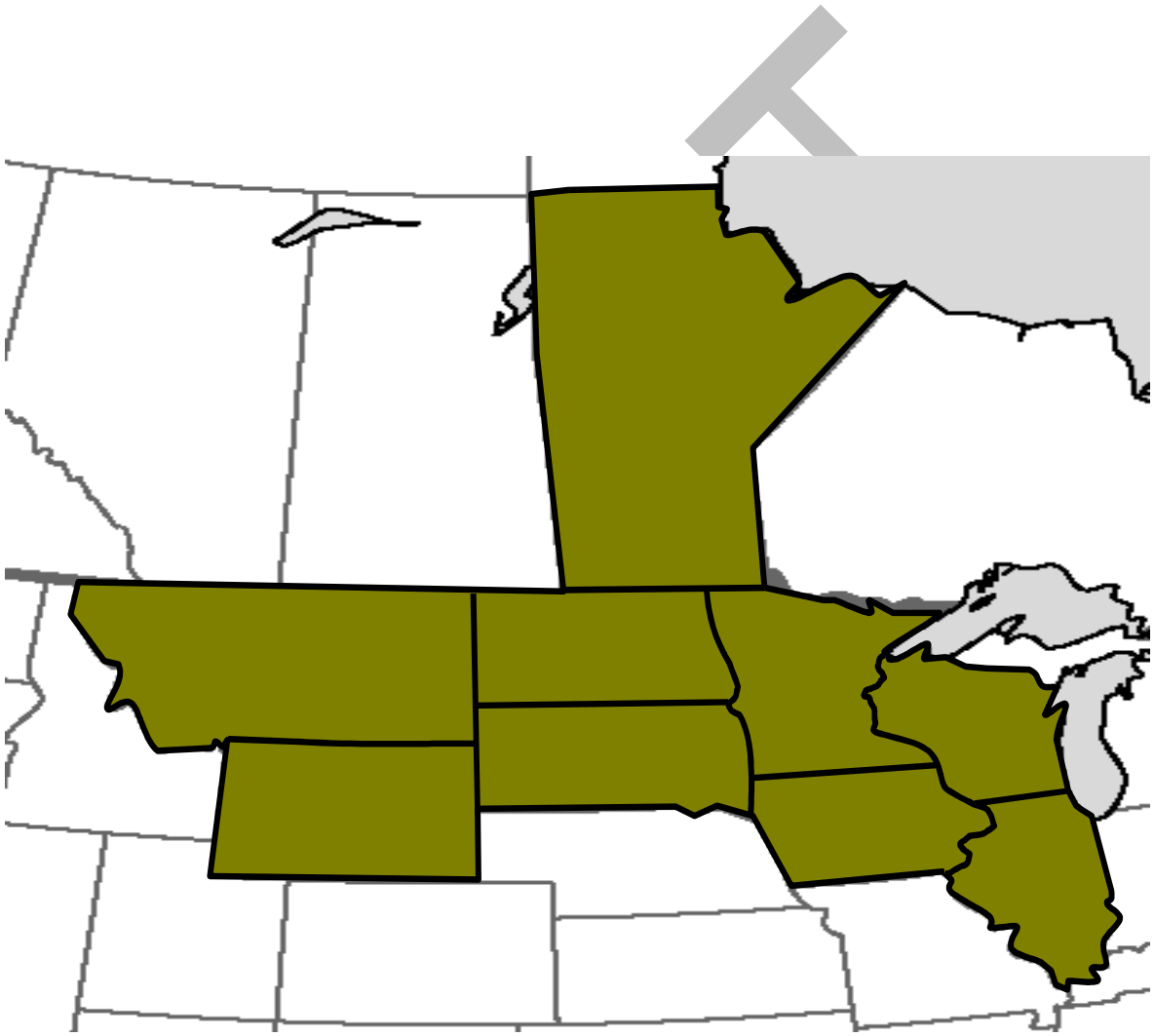
Where? A Nine-Jurisdiction Region

The region encompassed by this energy roadmap and the accompanying scenario analysis conducted by the University of Minnesota and the Great Plains Institute includes the following jurisdictions: Illinois, Iowa, Manitoba, Minnesota, Montana, North Dakota, Wisconsin, and Wyoming.



Who? Powering the Plains and Its Diverse Participants

For over four years, over 20 representatives from the energy industry, agriculture, governments and environmental organizations have worked together through the Great Plains Institute's voluntary, public-private *Powering the Plains (PTP)* program to lay the groundwork for an energy transition in our region. The following leaders from Iowa, Manitoba, Minnesota, North Dakota, and South Dakota currently participate in PTP:

- **Ellen Anderson (D)**, Chair, Energy, Jobs and Community Development Committee, Minnesota Senate, St. Paul, MN
- **Jim Burg**, Farmer and Former South Dakota Utilities Commissioner (D), Pierre, SD
- **Kim Christianson**, Energy Program Manager, North Dakota Dept. of Commerce, Bismarck, ND
- **Garry Connett**, Manager, Demand Side Management and Member Services, Great River Energy, Elk River, MN
- **Larry Diedrich (R)**, Farmer, former State Senator and Past President, American Soybean Growers, Elkton, SD
- **Mike Eggl**, Vice President, Government Affairs, Basin Electric Power Cooperative, Bismarck, ND
- **Bill Grant**, Midwest Director, Izaak Walton League of America, St. Paul, MN
- **William Hamlin**, Manager, Emissions and Credit Trading, Manitoba Hydro, Winnipeg, MB
- **Dave Miller**, Farmer and Director, Commodity Services, Iowa Farm Bureau, Des Moines, IA
- **Jon Nelson (R)**, Farmer and Chair, House Natural Resources Committee, Wolford, ND
- **Michael Noble**, Executive Director, Minnesotans for an Energy-Efficient Economy, St. Paul, MN
- **Phyllis Reha**, Commissioner, Minnesota Public Utilities Commission, St. Paul, MN
- **Lola Schoenrich**, Senior Program Director, The Minnesota Project, St Paul, MN
- **John Sellers, Jr.**, Farmer and Forages Coordinator, Leopold Center for Sustainable Agriculture, Corydon, IA
- **Kurt Simonsen**, Manager, Utilities and Energy Issues, Manitoba Energy Development Initiative, Winnipeg, MB
- **Beth Soholt**, Director, Wind on the Wires Project, St. Paul, MN
- **Patrick Spears**, President, Intertribal Council on Utility Policy, Ft. Pierre, SD
- **Michelle Swanson**, Manager for Policy Development, Xcel Energy, Minneapolis, MN
- **Paul Symens (D)**, Farmer, Feedlot Owner, and Former State Senator, Amherst, SD
- **Ed Woolsey**, Consultant, Union of Concerned Scientists and Iowa RENEW, Prole, IA

In addition, a wide range of leaders from industry, agriculture, government and the non-profit sector take part in related regional work groups. They have also contributed to this roadmap (see Attachment I for participants in the Upper Midwest Hydrogen Initiative, Coal Gasification Work Group, and Next Generation Biomass Work Group).

What? Regional Energy Transition Roadmap

Our future prosperity depends on clean and ultimately inexhaustible energy supplies. Yet, rising energy prices, growing dependence on unstable regions of the world, and mounting evidence of climate change have converged to place our collective energy future in doubt. For these and other reasons, energy has climbed to the top of the agenda around the world and across our region.

Responding effectively to these new realities is among the most urgent and important challenges of our time.

Purpose of this Roadmap

The purpose of this Roadmap is to position the region to prosper under several possible energy development scenarios over the next 50 years. Succeeding at this task means identifying and encouraging policy and technology pathways that appear to be wise under a wide range of future circumstances.

The purpose of this Roadmap is to position the region to prosper under several possible energy development scenarios over the next 50 years. The Roadmap aims at nothing less than fostering — as quickly as possible — an economically advantageous transition to a renewable and carbon-neutral energy system based on the native energy resources of this region.

Key Roadmap Conclusions

The scenario analysis that lies behind this Roadmap suggests that many different combinations of resources and technologies can not only meet future energy demand at moderate cost, but also lead to an 80 percent reduction of carbon dioxide emissions from the electric sector by mid-century.

No one energy sector must decline in favor of another during the transition, since all major energy resources must contribute to the region's portfolio low and zero-carbon energy options, if we are to accomplish the above.

- **Invest in energy efficiency** until the point at which other energy options become less expensive;
- **Accelerate commercialization of advanced coal technologies** with the capture and geologic storage of CO_2 emissions;
- **Maximize economic and reliable integration of wind energy** onto the electrical grid and harness the region's wind energy resource for non-electric applications;
- **Launch a biorefinery industry** that produces liquid fuels, biogas, electricity and bio-products from cellulosic biomass;
- **Advance new low-impact hydropower development** as part of a broader portfolio of energy options;
- **Build a hydrogen and fuel cell industry** based on regional renewable and carbon-neutral energy resources; and
- **Expand electric transmission and energy delivery capacity** to accommodate the substantial increases needed in low and zero-carbon energy production.

The good news is that harnessing the region's energy sources and ingenuity *can* make us less dependent on uncertain sources of energy, stimulate jobs and economic development, and offer a prudent hedge against volatile energy prices and global warming.

There is no agreement in the region on particular targets for reducing greenhouse gas emissions. However, Canada has already become a signatory to the Kyoto Protocol with its binding commitments to reduce carbon dioxide (CO_2) emissions. The U.S. does not yet regulate the emissions of CO_2 at the federal level, but individual states and regions have taken initial legislative and regulatory steps to do so.

Leaders of all political stripes in both public and private sectors recognize that federal carbon regulation is likely in the near to medium-term even while they may disagree on what form that regulation will or should take. The diverse stakeholders behind this Roadmap also agree that it is responsible and prudent for the Region to prepare for an eventual federal policy in the U.S., and to take steps now so that our energy and agriculture sectors have the technologies, policies, infrastructure and institutional mechanisms in place to do well under such a policy. In addition, the abundance of renewable energy resources in the region presents an opportunity to stimulate new rural economic development and growth.

Toward that end, this Roadmap attempts to offer strategic advice covering[1]:

A. Energy efficiency;
B. Coal and the capture and storage of its CO_2 emissions;
C. Wind (both conventional and emerging wind technologies);
D. Biomass and capture and storage of atmospheric carbon in soils, wetlands and woodlands;
E. Hydropower;
F. Nuclear power; and
G. Hydrogen, fuel cells and related technologies.

Why a Roadmap at all?

In 2003, the Great Plains Institute (GPI) led a U.S.-Canadian delegation to Denmark, Germany, the Netherlands and Iceland to better understand how those countries are approaching renewable energy development, climate change and the emergence of hydrogen. While none of these countries enjoys the extraordinary renewable and fossil energy potential of the Region, they each offered striking examples of what is possible when there is broad agreement across society on a long-term energy vision and strategy.

The trip proved a turning point for the diverse stakeholders who make up GPI's Powering the Plains initiative. The trip showed participants that a new energy agenda that responds to the global

[1] The Roadmap does not cover all possible energy options (e.g., solar). This is not because other energy options are unimportant or will not play an important role in the energy mix, but because Powering the Plains participants either did not see them as a core strength for the region or have not addressed them in their work.

warming challenge can, in some cases, actually generate economic advantages and new markets for industry and agriculture.

One of the key lessons from the European trip was the political and economic value of establishing consensus on a long-range energy vision and measurable targets for achieving that vision, regardless of which political party holds power.

Like turning a large tanker, it takes a long time to influence the overall direction of the energy system. Power plants, refineries, wind farms, and other energy production facilities and infrastructure require major investments that can last 25 to 50 years or more. Influencing the nature and timing of these investments must happen incrementally, year after year, over a long period of time to have any hope of arriving at the desired destination. Having policies and regulations in place that encourage innovation and reinvention at those critical moments when energy infrastructure is replaced, upgraded or expanded can make the difference between advancing new technologies and practices or being stuck with last century's inventions and suffering unnecessary economic harm as a result.

The events of the past few years underscore the future costs of being unprepared for change: greater economic uncertainty from volatile energy markets, strategic risks from growing dependence on imported energy, worsening effects of rising greenhouse gas emissions and, ultimately, greater economic burdens on local businesses and consumers. Those factors have already begun to influence policy-makers and the private sector in our region as evidenced by the accelerating development of wind farms and ethanol and bio-diesel plants, as well as early steps toward demonstrating and commercializing renewable hydrogen production from wind and advanced coal technologies with carbon dioxide (CO_2) capture and storage.

The challenge is to build on these encouraging energy trends and act *now* to pursue strategies that will yield benefits for years, decades and even generations to come.

What the Roadmap is not

A "roadmap" is a useful metaphor, but it runs the danger of suggesting to its readers that there is only *one* right way to move forward, and that the authors of the roadmap have discovered that optimal path. By contrast, this Roadmap does not lay out one "right" energy future, but rather a selection of possible futures. **The point is not to pick one of the three scenarios presented here, but instead to understand that multiple roads could lead to a renewable and carbon-neutral energy system.**

The most important thing is to take steps *now* to ensure that our region utilizes the combination of resources, technologies and policy options needed to meet future energy challenges.

Legislative Charge: How Did This Roadmap Come About?

In 2004, in response to PTP's consensus conclusions (including those drawn from its delegation to northern Europe), the bi-partisan International Legislators Forum[2] passed a resolution stating that **this region has "comparative advantages to lead a long-term energy transition in North America that relies on clean energy production and sequestration of carbon dioxide."**

In their resolution, the legislators articulated the region's comparative energy advantages:

- Renewable resources, such as wind, biofuels, biomass, and hydropower;
- Experience with coal gasification & geologic storage of the CO_2;
- Hydrogen production from renewable energy and the gasification of coal;
- Sequestration of atmospheric carbon in soils, wetlands, and woodlands; and
- Marketing renewable energy and carbon credits**.**

Legislators Forum delegates requested that PTP stakeholders:

1. "prepare preliminary scenarios, goals and measurable targets outlining a potential regional energy transition; and
2. identify legislative measures and institutional arrangements needed to implement such a transition roadmap inter-jurisdictionally over time."

The Roadmap's Technical Basis: Regional Scenario Analysis

The first step in developing an energy roadmap was to develop a modeling tool that would allow the project team and PTP participants to ask and answer "what if?" questions about energy technologies, costs, and the impacts of different choices.

GPI staff worked with faculty at the University of Minnesota to secure funding and establish a scenario research team that worked in partnership with PTP stakeholders to assemble data and build a computer model capable of answering these questions. Only scenarios that could meet the following four over-riding objectives survived the analysis. The project team and PTP agreed that each viable scenario must:

1. Provide an affordable, reliable and diversified portfolio of regional energy resources;
2. Enhance the region's economy and further develop its energy, agriculture and other key economic sectors;
3. Achieve ever greater levels of energy efficiency; and
4. Avoid, reduce and offset emissions of CO_2.

[2] Representing 32 legislators representing all political parties from the Dakotas, Manitoba and Minnesota, the Legislators Forum began after the devastating 1997 floods in the Red River Valley and now meets annually on issues of regional concern.

For analytical purposes only, the project team ran scenarios based on the objective of reducing CO_2 emissions 80 percent from 1990 levels by 2055 in the region's power sector. According to scenarios developed by the Intergovernmental Panel on Climate Change, 50-80 percent reductions in total CO_2 emissions will be necessary to stabilize atmospheric CO_2. This regional analysis deals only with CO_2 emissions from electricity production. Reductions from other sources, and of other greenhouse gases, will be necessary to stabilize total greenhouse gas emissions. Neither PTP stakeholders nor the research team have endorsed this numeric target as a recommendation to policy-makers.

The research and modeling is based on existing technologies and costs only, even though no other time in history has yielded zero innovation. Therefore, the scenarios are inherently conservative. We know that, in reality, the next few decades will bring remarkable technological advancements, reduced costs and greater efficiencies, many of which cannot even be imagined at this time.

While the regional roadmap extends beyond energy resources and technologies for electric power generation (it also includes liquid fuels, bio-gas and syngas, and industrial products produced from renewable and fossil energy), the regional scenario analysis has initially focused on the power sector only. Therefore, the scenario analysis and roadmap should not be interpreted as comprehensive. In particular, further work needs to be done to expand the analysis and roadmap to encompass the region's transportation sector and take into account the possible electrification of the transportation sector over time.

Energy Objectives and Key Options

To the extent that federal and state/provincial policy-makers take future steps to reduce greenhouse gas emissions, PTP participants have identified several potential pathways, all of which meet projected energy demand and reduce CO_2 emissions 80 percent by 2055:

Initial Scenario Assumptions - Draft Results				
	Business as Usual	**Scenario 1** **High Efficiency Modest Coal & Renewables**	**Scenario 2** **High Renewables Modest Coal & Efficiency**	**Scenario 3** **High Coal Modest Renewables & Efficiency**
Reduces CO_2 80%?	NO	YES	YES	YES
Demand management (US$ Million per jurisdiction annually)	0	$200	$90	$90
Cost of Demand management ($/MWh avoided)	$20	$20	$20	$20
CO_2 maximum (tons CO_2/MWh)	None	0.2	0.2	0.2
Maximum Technology Penetration				
Hydro	20%	20%	no max.	20%
Wind	20%	20%	40%	20%
Nuclear	no max.	10%	10%	10%
Minimum Technology Penetration				
Biomass IGCC*			10%	
1.7cent /kWh production tax credit applied for:	Biomass, Waste Biomass, wind, PV,	Biomass, Waste Biomass, wind, PV, Coal IGCC w/CCS	Biomass, Waste Biomass, wind, PV, Coal IGCC w/CCS	Biomass, Waste Biomass, wind, PV, Coal IGCC w/CCS

* IGCC stands for "Integrated Gasification Combined Cycle" and CCS stands for "carbon capture and sequestration." IGCC power generation technology can utilize a wide range of carbon-rich fuel sources.

Scenario Characteristics

	Business as Usual		Scenario 1 High Efficiency Modest Coal & Renewables		Scenario 2 High Renewables Modest Coal & Efficiency		Scenario 3 High Coal Modest Renewables & Efficiency	
Demand in 2055 (TWh)	848		515		619		653	
Avg. power cost in 2055 (US$/MWh)	$33.91*		$48.77		$45.68		$44.33	
Cumulative 50-year power cost (US$ billions)	$1,008		$926		$1,036		$1,049	
Production Type	**TWh**	**Thousand MW**	**TWh**	**Thousand MW**	**TWh**	**Thousand MW**	**TWh**	**Thousand MW**
Biomass IGCC	0	0	0	0	82	11	0	0
Waste biomass combustion	61	9	37	5	71	10	64	9
Coal IGCC w/ CCS	0	0	220	30	118	16	336	45
Hydro[3]	157	36	70	16	76	17	122	28
Natural Gas	4	1	0	0	4	1	0	0
Nuclear[4]	31	4	31	4	31	4	30	4
Wind[5]	178	51	157	45	237	68	101	29
Pulverized coal	417	56	0	0	0	0	0	0
Total	**848**	**156**	**515**	**100**	**619**	**127**	**653**	**115**

[3] Hydroelectric and wind development are larger in the BAU scenario because that scenario needs to supply more energy to meet demand due to the lack of an energy efficiency component.
[4] Given the lack of consensus in the region about whether to develop new nuclear power, the scenario team opted to hold nuclear power constant, or allow it to decrease as plants retired. If nuclear were allowed to increase, the model predicts considerable new nuclear power development.
[5] See footnote 5.

Regardless of the precise mix of energy efficiency and new energy production, achieving an energy system anything like the kind described by the three scenarios above will require significant new investment and broad coalitions of support for demonstration of new technologies and policy change.

Maximizing energy efficiency is the lowest cost scenario

	Total Cost (US$ billions)	Unit Cost (US$/MWh)	CO_2 Limit
Business as Usual	**$1,008**	**$33.91**	**NO**
High Efficiency	**$ 926**	**$48.77**	**YES**
High Renewables	**$1,036**	**$45.68**	**YES**
High Coal (IGCC w/CCS)	**$1,049**	**$44.33**	**YES**

* While the unit cost of electricity per MWh is highest under High Efficiency, greater deployment of energy efficiency significantly reduces demand and thus total regional expenditure for electric power.

Desired Characteristics for the Region's Future Energy System

PTP stakeholders have agreed that the region's future energy system should:

- Provide an affordable, reliable and diversified portfolio of regional energy resources;
- Enhance the region's economy and further develop its energy, agriculture and other key economic sectors;
- Achieve ever greater levels of energy efficiency; and
- Avoid, reduce and offset emissions of CO_2.

Key Options for Consideration by Policy-Makers

PTP participants have also identified the following options by energy sector for policy-makers to consider:

A. Options Applicable Across Energy Sectors

1. Establish quantifiable goals in each jurisdiction for energy efficiency and specific generation resources.
2. Complete the design and implementation of the Midwest Renewable Energy Tracking System (M-RETS) to facilitate the trading of renewable electricity credits (wind, biomass and hydropower).
3. Support and expand ongoing collaborative efforts at regional transmission planning to explore the potential for shared transmission corridors to benefit all the region's renewable and near-zero carbon generation resources.
4. Define and support a large-scale, multi-jurisdictional energy project that combines multiple low- and zero-carbon generation options. Elements to consider include, but are not limited to:
   - Common transmission corridor serving several jurisdictions (upgrade of an existing corridor or a new one);
   - Multiple wind farms in participating jurisdictions, including some projects with local ownership components;
   - Wind-hydro, wind-biofuels, and wind-compressed air demonstrations with the potential to qualify for 65 percent "firm" capacity payments (Federal Energy Regulatory Commission tariff for renewable generators);
   - Demonstration baseload IGCC coal plant with CCS; and
   - Associated hydrogen and fertilizer production applications using wind, IGCC coal and possibly biomass or bio-fuels as energy sources.

B. Energy Efficiency Options

1. Fund research within each jurisdiction to quantify the amount of energy efficiency that would cost less per kilowatt-hour than the next most expensive energy source.
2. Explore innovative policy options for combining energy efficiency and renewable energy policies and goals, giving utilities increased flexibility.
3. Strengthen existing state/provincial and federal energy efficiency programs and incentives.

4. Require regulated utilities to make energy efficiency a priority and to include it as a standard part of their integrated resource plans.
5. Develop strategies to help rural electric cooperatives and municipal utilities prioritize and implement efficiency programs and investments.
6. Make energy efficiency and electricity sales equally profitable for utilities.
7. Adopt more aggressive building codes and appliance standards.
8. Encourage customer-side adoption of combined-heat-and-power, using waste heat to improve energy efficiency.
9. Have the public sector lead by example by incorporating best practice efficiency technologies and practices in government buildings and other operations.

C. Coal Options

1. Create a policy and regulatory environment that provides incentives for building coal plants as soon as possible with carbon-neutral technologies and permanent capture and storage of the resulting CO_2. This would mean using environmentally benign resources to defer construction of traditional pulverized coal plants, to the degree possible, until coal technologies with low or negligible environmental impacts are commercially ready.
   - Provide financial and regulatory support for front-end engineering and design (FEED) packages. FEED packages are the upfront studies needed to provide good cost estimates for power plant projects;
   - Provide direct financial incentives (tax credits, loan guarantees, etc.);
   - Allow regulated utilities cost recovery for important demonstration projects; and
   - Enhance integrated resource planning (IRP) policies by using them to encourage carbon-neutral coal technologies and CO_2 sequestration.
2. Support the demonstration and commercialization of new carbon capture technologies at existing coal facilities.
3. Conduct comprehensive assessments of geologic reservoirs at state and federal levels to determine CO_2 storage potential and feasibility.
4. Support the demonstration of large-scale carbon sequestration projects.
5. Develop the legal and regulatory frameworks needed for coal gasification and geologic storage of CO_2.
6. Begin now to develop the physical infrastructure that will be needed to permanently sequester CO_2 on a large scale.
7. Assess the feasibility of CO_2 transport and "advanced sequestration" options for states and provinces with no documented geologic sequestration potential, such as Minnesota and Wisconsin.

D. Wind Options

1. Support a long-term extension of the U.S. federal production tax credit.
2. Consider additional policy approaches to encouraging wind energy development in the Dakotas, which currently lack renewable energy standards or objectives.
3. Incorporate transmission development requirements into existing state and provincial renewable energy objectives and standards.
4. Encourage a diversity of approaches to wind development, including projects that have significant components of local ownership.
5. Define and support a large-scale, multi-jurisdictional wind energy project.
6. Demonstrate technology and engineering strategies for achieving greater than 20 percent of total electricity generation from wind.
7. Develop policies to attract wind energy component manufacturers and service providers to locate their operations within the region.

E. Biomass Options

1. Demonstrate and commercialize a wide range of biomass technologies to show that they can compete in the marketplace.
2. Reduce the carbon intensity of biomass production and conversion (e.g. fossil fuel and fertilizer inputs).
3. Encourage best management practices in biomass production that increase sequestration of carbon in soils, woodlands and wetlands.
4. Modify federal and state agricultural conservation programs to promote production and harvest of biomass for energy and bio-products, consistent with programs' established conservation objectives.
5. Implement programs and incentives that foster markets for bio-fuels and bio-based products, including certification programs and government procurement.
6. Accelerate the demonstration and commercialization of cellulose-based biofuels and biorefineries through research, investment, incentives, and cost-share.
7. Provide assistance all along the value chain to those involved in bringing biomass and bio-based products to market.

F. Hydro Options

1. Determine practical scenarios for the magnitude and timing of new hydro potential in Manitoba that can be delivered to U.S. markets and for the associated transmission requirements.
2. Allocate emission reduction credits to new hydro generation (e.g. based on combined cycle gas turbine emission levels).
3. Provide policy support for new, low-impact hydro generation that is extended to other near-zero emission resources.
4. Explore potential synergies between hydro, wind and other renewable and near-zero emission technologies.

G. Nuclear Options (none at this time)

The region's utilities have not identified new nuclear generation capacity as a short to medium-term option (only seeking relicensing of existing facilities), and it does not appear today that regional consensus on new nuclear power is obtainable at this time.

Thus, the Roadmap does not include any specific strategies for encouraging or discouraging additional nuclear power. Instead, this chapter attempts to shed light on those issues that need to be addressed and resolved in order for nuclear power to play any larger role than it currently does in the region's energy mix.

H. Hydrogen Options

1. Identify and encourage early niche markets for hydrogen and fuel cell applications (e.g., fork lifts, back-up power, transit buses, and ammonia production for fertilizer).
2. Explore hydrogen's potential for bringing renewable energy sources to market (e.g., ammonia production from wind-powered water electrolysis).
3. Provide matching funds and policy support for strategically important early deployment projects, including systematic build-out of the Northern H, a network of multi-fuel hydrogen stations along the region's key trade corridors. This is the Upper Midwest's version of "hydrogen highway" efforts emerging worldwide.
4. Implement policies and incentives to accelerate renewable and carbon-neutral hydrogen production and stimulate market demand:
   - Establish a hydrogen production incentive for renewable and carbon-neutral hydrogen production and use (i.e. similar to PTC for wind energy);
   - Incorporate hydrogen technologies into government and other public purchasing guidelines and contracts;

- Adopt uniform codes and standards and siting requirements for hydrogen infrastructure;
- Appropriate funds for education and outreach to key audiences on hydrogen, fuel cells and related technologies, and their role in the future energy mix; and
- Support publicly-funded basic and applied research at the region's respective research institutions.